TRANSPORTATION PLANNING HANDBOOK

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FOURTH EDITION

Institute of Transportation Engineers

Michael D. Meyer

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Preface

The original intent of the update to the *Transportation Planning Handbook* (third edition) was to simply provide more recent references and add material on topics that had surfaced as an important planning topic since the publication of the third edition nine years ago. In updating each chapter, however, it became apparent that much has happened since the mid-2000s in transportation planning. Important changes have included a focus on performance-oriented planning, an increased emphasis on environmental and social justice, a continuing revolutionary change in transportation system and vehicle technology, a similar revolution in the technology of data collection, the expanding options for transportation finance, and a continuing trend in changing socio-demographic characteristics that will fundamentally affect how travel occurs. What had begun as a simple update evolved into a major rewrite when it became apparent that transportation planning is now facing many important challenges and opportunities that were just becoming apparent in the mid-2000s.

In addition to the updates of the chapters found in the third edition, new chapters have been added to this edition reflecting the importance of these topics to contemporary transportation planning. These chapters include transportation finance and funding, highway system planning, travel demand management, local/municipal transportation planning, and public engagement. These chapters were written by the editor.

Finally, the technology of publishing has changed dramatically since the mid-2000s such that we can now cross reference and link key concepts from one chapter to another. This handbook does not repeat concepts that are inherent to transportation planning whether focusing on state, metropolitan, or local planning contexts. For example, Chapter 1 presents an organizing framework for transportation planning that outlines the major steps inherent in any planning process. The chapters on statewide, metropolitan, and local transportation planning simply reference this framework rather than repeat the framework in each chapter. Thus, those who are using individual chapters for teaching and/or reference should be aware that each chapter might reference material in other chapters that is needed to obtain a complete picture of the substance and concepts in a targeted chapter.

The experience in updating this handbook reflects the dynamic nature of transportation planning. As noted by the editor in other publications and in previous editions of the handbook, transportation planning relates to the key policy issues and decision contexts of the day. Although transportation planners in the mid-2000s would recognize much of what planners are doing today, they would be surprised by planning interest in climate change, autonomous vehicles, 3D printing (and its impact on logistics), cloud sourcing as a tool for public engagement, and many other capabilities and issues that have been enabled by changing socio-demographic characteristics and new technologies. The planning process outlined in this handbook is one that is future-oriented, anticipating societal and technological characteristics that will affect future transportation system performance. In addition, it is one that is flexible to allow policy issues and new analysis capabilities to be included as they become important topics to planners and decision makers. In this way, transportation planning will continue to stay relevant to the decisions that decision makers today and in the future will be making to improve the vitality of our communities.

Acknowledgments

The preparation and production of the fourth edition of the Transportation Planning Handbook has been a collaborative and intensive effort. One person in particular has been instrumental in working with the editor in all aspects of the handbook preparation … from obtaining resource information to reviewing chapters for consistency and quality. This handbook could not have been prepared without the work of Adam N. Rosbury, who deserves much credit for the final product.

The fourth edition has also greatly benefited from the efforts of numerous individuals who helped create the overall outline for the handbook and who volunteered to review individual chapters and in the process greatly improved the quality of the handbook. An initial advisory panel reviewed early versions of the new handbook outline and provided feedback on some of the early chapters. Panel members included:

Thomas W. Brahms

Steven B. Gayle

Jamie Henson

Aliyah Horton

Leslie Meehan

Michael D. Meyer

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The following subject matter experts served as volunteer reviewers of the draft handbook chapters:

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ITE staff members have also been an important contributor to handbook development. Thomas W. Brahms articulated the original vision for the handbook and provided input on the handbook outline. Courtney L. Day was instrumental in coordinating the chapter review process and in interfacing with the publisher.

Finally, the concept of this handbook was to update the chapters in the third edition of the handbook and to add several new chapters that reflected the changing professional interests since 2009. Thus, much of the material in this handbook was produced by the original authors, updated to reflect more recent references and examples. The original authors included:

Marsha Bomar Anderson

Song Bai

Sandra K. Beaupre

Greg Benz

Wayne Berman

Stephen B. Colman

Jeffrey M. Cosello

Paula Dowell

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Mary S. Smith

Vukan R. Vuchic

The editor takes responsibility for changes and additions to the fourth edition of the Transportation Planning Handbook.

Michael D. Meyer, Ph.D., P.E., M.ITE,
and F.ASCE, Editor

About the Editor

Dr. Michael D. Meyer is a senior advisor to WSP/Parsons Brinckerhoff, Inc., Co-founding Principal of Transport Studio, LLC, and president of Modern Transport Solutions, LLC. He was the Frederick R. Dickerson Professor of Civil Engineering and Director of the Georgia Transportation Institute at the Georgia Institute of Technology until 2012 when he retired. From 1983 to 1988, Dr. Meyer was Director of Transportation Planning and Development for Massachusetts where he was responsible for statewide planning, project development, traffic engineering and operations, and transportation research. As Director, Dr. Meyer spent considerable time with the state's transportation planners developing statewide, metropolitan, and corridor-level transportation plans. In addition, he worked closely with local officials in developing institutional collaborations for compatible land-use and development strategies. Prior to this, he was a professor in the Department of Civil & Engineering at M.I.T. He is currently an adjunct professor at Denver University's Transportation Institute.

Dr. Meyer has written over 200 technical articles and has authored or co-authored 28 books or book chapters, many on transportation planning and policy, including a major college textbook on transportation planning. Dr. Meyer has given over 300 speeches or keynote conference addresses over the past 20 years and testified to Congressional committees on a variety of topics relating to transportation policy and planning, including most recently the importance of incorporating sustainability into transportation decision making. He was one of the first researchers in the United States to examine the role of performance measures in transportation planning and decision making, and more recently he has been one of the first transportation professionals to write extensively on the relationship between climate change and transportation system performance. He has received numerous professional awards, and was chair of the Transportation Research Board Executive Committee in 2006.

Introduction to Transportation Planning[1]

I. INTRODUCTION

The economic health and quality of life of a nation's communities depend on a well-functioning and safe transportation system. For example, following housing costs, transportation is one of the biggest expenses faced by an average household in the United States and in many other countries. This is usually measured by the actual out-of-pocket costs associated with owning and operating vehicles or paying for transit fares. When one considers the value of time it takes to travel from one location to another, often in congested conditions, this cost increases significantly. The cost of freight and goods movement is also an economic cost passed on to consumers that will vary depending on the price of transportation.

The accessibility and mobility provided by transportation systems can influence land use patterns and, thus, over time affect how we live. The best example of this relationship is the large-scale suburbanization of U.S. metropolitan areas and of those in many other countries after World War II when massive investment was made in suburban freeways. Today, transportation investment is often an integral part of economic and development plans, usually including transit, pedestrian, bicyclist facilities, and actions to manage transportation demand. The importance of transportation investment in transforming communities raises questions of who is benefiting and who is carrying additional burdens after the system has changed. These are questions that are part of many transportation planning studies.

The public is also concerned about the environmental impacts linked to transportation systems and their operation. This has been manifested in many environmental laws and regulations that affect how transportation planning is conducted and the types of data and tools that must be used.

These, along with many other reasons, suggest that the transportation system is a critical component of a successful modern community and economy. Thus, anticipating the challenges and opportunities relating to transportation system performance is critical not only to future transportation system effectiveness, but also to the economic and social well-being of our communities.

This handbook examines many facets of transportation planning. Transportation planning can be a highly technical process, which often relies on computer models and other sophisticated tools to simulate the complex interactions of transportation system performance. It is a public relationship-oriented process in that transportation planners often interact with a wide range of stakeholders and members of the public. Transportation planning can also become intertwined with the politics of any given decision.

Some transportation planners and engineers focus on transportation supply—the facilities and services needed to handle expected demands and characteristics of the infrastructure to provide such service. Others are more interested in influencing travel behavior to promote more cost-effective and environmentally sustainable options for travelers.

Given the breadth of topics and issues that transportation planners can become involved in, transportation planning necessarily includes a wide range of interests, skills, and expertise. Perhaps the most important characteristic of any transportation planning process is to remain flexible given the dynamic nature of community planning and decision making, and the importance of transportation planning providing input into this process. This need for flexibility will be particularly important as the types of investment decisions for transportation systems evolve over the next several decades in response to changing demographic and technology factors.

[1] The original chapter in Volume 3 of this Handbook was written by Michael D. Meyer, WSP/Parsons Brinckerhoff. Changes made to this updated chapter are solely the responsibility of the editor.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

II. ORGANIZATION OF THIS HANDBOOK

This handbook is organized to reflect different levels of user familiarity with transportation planning. Not only do transportation planners need to know about the defining characteristics of the transportation system itself, but given a variety of transportation planning contexts, they must also understand the specific application contexts they are working in. In addition, transportation planning can be applied at a multimodal level, for example, statewide or metropolitan transportation planning efforts where all modes of transportation are considered, or it may target a very specific transportation strategy or element, such as freight planning.

The handbook is organized to answer six major questions:

What is transportation planning?

Chapter 1: Introduction to Transportation Planning

What are the basic concepts for understanding transportation systems and their relationship to the community?

Chapter 2: Travel Characteristics and Data

Chapter 3: Land Use and Urban Design

Chapter 4: Environmental Considerations

Chapter 5: Transportation Finance and Funding

What are the types of tools and analysis methods used in transportation planning?

Chapter 6: Travel Demand and Network Modeling

Chapter 7: Evaluation and Prioritization Methods

Chapter 8: Asset Management

How does one plan for mode-specific transportation networks?

Chapter 9: Road and Highway Planning

Chapter 10: Transportation System Management and Operations

Chapter 11: Planning for Parking

Chapter 12: Transit Planning

Chapter 13: Planning for Pedestrians and Bicyclists

Chapter 14: Travel Demand Management

How does one plan for multimodal transportation networks?

Chapter 15: Statewide Transportation Planning

Chapter 16: Metropolitan Transportation Planning

Chapter 17: Corridor Planning

Chapter 18: Local and Activity Center Planning

Chapter 19: Site Planning and Impact Analysis

Chapter 20: Rural Community and Tribal Nation Planning

Chapter 21: Recreational Areas

What are some special planning applications transportation planners should know about?

Chapter 22: Integrating Freight into the Transportation Planning Process

Chapter 23: Playing it Safe—Safety Considerations in the Transportation Planning Process

Chapter 24: Public Participation and Engagement

Individual chapters provide linkages to relevant information in other chapters of the handbook. For example, transportation professionals interested primarily in chapter 12 on transit planning, will find references to other chapters on travel demand models and data collection that provide more in-depth coverage of a transit-related application. Thus, in some cases, chapters that in other texts would have spent considerable time discussing some aspect of a particular topic (such as transit demand modeling), the reader is directed to other parts of the handbook. Given the breadth of many transportation planning studies, it should not be surprising that, in some instances, almost every chapter in the handbook could be relevant to a particular study.

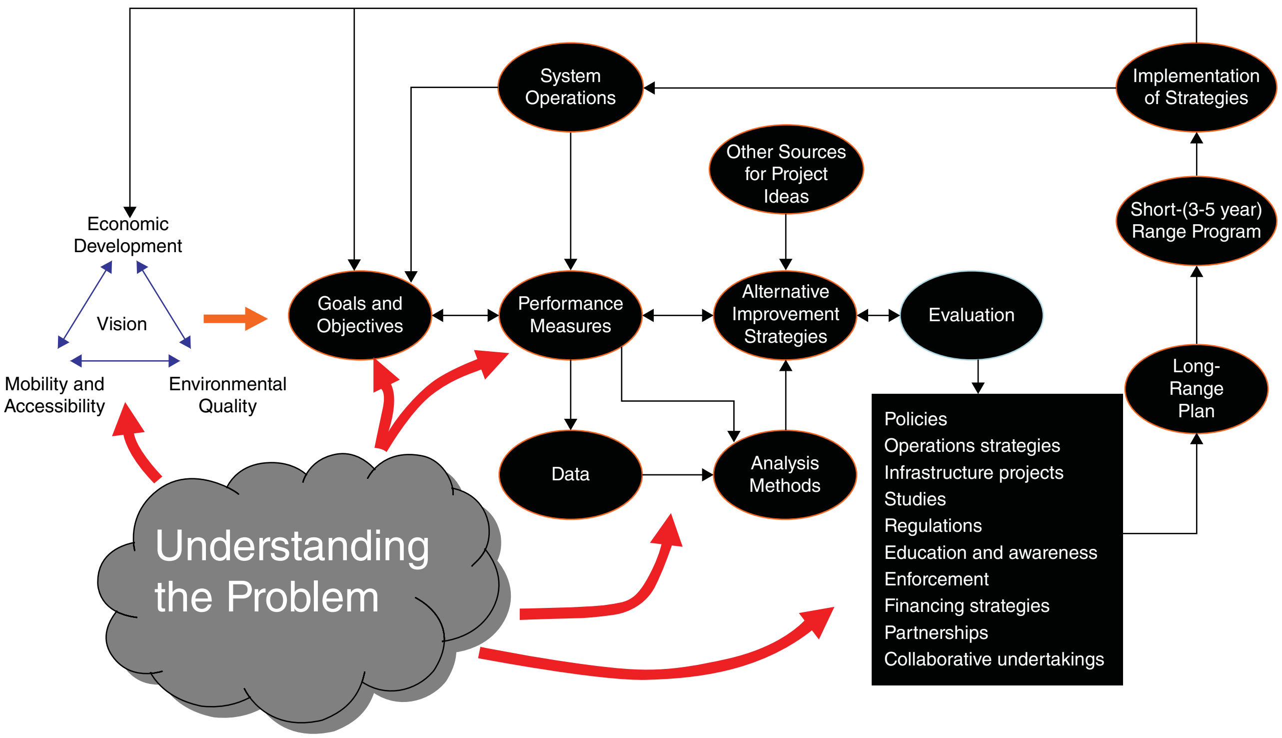
In addition, given the importance of performance measures in today's transportation planning, instead of discussing their definition and role in one chapter, the discussion of performance measures is found in each chapter where appropriate. In this way, performance measures can be discussed with specific reference to how they can be used for different modes and planning efforts.

The remainder of this chapter describes the transportation planning process and the legal/regulatory foundation in the United States for much of what occurs in transportation planning today.

III. THE TRANSPORTATION PLANNING PROCESS

Transportation planning is often portrayed as an orderly and rational process of steps that logically follow one another. In reality, planning and project development are much more complex, often with many different activities occurring concurrently. Shown in Figure 1-1, the planning process starts with understanding the problems facing a community and ending with a solution to identified problems (projects programmed and designed). In a typical planning context,

Figure 1-1. Conceptual Framework for Transportation Planning



Source: Adapted from Meyer and Miller, 2014, Reproduced with permission of M. Meyer.

many of these steps may have already occurred and therefore are not relevant to a particular planning effort. For example, metropolitan planning organizations (MPOs) in the United States have been developing transportation plans for decades, and as a result, a typical planning effort might simply be updating an existing transportation plan. In the context of Figure 1-1, the development of goals, objectives and performance measures might consist of validating those that were developed for the prior version of the plan. Even with these caveats, the planning process shown in Figure 1-1 helps identify important components of the planning process and how they relate to one another. The planning process in Figure 1-1 will be referenced throughout this handbook.

A. Major Steps in Transportation Planning

The planning process begins with an *understanding of the socio-demographic, land-use, and economic context* within which a transportation system operates. This is followed by becoming aware of the problems, challenges, opportunities, and deficiencies of transportation system performance within this context, be it a state, province, region, or community. This usually entails some form of analysis and assessment of the changing context of transportation system performance and an examination of both the existing and expected challenges facing the transportation system. This initial step is important because a planning agency usually begins a planning study based on the planning and analysis that has preceded it. More often, a transportation plan is being updated, or some specific problems have been identified that require a planning effort to be undertaken. Understanding the nature of the challenges facing a community thus becomes an important starting point for the planning steps that follow.

The next step is *developing a community or study area vision*. The dimensions of the vision portrayed in Figure 1-1 reflect the interaction among desired states of economic prosperity, environmental quality, and social equity/ community quality of life. These three factors have been chosen purposely as defining a vision because they are often considered to be the three major elements of sustainable development; a concept well-developed and accepted in recent years (see chapter 3). The vision can consist of general statements of desired end states or can be as specific as a defined land-use scenario. The visioning process often relies on extensive public outreach and is considered one of the most community-interactive steps of the planning process.

Once a vision has been defined, the next step is to *acquire more specific information* about what the vision means. What is the desired performance of the transportation system? What characteristics of community life can be most positively affected by transportation improvements? This more specific definition of a community's future is usually accomplished by *defining goals and objectives* that provide overall direction to the planning process. These goals and objectives not only help define the purposes of the planning process for the public, but can also help identify criteria to evaluate different transportation system options and alternatives.

Goals and objectives can also lead to the identification of *system performance measures*. Using measures to monitor the performance of the transportation system and the progress of transportation plans and programs is relatively new to the transportation field (see, for example, the performance management requirements of the 2012 U.S. federal transportation law—Moving Ahead for Progress in the 21st Century (MAP-21)). The primary purpose of collecting data on key system performance characteristics is to provide information to decision makers on the aspects of performance that are most important to them. Performance measures can be used to monitor whether congestion, average speeds, system reliability, and mobility options have changed over time. Many planning programs have also developed performance measures relating to such things as environmental quality, economic development, and quality of life. In these cases, transportation is just one factor that contributes to achieving overall community goals.

Collecting and analyzing data, the next step of the planning process, is key to understanding the problems and potential challenges facing the transportation system and the surrounding community. This analysis process primarily focuses on understanding how a transportation system and its components work and how changes to the system will alter its performance. A large part of the analysis step is identifying the current status of system performance. Analysis also includes identifying alternative strategies or projects that meet the objectives of the study. Analysis tools, ranging from simple data analysis to more complex simulation models, are used to produce the information that feeds the next step of the process, which is evaluation.

Evaluation is the process of synthesizing the information produced during the analysis step (for example, the benefits, costs, and impacts of different alternatives) so that judgments can be made concerning the relative merits of different actions. As noted by Meyer and Miller [2014], evaluation should incorporate the following characteristics:

- Focus on the decisions being faced by decision makers.
- Relate the consequences of alternatives to goals and objectives.
- Determine how different groups are affected by transportation proposals.
- Be sensitive to the time period in which project impacts are likely to occur.
- In the case of regional transportation planning, aggregate information in a way that allows planners to assess the likely effects of alternatives at varying levels.
- Analyze the implementation requirements of each alternative.
- Assess the financial feasibility of plan recommendations.
- Provide information on the value of alternatives in a readily understandable form and timely fashion for decision makers.

One of the most common ways to ensure that the results of the evaluation process are linked closely to decision making is through the evaluation criteria used to assess the cost-effectiveness of individual alternatives or strategies and that reflect important decision-making concerns. These criteria provide important guidance to planners and engineers on the type of data and analysis tools to be used in producing the desired information.

Note in Figure 1-1 that planning can result in many different products. Studies can recommend the pursuit of specific transportation projects or services; they can recommend changes to institutional structures or funding programs that would make the management of the transportation system more effective. Some studies might recommend specific policy changes, such as how land-use and development plans should be linked to the transportation plan. In the United States, one of the most important products of the statewide and metropolitan transportation planning process is the development of a transportation plan. Much of what is covered in this handbook focuses on the steps necessary to develop such a plan. However, it is important to recognize that the ongoing planning process actually results in many different products aimed at improving the performance of the transportation system and in enhancing the economy and quality of life of the community it serves.

The actual program of action—in the United States called the transportation improvement program (TIP) for a metropolitan area or a state transportation improvement program (STIP) for a state—is connected to the plan through a process called *programming*. Programming matches the most desirable actions that have surfaced through the evaluation process with available funds. Priorities must be set when there are insufficient funds to satisfy all of the funding needs. This process can take many forms, ranging from political considerations to the use of systems analysis tools to assign priorities to different projects or alternatives.

Once a project or action has been programmed for implementation, its design and operation must be further refined, and likely impacts further explored. This process of refinement is called *project development*. Project development takes various forms, depending on the scope and magnitude of the project and the expected effects. Three major steps in project development include: developing project concepts, planning the project in finer detail than typically occurs in systems planning, and preliminary/final engineering. When significant environmental impacts are expected, the project development process will usually (depending on federal and state laws) include an environmental analysis process whose steps are well laid out in rules and regulations.

The final component of the framework is *system monitoring*. Note in Figure 1-1 that system monitoring provides feedback to the definition of goals and objectives and the use of performance measures. Poor system performance can lead to further planning analysis to better understand the dynamics of the underlying problem, or it might very well lead to the identification of new goals and objectives.

The planning process shown in Figure 1-1 is very different from more traditional constructs. First and perhaps most significantly, system planning as shown encompasses a broad set of planning steps. Many books on transportation planning have focused almost exclusively on analysis and evaluation, with the visioning process, program and/or project implementation, and system monitoring occurring outside the planners' purview. The approach toward planning in this handbook adopts a much broader perspective to transportation planning.

Second, the use of performance measures is a relatively new addition to systems planning, and as shown in Figure 1-1, is a central concept to the overall process. Given the important linkage between planning and decision making that serves as the core concept in the definition of planning used in this handbook, performance measures should focus on the information of greatest concern to decision makers. Performance measures not only help define data requirements and influence the development of analytical methods, but also become a critical way of providing feedback to the decision-making process on the results of previous decisions.

Third, a major purpose of planning is to identify and analyze alternative improvement strategies and projects, which could include traditional infrastructure projects, but also actions to influence travel behavior and system performance. For example, travel demand management (TDM) strategies, such as variable work hours, rideshare programs, and parking pricing, have become important options in many metropolitan areas for reducing demand for transportation. Likewise, many intelligent transportation system (ITS) actions are not really projects as much as they are efforts to better improve transportation system performance through the use of technology. The planning process in Figure 1-1 provides for a much wider consideration of actions and strategies than what is usually considered part of the transportation planning process.

Figure 1-1 was presented primarily as a structure for planning in the United States. Other countries have their own requirements for transportation planning, or in the case of developing countries, they often follow the guidance of international lending institutions, such as the World Bank. However, although the goals and objectives, models and analysis tools, and strategies might be different from those found in the United States, the overall approach to planning in other countries is still similar to what is shown in Figure 1-1.

A final characteristic of planning proposed here is the periodic feedback provided to the original vision definition, goals statement, and identification of performance measures through system management and operations. System management and operations serves as a major source of information on transportation system performance and thus is an important indicator of system deficiencies or opportunities for improvement.

One of the useful aspects of the process shown in Figure 1-1 is that it provides a framework for assessing how comprehensive a planning process is for addressing specific issues. For example, Table 1-1, structured from Figure 1-1, is an example of how to assess the effectiveness of a transportation planning process with respect to safety issues. Similar constructs could be developed for almost any issue of concern to a community.

B. Linkage to Policy and Other Planning Efforts

Because much of transportation planning has developed in response to the needs of a nation, individual states or provinces and municipalities, a great deal of what a transportation professional does is defined by law. In the United States, for example, the Constitution establishes the structure of government and the powers, responsibilities, and limits of the different branches and levels of government. Those powers vested in the federal government take precedence over the actions and authority of state and local governments. Thus, although state departments of transportation (DOTs) and MPOs focus on state and metropolitan/local issues, respectively, federal law often requires that certain actions be taken. For example, federal law requires that each state and metropolitan area have its own transportation plan. Federal law, interpreted through regulations, requires that the process for developing these plans must have certain characteristics, such as an effective public participation process. In those areas that have not attained air-quality standards as set forth in federal regulations, the transportation system plan, improvement program and selected projects must be found to be in conformance to the adopted air quality plan. It is beyond the scope of this chapter to identify all of the U.S. federal requirements that influence transportation planning; however, some additional description of key laws that transportation planners in the United States will be exposed to is important (for more a more exhaustive presentation of relevant federal laws see [Gayle, 2009; Meyer and Miller, 2014]).

Federal guidance on transportation planning is justified by the importance of transportation to the nation—the economy, national security, and health and welfare of its citizens. It is this national purpose that generates the need for an informed and consistent approach to transportation investment across the nation, especially where federal funds are involved. Congress first established a federal requirement for metropolitan transportation planning in the Federal-Aid

Table 1-1. Assessing the Consideration of Safety in the Transportation Planning Process

Vision

- Is safety incorporated into the current vision statement of the jurisdiction's transportation plan? If not, why not?
- Is safety an important part of the mandates and enabling legislation of key agency participants in the planning process?
- Is safety an important concern to the general public and planning stakeholders? If not, should it be?
- How is safety defined by the community?
- What type of information is necessary and desired to educate the community on the importance of a safe transportation system?

Goals and Objectives

- Is safety incorporated into the current goals and objectives set of the jurisdiction's transportation plan? If not, why not? If so, what, if anything, needs to be changed in the way safety is represented?
- How does the safety goal relate to the community understanding of safety as discovered through the vision development process?
- Does the safety goal lead only to recommended project construction and facility operating strategies, or does it also relate to strategies for enforcement, education, and emergency service provision?
- Does the safety goal reflect the safety challenge of all modes of transportation, that is, is it defined in a multimodal way?
- Are there goal-related objectives that provide more specific directions on how the goal is going to be achieved? Are these objectives measurable?
- Do the objectives reflect the most important safety-related issues facing a jurisdiction?
- Can the desired safety-related characteristic of the transportation system be forecast or predicted? If not, is there a surrogate measure or characteristic that will permit one to determine future safety performance?
- What type of information is necessary and desired to educate the community on the importance of a safe transportation system as it relates to planning goals and objectives?
- If target values are defined in objective statements (for example, fatal crashes will be reduced by 20 percent), have these targets been vetted through a technical process that shows that the target value can be reached?

Performance Measures

- What are the most important safety-related characteristics of the transportation system that have resulted from community outreach efforts to date? If performance measures are used, are these characteristics reflected in the articulated set of performance measures?
- Will the safety performance of the transportation system (as defined in the performance measures) likely respond to the types of strategies and projects that will result from the planning process? That is, are the performance measures sensitive enough to discern changes in performance that will occur after program implementation?
- Are the number of safety performance measures sufficient to address the safety concerns identified in the planning process? Alternatively, are there too many safety measures that could possibly "confuse" one's interpretation of whether safety is improving?
- Does the capability exist to collect the data that are related to the safety performance measures? Is there a high degree of confidence that the data and the data collection techniques will produce valid indicators of safety performance? Who will be responsible for data collection and interpretation?
- Can the safety performance measures link to the evaluation criteria that will be used later in the planning process to assess the relative benefits of one project or strategy over others? If so, can the safety performance measures be forecast or predicted for future years?

(*continued*)

Table 1-1. (*Continued*)

Analysis—Data

- Given the definition of safety that resulted from the visioning and goals/objectives phases of the planning process, what types of data are needed to support the safety desires of the community?
- Are these data available currently? If not, who should collect these data? Are there ways of collecting these data, or are there surrogate data items that can be used to reduce the cost and burdens of data collection?
- Does the state (or region) have a systematic process or program for collecting safety-related data? If not, who should be responsible for developing one?
- Is there a quality assurance/quality control strategy in place to assure the validity of the data collected? If not, who should develop one?
- Are there opportunities to incorporate data collection technologies into new infrastructure projects or vehicle purchases (for example, surveillance cameras or speed sensors)?
- Does the safety database include safety data for all modes of transportation that are relevant to the planning process (for example, pedestrians, bicyclists, transit, intermodal collisions, etc.)? If not, what is the strategy for collecting such data? Who should be responsible?
- What types of database management or data analysis tools are available to best use the data (for example, a geographic information system)? Are such tools available to produce the type of information desired by transportation decision makers?
- Are there other sources of data in your state or region that might have relevant data for safety-related planning (for example, insurance records, hospital admissions, nonprofit organizations, etc.)? If yes, who should approach these groups to negotiate the sharing of data?
- Are there any liability risks associated with the collection and/or reporting of crash data? If so, how can your agency be protected against such risk?

Analysis—Tools

- What is the scale of the safety problem being faced? Regional? Corridor? Site-specific? Are tools available that analyze safety problems at the same scale of analysis?

Source: Washington, Meyer, et al. 2006. Permission granted by the Transportation Research Board.

Highway Act of 1962. To receive federal transportation funds, this law required urbanized areas with a population greater than 50,000 to develop a *continuing, comprehensive* transportation plan that was a *cooperative* venture with state and local governments. This requirement, known as the 3C planning process, still serves as the foundation of today's transportation plans.

The 1973 Federal-Aid Highway Act and subsequent FHWA-Urban Mass Transportation Administration (UMTA) Joint Regulations on Transportation Planning had a profound impact on the institutional responsibilities for transportation planning. For the first time, federally supported urban transportation planning was funded separately: half of 1 percent of all federal-aid funds were designated for this purpose and apportioned to the states on the basis of urbanized area population. These funds were to be made available to "metropolitan planning organizations (MPOs) responsible for comprehensive transportation planning in urban areas." The Joint Planning regulations thus required that an entity called the metropolitan planning organization be established in every urbanized area with a population of more than 50,000.

A multiyear prospectus and annual unified work program had to be submitted specifying all transportation-related planning activities for an urban area as a condition for receiving federal planning funds. The urban transportation planning process was required to produce a long-range transportation plan, which had to be reviewed annually to confirm its validity. The transportation plan had to contain a long-range element and a shorter-range "transportation systems management element" (TSME) for improving the operation of existing transportation systems without new facilities. A multiyear "transportation improvement program" (TIP) also had to be developed consistent with the transportation plan. The TIP had to include all highway and transit projects to be implemented within the coming five years. The TIP had to contain an "annual element" that would be the basis for the federal funding decisions on projects for the coming year. The consequences of these requirements were that they changed the emphasis from long-term planning to shorter range transportation system management, and provided a stronger linkage between planning and programming. [Weiner, 1992, 2008] Most of these requirements, except the TSME of the long-range transportation plan, are still operative today.

In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) ushered in what many saw as a new era for transportation planning in the United States at both the metropolitan and statewide levels. This law fully established MPOs as the central forum for making transportation planning and investment decisions in metropolitan areas; it required a robust public involvement process, and it provided new flexibility in the use of federal capital program funds so that MPOs and states could find the best solutions to their transportation problems, rather than funding projects that fit the eligibility requirements of specific categorical funding programs. Different planning factors were to be addressed in the transportation planning process, including the need for the plan to be multimodal and intermodal, and to better understand the linkage between land use and transportation. ISTEA also required that both the plan and the TIP be fiscally constrained to only those projects that had a reasonable expectation of funding.

Prior to ISTEA, there was no federal requirement for statewide transportation planning, although many states do such planning. Along with the new requirements for metropolitan planning, ISTEA required states to create a planning process that would produce a long-range, intermodal statewide transportation plan and a short-range program of projects. While the process and content of the statewide plan did not have to be as rigorous as the MPO plan, Congress did include a list of planning factors that states were to consider.

The Moving Ahead for Progress in the 21st Century Act (MAP-21) passed in 2012 consolidated numerous categorical funding programs into a much smaller number of programs. For transportation planning, its biggest impact was in its requirement for state DOTs and MPOs to adopt performance measures. [FHWA, 2014a] The U.S. DOT was required to establish performance measures for safety, pavement conditions, bridge conditions, operational performance of the Interstate, operational performance of the non-interstates on the National Highway System (NHS), freight movements, mobile source emissions, and congestion. For transit, the U.S. DOT must "establish a national transit asset management system and performance measures for keeping transit in a state of good repair." States and MPOs were to establish targets for each performance measure, and adopt a "performance-based approach" in planning and programming transportation projects. This performance-based planning and programming approach was more than just imposing performance measures on states and MPOs; it also required MPOs to measure and report on the outcome of investments from the TIP/STIP as they affected the travelling public. [FHWA, 2014a]

In recognition of the important role that freight plays in the national, state, and regional economies, MAP-21 required the U.S. DOT to report biennially on the conditions and performance of the "national freight network," and to develop tools for "an outcome-oriented, performance-based approach to evaluate proposed freight-related and other transportation projects." The transportation goals specified in this law for the federal highway programs included:

- "*Safety* — To achieve a significant reduction in traffic fatalities and serious injuries on all public roads.
- *Infrastructure Condition* — To maintain the highway infrastructure asset system in a state of good repair.
- *Congestion Reduction* — To achieve a significant reduction in congestion on the National Highway System.
- *System Reliability* — To improve the efficiency of the surface transportation system.
- *Freight Movement and Economic Vitality* — To improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development.
- *Environmental Sustainability* — To enhance the performance of the transportation system while protecting and enhancing the natural environment.
- *Reduced Project Delivery Delays* — To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices." [FHWA, 2014b]

The most recent federal transportation legislation (as of the date of publication of this handbook) is the Fixing America's Surface Transportation (FAST) Act. This law reaffirmed the planning requirements of MAP-21 and added the following requirements to the metropolitan planning process.

- "Continue to require metropolitan transportation plans and transportation improvement programs (TIPs) to provide for facilities that enable an intermodal transportation system, including pedestrian and bicycle facilities. It adds to this list other facilities that support intercity transportation (including intercity buses, intercity bus facilities, and commuter vanpool providers).
- Expand the scope of consideration of the metropolitan planning process to include: improving transportation system resiliency and reliability; reducing (or mitigating) the stormwater impacts of surface transportation; and enhancing travel and tourism. Specifically, it required the consideration of strategies to reduce the vulnerability of existing transportation infrastructure to natural disasters. [FHWA, 2016]
- Add public ports and certain private providers of transportation, including intercity bus operators and employer-based commuting programs to the list of interested parties that an MPO must provide with reasonable opportunity to comment on the transportation plan."

Given that transportation plays such a critical role in a nation's economy and in promoting the well-being of its citizens, it should be no surprise that transportation is part of many other legislative initiatives aimed at achieving nontransportation goals such as economic development and environmental quality. Again, it is beyond the scope of this handbook to identify all such laws. In terms of impact on transportation planning and project development, the most notable are the National Environmental Policy Act (NEPA), the Clean Air Act (and its amendments), and the Americans With Disabilities Act (ADA). [Gayle, 2009] Chapter 4 on environmental considerations in the planning process discusses these and other laws and regulations relating to environmental factors; chapter 12 and chapter 13 on transit planning and pedestrian and bicycle planning, respectively, describe ADA requirements for transit and pedestrian facilities; and chapter 15 and chapter 16 discuss the laws and regulations relating specifically to statewide and metropolitan transportation, respectively.

State governments also create and enforce laws relating to transportation (where not superseded by federal law). For example, a state can pass laws regulating the licensing and operations of trucks or other vehicles moving freight, but state laws cannot impede interstate commerce, which is protected by the Constitution. State laws are important in transportation for several reasons. First, they create the institutional structure for transportation planning at the state and, in many cases, metropolitan levels. That is, state DOTs and their roles and responsibilities are defined in state statutes, as are the roles and responsibilities of MPOs. Second, local units of government such as cities and counties are created by state governments. These local governments often cannot adopt laws and policies or raise taxes without enabling legislation from the state legislature. For example, in most states, a city cannot adopt a sales tax for transportation purposes without approval from the state. Third, state governments pass laws that can have significant impact on transportation planning. In Washington state and California, for example, state environmental laws require that statewide and metropolitan transportation plans undergo an environmental review to determine potential environmental consequences of the plan's proposed investment strategy. Finally, state governments establish their own sources of funding for transportation investment, which are even more important than federal sources for supporting a state's transportation system.

Similar to federal laws that recognize transportation's influential role in achieving nontransportation goals, other types of state-mandated planning often include transportation as a means of accomplishing program goals and objectives. Some examples of the linkage between transportation planning and other planning efforts are provided below to illustrate how transportation planning influences, and is influenced by, other planning activities.

Oregon: In many states, land use planning is the responsibility of local governments with only minimal guidance from state law. In 1973, the state of Oregon established the Land Conservation and Development Commission along with fairly rigorous (at least by the standards of most states) policy requirements for local planning. Subsequent goals adopted by the commission, which by reference have the force of law, cover numerous topics including the relationship between transportation and urbanization. The adopted transportation goal spells out the required content of transportation plans, while the urbanization goal includes adopting urban growth boundaries. In Oregon, state law clearly influences the range of actions to be considered in the transportation planning process. [Abbot, 2014]

New Hampshire: Transportation plans often demonstrate the need for future travel corridors in a metropolitan area or state, whether highway or transit. However, once a corridor is designated in a plan, developers may see it as a preferred development site because of improved access. If future rights of way are built upon, the construction of the planned facility will be more expensive because of higher land acquisition cost. The New Hampshire legislature passed a law permitting the commissioner of transportation to designate corridors for planning purposes that provides both funding flexibility and land use protection (called corridor preservation). [New Hampshire Statutes, 1993]

Georgia: Many states require local jurisdictions to conduct comprehensive planning and to prepare plans that foster orderly growth. Georgia's local comprehensive planning law requires the evaluation of the following transportation assets as part of a community's comprehensive plan. [Georgia DCA, 2013]

- Road network: Roads, highways, and bridges.
- Alternative modes: Bicycle, pedestrian facilities, public transportation, or other services for populations without automobiles.
- Parking: Areas with insufficient parking or inadequate parking facilities.
- Railroads, trucking, port facilities, and airports.
- Transportation policies, programs, and projects and their alignment with local land use development policies.

Many states have passed smart growth legislation whose purpose is to guide development in the state and in communities where transportation or other infrastructure already exists or where it can be provided through developer contributions. Chapter 3 describes smart growth efforts in more detail.

Local governments, such as counties, cities, towns, and municipalities, also pass laws to protect the health, safety, and general welfare of their citizens. Local governments can influence transportation planning through their control of local street systems as well as their legal responsibilities for land-use zoning. Zoning ordinances empower local governments to take actions that protect the health, safety, and general welfare of their populace. These local policy and regulatory roles are critical to metropolitan transportation planning because of the close linkage between transportation and land use. As comprehensive plans and zoning codes define the location of different land uses and the density of development, they create over time an urban form that places demands and constraints on the transportation system. In addition, the provision or improvements to the transportation system can influence where development occurs. If both do not proceed in a coordinated fashion, the respective decisions may not always be compatible.

Local governments use a number of legal tools to address traffic impacts, including access management regulations, Complete Street requirements, impact fees and adequate public facilities ordinances. Some notable examples include:

- *Access management* is a strategy to reduce the number of conflict points on arterial streets, thereby increasing both capacity and safety. It is applied primarily where there is continuous retail and commercial development along an arterial road, where the tendency is for each site to have its own driveway access points.
- *Adequate public facilities ordinances* were developed in response to the need for public agencies to provide infrastructure to accommodate the needs of private development. Such ordinances are used to assure that public schools, roads, sewers, police and rescue response times, and/or other infrastructure or services are "adequate" to support proposed new development. For example, large subdivisions were often built with the developer providing only the internal infrastructure. The presumption was that the local government, pleased with the addition to its property tax base, would solve any resulting problems of traffic congestion, overcrowded schools, lack of public parks, demands on sanitary sewers and treatment plants, and so forth. Local governments in growing regions came to understand that the cost of providing all of the supporting infrastructure and services could outweigh the tax benefits of the development. The response was adopted ordinances requiring developers either to demonstrate the availability of adequate public facilities or to build whatever may be necessary to accommodate the needs of the new residents.
- *Traffic or transportation impact fees* are used by governments to internalize the cost of transportation improvements associated with development proposals. Such fees are typically enabled by state law and created by local government ordinance. The revenue generated by the fee is used by the local government to defray the cost of off-site transportation improvements. This model is most often used in high-growth areas as a way to capture the cumulative impact of numerous individual site developments.

More is said about the tools available to local communities and their impact on transportation planning in chapter 3 on land use.

The preceding discussion focused on the U.S. policy and legal context for transportation planning. Other countries have similar structures establishing the legal foundation for planning activities (countries in the British Commonwealth, for example, have a long legacy of comprehensive planning legislation that has included transportation in significant ways). Transportation planning, no matter where practiced, reflects the institutional structure for such planning established by national, state/provincial, and local governments. In addition, transportation planning is influenced by the societal, economic, and technological factors that define the context within which transportation planning occurs. As such, it is important for transportation planners to think about those trends and the likely characteristics of the future that will influence the use and performance of the transportation system.

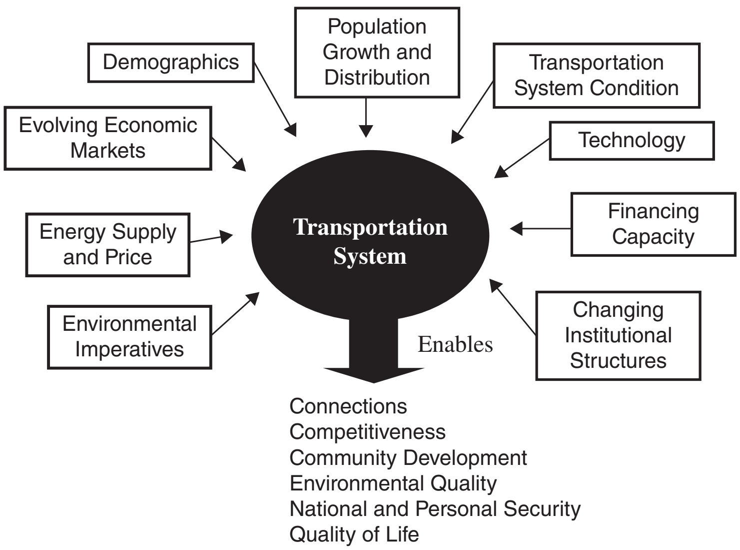
IV. CHANGING CONTEXT FOR TRANSPORTATION PLANNING

The issues considered in a transportation planning process often reflect the changing characteristics of society as a whole. In addition, changes in economic markets and transportation technology often provide challenges as well as opportunities to enhance transportation system performance. Figure 1-2 presents one way of looking at how these changes feed into a planning vision. As noted by Meyer (2007), the 10 factors likely to influence how transportation systems are planned and perform in the future include:

1. Population Growth

Population growth and where populations locate place increasing pressures on governments at all levels to provide transportation infrastructure and services, even though the mechanisms for providing this service might be very different from historical practice. The United States will see an increase in population over the next several decades, with immigration providing a large portion of this increase. For example, the 30 years between 2015 and 2045 will see 70 million more people added to the U.S. population, more population than currently in New York, Florida, and Texas combined. [U.S. DOT, 2015] In the absence of policies that influence development patterns, a large portion of this growth will likely continue to occur in suburban areas. However, center cities are also likely to experience growth (depending on the metropolitan area), especially as "empty nesters" move back into urban centers.

Figure 1-2. Changing Context of Transportation Planning



Source: Meyer, 2007, Reproduced with permission of M. Meyer.

2. Changing Demographics

The aging and changing demographics of the U.S. population will have profound and lasting effects on personal transport and will increase demands for services to population groups that could be very different than today, such as the elderly. For example, on average, Americans over the age of 65 drive half the amount of Americans aged 25 to 64. In 2009, Americans between the ages of 18 and 34 drove 21 percent fewer miles than those in that age group did in 2001. Between 2000 and 2013, the population of low-income Americans in suburbs grew twice as fast as low-income populations in cities. [U.S. DOT, 2015] New demands for housing choices and community services; improved access to cultural and recreational sites; and easy access to interstate travel all lead to a transportation system that is not focused as much on aggregate flows as it is on individual and group travel patterns.

3. Evolving Economic (and Thus Geographic) Markets

Future U.S. economic success will be tied closely to the ability of the nation's economic centers or megaregions to connect to the global economy. For example, in 2008, eleven identified megaregions in the United States included 75 percent of the U.S. population and employment, more than 80 percent of the gross regional products, 92 percent of the Fortune 500 company headquarters, and were the source of over 92 percent of the patents issued in the United States. [Ross and Woo, 2011] This suggests that not only should transportation investment be focused on the nation's major ports of entry and the transportation facilities serving them, it should also be focused on the effectiveness of the internal transportation system in these economic centers.

4. Transportation System Preservation

It is safe to say that system preservation already dominates transportation program expenditure in many countries; this is not an emerging issue as much as a consequence of the age of infrastructure building boom of the 1960s–1970s. Of the 607,000 public road bridges in the United States, about 67,000 were classified as structurally deficient in 2012 and another 85,000 were classified as functionally obsolete. Over the past 10 years, more than 15 percent of state capital spending on highways has gone to bridge rehabilitation and replacement. [U.S. DOT, 2015] Although certainly not one of the most stimulating issues in political forums, preserving and maintaining the existing transportation system infrastructure will increase in importance even more during the next several decades. In most states and metropolitan areas, these needs will dominate investment priorities in the near future.

5. Transportation System Resiliency

Transportation systems tend to be vulnerable to disruption from natural or man-made causes. It is not surprising that the largest number of targets for terrorist attacks around the world is some component of a transportation system. . . . buses in Israel, the Tokyo subway system, buses in London, commuter rail in Madrid, and reported attempts to derail Amtrak trains in the United States. Extreme weather events, such as hurricanes, heavy precipitation storms resulting in floods, extreme temperatures, drought, and tornadoes, also often cause major disruptions to a transportation system. Hurricanes Katrina and Sandy in the United States, for example, caused billions of dollars in damage to roads, bridges, railroads, airports, and ferry terminals. Over the longer term, climate change could exacerbate the risk of transportation system disruption from weather events. Transportation planners and engineers need to be concerned about how to plan and design transportation systems that are not only resilient—that is, systems that can survive and/or recover quickly from disruptions—but also systems that can act as lifelines for emergency relief and recovery after a disaster occurs.

6. Technology

Modern society is largely defined by the technologies used to support individuals' everyday activities and the foundational technologies that keep communities functioning, such as water, transportation, waste removal, and power technologies. Absent any major disruption in the nation's economic structure, new technologies will likely play a significant role in how the nation and individual citizens conduct their business in future years. This is likely to be especially true for the management and use of the transportation system. Of particular interest today is the rapid technological advancements in autonomous (self-driving) vehicles, the application of vehicle-to-infrastructure technologies, and 3D printing (used in long-distance manufacturing). A recent U.S. DOT report on the future of transportation identified the following likely characteristics of technology applications in transportation. [U.S. DOT, 2015]

- Data collection and analysis will become cheap and widespread.
- Payment (for transportation) will be easy, frequent, and inexpensive.
- New methods of payment will enable transportation agencies to develop more targeted user-fee-based revenue streams.
- 3D printing has the potential to disrupt traditional supply chains and counteract the growth of imports by reducing the need for large-scale manufacturing, transportation, and storage.
- Robotics research is advancing across all transportation modes.
- Automation will have a potentially transformative impact across all transportation modes, increasing productivity, improving safety, and enhancing the capacity of existing infrastructure.
- The automation of motor vehicles is likely, and has the potential to revolutionize ground transportation.
- While many emerging technologies could have major safety and security benefits when applied to transportation, in some cases they could also create new vulnerabilities.
- Rapidly evolving technology will demand government flexibility: regulations may be necessary, but in order to advance and encourage innovation, not prevent it. Government must also ensure the primacy of safety as new technologies are implemented.

The implications of these new technologies on transportation system decision making and finance are largely unknown.

7. Financing Capacities

Increasing vehicle fuel efficiency and reduced vehicle miles traveled resulted in an inflation-adjusted federal gas tax revenue decline of $15 billion, or 31 percent, from 2002 to 2012. Over the same period, state gas tax revenues decreased by $10 billion, or 19 percent, adjusting for inflation. The FHWA has estimated that at least $24 billion in additional capital spending would be required from all levels of government to improve highway system performance. [U.S. DOT, 2015] The future will see a much wider variety of financing strategies used to support the transportation system. In the short term, however, the gasoline tax will likely continue as the major source of road financing. New finance strategies will include a combination of public and private initiatives and the application of pricing schemes resulting in some additional financial resources.

8. Changing Institutional Structures

Due to the changing financing strategies of future investment programs and the geographic definition of markets, future institutional arrangements will likely include many different structures and strategies than are seen today. For example, one is likely to see more regional organizations focusing on problems and challenges that cross jurisdictional boundaries. Likewise, given the local nature of many transportation problems, many regions will likely see a growth in transportation-related civic groups. In addition, as noted above, private companies and firms will play a more important role in transportation finance.

9. Environmental Imperatives

One of the most significant factors affecting the future of transportation decision making is likely to be the continuing public and policy concern for preserving and enhancing environmental quality. Traditionally, this has included concerns for air quality, noise, water quality, habitat and wildlife preservation, and the like. In the future, this concern will likely include attention to the emission of greenhouse carbon gases and their long-term impact on the climate. Many areas of the world and in the United States are already experiencing higher-than-normal extreme weather events. Such events coupled with the longer-term challenges given a changing climate (for example, sea level elevation for coastal communities) represent one of the most important emerging environmental imperatives in many communities around the world.

10. Energy

Energy supplies and pricing in the long term could be one of the defining characteristics of how the U.S. transportation system is managed and used. Moving toward energy independence will require a concerted effort over many decades in both developing and implementing new technologies to transform the U.S. transportation system. With the discovery of new sources of petroleum in the United States, it is not clear whether future prices will increase (in relative terms), fluctuate as they have in the past, or remain at low levels due to overproduction. Given that the transportation system is one of the highest consumers of petroleum-based fuels, the price of fuel, and/or the substitution of petroleum-based fuels with alternative fuels, could be one of the most important factors influencing future transportation demand and travel behavior.

Many issues unforeseen today could also become critical considerations for transportation planning in the years ahead. No matter what form these issues take, this handbook's basic approach is that the planning framework shown in Figure 1-1 can be used to provide the best possible approach to problem solving.

V. ADDITIONAL SOURCES OF INFORMATION

Many different organizations provide information on transportation planning and on the various aspects of how transportation affects a community. Every state DOT and MPO has information on their respective websites relating to the issues facing the state or metropolitan area. Federal agencies such as the U.S. DOT, FHWA, Federal Transit Administration (FTA), and Environmental Protection Agency (EPA) also produce technical guidance and reports on transportation planning topics. For example, one of the most recent reports from the U.S. DOT, *Beyond Traffic,* provides an excellent background on the trends that are likely to affect the future of transportation. [U.S. DOT, 2015]

Among professional organizations, the American Association of State Highway and Transportation Officials (AASHTO), the American Planning Association (APA), the Association of Metropolitan Planning Organizations (AMPO), the National Association of Regional Councils (NARC), and the Institute of Transportation Engineers (ITE) provide books and reports on different aspects of transportation planning.

The Transportation Research Board (TRB) is one of the major sources of information on the latest concepts and approaches used by transportation planners. The TRB *Journal of the Transportation Research Board* annually publishes articles on a wide-ranging set of topics as well as research reports from the National Cooperative Highway Research Program (NCHRP), Transit Cooperative Research Program (TCRP), National Cooperative Freight Research Program (NCFRP), and the Strategic Highway Research Program 2 (SHRP 2). For example, NCHRP recently published a series of future-looking reports focusing on the following topics that are highly relevant to transportation planning:

- Freight: Economic Changes Driving Future Freight Transportation
- Climate Change: Climate Change and the Highway System: Impacts and Adaptation Approaches
- Technology: Expediting Future Technologies for Enhancing Transportation System Performance
- Sustainability: Sustainability as an Organizing Principle for Transportation Agencies
- Energy: Preparing State Transportation Agencies for an Uncertain Energy Future
- Socio-Demographics: The Effects of Socio-Demographics on Future Travel Demand

Interested readers are referred to: http://www.trb.org/NCHRP750/ForesightReport750SeriesReports.aspx.

SHRP also produced a useful web tool called *PlanWorks*, which allows planners to identify different components of the transportation planning process to obtain information on the data and tools that are available (see https://fhwaapps.fhwa.dot.gov/planworks/DecisionGuide).

It is also not unusual for nonprofit organizations to produce technical guides and information reports on targeted topics, such as pedestrian and bicyclist planning, transit planning, and public participation.

The reader is encouraged to search these and other sources for the latest information on transportation planning.

VI. SUMMARY

The rest of this handbook describes key components of the transportation planning process and presents tools that transportation planners can use to provide information for those who make decisions. Any transportation planning process consists of multiple steps, with the scope and scale of each step depending on the context of a planning study. Planning begins with "understanding the problems," which could include nothing more than an analysis of the latest data (for example, crash statistics) to a much more involved public participation process that provides planners with a range of input on the challenges facing a study area. The next steps in the process include identifying goals, objectives, and performance measures. This step is critical for defining the criteria to be used later to assess the relative effectiveness of different alternatives and thus in identifying the types of tools and data to be used during the analysis. The following analysis step consists of the data, analysis tools, and models used to identify the likely impacts or consequences of implementing different strategies or actions. This is the step that has received most attention through the decades in terms of model enhancements and improved data collection techniques.

The next step, evaluation, is perhaps most closely linked to the major purpose of planning, that is, to provide information to those making decisions. Evaluation takes the information from the analysis step and determines the trade-offs associated with pursuing one alternative versus another. This usually involves extensive public engagement as well as the application of methodologies, such as benefit/cost analysis, that allow the planner to assess the relative merits of alternatives. The results of evaluation then feed into a plan (in a more formal planning process) or in reality can lead to a range of actions … additional studies, investment strategies, enforcement/education efforts, and so on. In the United States, a formal plan is required for every urbanized area over a 50,000 population. In addition, a transportation improvement program (TIP) is required that lays out the project priorities and agency responsibilities for delivering the capital program. Over time, the impact of these new investments on the performance of the transportation system are reflected in the ongoing monitoring program and then fed back into performance measures … and the planning process begins again.

The transportation planning process lays the foundation for the decisions to improve the transportation system. Accordingly, it is important that transportation professionals understand the key components of the process, and are familiar with the analysis and evaluation approaches that are typically used as part of this process. The following chapters provide such an understanding.

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Travel Characteristics and Data[1]

I. INTRODUCTION

Understanding how and why travel occurs is one of the most important tasks of transportation planning. Every planning study begins with a review of the data available on the use and performance of the current transportation system. Not only are such data critical for identifying where problems exist today or will likely exist in the future, these data are also often used to develop analysis tools and models that predict future trip-making patterns and behavior. Performance and condition characteristics of an urban area's transportation system also serve as criteria for evaluating the relative effectiveness of investment options. For example, defining and identifying congested road segments not only pinpoints locations where improvements are needed, but also the impact of these strategies on congestion becomes an important measure for determining which set of strategies will be most cost-effective in other locations. Given the importance of data to the planning process, it is not surprising that many transportation planning studies spend a considerable amount of the budget on data collection and analysis.

The type of transportation system information important for transportation planning varies according to the overall goals of the transportation decision-making process. For example, the owners of transportation infrastructure might be concerned about the physical condition of roads and bridges and spend considerable time monitoring asset condition (see chapter 8 on asset management). Those interested in operating transportation systems might focus on characteristics of system use, such as average delay, safety, travel reliability, measures of throughput, and bottleneck locations. Planning agencies concerned about the system's future ability to handle demands might be most interested in measures of capacity as well as operating characteristics.

It is beyond the scope of this chapter to describe all of the possible measures of system condition and performance and, therefore, the data and information produced by the planning process. Interested readers are referred to the biennial report to Congress prepared by the Federal Highway Administration (FHWA) on highway and transit condition and performance for a comprehensive examination of a range of system performance and condition measures (FHWA, 2013a). Subsequent chapters in this handbook discuss in greater detail the system performance measures that are most useful for particular planning issues. This chapter focuses on the most common data and information used in transportation planning.

II. TRANSPORTATION SYSTEM CHARACTERISTICS

Several characteristics of the transportation system are measured and used in almost every transportation planning process. This section discusses five of these characteristics: functional classification, system extent, system usage, system performance/capacity, and system condition.

A. Functional Classification

Transportation system data are categorized in a variety of ways to allow transportation professionals to understand the performance of different components of the system for which they are responsible. System-level measures, such as crash rates, pavement condition levels and average travel time, provide a broad overview of how the system is performing, and provide a context for strategic decisions about where additional investment at the

[1]The original chapter in Volume 3 of this handbook was written by Marsha D. Anderson Bomar, Stantec, Inc. Changes made to this updated chapter are solely the responsibility of the editor.

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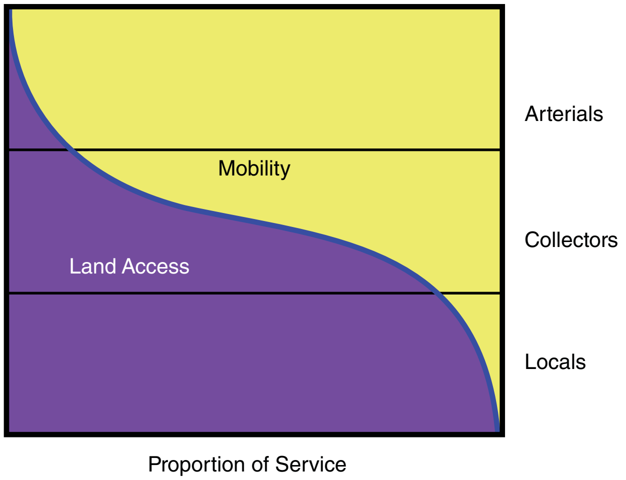
program level might be necessary. A more detailed examination of the data, however, could be useful in understanding where problems exist and what types of strategies might be appropriate. For example, crash rates and the types of crashes occurring on interstate highways are very different from those occurring on rural two-lane highways. Performance characteristics for bus services are very different from those for rail lines. To provide more useful information about transportation system performance, transportation engineers and planners categorize data using different classification schemes.

A basic characterization of the road network used in many parts of the world is to describe different road segments by the function they serve in the network. Roads that are high on the functional classification scale provide mobility, while roads with lower classifications serve an accessibility role (see Figure 2-1). Typical road functional classifications include:

Figure 2-1. Relationship Between Road Classification and Road Function



Source: Federal Highway Administration, *Our Nation's Highways 2011* http://www.fhwa.dot.gov/policyinformation/pubs/hf/pl11028/onh2011.pdf

Interstates are highest level of arterials with the longest uninterrupted distances and the highest speeds.

Other Arterials include other forms of limited access roads as well as connections to major urbanized areas and tie the national defense system (the interstates) to the cities and industrial centers.

Collectors involve both land access and traffic circulation. They link local roads to arterials and are generally lower-speed facilities.

Local Roads primarily serve the adjacent land use with access to higher-order roads.

In 2013, there were just over 4 million miles of road in the United States. [BTS, 2015] The availability and use of these roads are shown by functional class in Table 2-1. As can be seen, the higher classified roads, that is, the interstates and arterials, constitute 11.2 percent of the nation's road mileage, but 71.9 percent of the vehicle miles traveled (out of a total 2.97 trillion miles).

It should be noted that this traditional way of classifying the role of transportation facilities has been criticized because of its focus on the role of individual facilities in the transportation system, rather than the role they play in the surrounding community. This concept has also been found in design approaches called *context-sensitive solutions (CSS)* and *Complete Streets*, which encourage road designs that better "fit" into the community and natural environment. Chapter 3 on land use and urban design and chapter 9 on road and highway planning discuss both concepts in more detail.

B. System Extent

The extent of a transportation system relates to the size or number of assets that compose that system. For example, a state or metropolitan area might have *x* miles of interstate highways, *y* number of transit vehicles, and *z* number of airports. This information, which is often incorporated into an *inventory* database, is used to compare one system to another and to calculate productivity factors for agency operations (such as dollars expended per lane-mile of major arterial road or per bus seat-mile). The inventory is also used to define ownership of the different transportation assets. Table 2-2 shows the extent of the U.S. transportation system.

Statistics on the extent of state road networks can be found in the Federal Highway Administration's (FHWA) *Highway Statistics* series. Similar types of information for transit systems can be found in the Federal Transit Administration's (FTA) National Transit Database (NTD). Other statistics on the U.S. transportation system can be found at the Bureau of Transportation Statistics (BTS) website, www.bts.gov, and in Canada at the website for Statistics Canada, http://www5.statcan.gc.ca/subject-sujet/theme-theme.action?pid=4006&lang=eng&more=0.

Table 2-1. Percentage of Highway Miles, Bridges, and Vehicle Miles Traveled by Functional System, United States, 2013 (2015 for Bridges)			
Functional System	**Miles**	**Vehicle Miles Traveled**	**Bridges**
Rural Areas			
Interstate	0.7%	7.8%	4.1%
Other freeway and expressway	0.1	0.7	NA[a]
Other principal arterial	2.2	6.5	6.0
Minor arterial	3.2	4.8	6.2
Major collector	10.1	5.6	15.1
Minor collector	6.4	1.8	7.8
Local	48.7	4.3	33.2
Subtotal Rural	71.4	31.5	72.4
Urban Areas			
Interstate	0.4%	16.9%	5.2%
Other freeway and expressway	0.3	7.5	3.4
Other principal arterial	1.6	15.5	4.8
Minor arterial	2.7	12.8	5.0
Major collector	2.9	6.1	3.7
Minor collector	0.1	0.2	NA[a]
Local	20.6	9.5	5.5
Subtotal urban	28.6	68.5	27.6
Total	100.0	100.0	100.0

[a]Bridges on rural other freeway and expressway included under rural other principal arterial; bridges on urban minor collector included under urban major collector

Source: FHWA, 2015

Table 2-2. Extent of the U.S. Transportation System	
Mode	**Components**
Highway	
Public road miles (as of 2013)	4,115,462
Public road lane–miles (as of 2013)	8,656,070
Bridges (as of 2014)	610,749
Air (as of 2014)	
Total number of airports	19,299
General aviation airports	18,762
Rail (as of 2014)	
Class I freight railroad track miles[a]	95,235
Amtrak (passenger) track miles[b]	21,356
Public transit (as of 2013)	
Commuter rail track miles	7,731
Heavy rail track miles	1,622
Light rail track miles[c]	1,836
Water (as of 2013)	
Miles of navigable waterways	25,000
Pipeline	
Miles of gas pipeline	2,149,299
Miles of oil pipeline	19,417
Trade Gateways	
Number of gateways handling $50 billion or more of international trade	21

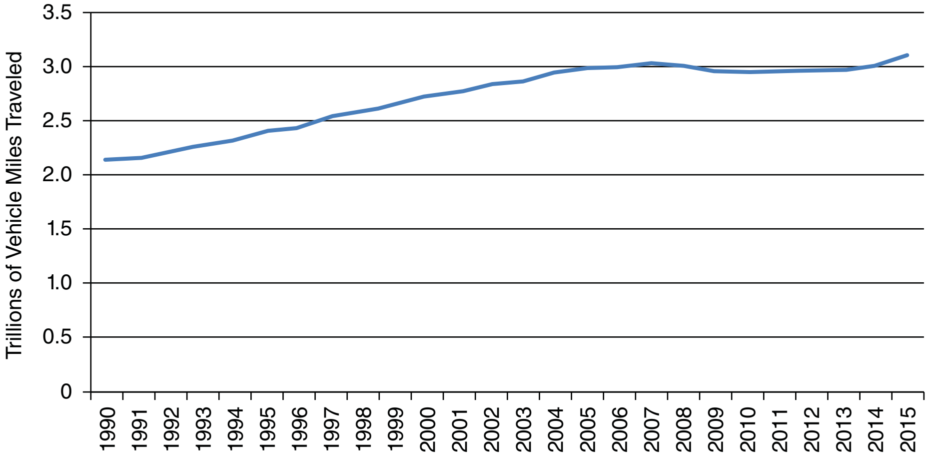
[a]Includes 561 miles of the U.S. Class I freight railroad system owned by Canadian railroads.

[b]Approximately 97 percent of the trackage on which Amtrak operates is owned by other railroads.

[c]Includes directional route-miles on exclusive right-of-way, controlled right-of-way, and mixed traffic.

Source: Bureau of Transportation Statistics. 2015b.

Figure 2-2. Highway Travel in the United States, 1990–2015



Source: BTS, 2015a

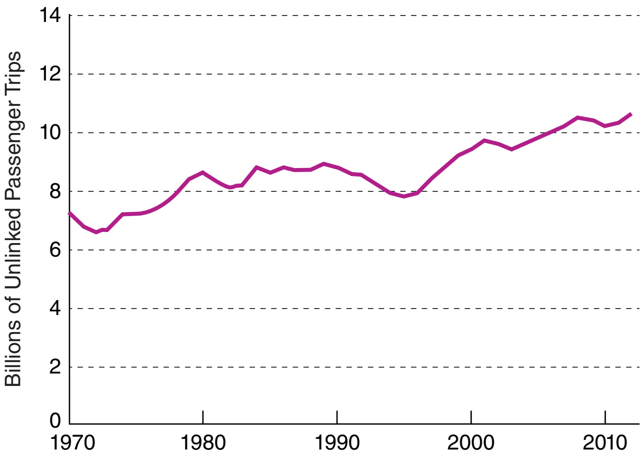
C. System Use

An important indicator of the value of a transportation system is how much it is used. Existing usage is also the baseline for predicting future system use. Thus, transportation planners spend considerable effort in determining the current travel volumes on transportation systems. Such use is particularly impressive for the U.S. road network. In 2013 an estimated 2.9 trillion vehicle-miles were traveled on the U.S. road network. [BTS, 2015a] This was an approximate 38 percent increase from the level estimated in 1990. The data show that urban vehicle-miles traveled (VMT) outpaced those for rural highways, which is a result of both the substantial growth in urban population during this time period and the redesignation of urban area boundaries to place more road mileage within urban areas. However, since the early 2000s, the national VMT has declined and stabilized, as shown in Figure 2-2. The reasons for this include the dampening effect on travel of a national economic recession, more efficient travel patterns, and more urban travelers who use either other modes or have shorter trips. For a good discussion of the impact of an economic recession on travel, see [BTS, 2015b].

With regard to passenger trips, over 4.9 trillion passenger-miles (a person traveling one mile on a mode of transportation) occurred in 2013 on the U.S. transportation network: 4 billion by cars and trucks, 590 billion via airplane, 56.5 billion via passenger transit and intercity bus systems and 7.3 billion on Amtrak (the U.S. national rail service). [BTS, 2015b] Approximately 5.9 trillion ton-miles of freight (one ton moving one mile) moved on the U.S. freight system in 2011, with 2.6 trillion moving by truck, 1.7 trillion by rail, 1 trillion by pipeline, 500 billion by domestic water transportation, and 12 billion ton-miles by aviation. [BTS, 2015b]

Figure 2-3 shows the number of unlinked transit trips in the United States from 1970 to 2012. (Unlinked trips are individual trips on a trip segment. For example, a bus trip that transfers to another bus or a rail trip would be two unlinked trips). As seen in this figure, beginning in the mid-1990s, transit ridership in the United States has begun to increase after years of declining or relatively flat growth. From 1995 to 2009, the percent of U.S. daily trips occurring on bus transit rose from 3.0 percent to 3.3 percent, with rail staying at 0.6 percent (motor vehicle trips accounted for 83.4 percent of daily travel). [BTS, 2015] With respect to walking and bicycling, the percent of U.S. daily travel for these modes rose from 5.5 percent in 1995 to 10.4 percent in 2009 for walking and from 0.9 percent to 1.0 percent for bicycling over the same time period.

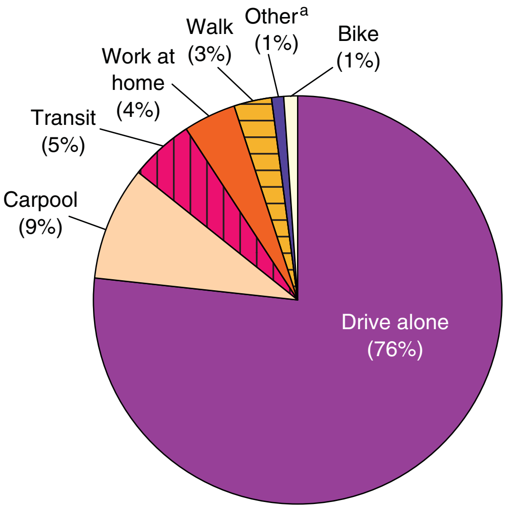
Figure 2-3. Unlinked Passenger Transit Trips, United States, 1970–2012



Source: BTS, 2015

The percent of daily travel by mode will vary by trip purpose and by time of day. Figure 2-4 shows the U.S. mode share for commute trips in 2013. As can be seen, the mode share percentages for the commute trip are different than that described above for all trips taken during the day.

Figure 2-4. Commute Mode Share, United States, 2013



[a] Includes motorcycle, taxi, and other means

Notes: Percents do not add up to 100 due to rounding. The *American Community Survey* asks for the mode usually used by the respondents to get to work. For more than one mode of transportation, respondents select the mode used for most of the distance.

Source: U.S. Department of Commerce, U.S. Census Bureau, American Community Survey, 1-Year Estimates, available at www.census.gov/acs as of September 2014.

D. System Performance

Transportation system performance is one of the most visible and important transportation system characteristics to local decision makers and the general public. Traffic congestion and traffic delays have engaged—and will likely continue to involve—transportation planners and engineers in discussions and debates about how transportation problems can be solved. Several characteristics of system performance, including mobility and accessibility, are key decision criteria and are evaluated and monitored by transportation agencies.

1. Mobility

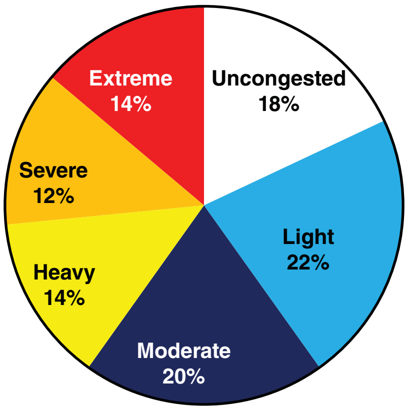
Mobility reflects those travel conditions associated with the ability to travel, such as average speed, delay, congestion levels, and the availability of modal options. Mobility is provided by multiple modes, including many trips that require the use of more than one. For example, driving a car to a work place or school usually includes a walk trip at either end. Many transit trips also include not only walk trips but often transfers to other transit modes. Mobility is thus inherently a part of a multimodal measure of system performance. However, there are very few instances in practice where multimodal measures of mobility have been developed; instead, measures of the individual modal components of a trip are usually reported by planners, for example, levels of congestion on the road network or transit line. The following sections discuss system performance from a modal perspective. The reader should be aware, however, that a true measure of system performance should include the performance contribution from multiple modes.

Road Mobility. The Texas A&M Transportation Institute (TTI) and INRIX produce information biennially on levels of congestion on the U.S. road system. An interesting aspect of the *Urban Mobility Report* is that it represents a combination of data sources, including INRIX data, which are collected via global positioning system (GPS) probe vehicles. As noted in the preface to the report, this represents, "hundreds of speed data points on almost every mile of major road in urban America for almost every 15-minute period of the average day of the week. For the congestion analyst, this means 900 million speeds on 1.3 million miles of U.S. streets and highways."

Figure 2-5 shows data from the Institute's *Urban Mobility Report 2015*. [Schrank et al., 2015] According to the report, "average daily percent of vehicle miles traveled (VMT) under congested conditions" is an indicator of the portion of daily traffic on freeways and other principal arterials in an urbanized area that moves at less than free-flow speeds. As shown in the figure, approximately 40 percent of urban travel in the United States in 2014 occurred in extreme, severe, or heavy congested conditions.

Figure 2-6 shows that the change in the hours of delay per automobile commuter has varied by urbanized area size. In areas with over one million persons, 2014 auto commuters experienced an average of 63 hours of extra travel time, a road network that was congested for 6 hours of the average weekday, and experienced an average congestion "cost" of $1,440 (primarily the value of time lost). Even in small and medium-sized urbanized areas,

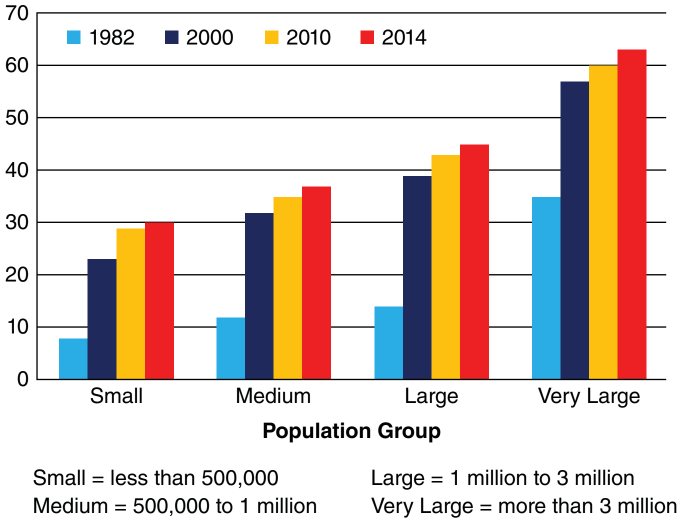
Figure 2-5. Vehicle Travel in Congestion Conditions, United States, 2014



Source: Schrank et al., 2015, Reproduced with permission of the Texas A&M Transportation Institute.

the hours of delay have increased (small urbanized areas are those with a population less than 500,000; medium areas have a population between 500,000 and 999,999; large areas have a population between 1 and 3 million; and very large areas have above 3 million in population). Of course, individual urbanized areas will experience different trends. It is interesting to note that while the hours of delay per automobile commuter increased from 18 to 37 hours between 1982 to 2000, the period from 2000 to 2014 saw this average stabilizing between 40 and 42 hours, primarily due to the impact of an economic recession. [Schrank et al., 2015, Exhibit 2] The cost of congestion, estimated as part of the TTI *Urban Mobility* report, consists primarily of travel time delays, crashes, and fuel. This estimated cost rose from a national total of $24.4 billion in 1982 to $160 billion in 2014 (in $2014).

Figure 2-6. U.S. Congestion Conditions by Year, by Metropolitan Area Size



Source: Schrank et al., 2015, Reproduced with permission of the Texas A&M Transportation Institute.

The *Urban Mobility Report* also measures the *Travel Time Index (TTI)*, a common metric for congested networks used in many planning studies, especially in larger urban areas. The TTI is the ratio of existing motor vehicle trip travel time to the travel time under free-flow conditions. Thus, a TTI value of 1.18 means that travelers take 18 percent (1.18–1.00) more time to travel than a similar trip with no delays. The national TTI value has increased from 1.07 in 1982 to 1.22 in 2014. Not surprisingly, TTI values in 2014 varied by urban area size: very large urban areas (15 total), 1.32; large urban areas (31 total), 1.23; 33 medium urban areas, 1.18; and small urban areas (22 total), 1.14. [Schrank et al., 2015]

Although travel time has historically been the measure of most interest to transportation planners and system operators, there has been a recent shift in interest from absolute travel time toward travel time reliability. The 2015 *Urban Mobility Report* reported on a measure of reliability called the *Planning Time Index (PTI)*. The PTI is "based on the idea that travelers would want to be on time for an important trip 19 out of 20 times; so one would be late only one day per month (on time for 19 out of 20 work days each month)." [Schrank et al., 2015] A PTI value of 3.00 indicates that a traveler should allow 60 minutes to make an important trip that takes 20 minutes in uncongested traffic (3×20). In essence, the 19th worst commute is affected by crashes, weather, special events, and other causes of unreliable travel and can be improved by a range of transportation improvement strategies. Similar to the TTI, the values of PTI vary by size of urban area. Very large urban area freeways had an average PTI value of 3.06 (top three areas were Los Angeles 3.75; Washington, D.C. 3.48; and Seattle 3.41); large urban area freeways had an average of 2.46 (top three areas were Portland, Oregon, 3.27; San Jose, California, 3.24; and Riverside/San Bernardino, California, 3.21); medium-sized urban area freeways had an average of 2.08 (top three areas were New Orleans, 3.46; Bridgeport/Stamford, Connecticut, 3.32; and Baton Rouge, Louisiana, 2.80); and small urban area freeways had an average of 1.76 (top three areas were Boulder, Colorado, 2.48; Stockton, California, 2.27; and Anchorage, Alaska, 2.26).

A recent study forecasts congestion and associated costs for individual households and national economies in the United States, United Kingdom, France, and Germany. The forecasts were based on forecasted levels of urbanization and increased GDP per capita from 2013 to 2030. [INRIX, 2015] The study concluded:

- The combined annual cost of congestion in these countries is expected to increase to $293.1 billion by 2030, an estimated 50 percent increase from 2013.
- The cumulative cost of congestion for the countries combined is estimated to be $4.4 trillion.
- The overall economic impact is greatest in the United States where the estimated cumulative cost of traffic congestion by 2030 is $2.8 trillion.
- The UK (at 66 percent) and London (at 71 percent) will see the greatest annual rise in the cost of congestion by 2030, mainly as a result of seeing the highest increase in urbanization.

- Traffic congestion costs drivers $1,740 in 2014 on average across the four countries. This number is expected to grow more than 60 percent to $2,902 annually by 2030.

Transit Mobility. Data relating to transit system performance in the United States are collected by transit agencies and reported to the National Transit Database (NTD), which is managed by the U.S. Federal Transit Administration (FTA). Average transit vehicle operating speed, an approximate measure of the speed experienced by transit riders, varies by transit mode. In 2010, the average operating speed for heavy rail was 20.2 mph (32.5 kph); for light rail, 15.0 mph (24.1 kph); and for bus, 12.5 mph (20.1 kph). [FHWA, 2013] According to the 2009 National Household Travel Survey (NHTS), 49 percent of all passengers who ride transit wait for 5 minutes or less for a vehicle to arrive, and 75 percent wait 10 minutes or less.

In Canada, the average transit commute travel time by public transit is 44 minutes, varying from 39 minutes in Montreal to 49 minutes in Toronto. Not surprisingly, commute times for public transit for commute trips varies significantly by the residential density of the workers' home neighborhood . . . . 51 minutes for the lowest residential density to 36 minutes for the highest residential density. [Turcotte, 2011]

More meaningful transit performance data is collected by transit agencies so as to provide the best service to their customers. For example, on-time performance is a widely used metric that provides customers with a sense of service reliability. Other measures such as dollar expended per revenue mile, farebox recovery, and percent of the population within ½ mile of transit service are used to provide a broader perspective on the effectiveness of the transit system overall. Additional information on transit system performance is provided in chapter 12 on transit planning.

2. Accessibility

Whereas mobility performance reflects the ease with which travelers can make a trip, accessibility relates to a traveler's ability to reach a destination, and includes such measures as percent of employment within a certain distance of a transit station. In broad terms, mobility is more directly influenced by physical characteristics of the infrastructure and operating characteristics of the system. For example, an interstate highway may provide great mobility, but limited accessibility to adjacent land uses, while a driveway to an office building provides excellent accessibility to that facility, but limited mobility. Accessibility is a function of how a transportation network is structured, but it also depends on land use patterns, available modes, and geographic area. When land is developed with greater density and multiple land uses are clustered together, accessibility to goods and services may be enhanced. In a suburban setting, a combination of walking, driving, riding transit, and using parking facilities may be needed to accomplish a set of tasks or errands. In a dense urban environment with mixed land uses clustered together, it might be possible to reach all of the desired destinations by walking or riding a bus (see chapter 19 on site planning and traffic impact analysis).

Moving people is an important goal of most transportation agencies. In an urban environment, however, restricting access to individual properties may be necessary to allow for the smooth, uninterrupted flow of traffic on the adjacent roads (called access management, see chapters 3 and 19). Accessibility determines the adequacy of the transportation system and the value to related activities, such as commerce, employment, recreation, and overall quality of life. A balance between mobility and accessibility is often necessary to achieve community goals.

3. Safety

Transportation safety is often identified as the most important goal of transportation agencies. Therefore, it is monitored by agencies at the national, state/provincial, and local levels. Four important measures are often used to monitor the trends in transportation safety: number of fatalities, number of injuries, fatalities per100 million vehicle miles traveled (MVMT), and injuries per 100 million vehicle miles traveled. The latter two are called fatality and injury rates, and reflect the amount of exposure travelers will have to the transportation system itself. Note that in some cases, the measures could lead to different conclusions. For example, the number of fatal crashes might increase over a particular time period, but because the number of vehicle miles traveled increased at a proportionately higher percentage, the fatality rate might decrease. So, one indicator suggests that the safety problem has become worse, and the other shows improvement.

Table 2-3 shows the change in crash and injury statistics in the United States from 2002 to 2013. As shown, the trend in every category (except in public transit, motorcyclists, and pedacyclists) has been to fewer fatalities. With respect to injuries, the largest increases have occurred for motorcyclists and transit rail (most likely because of the opening of new services).

Table 2-3. Transportation Fatalities and Injuries, United States, 2002 and 2013				
	2002		2013	
Mode	**Fatalities**	**Injuries**	**Fatalities**	**Injuries**
Aviation	616	337	429	250
Highway	43, 005	2, 925, 758	32, 719	2, 313, 000
Car occupants	20, 569	1, 804, 788	11, 977	1, 296, 000
Motorcyclists	3, 270	64, 713	4, 668	88, 000
Light truck occupants	12, 274	879, 338	9, 155	750, 000
Heavy truck occupants	689	26, 242	691	24, 000
Bus occupants	45	18, 819	48	13, 000
Pedestrians	4, 851	70, 664	4, 735	66, 000
Pedacyclists	665	48, 011	743	48, 000
Other	642	13, 182	702	16, 000
Rail Crashes With Cars				
Highway/road crossings	357	999	231	972
Transit (as of 2012)				
Bus	78	11, 995	97	11, 872
Light rail	13	557	45	888
Heavy rail	73	4, 806	102	7, 212
Commuter rail	116	1, 483	112	1, 575
Water	863	4, 856	642	3, 432

Source: BTS, 2015b

Road Safety. As noted earlier, there is a difference between fatalities and injuries and fatality and injury rates. Just as the number of fatalities and injuries has declined over the past 10 years, so too has the fatality rate. In 1995, the fatality rate per 100 million VMT was 1.73, which dropped to 1.09 in 2013. [Insurance Institute for Highway Safety, 2015] This decrease in rate was due to an increase in VMT as well as an increase in seatbelt use and vehicle safety improvements. Fatality rates are generally lower in urban areas than rural areas and for higher functional systems than lower functional systems. For example in 2010, the fatality rate per 100 million vehicle miles traveled was 2.5 times higher in rural areas than in urban areas (1.83 and 0.73, respectively).

Chapter 23 on safety provides more information on the current performance of the transportation system. From a planning perspective, it is important to note where crashes occur (for example, approximately 40 percent of the total number of crashes in any given year occur at intersections), who is involved in crashes (for example, males aged 20–24 and 85 and older had the highest rates of crash deaths), and the cause of crashes (for example, speeding has been a factor in about 30 percent of crash deaths since 2004).

Good sources for transportation safety statistics include:

- Insurance Institute for Highway Safety (http://www.iihs.org/iihs/topics/t/general-statistics/fatalityfacts/overview-of-fatality-facts/2013#Trends).
- National Highway Traffic Safety Administration (http://www.nhtsa.gov/NCSA).
- U.S. Census (http://www.census.gov/compendia/statab/cats/transportation/motor_vehicle_accidents_and_fatalities.html).

Transit Safety. For transit systems, the number of fatalities increased from 280 in 2002 to 356 in 2012, and fell from 0.66 per 100 million person-miles traveled (PMT) in 2002 to 0.54 per 100 million PMT in 2012. Fatalities, weighted by PMT, are lowest for motorbuses and heavy rail systems. Fatality rates for commuter and light rail are, on average, higher than fatality rates for heavy rail, most likely because of the at-grade road crossings that often characterize these services. Incidents (safety and security combined) and injuries per 100 million PMT declined for all transit modes from 2002 to 2012. Incidents and injuries, when weighted by PMT, are consistently lowest for commuter rail and highest for demand-responsive systems.

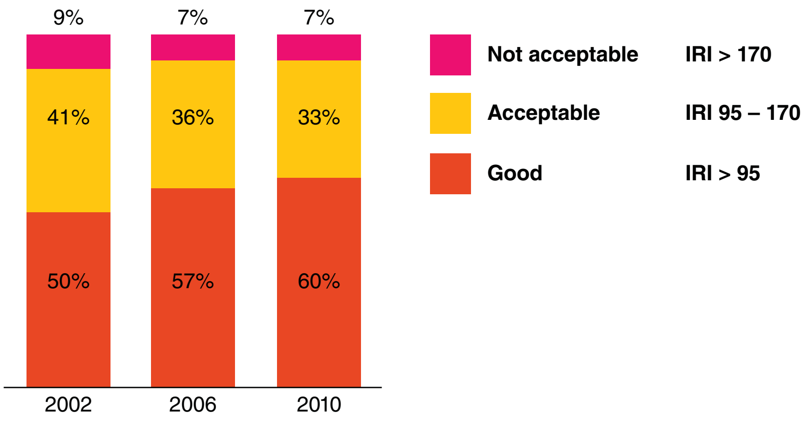
Other Countries. Countries with different legal requirements and enforcement strategies have a very different safety record than the United States. Countries like Australia, Denmark, England, and Sweden have applied very aggressive enforcement strategies and as a result have reduced their fatality levels by more than 50 percent. In contrast, many developing countries experience skyrocketing fatality rates as automobile ownership increases dramatically and as motor vehicle–based mobility has replaced slower modes of transportation. See chapter 23 for further discussion on transportation safety.

4. System Condition

A deteriorating physical condition of transportation system assets is one of the significant challenges facing transportation systems in many countries. In many developed countries, for example, much of the highway and transit infrastructure was built 40 to 50 years ago and is nearing the end of its useful life. Most of the transportation plans in U.S. metropolitan areas have the majority of investment targeted at preserving infrastructure. Data on the condition of transportation infrastructure are critical for identifying investment priorities, such as needs related to deteriorating pavement and bridge conditions (see chapter 9 on road and highway planning).

Figure 2-7 shows the percentage of VMT on the National Highway System (higher functionally classified roads) by pavement rated as "good," "acceptable," and "not acceptable" from 2002 to 2010. As seen, the percent of VMT with "good" ride quality increased between 2002 and 2010, primarily because of improved pavements on rural interstates. For urban areas, the percent of "good" ride quality road miles declined, in this case primarily because of deteriorating pavement conditions on lower functionally classified roads. When weighted by VMT, the percentage of roads with "good" ride quality increased in both urban and rural areas, again because of pavement improvements in the higher functionally classified roads that carry more traffic.

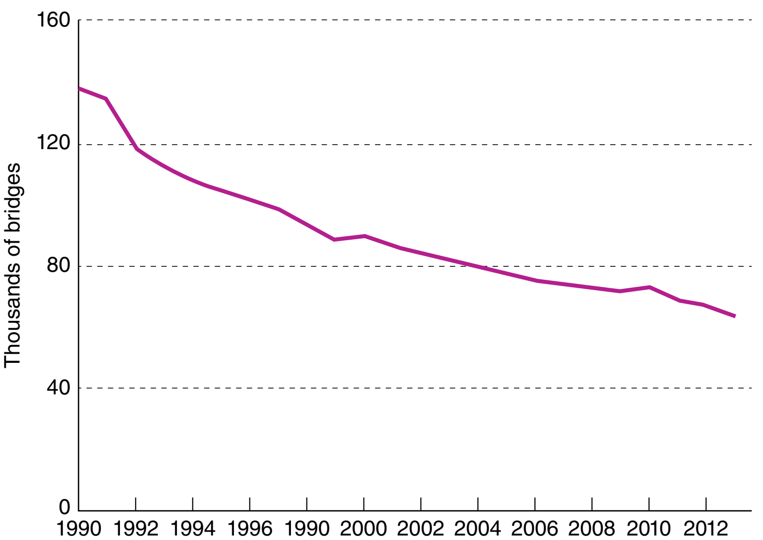
Figure 2-7. Pavement Condition on the National Highway System, United States, 2002–2010



Source: FHWA, 2013a

Figure 2-8 shows the change in structurally deficient bridges in the United States between 1990 and 2013. The bridge assessment process (that is, identifying those bridges that are structurally deficient and/or functionally obsolete) is based on load-carrying capacity, deck geometry, clearances, waterway adequacy, and approach roadway alignment. As noted by FHWA, "structural assessments" together with ratings of the physical condition of key bridge components determine whether a bridge should be classified as "structurally deficient." Functional adequacy is assessed by comparing the existing geometric configurations and design load-carrying capacities to current standards and demands. Disparities between the actual and preferred configurations are used to determine whether a bridge should be classified as "functionally obsolete" (see chapter 9 on road and highway planning). [FHWA, 2013a]

Figure 2-8. Structurally Deficient Bridges, United States, 1990–2013



Source: FHWA, 2013a

With respect to transit, according to the U. S. DOT's *2013 Condition and Performance Report to Congress*, the condition of the nation's urban bus fleet was at the bottom of the "adequate" rating in 2010, with an average vehicle age of 6.1 years. The average condition of rail vehicles was slightly better, but with an average age of 18.9 years. Of some concern, close to 2,000 rail vehicles exceeded 35 years in age. The report also noted that 19 percent of train communications systems, train control systems, and traction power systems were in "poor" condition, and 17 percent of rail guideway elements (such as track) were in "poor" condition.

What this national data on highway and transit infrastructure and vehicle condition suggest is that there is a serious national backlog in needed investments. As seen over the past 10 years in transportation plans and transportation improvement programs, a large share of future investment dollars is going to be allocated simply to keep the existing infrastructure in a state-of-good repair. This raises a serious question of where the dollars are going to come from to invest in new projects (see chapter 5 on transportation finance and funding).

III. URBAN TRAVEL CHARACTERISTICS

Urban travel and trip patterns are influenced by numerous factors. The most important patterns relate to the availability and costs (real and perceived) of different modes of transportation. Thus, for example, if a traveler has an option of reaching a destination by driving, taking a bus, or ridesharing, the decision of which to choose depends on that traveler's perception of how much time each will take, how much it costs, how comfortable and safe it is, and what other activities the traveler might want to accomplish during the trip. The trip patterns resulting from the collective trip-making decisions of an urban area's population are also influenced by population demographics, land-use patterns in the metropolitan area, and the travel options that are available for each type of land use.

Table 2-4 shows how some of the key factors that influence travel behavior have changed since 1969. Each of these factors is an important predictor of some aspect of travel behavior. The following sections present data on these and other characteristics of urban travel and the factors influencing it. It should be noted that much of this data was obtained years ago; for example, much of the travel behavior data is collected by the decennial census, thus reflecting travel behavior and transportation system performance and cost characteristics facing travelers at that point in time. Alan Pisarski has developed a report over the past two decades entitled, *Commuting in America*, largely based on an analysis of the latest Census information. This report series has become an important "big picture" study of the factors that affect commuting in the United States—see http://traveltrends.transportation.org/Pages/default.aspx for the most up-to-date information. Much of the information found in the following sections comes from this document.

Although these data are important for understanding historic patterns in travel behavior, they should not necessarily be viewed as a picture of what behavior might be today or certainly what future behavior might look like. Fuel cost, for example, has been historically low in the United States, which has undoubtedly contributed to the high automobile mode share seen in U.S. urban areas. If fuel costs were to increase significantly, it is likely that some travel behavior would change, and if the cost of energy continued to stay high over the longer term, land-use patterns (and the corresponding effect on travel) might also change. Economic conditions are another strong influence on travel behavior—during economic recessions, traveling declines as more people are without jobs and fewer discretionary trips are taken in order to minimize household costs.

Table 2-4. Change in Factors Influencing Vehicle Travel, United States, 1969–2009

	1969	2009
Total number of drivers	100 million	200 million
Average vehicles per licensed driver	0.7	1.1
Average daily vehicle trips per driver	2.3	3.3
Average daily person miles per household	61.6	95.5
Average daily vehicle miles per household	34.0	58.1
Average household size	3.2	2.6
Percent single-person households	13%	27%

Source: FHWA, 2013b

A. Population Characteristics

Urban travel is heavily influenced by the demographic characteristics of the traveling population. Thus, not surprisingly, transportation planning relies heavily on credible population and employment forecasts. Fifty years ago, the average U.S. household consisted of two young to middle-aged, English-speaking parents, two children, a single wage earner, and minimal disposable income. Today, U.S. households exhibit a range of characteristics, including single adults with no children, many non-English-speaking adults, many older heads of household, and many two-career households of younger adults with substantial disposable income. These characteristics strongly influence where people live, the types of jobs they have, and how time is spent outside the household. All of these activities affect travel behavior.

In the United States and in many other countries, the census is a major source of data on population characteristics. The U.S. Census Bureau provides numerous single-variable tables at different geographic levels, and as well provides special tabulations of key variable relationships (see http://factfinder.census.gov). For many planning efforts, such as establishing the relationships among the variables that influence travel decisions, the Bureau provides public use microdata sample (PUMS) datasets. According to Tierney, PUMS is used by many state DOTs and MPOs for the following reasons:

1) Developing cross-tabulations of variables not readily available from for other sources especially analyses that examine population characteristics of special subpopulations (for example, members of ethnic groups, people of certain ancestries, group quarters residents, or bicycle commuters).
2) Developing cross-tabulations of variables that might already be available to transportation planners, but can now be done with more currency. PUMS data are available on an ongoing basis and thus the most recent data can be used for cross tabulations.
3) Conducting disaggregate analyses at the household- or person-level to develop models relying on the interrelationships among household and person characteristics. PUMS allows the planner to identify variable relationships at the housing unit and person level.
4) Comparing different jurisdictions and regions, PUMS provides common data sets for all regions of the country, which thus allows consistent comparisons.
5) Comparing relationships over time—PUMS data can be used to track changes in housing and person characteristics and changes in the interrelationships between these characteristics over time.
6) Validating other data sources—PUMS data can be used to check relationships based on other data sources, such as travel surveys, demographic estimates, and modeling results. [Tierney, 2012]

The census is an important source of demographic and household data and thus transportation planners should be familiar with how such data is accessed and utilized.

1. Population Growth

Estimating the number of people who will be living, shopping, or working in a study area, usually at some target year (for example, 25 years from today), is often a starting point for many planning studies. The census in most countries is an excellent source of socio-demographic statistics describing national, state, and metropolitan area trends (for the United States, see www.census.gov).

At a national level, the U.S. population is expected to grow over the next 50 years. The current U.S. population is just over 320 million (2015), with a growth of approximately 25 to 30 million each decade. Over the past two decades, substantial immigration to the United States, which is expected to continue albeit at slower rates than historically, has significantly increased the population beyond what would have occurred through natural birth/death rates. Many of these immigrants are 25 to 45 years old and seek jobs, thus immediately becoming part of the commute travel market. Although the U.S. population as a whole is increasing, some regions or communities are expected to grow, while others are expected to lose population. Thus, it is important for every transportation planning study to obtain the latest information on expected population growth or decline in the study area.

The level of population growth is not the only population-related variable used by transportation planners. Another important characteristic is the age distribution of this population. For example, between 2000 and 2010, those older than 55 continuing to work grew by more than 60.8 percent, while the actual numbers of individuals over 55 grew by only 12 percent. This is an important phenomenon because the number of individuals 55 or older will be 28.7 percent of the population by 2020. The number of individuals in the labor force who are 65 years or older is expected to grow 75 percent by 2020, while the number of individuals in the workforce who are 25 to 54 is only expected to grow by 2 percent. In 2016, one-third of the total U.S. workforce is 50 years or older—a group that may number 115 million by 2020. The extent to which many in this age group continue to work will have important implications for transportation.

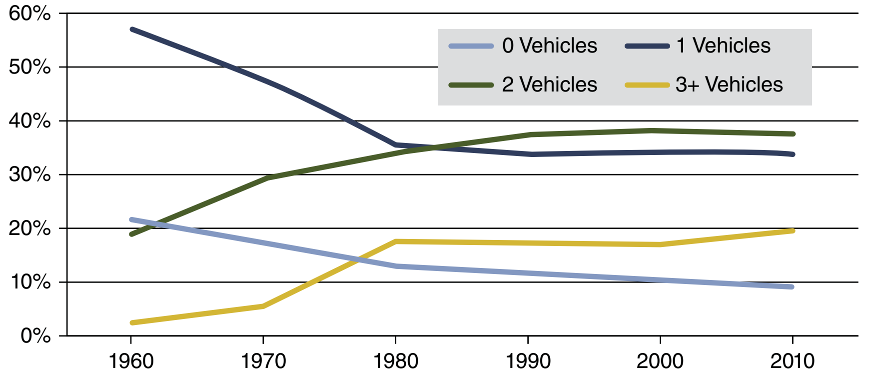
2. Household Characteristics and Vehicle Availability

The household is an important variable in transportation planning because many modeling tools use household characteristics to predict future travel. For example, households with different numbers of workers, automobiles, and/or children will exhibit differences in daily travel behavior. Many data sources, such as those from the U.S. Census, produce and report their information based on households.

As indicated in Table 2-4, the number of persons per household has declined dramatically since 1960, while at the same time the number of households has greatly increased. The number of households has grown at twice the rate of population during the past 40 years, with many of these households being single adults, single parents, elderly, or young childless couples.

Figure 2-9 shows the relationship between households and automobile ownership; the largest shares of households without cars are renters. Figure 2-9 suggests that the percentage of households having a set number of vehicles seems to have stabilized with approximately 38 percent of the U.S. households having two cars, 35 percent having one, 17 percent having three or more, and 10 percent having no vehicles (New York City accounts for 20 percent of the U.S. households without vehicles).

Figure 2-9. Percentage of Households by Number of Vehicles Owned, United States, 1960 to 2010



Source: AASHTO, 2013a, Reproduced with permission of AASHTO.

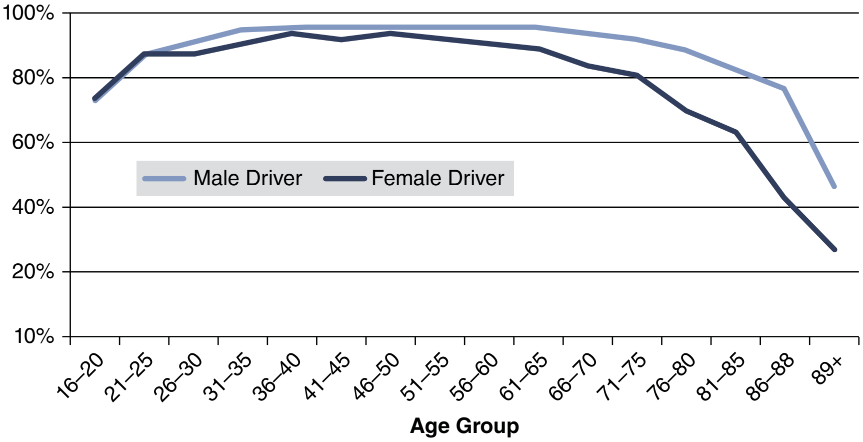
Figure 2-10 illustrates two characteristics of the U.S. population that have an important influence on mode choice. First, the percentage of older Americans having a driver's license has historically been much lower than that for those younger. This, however, is likely to change over time as the younger drivers grow older. Second, most Americans in the 16 to 50 age group have a driver's license, although male drivers have a higher rate of licensure than females.

3. Spatial Distribution of Growth

More than 200 regions in the United States are classified as large metropolitan statistical areas (MSAs). These represent the largest of the nation's urban areas and have populations exceeding 250,000. From 2000 to 2010, the rate of growth in MSAs was mostly in the double digits, with many areas experiencing growth exceeding 20 percent. Some achieved growth rates in excess of 50 percent (see the U.S. Bureau of the Census website for current growth rate data for MSAs, www.census.gov).

One of the defining trends during the past 50 years in the United States and in many other countries has been the rapid population and employment growth in the suburbs. Prior to 1960, the majority of the U.S. population lived in nonmetropolitan areas with the suburbs of metropolitan areas having the smallest percentage of the population. By 2000 this ratio was reversed, with approximately 50 percent of the U.S. population living in the suburbs.

Figure 2-10. Persons Ages 16+ with Driver's Licenses, United States



Source: AASHTO, 2013a, Reproduced with permission of AASHTO.

Table 2-5. U.S. Population Trends by Geographic Area

	1990			2000			2010		
	Count (millions)	% of U.S. Total	% of Metro Total	Count (millions)	% of U.S. Total	% of Metro Total	Count (millions)	% of U.S. Total	% of Metro Total
Total Population	248.7	-	-	281.4	-	-	308.7	-	-
Living in Metro Areas	198.2	79.7%	-	232.6	82.7%	-	262.5	85.0%	-
Living in Central Cities	65.8	26.5%	33.2%	70.3	25.0%	30.2%	75.3	24.4%	28.7%
Living in Other Principal Cities	12.9	5.2%	6.5%	23.6	8.4%	10.1%	24.1	7.8%	9.2%
Living Outside Principal Cities (Suburbs)	119.5	48.0%	60.3%	138.7	49.3%	59.6%	163.1	52.8%	62.1%
Living Outside of Metro Areas	50.5	20.3%	-	48.8	17.3%	-	46.2	15.0%	-

Source: AASHTO, 2013b, Reproduced with permission of AASHTO.

Table 2-5 shows the trend in the United States from 1990 to 2010. In 2010, the percentage of the U.S. population residing in MSAs increased to approximately 85 percent. What is interesting about this table is the growth in central city population during this period (indicated in gray areas), although on a percentage of the region basis, the proportion of central city population declined over the 20-year period. Some U.S. cities, such as Atlanta, Phoenix, Denver, and Tampa, saw much greater migration to the central city from domestic origins than from immigrants. In the Atlanta metropolitan area, for example, the last 20 years have seen a movement of population back into the central urban area. The increase in growth rates above might suggest that this is occurring in other parts of the country as well.

One can also see from Table 2-5 the increase on a percentage basis (also shown in gray) of those living in the suburbs, and a corresponding decline in the percentage of U.S. residents living outside metropolitan areas. Table 2-6 shows that metropolitan and nonmetropolitan areas had different growth rates (or decline) in population between 2000 and 2010: [AASHTO, 2013b]

The growth in metropolitan areas exceeding 5 million population is slightly misleading, because only 8 million of this population increase was actual new growth. The remaining 24 million in growth resulted from different U.S. metropolitan areas being combined by the Census (such as Baltimore and Washington, DC), thus putting this combined area into the 5 million population range. As of 2010, there were 8 metropolitan areas with populations exceeding 5 million and 52 metropolitan areas with populations over 1 million in the United States.

Table 2-6. Metropolitan Area Growth Rates, by Size, United States, 2000 to 2010	
Metropolitan Area Population	**Growth Rate**
>5 million	26.6%
2.5 to 5 million	18.8
1 to 2.5 million	6.5
0.5 to 1 million	34.4
250,000 to 500,000	−18.8
100,000 to 250,000	−21.0
50,000 to 100,000	−10.0
All metropolitan areas	12.8
Nonmetropolitan areas	−5.2

Source: AASHTO, 2013b, Reproduced with permission of AASHTO.

The implication of this population trend toward urban areas is that many of the future mobility and accessibility challenges in the United States (and in other countries) will be primarily urban in nature.

B. Travel Characteristics

Whereas the previous sections focused on the characteristics of travelers, transportation planners also use data on the trip itself, such as trip purpose, mode choice, time of travel, and so forth. This section discusses the trip characteristics that are most important to the transportation planning process.

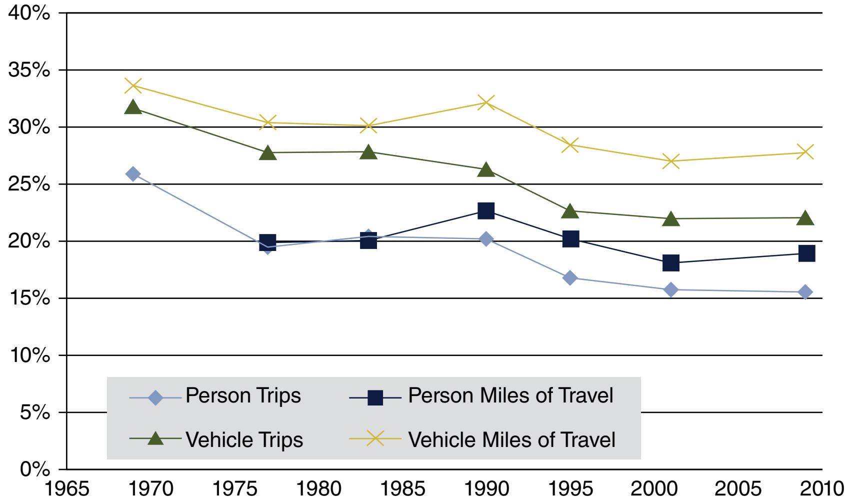
1. Trip Purpose

Travel demand is considered a *derived demand*, meaning that trips are taken to achieve some purpose at a destination. For transportation analysis purposes, therefore, it is important to know why trips are being made. This is referred to as *trip purpose*. Although traditionally many transportation studies have focused on the commute or work trip, in reality the greatest increase in trip-making during the past two decades has been for other trip purposes, especially in family/personal business and social/recreational trips. Figure 2-11 shows the relative magnitude of commute travel as it has changed over time. As shown, work travel has declined as a percentage of total travel as reflected in several different performance measures. Figure 2-12 shows how the number of trips per day for different trip purposes has changed from 1977 to 2009. Note in Figure 2-12 that trip purpose has been aggregated to five major types—work, family/ personal business, school/church, social/recreational, and other. In many transportation studies, additional trip purposes are added to the study, depending on the types of trips that need to be examined (such as airport trips) and the availability of data. As an example, the 2009 National Household Travel Survey listed 36 different trip purposes in its survey form.

Multipurpose single trips are another important phenomenon that has occurred with increasing frequency over the past several decades. Known as *trip chaining*, this travel characteristic presented challenges to transportation analysts who had traditionally based trip modeling on a single-purpose trip. According to Pisarski [2006], the attributes of trip chains include:

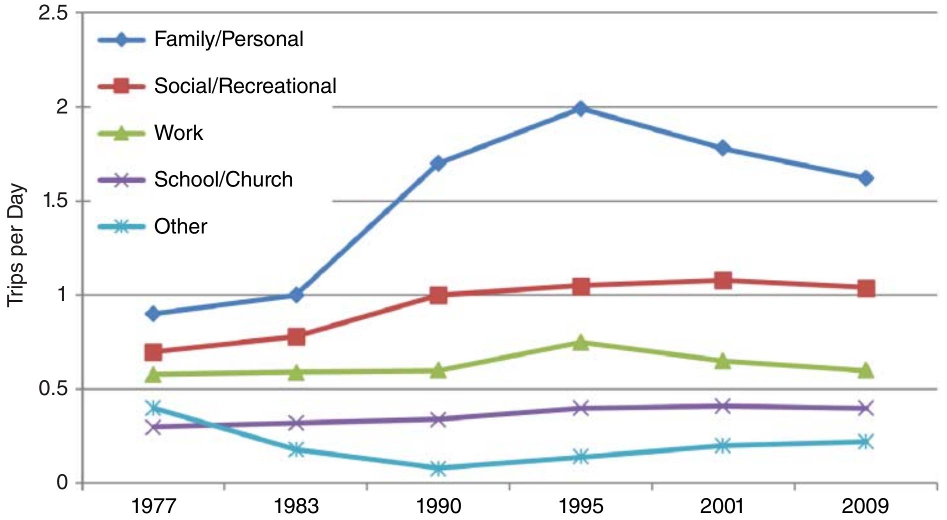
- Trips to work with stops are increasing, both in number of workers making stops and number of stops per worker.
- Persons with stops take longer in miles and minutes than they did in 1995 and are longer than those not making any stops.
- People who make stops tend to be those that live a greater distance from work.
- Suburbanites make more stops than urban dwellers.
- Stops are increasing for men as well as for women.
- Women still make the greater number of stops in both work and home directions.
- The greater increase has been by men in the work-bound direction, often just for coffee.
- Use of nonvehicular and nonpersonal auto modes drops sharply for those making stops.

Figure 2-11. Work Travel as a Percentage of Total Travel Using Key Travel Measures, United States



Source: AASHTO, 2013b, Reproduced with permission of AASHTO.

Figure 2-12. Change in Trip Purpose, United States, (Trips/Day), 1977–2009



Source: AASHTO, 2013a, Reproduced with permission of AASHTO.

Another qualifier often attached to "trip purpose" is whether one end of the trip occurs at the traveler's home. Thus, transportation planners often use terms such as home-based work, home-based shopping, home-based other, and non-home-based other to describe different types of trips made in a study area. Table 2-7 shows the percentage of these different types of trip purposes found in travel surveys undertaken in the 1990s in the United States. Although somewhat dated, the general percentages as shown for different trip types are similar to what is found today. (Note that travel demand modeling is evolving to a new form called activity-based modeling that no longer relies on such a distinction on individual trips. See chapter 6 on travel demand modeling.)

2. Travel Patterns

Transportation planners are very interested in travel patterns because to a large extent these patterns suggest what is needed with respect to transportation infrastructure and services. Alternatively, transportation officials can influence these patterns through public policies intended to affect land use and household/ employment location decisions. Similar to the trend of increasing suburbanization of population and employment during the past 50 years, the greatest growth in urban travel patterns has been in the suburb-to-suburb trip. Suburb-to-suburb commute travel accounts for 46 percent of metropolitan commuting activity, with only 19 percent of the typical metropolitan area commuting following the suburb-to-central city pattern. Commuting within the central city constitutes approximately 25 percent, and the reverse commute—from central city to suburb—accounts for 9 percent. Not surprisingly given these trip patterns, suburbs account for 53 million of the 107 million job destinations within U.S. metropolitan areas.

Table 2-7. Trips by Trip Purpose, Selected U.S. Metropolitan Areas, Most Recent Survey									
	% Trips by Type			Daily Trip Rate per Person			Daily Trip Rate per Household		
City	**HBW**	**HBO**	**NHB**	**HBW**	**HBO**	**NHB**	**HBW**	**HBO**	**NHB**
Albuquerque, NM	17.7%	53.9%	28.4%				1.70	5.20	2.80
Amarillo, TX	18.1	49.5	32.4	0.72	1.93	1.26	1.86	5.00	3.26
Atlanta, GA	21.6	51.3	27.1	0.71	1.68	0.89	1.83	4.33	3.20
Baltimore, MD	22.1	50.3	27.6	0.62	1.42	0.78	1.69	3.84	2.10
Brownsville, TX	15.2	57.2	27.6	0.48	1.74	0.85	1.80	6.51	3.17
Cincinnati, OH	18.1	51.6	29.7						
Dallas, TX				0.75	1.65	0.84	1.94	4.30	2.18
Eugene, OR	15.6	57.6	26.8	0.76	2.82	1.32	1.80	6.70	3.10
Ft. Collins, CO	13.0	60.0	27.0	0.55	2.55	1.15	1.39	6.40	2.88
Houston, TX	19.8	52.3	27.9				1.79	4.75	2.53
Las Vegas, NV	25.8	42.0	32.2				2.15	3.49	2.68
Los Angeles, CA	19.3	52.1	28.6	0.60	1.62	0.89	1.78	4.80	2.64
Madison, WI	19.6	36.6	19.0	0.75	1.40	0.73	1.91	3.57	1.85
Minn/St. Paul, MN	14.3	52.8	32.8	0.56	2.03	1.28	1.45	5.31	3.36
Phoenix, AZ	22.8	48.0	29.2				1.86	3.97	2.33
Reno, NV	28.1	40.8	31.1	0.89	1.29	0.98	2.15	3.12	2.37
San Antonio, TX	26.9	41.9	31.2	0.67	1.66	0.91	1.95	4.81	2.63
San Diego, CA							1.20	2.40	
San Francisco, CA	25.2	46.4	28.4	0.76	1.39	0.85	2.03	3.73	2.29
Seattle, WA	22.9	44.3	32.8	0.94	1.81	1.34	1.99	3.85	2.85
St. Louis, MO				0.64	1.73	1.04	1.70	4.58	2.77
Tucson, AZ	17.6	56.5	25.9	0.60	1.94	0.89	1.53	4.92	2.25
Wilmington, DE	32.1	49.6	18.3	0.71	1.11	0.39	1.82	2.89	1.02

HBW = Home-based work; HBO = Home-based other; NHB = Non-home-based

Source: Reno, Kuzmyak and Douglas, 2002. Reproduced with permission of the Transportation Research Board.

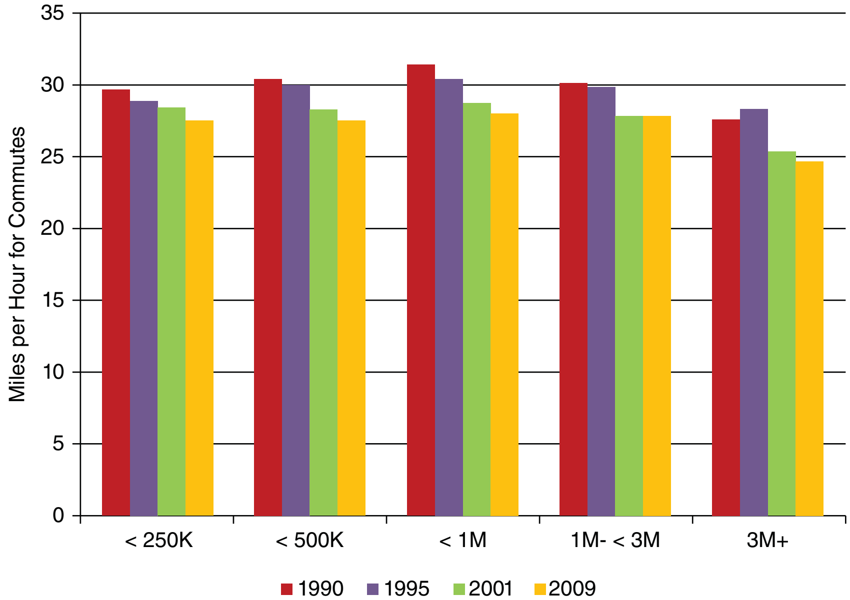
The percentage of the commute trips destined outside of the worker's home county is another characteristic of the growing trend in inter-suburban trips (note that this statistic will vary in different parts of the United States due to the size of counties). During 2006 to 2010, more than a quarter (27.4 percent) of U.S. workers traveled outside of their home county for the work trip. [McKenzie, 2013] In comparison, in 1960, approximately 15 percent of commuting included a work destination outside of the worker's resident county. Between 1990 and 2000, 51 percent of the new workers added to metropolitan areas worked outside of their home county. This longer distance travel has resulted in an increasing average commute trip length.

Average commute travel time has also increased due to longer trip distances and, more importantly, to the level of congestion faced during the trip. In the United States, the average commute travel time in 2011 was 38.0 minutes (measured over 498 urbanized areas), with 47 percent of workers traveling less than 20 minutes and 8 percent traveling more than 60 minutes. With longer trip distances and longer travel times, it is not surprising that average speed has declined as well (see Figure 2-13).

3. Temporal Distribution

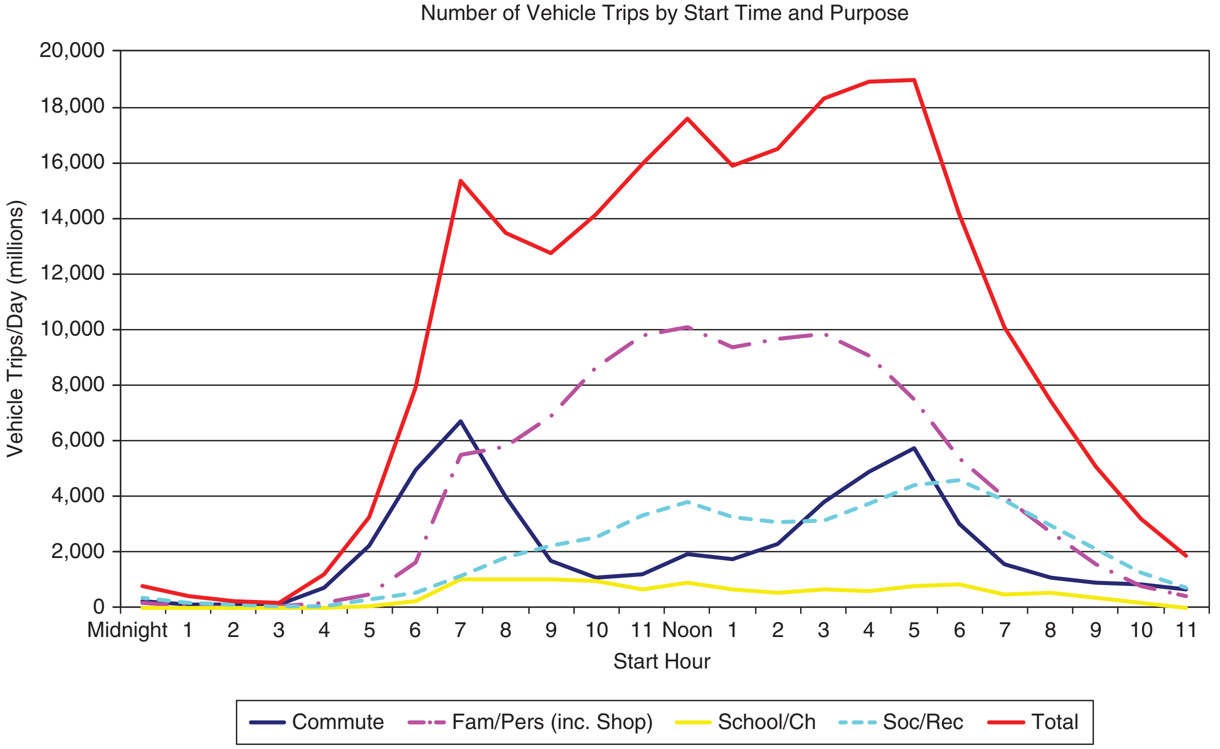
The time of day when trips occur is another important characteristic of urban travel patterns, one that leads to system congestion when many of these trips occur in the same time periods. In most cases, system capacity is available to handle daily trips; if trips were spread evenly over the 12 hours of daytime, there would be no traffic congestion. However, the trip peaking phenomenon reflects individual travelers' combined desires of being places more or less at the same time. Figure 2-14 shows data from the 2009 National Household Travel Survey, indicating the concentration of person trip-making during the daytime. Because of the limited capacity of transportation systems to handle the

Figure 2-13. Change in Average Commute Speed, United States, 1990–2009 (mph)



Source: Santos et al., 2011

Figure 2-14. Typical Percent of Daily Trips by Time Period



Source: Santos et al., 2011

peak loads, many metropolitan areas have found that travel is beginning to spread out into the very early hours or after the main peak is over. Figure 2-15 shows the percentage of a day's total delay that occurs by hour of the day. As can be seen, the afternoon peak period experiences the most delay of the day.

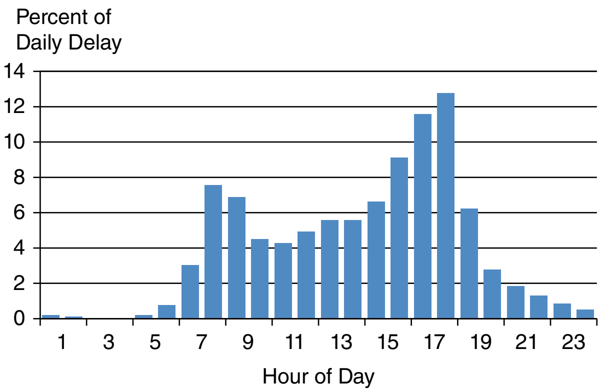
Unlike commuter trips, which generally peak between 7:00 to 9:00 a.m. and 4:00 to 7:00 p.m., truck trips tend to be at their highest levels between 10:00 a.m. and 4:00 p.m.

4. Mode Usage

The likelihood of individuals choosing one mode over another for different trip purposes depends on a variety of factors, many of which are often masked when using national data. For example, many urban corridors and activity centers show significant transit ridership, even though the metropolitan area average for transit mode share could be quite small. Thus, the following data should be viewed with an understanding that they represent national numbers, reflecting many different types of transportation contexts.

Both the number and the percentage of urban travelers driving a car have increased significantly since the 1950s. For example, the percentage of U.S. commute trips made in a single-occupant vehicle as compared to all other modes was 64.4 percent in 1980 and increased to 76.1 percent in 2009. Carpool and transit use has slightly increased in absolute number of trips but has declined in market share. Many of the differences in mode use seen historically have lessened somewhat during the past 30 years; however, there are still important differences that can affect transportation service:

Figure 2-15. Percentage of Daily Delay by Time of Day, United States



Source: Schrank, D., B. Eisele, and T. Lomax. 2015, Reproduced with permission of Texas A&M Transportation Institute.

- Women still have a higher propensity to use transit than men and use carpools almost the same amount as men.
- Working at home and walking are important transportation modes in higher age groups.
- Higher age groups tend to use transit less than younger age groups, particularly buses and the subway.
- Minority populations tend to use transit much more than Caucasians (African Americans have transit use levels four times that of Caucasians; Hispanics use transit at more than twice the level of nonHispanics).
- Carpooling by Hispanics is double that of nonHispanics (23 percent to 11 percent).
- The higher the household income, the less likely one is to use transit or carpool, until the highest incomes are reached and then the transit share increases (most likely due to increased commuter rail and ferry use). Lower-income households have a much higher use of transit, biking, walking, and taxicabs.
- As metropolitan size increases, transit use increases in both central cities and suburbs; carpool rates are much more stable across different metropolitan area sizes.
- Nonmotorized travel averaged about 14.6 percent of all trips nationally in 2009, which is a decrease in market share from 1990 but represents a larger number of trips than taken in 1990.
- Those who have resided in the United States for only a short period of time tend to use transit (13 percent market share), carpools (almost 26 percent), and walking (6.8 percent) at much higher rates than those who have lived in the United States for a longer time.

Much of urban transportation policy during the last 30 years has focused on increasing the mode share for nonsingle occupant vehicle modes, primarily transit. Understanding the socio-demographic characteristics of those who ride transit and perhaps more importantly those who do not becomes an important foundation for planning studies aimed at enhancing transit ridership. Many transportation plans outline a long list of policies and program initiatives aimed at increasing transit market share; transportation planners need to understand the behavioral aspects of encouraging more people to do so.

IV. ESTIMATING TRAVEL CHARACTERISTICS AND VOLUMES

Various types of data are used in different stages of the planning process. Needed data will vary by mode of transportation and the purposes for which the data will be used. Table 2-8 shows how different highway-related data might be used depending on what decisions will be made. The following sections provide an overview of the most important characteristics of data collection for transportation planning.

A. Road Traffic Data Definitions

Traffic volume counts are expressed by specific time periods, with the time period depending on the type of information desired and its application. For example, data can be obtained for intervals of 5, 15, or 30 minutes; 1 hour; a peak 3-hour period; 1 day; 1 week; or the entire year. Transportation planning studies normally focus on longer time periods, such as annual daily traffic, while traffic operations studies generally require peak hour or peak 15-minute periods. It is important to note that daily volumes are typically not differentiated by direction or lane, but are total two-way volumes for a facility at a given location. The following terms are often used in transportation planning studies.

1) *Annual traffic*—the estimated or actual volume at a specific location for an entire year. Annual traffic estimates are used to determine the traffic demand in a given geographic area, establish trends that can be related to future traffic growth, and estimate highway user revenue, especially for toll roads, bridges, and tunnels.

2) *Average daily traffic (ADT)*—average 24-hour traffic volume at a given location for some period of time less than one year. An ADT estimate is valid only for the period for which it was measured. However, adjustment factors can be used to estimate ADTs for longer periods of time based on historical records (thus, for example, an ADT count for a Tuesday could be adjusted for an average weekday ADT based on the relationship between Tuesday's ADT and the historic average weekday ADT). These estimates are used to measure the existing vehicular use of the streets and highways in a study area. Such data can be used to determine facility performance, establish a major or arterial street network, and act as indicators of where additional person-flow capacity is needed. ADT volumes are also used to prepare benefit-cost analyses and to program capital improvements.

Table 2-8. Examples of How Traffic Characteristics Data Are Used in Road Planning

Highway Activity	Traffic Counting	Vehicle Classification	Truck Weighing
Engineering	Highway Geometry	Pavement Design	Structural Design
Engineering Economy	Benefit of Highway Improvements	Cost of Vehicle Operation	Benefit of Truck Climbing Lane
Finance	Estimates of Road Revenue	Highway Cost Allocation	Weight Distance Taxes
Legislation	Selection of Highway Routes	Speed Limits and Oversize Vehicle Policy	Permit Policy for Overweight Vehicles
Maintenance	Selecting the Timing of Maintenance	Selection of Maintenance Activities	Design of Maintenance Actions
Operations	Signal Timing	Development of Control Strategies	Designation of Truck Routes
Planning	Location and Design of Highway Systems	Forecasts of Travel by Vehicle Type	Resurfacing Forecasts
Environmental Analysis	Air Quality Analysis	Forecasts of Emissions by Type of Vehicle	Noise Studies, Nitrous Oxide Emissions
Safety	Design of Traffic Control Systems and Accident Rates	Safety Conflicts Due to Vehicle Mix and Accident Rates	Posting of Bridges for Load Limits
Statistics	Average Daily Traffic	Travel by Vehicle Type	Weight Distance Traveled
Private Sector	Location of Service Areas	Marketing Keyed to Particular Vehicle Types	Trends in Freight Movement

3) *Average annual daily traffic (AADT)*—the average 24-hour traffic volume at a given location throughout a full 365-day year. This is calculated by dividing the total number of vehicles passing a site in a year by 365 days. As noted above, AADT can be estimated based on historical adjustment factors that relate ADT to AADT (in other words, ADT × adjustment factor = AADT).

4) *Average weekday traffic (AWT)*—the average 24-hour traffic volume occurring on weekdays for some period of time less than one year. This measure does not include weekends. Similar to the relationship between ADT and AADT, AWT can be used to estimate AAWT (see next definition) through the use of an appropriate adjustment factor based on established relationships.

5) *Average annual weekday traffic (AAWT)*—the average 24-hour traffic volume occurring on weekdays throughout a full year. This volume is of considerable interest when weekend traffic is light, so that averaging weekday volumes over 365 days would mask the impact of weekday traffic. AAWT is computed by dividing the total weekday traffic for the year by 260. (Note: In some cases, the divisor is 250 to remove holiday traffic so that a true representation of weekday traffic can be obtained.)

6) *Average vehicle occupancy*—average number of persons per vehicle. Vehicle occupancies are obtained by observers recording the number of occupants in each vehicle passing a given point. This is relatively easy for automobiles (except for heavily tinted windows in some limousines), vans, and trucks. Transit vehicle occupancy is obtained based on ride counts from in-vehicle counters or estimated from visual inspection as a transit vehicle passes a given point. The results are expressed in terms of persons per hour or average number of persons per vehicle. New infrared scanning technologies are being developed that could be used to determine the number of occupants of a vehicle as they pass by a given point.

7) *Hourly traffic*—hourly traffic flows in vehicles per hour. These estimates are commonly used in traffic engineering studies, but are also used in planning studies to validate travel forecasting models. Information on vehicle types and turning movements help assess existing or future traffic performance.

8) *Short-term counts*—short-term counts covering 5, 6, 10, 12, or 15-minute intervals. These counts are useful in determining peak flow rates, establishing flow variations within the peak hour, and identifying capacity limitations.

9) *Space mean speed*—average speed of all vehicles occupying a given section of a highway over some specified time period. The equation for space mean speed is:

$$\textit{Space mean speed} = \frac{d}{\left(\sum_{i=1}^{n} t_i\right)/n} = \frac{n \times d}{\sum_i t_i} \tag{2-1}$$

10) *Time mean speed*—average speed of all vehicles passing a point on a road over some specified period of time. The equation for time mean speed is:

$$\textit{Time mean speed} = \frac{\sum_{i=1}^{n} \left(d/t_i \right)}{n} \tag{2-2}$$

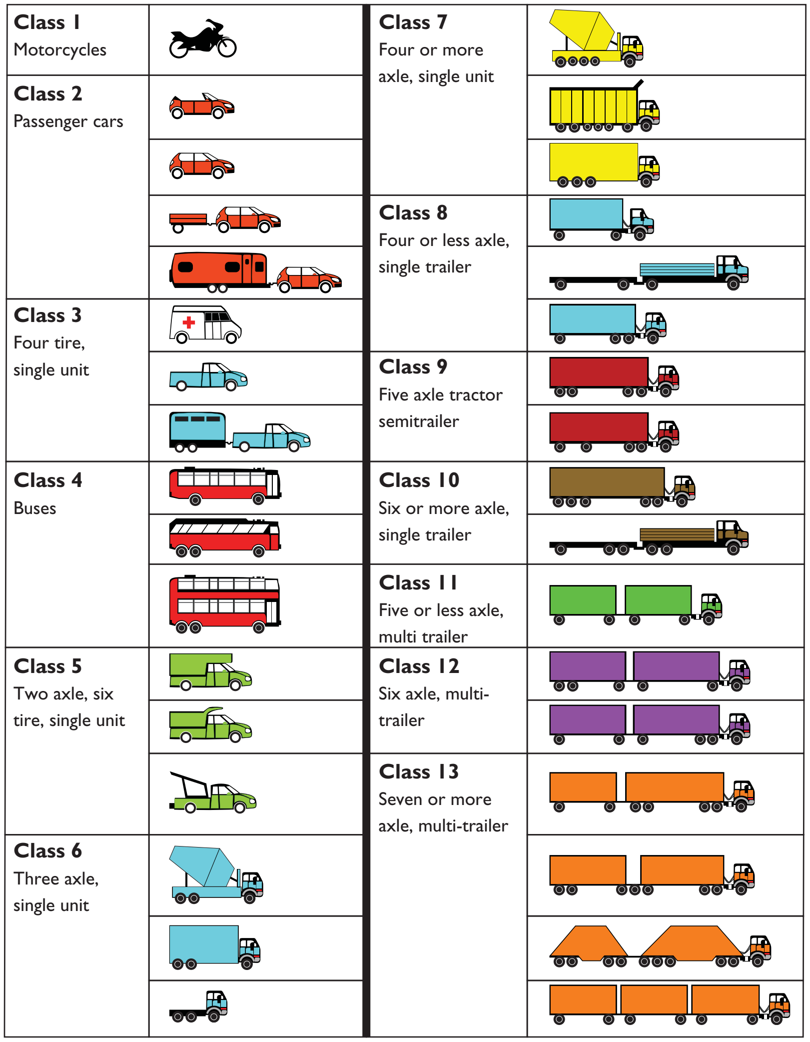
Where:

d = distance traversed (feet, mile, kilometer)
n = number of travel times observed
t_i = travel time of the i^{th} vehicle (seconds or hours)

11) *Traffic density*—vehicles per lane per mile, obtained by dividing the hourly lane volume by the average speed. Traffic density is considered a better measure of street service than flow rate for uninterrupted flow along freeways, expressways, and major arterials. Density continues to increase as congestion increases, while flow rate reaches a maximum value under moderate congestion and then decreases as congestion increases. Should a full stoppage occur, density is at its maximum when the flow rate is zero.

12) *Vehicle classification*—classifying a traffic flow by the types of vehicles found in that flow. For freight planning, vehicle classification data are the basis for estimating annual travel by each type of truck, ton-miles

Figure 2-16. FHWA 13 Category Vehicle Classification



Source: FHWA, 2013c

of cargo hauled on highways, and changes in axle and gross weight frequencies on the highways. Vehicle classification data are also used in the development of transportation policy, the allocation of highway costs and revenues, the regulation of size and weight, the establishment of geometric design criteria related to size and weight of vehicles, and the study of pavement and bridge deterioration, as well as for various special studies. Vehicles are often classified based on schemes adopted by the data collection agency. For example, Figure 2-16 shows the vehicle classification scheme from FHWA for classifying vehicles. The classification scheme is separated into categories based on whether the vehicle carries passengers or commodities. The number of axles and number of units, including both power and trailer units, further subdivide nonpassenger vehicles.

13) *Vehicle miles traveled (VMT)*—the amount of travel on a road system estimated by multiplying the daily (or annual) traffic volume on each section or link by its length. Estimates of annual VMT are useful in computing crash rates and estimating pollutant emissions. Where peak-hour traffic counts (or flow maps) are available, peak-hour VMT can be estimated. In urban areas, sampling procedures can be used to estimate daily VMT. The road system should, at a minimum, be classified as freeways, arterial streets, and local streets. Where possible, freeways should be further stratified by lanes or ADTs and arterials should be grouped by lanes, geographic area, or other features. Stratified random sampling procedures (discussed in the last section of this chapter) should be utilized taking into account the spatial, temporal, link length, and similar variations to obtain a composite variance for each class (see FHWA's Traffic Monitoring Guide [FHWA, 2013c] for more detailed discussion of estimating VMT).

B. Traffic Count Techniques

Traffic volume estimates are obtained through a variety of traffic counting techniques. Agencies such as state departments of transportation have a systematic and periodic traffic counting program. In other situations, such as in site impact analysis, special counts are taken for use in the analysis (see chapter 19 on site planning and traffic impact analysis).

ADT and AADT counts are usually obtained through machine counts using either with tubes and air switches or permanently located detector sensors (such as inductive loops or magnetometers) and appropriate detector electronic units. Counters are used to obtain 24-hour counts, often without regard to direction. Two separate directional counts at the same location can be summed to obtain a total road volume count. Twenty-four-hour counts are used primarily to develop traffic flow maps and determine traffic trends. Directional counts are used for capacity analyses, planning improvements, obtaining accumulations within a cordon area, and other such purposes.

Many states and cities have established generalized monthly and daily factors for various types of roads to adjust 24-hour counts for a given day to AADT. Two types of data collection are used to define these adjustment factors. *Continuous traffic monitoring data collection programs* are used to collect traffic counts every day of the year. The types of instruments used for such data collection include:

- Automatic traffic recorders (ATRs).
- Automatic, continuous vehicle classifiers used to supplement the ATR program.
- Continuously operating weigh-in-motion (WIM) scales placed to monitor statewide trends in vehicle weights.
- Continuously operating WIM scales used to identify trucks that need to be weighed statically at an enforcement scale.
- Volume and speed monitoring stations that provide facility performance data to centralized traffic management systems.

Another approach involves locating control stations throughout the road network to sample traffic volumes on the major road system. For such *control station counts,* it is desirable to have at least one control station located on each freeway and major street. The minimum recommended duration and frequency of counting is a 24-hour directional machine count every second year. Selected control stations—called key count stations—are used to obtain daily and seasonal variations in traffic volumes. At least one key count station should be selected from each class of street in both the major and the minor systems. Key count stations are counted for one continuous week each year and for one 24-hour weekday each month. These counts provide factors that can be used to adjust other traffic counts taken on shorter time periods.

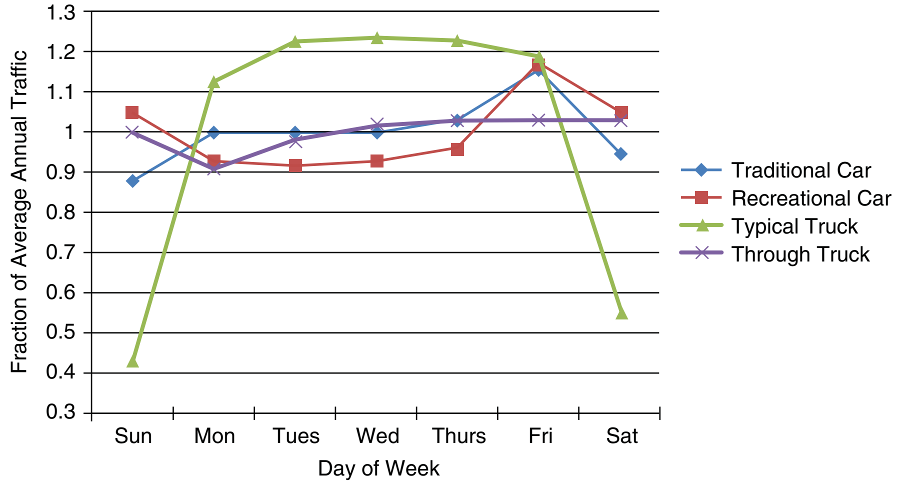
Coverage counts are used to estimate ADTs at many different locations throughout the street network. Major streets are divided into segments with uniform traffic conditions, and a 24-hour, nondirectional count is made in each segment. The count is adjusted using the factors developed from the appropriate key count station to obtain the estimated ADT. Coverage counts are normally repeated every 4 years, but significant changes in traffic due to road improvements, land-use changes, or other factors may dictate more frequent recounts. For the minor street network, one 24-hour, nondirectional count should be taken for each mile (1.6 kilometers) of street. Counts are repeated when local circumstances indicate a need.

Traffic volume graphs are sometimes prepared to show the monthly and daily traffic variations at a given location. Figures 2-17a and b give examples of such a graph (note: daily variation was shown in Figure 2-14).

Hourly traffic counts by direction of travel can be made for 12, 18, or 24-hour time periods by recording counters. Volumes are recorded in either 15-minute or hourly intervals by printing on paper tape, punching or encoding on machine-readable tape, recording electronically for subsequent insertion in a personal computer, or being digitally transmitted to a central computer.

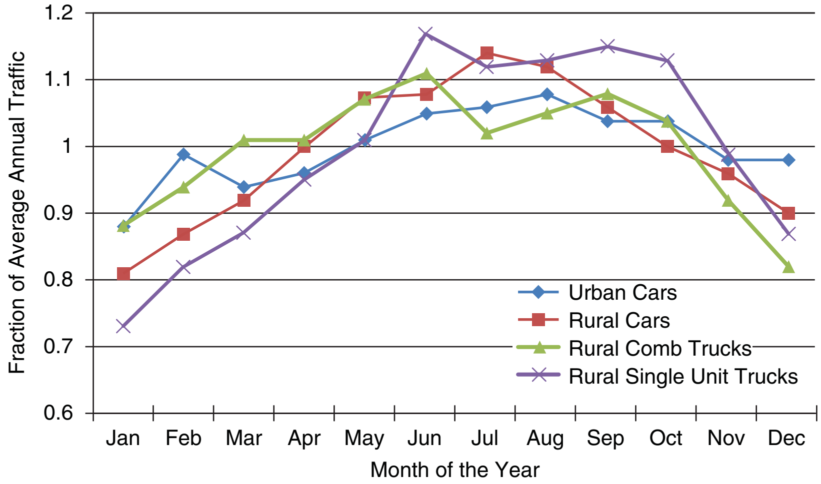
When traffic volume data from coverage counts are maintained at levels of aggregation below that of a daily total, such as by hour and direction, the data have additional uses, such as traffic signal timing, air quality analysis, noise analysis, planning studies, and planning the timing of maintenance and construction activities.

Figure 2-17a. Temporal Variation in Traffic Volumes. Typical Day-of-Week Traffic Volume Distribution by Vehicle Type, United States



Note: Typical trucks are primarily local trucks used for pickup and delivery; through trucks are typically trucks traveling long distance.

Figure 2-17b. Temporal Variation in Traffic Volumes. Typical Month-of-Year Traffic Volume Distribution by Vehicle Type, United States



Source: Hallenback et al., 1997 as reported in FHWAc, 2013

To compute AADT from a short duration count, the data collected during the short counts must be adjusted to annual conditions. These adjustments include:

- Axle corrections (for counts made with single axle sensors; there would be no correction factor for counts taken by an induction loop that senses vehicles).
- Day of week (for counts taken for less than one week).
- Seasonal (to account for changes in volume that occur from one time of year to another); and time of day (for counts taken for less than 24 hours).

See the ITE's *Traffic Engineering Handbook* for further details. [Pande and Wolshon, 2016]

Manual traffic counts are widely used to obtain hour-by-hour variations in traffic flows, traffic composition, turning movements, and pedestrians. This information is used to define the duration and intensity of peak periods, evaluate street capacity deficiencies, assess the need for various traffic controls, develop street designs, and determine the effects of new developments on changed land uses. They also provide inputs for traffic model validation.

Turning movement counts are often collected at intersections for a variety of analyses, including signal timing, capacity, impact of physical changes to the intersection, or nearby land uses. These counts are collected in 15-minute increments for at least a 2-hour period in the morning peak, evening peak, and in the vicinity of heavy commercial land use, on a Saturday peak. To avoid the high costs associated with turning movement counts, sample "short" counts are sometimes used. One method is to count each intersection approach for a definite time period (such as 5 to 10 minutes per hour). When intersections are close to each other, it is possible to sample count each intersection on a rotating basis. Counts should be done on a per signal cycle basis rather than for specified time periods. These methods should be used only when traffic conditions are relatively constant throughout the study period.

Vehicle occupancy counts are usually estimated through sampling procedures. The number of separate counting efforts needed for a given time period can be obtained by the following equation:

$$n = \frac{Z^2(S_1^2 + S_2^2 + S_3^2)}{E^2} \tag{2-3}$$

where:

- E = Allowable error or tolerance (as a decimal, 5 percent is denoted 0.05)
- S_1 = Standard deviation of average occupancy across days in a single season
- S_2 = Standard deviation of average occupancy among seasons
- S_3 = Standard deviation of average occupancy across time periods during a day (time period of concern) at a location
- n = Number of counts at a location
- Z = Standard normal variate

The values for standard deviation should ideally come from previous data collection efforts. Typical values of these standard deviations include:

- S_1 = 0.063
- S_2 = 0.015
- S_3 = 0.017

Further details on procedures and applications for vehicle classification and occupancy counts are found in the FHWA's *Guide for Estimating Urban Vehicle Classification and Occupancy* (2001).

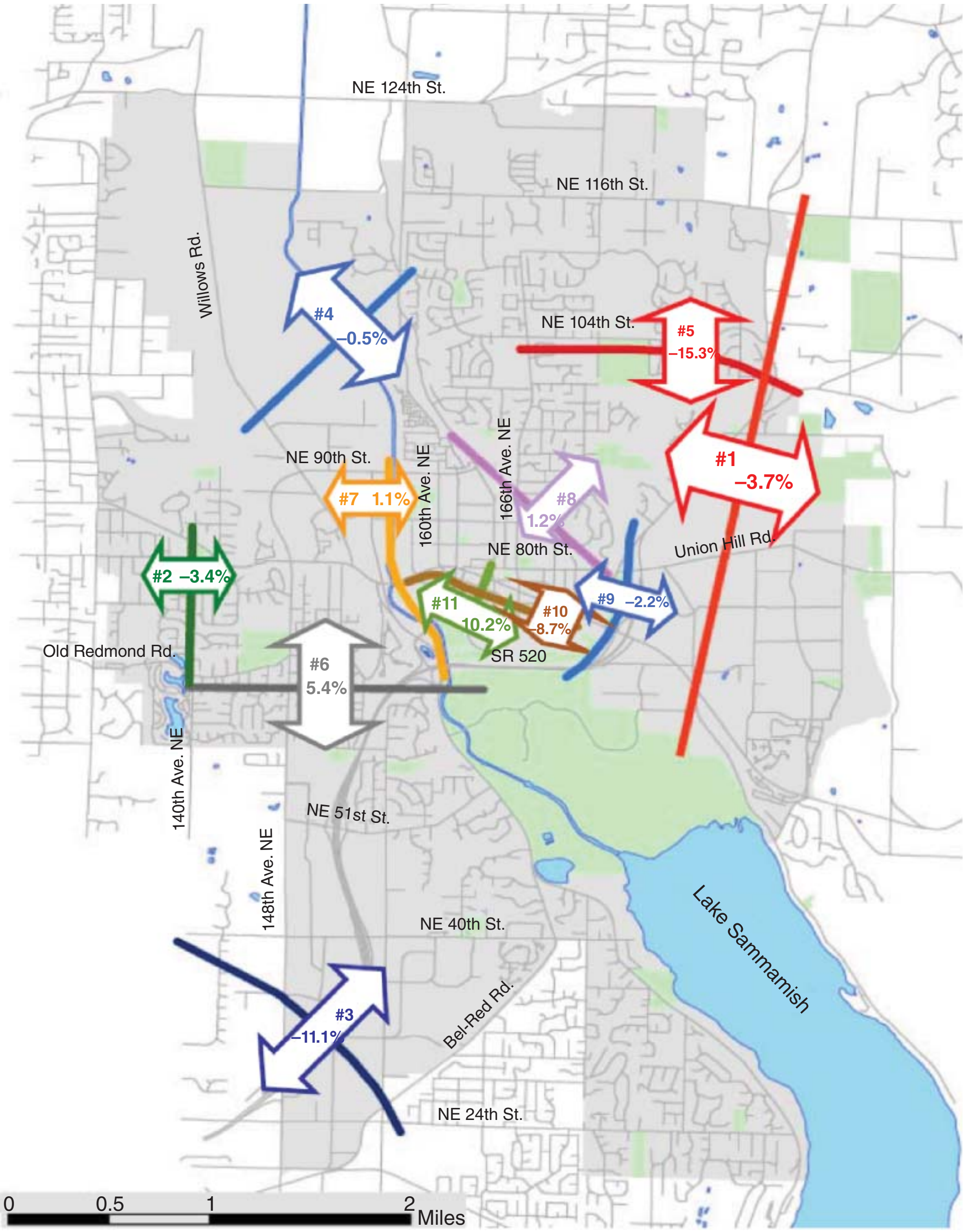
Screenline counts are taken at imaginary lines that bisect a study area or a major facility. The screenline is usually drawn along natural boundaries, such as rivers, escarpments, or railroad rights of way, to minimize the number of vehicular crossings and, therefore, the number of counting stations needed (see Figure 2-18). Screenline counts are used in conjunction with origin-destination studies to expand sampled volumes to represent the total (sometimes referred to as the universe) amount for the study area or to check the accuracy of origin-destination trip tables. Trip table crossings of the screenline are aggregated and compared to the actual ground counts at the screenline. The total trip tables are then adjusted to reconcile the differences.

Screenline counts are also used to help calibrate travel demand models and to detect trends or long-term changes in volume and direction of travel due to significant changes in population, land use, commercial and business activity, and travel patterns. In some situations it is not necessary to count all crossings of a screenline as long as traffic or ridership is not diverted to uncounted crossings. Counts might be taken every year or every second year. Counts should be made on an hourly basis to allow hour-by-hour comparisons with origin-destination data.

Cordon counts are imaginary lines where the trips crossing the lines are counted by direction of travel. The study area may be an entire urbanized area, a transportation study area, a city, a central business district (CBD), a neighborhood, an industrial area, or any other definable planning area. The counts determine the number of vehicles and people entering, leaving, and accumulated within the cordon area by mode of travel and time of day (including pedestrians and bicyclists). Vehicles are classified by type—bicycles, automobiles, light trucks, heavy trucks, carpools, taxis, buses, light rail transit, rapid transit, and commuter rail trains. Vehicle occupancies are determined for each vehicle type and travel mode (some agencies do not include truck drivers in their summaries of person movement). The counts may cover a full 24-hour period (particularly when recording counters are used), but more frequently cover 16 hours (5:30 a.m.–9:30 p.m. or 6:00 a.m.–10:00 p.m.) or 12 hours (7:00 a.m–7:00 p.m.).

CBD cordon counts are often used to measure the transportation activity generated by the CBD. These counts are repeated on an annual or biennial basis to evaluate trends or changes in activity within the CBD. They are useful in identifying the roles and importance of various transportation modes and in establishing transport policy.

Figure 2-18. Use of Screenlines in Redmond, Washington, Showing Traffic Growth, 2006/07 to 2007/08

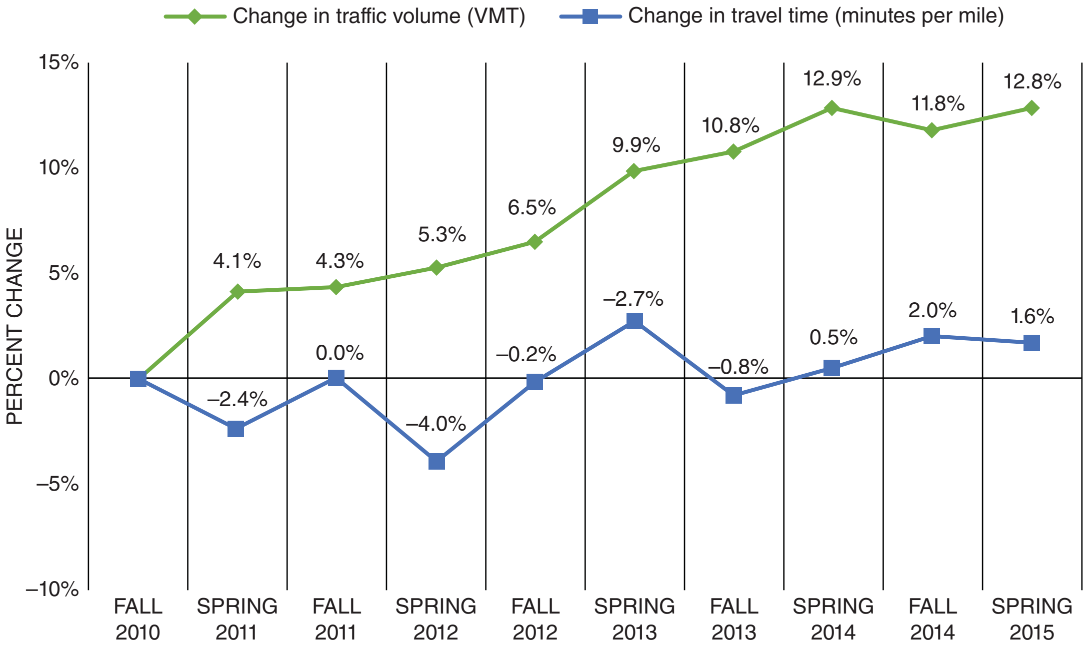


Source: City of Redmond Public Works Department. 2009. Reproduced with permission of the City of Redmond.

Results are summarized in graphic and tabular form to indicate daily and peak-hour person movements, vehicle movements and occupancies by travel mode, and vehicle occupancy and accumulation of people by mode of travel throughout the day**.** An important planning use of the CBD cordon count is to compare transit ridership projections with actual cordon crossings as part of a reasonableness check of ridership forecasts.

Many studies rely on a combination of traffic counting techniques to "tell a story." This is especially true in situations where there is a high variability of travel times and speeds on the facilities being measured. For example, the Georgia Department of Transportation is monitoring the performance on several major arterials in the Atlanta region using a combination of traditional counting methods, probe vehicle studies, and Bluetooth sensors. Data is formulated into biannual reports that highlight changes in performance so that investment decisions can be targeted on those arterial segments that will provide the best incremental benefit. Figure 2-19 shows the changes in traffic volume and travel time since the 2010 start of the regional traffic operations program. Maintaining consistent and reliable performance

Figure 2-19. Change in Arterial Peak Period VMT and Peak Period Travel Time per Mile, Atlanta



Source: Georgia Department of Transportation, 2015.

in the face of increasing traffic demand was accomplished through improved signal timing, enhanced communication with drivers on congested locations, and active management strategies.

C. Data Collection Standards

Traffic monitoring programs usually establish a recommended counting frequency, representing a compromise between the cost of data collection and count accuracy. For example, FHWA's *Traffic Monitoring Guide* recommends that coverage counts be 48 hours in duration and repeated every third year, with growth factors being applied in the intervening two years. As count duration and frequency increase, program cost increases while the level of inaccuracy in AADT estimation is reduced. [Hallenback and Bowman, 1984] A point is reached in this relationship, however, where the marginal improvement in accuracy is not worth the cost of collecting the extra data.

Federal guidance is available for traffic counting programs that relate to roads receiving federal aid, such as the interstate system. Transportation planners should be aware of the data collection standards that apply to the types of travel patterns being monitored. Many traffic counting programs also have a specified minimum level of precision and permissible error. This is discussed in the section on statistics.

D. Highway Performance Monitoring System (HPMS)

In the United States, the federally required Highway Performance Monitoring System (HPMS) is part of a state DOT's data collection program. Beginning in the mid-1980s, the federal government required states to collect performance and condition data on their road networks and to submit these data to FHWA. The data are collected based on samples and a universe section. Two types of data are collected and reported to the FHWA. [FHWA, 2014] Full extent (that is, systemwide) data are collected on selected networks such as the National Highway System (NHS) routes and all other roads, excluding minor collectors in rural areas and local roads in any area. The data collected relate to inventory (physical characteristics), route (for example, route number and road signing), traffic (for example, Annual Average Daily Traffic–AADT, single-unit truck & bus AADT, and combination truck AADT), pavement (for example, International Roughness Index (IRI)), and any special network designation.

Data are also collected on a random sample of roadway sections that represent attributes at a systemwide level. These sections of the network are referred to as sample panel sections. The sections are selected randomly and are intended to give a statistically valid representation of a state's road network. The data collected on the road samples are much more detailed and include the data categories listed above. Sample panel data also include geometric characteristics (for example, lane width, shoulder type, and peak parking) and much more data on traffic and pavement characteristics.

Each NHS, principal arterial, and sample section must be counted at least once every three years. Additionally, each state should maintain cyclic count coverage data on all arterial and collector roadways covered by the HPMS sample so that those sections can be accurately assigned to HPMS volume strata. This is necessary to expand the HPMS sample counts into accurate estimates of statewide VMT. Pavement condition data must be collected no more than every two years.

The HPMS data collection effort is particularly important to state transportation agencies because some federal-aid funds are apportioned based on the data collected. In addition, HPMS data are used in a number of key analytical tools, including the HPMS Analytical Package, the Surface Transportation Efficiency Analysis System (STEAM), the Highway Economic Requirements System (HERS), and the ITS Deployment Analysis System (IDAS), as well as in a variety of state-specific planning and performance modeling systems. The HPMS database is also the basis for periodic reports to Congress on the status and condition of the U.S. road network. (See FHWA, 2014 for much greater detail on the traffic data collection program for the HPMS effort.)

E. Travel Time Studies

Travel time and delay studies are among the most basic and important of transportation analyses. Travel time studies have a wide range of uses and application (see Table 2-9). They provide measures of a facility's or system's operational performance (for example, amount of delay and average speed). They help assess the adequacy of existing and proposed facilities, feed into decisions relating to traffic control and infrastructure changes, serve as an important measure of

Table 2-9. Uses of Travel Time Measures in Planning and Project Development

Uses	Monitoring & Needs Studies	Design & Operations Analyses	Evaluation of Alternatives	TDM, TSM, and Policy Studies	Development Impact Evaluations	Route & Travel Choice	Education
Identification of problems	X	X	X	X	X	X	X
Basis for government action/investment/policies	X	X	X	X	X		X
Prioritization of improvements	X		X	X			X
Information for private sector decisions	X	X	X	X	X	X	X
Basis for national, state, regional policies and programs	X			X	X		X
Assessment of traffic controls, geometrics, regulations, improvements		X	X				X
Assessment of transit routing, scheduling, stop placement		X	X				X
Base case (for comparison with improvement alternatives)	X	X	X	X	X	X	X
Inputs for transportation models			X	X	X	X	X
Inputs for air-quality and energy models		X	X	X	X		X
Measures of effectiveness for alternatives evaluation		X	X	X	X	X	X
Measures of land development impact				X	X		X
Input to zoning decisions					X		X
Basis for real-time choice decisions						X	X

Source: Lomax, T. et al. 1997, Reproduced with permission of the Transportation Research Board.

the value of time delay (when combined with an economic estimate of the value of time), and provide inputs into travel demand models. They also help define markets for businesses (for example, how many households live within a 30-minute trip of a store?) and, when conducted on a periodic basis, quantify changes in mobility and congestion.

Travel time-related concepts include the following:

- *Portal-to-portal travel time* is the total time traveling from one location to another. It includes in-vehicle time (time actually spent traveling) and out-of-vehicle time (time spent waiting for transit service, transferring to another vehicle, and time spent in walking between the vehicle and the origin and destination at both ends of the trip).
- *Vehicle travel time* is the time taken by a vehicle to traverse a given network segment. It includes running time, the time a vehicle spends in motion and delay, and the time lost in traffic due to traffic control devices and congestion. For public transit, travel time includes dwell times at stops, which in congested systems can constitute a major source of delay.
- *Congestion* is travel time or delay in excess of that normally incurred under light to free-flow travel conditions.
- *Mobility* is the ability of people and goods to move quickly, easily, and cheaply to their destination, and thus travel time is often a component of system performance measures that relate to mobility.
- *Accessibility* is the achievement of travel objectives within time limits regarded as acceptable. (Note that, with telecommunications technology, people can have accessibility but not be mobile.) For accessibility measures, travel times become a modifier or the primary performance measure, an example being the number of low-income households within a 60-minute transit ride of community health or recreational facilities.

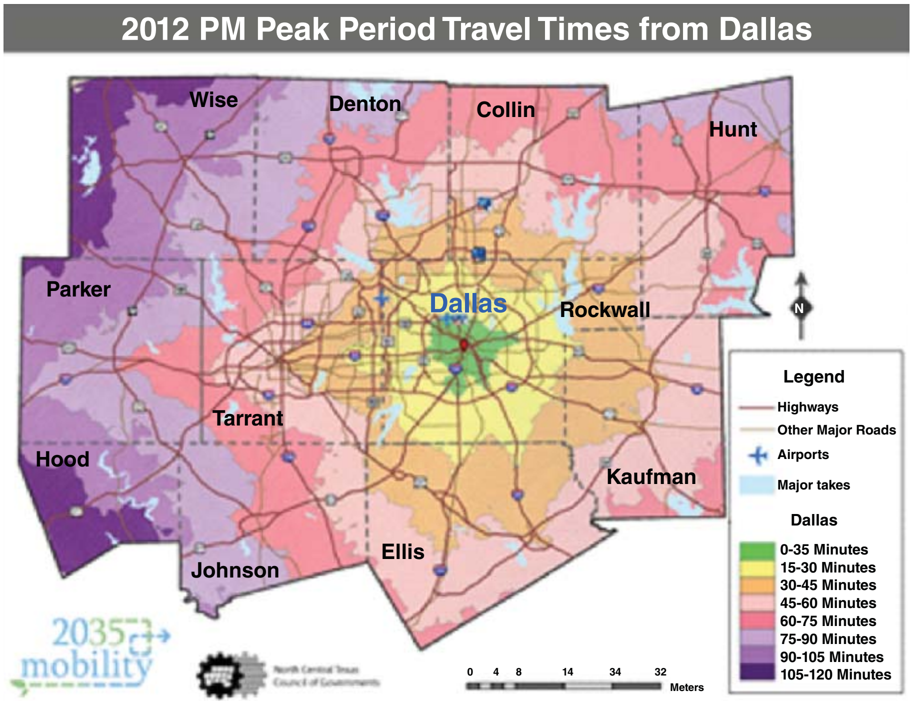
Travel times and delays should be obtained by direct measurement wherever possible. Methods for doing so include test vehicles, license plate matching, aerial photography, interviews, probe vehicles, cell phones, induction loops, sensors, and traffic reporting services. Travel time and delay data can be depicted either graphically or tabulated. Some typical means of conveying travel time and delay information include:

1) *Travel Time Contours*: Travel time contour or isochronal maps show the distance that can be reached from a common origin (often a CBD) in a given time period. They can compare peak and off-peak hours, thereby indicating the amount of congestion in each corridor. Contours can also compare travel times from year to year, thereby indicating the changes in system performance. Isochronal maps are also useful in defining the reach or market area for commercial developments (see Figure 2-20).
2) *Areas or Corridors*: Travel speeds along sections of roadways in a corridor or area can be presented as *speed flow maps* or delineated by legend. Alternatively, the distances traveled in 5-minute time intervals can be indicated.
3) *Routes*: Travel times and delays along a route can be depicted by profiles of speeds and delays along a route (see Figure 2-21) by graphic comparisons of peak and off-peak travel times or by time-space trajectories. Travel time and delay information can be summarized by component such as shown in Figure 2-22; data can also be aggregated by route.

F. Travel Surveys

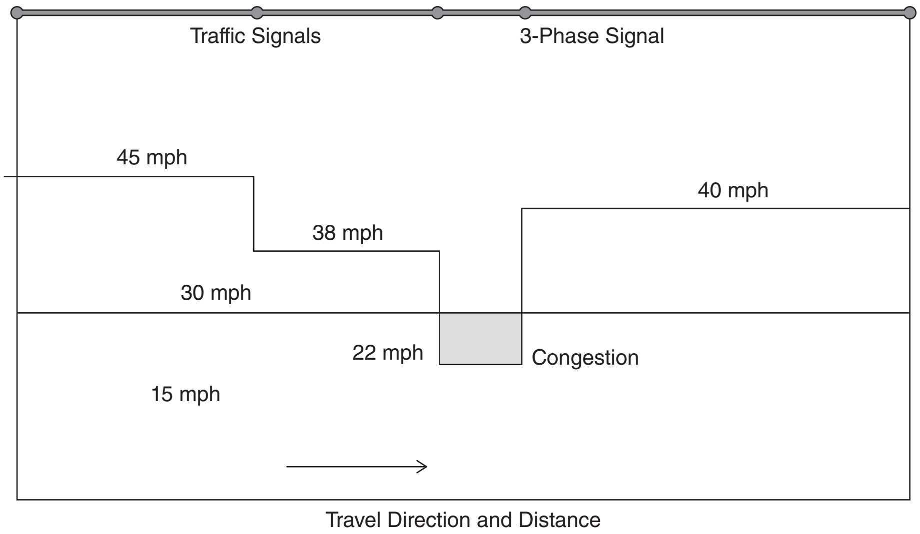
Most of the travel collection techniques discussed previously are designed to collect data at one location over a specified time period. In many ways, these techniques provide a static representation of what is happening on the transportation system. Often in transportation planning it is important to know the characteristics of the travelers as well as more detail on travel patterns, such as where trips are coming from and where they are destined. The primary means of collecting such information is through travel surveys. Travel surveys are designed to obtain data and information on the number, type, and orientation of trips in an area; they also include movements of passengers, vehicles, and cargo. The surveys estimate the nature and magnitude of existing travel and the characteristics of that travel, usually during an average weekday.

Figure 2-20. Travel Time Contours, Dallas–Ft. Worth



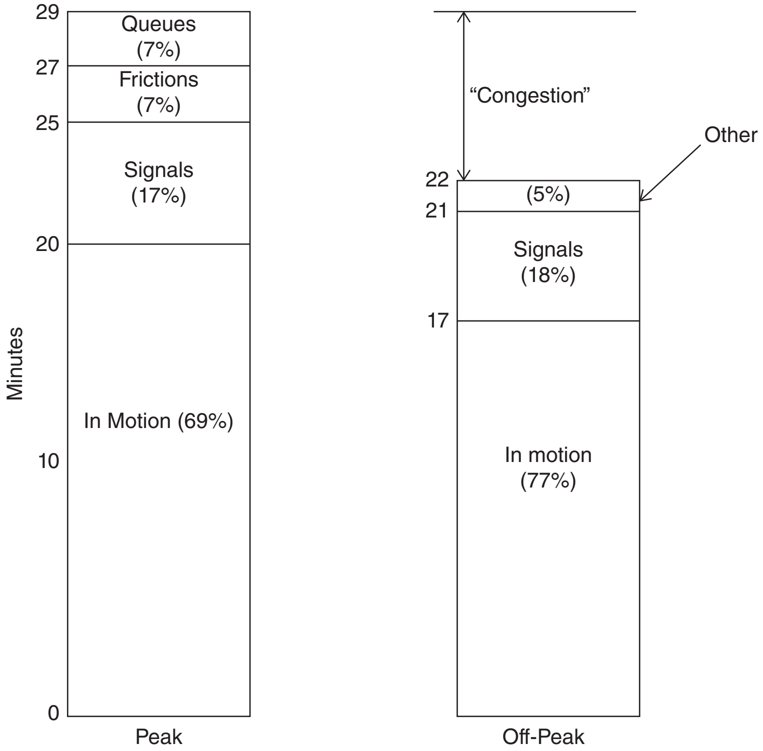
Source: North Central Texas Council of Governments, Accessed Feb. 24, 2016, from, http://www.nctcog.org/trans/data/traveltimes/Dallas.pdf

Figure 2-21. Illustrative Speed Profile



Travel patterns are commonly displayed as desire lines in which straight lines are drawn between origin-destination pairs with the width of each line proportional to the number of trips made between the two zones on an average weekday. A different type of desire line chart summarizes the data further and shows the aggregated through-trips, internal-external trips, external-internal trips, and internal-internal trips. Desire-line charts may also be prepared for special zones such as the CBD, a large industrial tract, a university, or a military installation. Contour maps (or isolines) showing the orientation and intensity of travel can also be prepared. Other data collected during the origin-destination study may be presented on maps of the area, sometimes keyed to analysis zones. Examples include population distribution or density, land use, and trip density.

Figure 2-22. Illustrative Graphic of Travel Times and Delays



The data collected by travel surveys can provide answers to questions concerning an individual's or household's travel patterns and desires with respect to new services. They indicate:

- When trips are made.
- Where the trips began and ended.
- What mode of travel was used (for example, auto driver, auto passenger, bus rider, taxi passenger, truck driver, bicyclist, or walker).
- Why the trip was made, that is, trip purpose (for example, work, shopping, business, or schools).
- Who is making the trip (for example, the characteristics of the travelers and for some types of surveys, household characteristics).
- How many people are traveling together.
- What travelers would like to see with respect to new transportation services.

Many of the surveys are complex, and there are continual changes in survey designs and methods (for more detail, see the Transportation Research Board's Committee on Travel Surveys website, http://www.fhwa.dot.gov/ohim/trb/reports.htm, and the online *Travel Survey Manual* at http://tfresource.org/Online_Travel_Survey_Manual).

The scope and scale of studies that utilize travel surveys vary widely. Surveys could be used to study a single highway interchange or a transit route, or a series of routes as in a financial feasibility or corridor study. The survey area may contain a single neighborhood, a subdivision, or a commercial development; or it may encompass an entire metropolitan area or state, as often occurs in comprehensive transportation studies.

Table 2-10 shows the common survey populations encountered in transportation planning studies and their use in the transportation planning and modeling process. These surveys generally form part of the comprehensive data collection effort that focuses on a sample of travelers who are assumed to be representative of all travelers in the urban area. The survey methodology with respect to such studies includes: (1) establishing zones for analysis purposes, (2) conducting external (or intercept) surveys, (3) conducting internal surveys, (4) processing data and performing accuracy checks, and (5) analyzing and expanding data.

The initial step in a planning study is to define the study area. For comprehensive metropolitan studies, this area should encompass those parts of the region that will be urbanized in the planning horizon year. A cordon line is established around the study area that minimizes the number of roads (and hence survey stations) that are crossed. Traffic analysis zones, rings, and sectors should be discretely numbered. The size of the zones is governed by survey area size, population density, desired data items, and study purpose. Zones are smaller in the downtown area and larger in the sparsely populated outlying areas. Trips with both origin and destination within the zones should not comprise more than 15 percent of all trips. Once the zonal system has been established, surveys can be used to collect desired data and information. Existing zonal structures, such as those used for a travel demand model, should always be considered when establishing a study framework. This will allow comparisons to be made and data to be shared.

Survey information is required for three categories of trips. Trips that traverse the study area are referred to as *through-trips*, *external trips*, or *external-external trips*. Trips that have either their origin or destination outside the study area while the other end of the trip is in the study area are referred to as *external-internal trips* or *internal-external trips*. The (usually) largest category of trips includes those that have both origin and destination inside the study area, referred to as *internal trips* or *internal-internal trips*. Data for these different categories of trips are collected in two

Table 2-10. Common Survey Populations and Uses of Data

Survey Type	Common Survey Populations	Common Modeling Uses of Data
Household travel of activity surveys	Household within a prespecified study area OR People within a prespecified study area	Trip generation, trip distribution, mode choice, time-of-day of travel, traveler behavior
Transit on-board surveys	Transit passenger trips on prespecified set of transit services	Mode choice
Vehicle intercept or external station surveys	Vehicle-trips on one or more highway segments, perhaps by direction OR Person-trips by vehicle on those highway segments	Trip distribution, model validation
Commercial vehicle surveys	Commercial vehicles garaged within a prespecified study area OR Commercial vehicle trips made by those vehicles	Commercial vehicle travel (generation, distribution, time-of-day)
Workplace, establishment and special generator surveys	Employees of prespecified establishments OR All trips to and/or from the establishment	Trip attraction models, parking and transit cost/subsidy
Hotel and visitor surveys	Hotel guests at prespecified establishments OR All trips to and/or from the hotel	Visitor models (generation, distribution, time-of-day)
Parking surveys	All vehicles parked at pre-specified locations during a prespecified time period OR All vehicle or person-trips to those parking locations	Parking cost (for mode choice)

Source: Transportation Modeling Improvement Program. Undated. *Travel Survey Manual*. Washington, DC. Accessed from, http://tfresource.org/Online_Travel_Survey_Manual on Feb. 25, 2016.

different types of studies. Through-trip data and external-internal trip data are obtained from *external* studies, while *internal* studies provide data on internal trips.

1. External Surveys

External (or intercept) surveys obtain travel information concerning external and external-internal trips. Separate surveys of rail, bus, and air travel may obtain additional travel information; these studies are specialized and depend on the particular information desired. Most are conducted by questionnaires distributed and filled out during individual trips. Common types of studies include roadside surveys, postcard mail-back surveys, license plate surveys, vehicle intercept surveys, and lights-on surveys.

Roadside Interview. Roadside interviews are the most common method of obtaining external travel information for comprehensive studies conducted in a large metropolitan area. Interview stations are established at all major roads and most other roads crossing the cordon line encompassing the study area (attempting to intercept at least 95 percent of the crossing traffic). Extreme care must be taken in locating and setting up the interview stations to ensure that vehicles can be safely stopped for interviews. A large sample of vehicles is stopped (one of the challenges with this method), and the drivers are asked the origin and destination of the current trip. Some studies obtain additional information, such as trip purpose, where the car is garaged, routes followed, and intermediate stops made. Roadside surveys are seldom used in large metropolitan areas today because of survey crew safety and the potential for traffic bottlenecks at interviewing locations. Other less intrusive methods are used.

Postcard Surveys. Where traffic is heavy, returnable postcards can be handed to drivers at the intercept stations. This method is often used in conjunction with interview studies, especially during peak periods when it is not possible to delay vehicles long enough to complete an interview (other surveys rely on postcards entirely for their data). Prepaid postcards are coded with survey station identification and time, and they request the recipient to list the origin and destination of the trip and to drop the card in any mailbox. A 20- to 40-percent response rate is common for this type of survey. Data are expanded by hour and to a 24-hour total. Through-trips must be halved because of the double interception of these trips, assuming that the trips have been picked up at two external survey stations as the trips traversed the study area. In some cases, a website address and password are provided so respondents can enter answers by filling out a web form. This may increase the response rate.

License Plate Surveys. A license plate study can be used instead of an interview or postcard survey. Even with interviews or postcards, a license plate study may be necessary at freeway crossings of a study cordon line. In this procedure license plate numbers are recorded either visually or with visual image readers along with the time of observation. Manual recording is usually accomplished through the use of tape recorders. Postcards or surveys are then sent to the address where the vehicle is registered. This type of study is conducted only during daylight hours, although where roadway lighting is of sufficient intensity, license numbers can be recorded during other periods. Returns are stratified by time of day. A 30-percent return of the questionnaires is considered excellent, although returns as low as 20 percent could produce statistically valid results. The information received from the returned questionnaires is expanded by three factors. The first is to expand the percentage return to 100 percent of the plate numbers recorded. This factor equals 100 divided by the percentage return. The second factor expands the sample of license plates recorded to the total volume passing the station during each hour the plate numbers were recorded. This hourly factor equals the total volume in each hour divided by the number of plates recorded in that hour. The third factor expands the data to the full 24-hour total volume divided by the sum of the hourly volumes during which license plate numbers were recorded. Other adjustments factors (for example, day of week, month of year) may also be applied. Finally, the through-trips must once again be halved because of the double exposure to intercept stations.

Vehicle Intercept Surveys. The vehicle intercept method can be used in small area studies. This procedure requires stations at all entrances and exits to the study area. Each entering vehicle is stopped and a coded or colored card is handed to the driver with instructions to surrender the card as he or she exits the area. Exiting vehicles are stopped and the cards collected, or the notation that they had not received a card is made. A variation of this procedure is to place colored tape on the bumper of the entering vehicle or to tape the colored card to the windshield. Given that the color code indicates at which entry point the vehicle entered the study area, this approach eliminates the need for stopping vehicles at the exits from the area. It also permits the collection of data at intermediate locations within the study area. However, it poses problems in certain weather and lighting conditions. The vehicle intercept survey is used to determine origin-destination travel patterns through a study area. More detailed information on traveler and trip characteristics is not collected with this method.

Lights-On Studies. A lights-on study is a variation of the vehicle intercept (or tag-on-vehicle study). This study traces individual vehicles from one entrance point to a maximum of two or three destination points, generally within one-half mile to 1 mile of each other. It is useful in tracing vehicles through a highway interchange or weaving area. Each entering vehicle is requested to turn its headlights on and to leave them on until it passes an exit station. This procedure only works during daylight hours. It is the least reliable of the surveys described, and it is only effective under very limited circumstances. A caution with using this approach is that in many circumstances (for example, in Canada), many vehicles operate with lights permanently on.

2. Internal Surveys

Typical types of internal surveys include household interviews, commercial vehicle surveys, surveys of workplaces and special generators, hotel, and visitor surveys, and transit-on-board surveys.

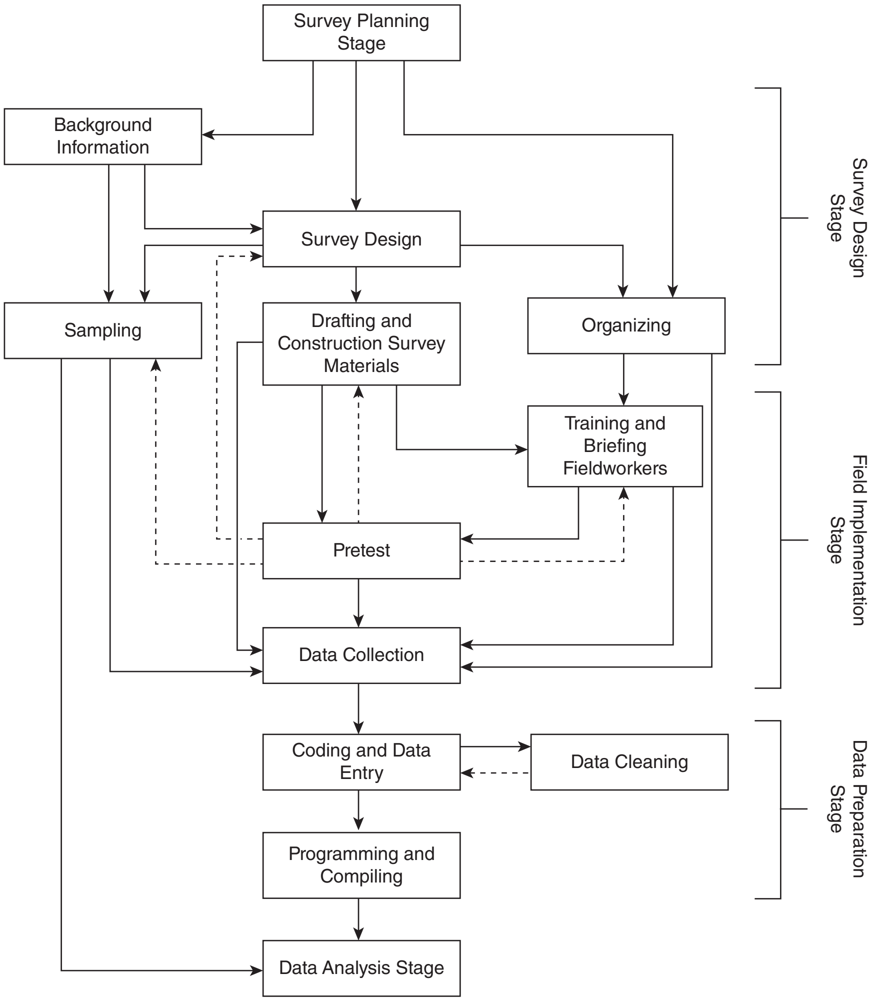
Household Surveys. Household surveys began during the 1940s and became common during the 1950s as part of the comprehensive urban transportation planning process. The initial studies involved home interviews in which respondents were asked to recall the trips made on the previous day. The samples ranged from about 2 percent in areas with populations exceeding 5 million to 20 percent in areas of less than 200,000 population.

Over the past 15 years, survey methods have changed dramatically. Surveys can be done over the Internet or by telephone, involve small samples, and include trips made by walking and bicycling as well as by auto or transit. More than 80 such surveys have been completed in the past 5 years.

The key steps in conducting a household survey are shown in Figure 2-23. An often neglected but important part of the survey process is a pilot survey, which should be used to test the survey instrument, sampling design, and interview process. The typical information collected is summarized in Table 2-11.

Household surveys include: (1) trip-based tools that directly gather information on people's trips over some period using either diary or recall methods, (2) activity-based surveys that gather information on respondent travel-related activities during a set time period, or (3) time-use-based surveys that gather information on all activities in which respondents participate during a set time period. Surveys commonly use motion recorders (such as GPS units) or activity diaries to minimize underreporting of certain trips (such as short trips). They may also be designed to obtain stated response (that is, stated preference) information. Figure 2-24a shows a survey form for a trip diary survey in Albuquerque, New Mexico. Figure 2-25 presents a travel survey instrument for Ames, Iowa.

Figure 2-23. Flow Diagram of the Survey Process



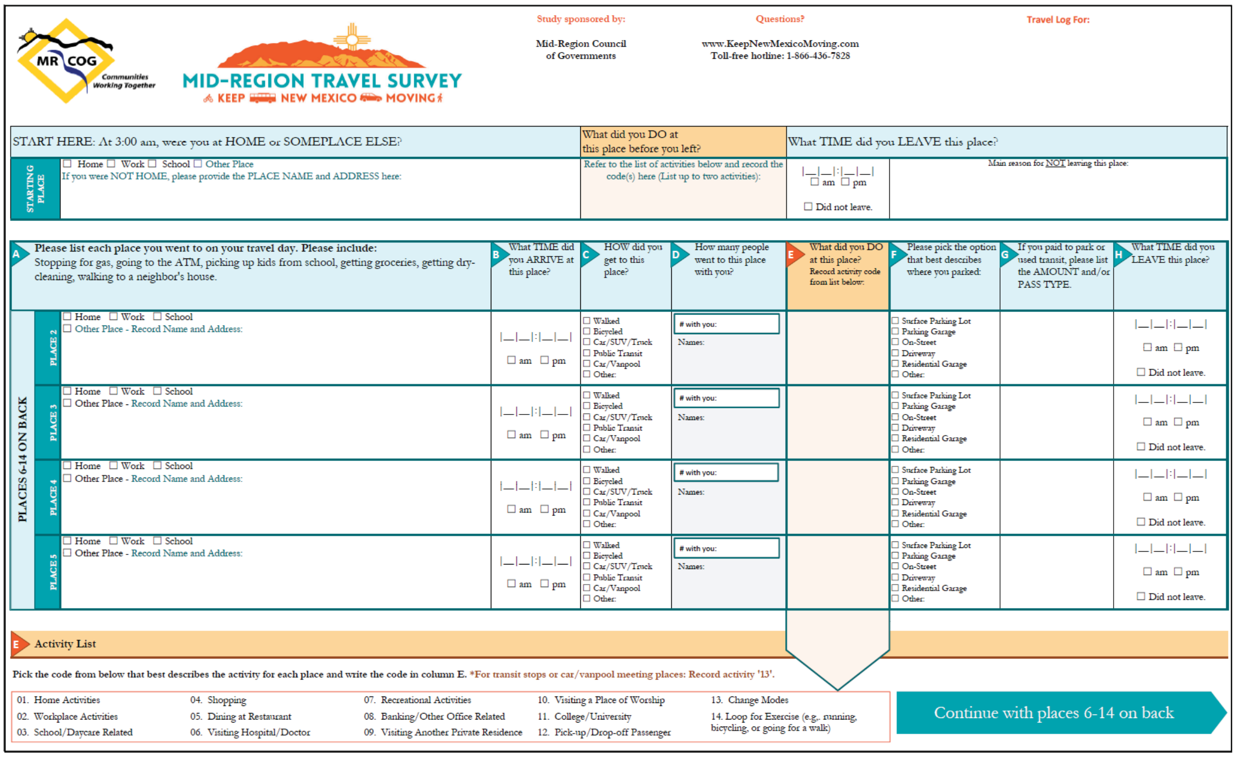
Source: FHWA, 2010

Table 2-11. Typical Information Collected in Internal Surveys

	Category	Variable
Movement	Order of stages in a trip Trip purpose Main mode/modes of stages	Number of passengers in the vehicle Location of trip ends Parking costs/transit fee Household vehicle used for trip
Person	Sex Age Household Participation in the labor market Profession Amount of work	Driving license status Relationship of each person Educational level Ethnic origin
Household	Number of persons Income Number of vehicles Dwelling-unit type	Length of tenure of household Prior residence Number of workers in the household
Vehicles	Existence Make Diary period Model	Year Odometer readings at beginning and end of the year

Source: Stopher et al., 2008, Reproduced with permission of the Transportation Research Board.

Figure 2-24a. Example Trip Diary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Travel Log For:

START HERE: At 3:00 am, were you at HOME or SOMEPLACE ELSE?	What did you DO at this place before you left?	What TIME did you LEAVE this place?	
STARTING PLACE: ☐ Home ☐ Work ☐ School ☐ Other Place If you were NOT HOME, please provide the PLACE NAME and ADDRESS here:	Refer to the list of activities below and record the code(s) here (List up to two activities):	|__|__|:|__|__| ☐ am ☐ pm ☐ Did not leave.	Main reason for NOT leaving this place:

	A Please list each place you went to on your travel day. Please include: Stopping for gas, going to the ATM, picking up kids from school, getting groceries, getting dry-cleaning, walking to a neighbor's house.	B What TIME did you ARRIVE at this place?	C HOW did you get to this place?	D How many people went to this place with you?	E What did you DO at this place? Record activity code from list below:	F Please pick the option that best describes where you parked:	G If you paid to park or used transit, please list the AMOUNT and/or PASS TYPE.	H What TIME did you LEAVE this place?
PLACE 2	☐ Home ☐ Work ☐ School ☐ Other Place - Record Name and Address:	|__|__|:|__|__| ☐ am ☐ pm	☐ Walked ☐ Bicycled ☐ Car/SUV/Truck ☐ Public Transit ☐ Car/Vanpool ☐ Other:	# with you: Names:		☐ Surface Parking Lot ☐ Parking Garage ☐ On-Street ☐ Driveway ☐ Residential Garage ☐ Other:		|__|__|:|__|__| ☐ am ☐ pm ☐ Did not leave.
PLACE 3	☐ Home ☐ Work ☐ School ☐ Other Place - Record Name and Address:	|__|__|:|__|__| ☐ am ☐ pm	☐ Walked ☐ Bicycled ☐ Car/SUV/Truck ☐ Public Transit ☐ Car/Vanpool ☐ Other:	# with you: Names:		☐ Surface Parking Lot ☐ Parking Garage ☐ On-Street ☐ Driveway ☐ Residential Garage ☐ Other:		|__|__|:|__|__| ☐ am ☐ pm ☐ Did not leave.
PLACE 4	☐ Home ☐ Work ☐ School ☐ Other Place - Record Name and Address:	|__|__|:|__|__| ☐ am ☐ pm	☐ Walked ☐ Bicycled ☐ Car/SUV/Truck ☐ Public Transit ☐ Car/Vanpool ☐ Other:	# with you: Names:		☐ Surface Parking Lot ☐ Parking Garage ☐ On-Street ☐ Driveway ☐ Residential Garage ☐ Other:		|__|__|:|__|__| ☐ am ☐ pm ☐ Did not leave.
PLACE 5	☐ Home ☐ Work ☐ School ☐ Other Place - Record Name and Address:	|__|__|:|__|__| ☐ am ☐ pm	☐ Walked ☐ Bicycled ☐ Car/SUV/Truck ☐ Public Transit ☐ Car/Vanpool ☐ Other:	# with you: Names:		☐ Surface Parking Lot ☐ Parking Garage ☐ On-Street ☐ Driveway ☐ Residential Garage ☐ Other:		|__|__|:|__|__| ☐ am ☐ pm ☐ Did not leave.

PLACES 6-14 ON BACK

E Activity List

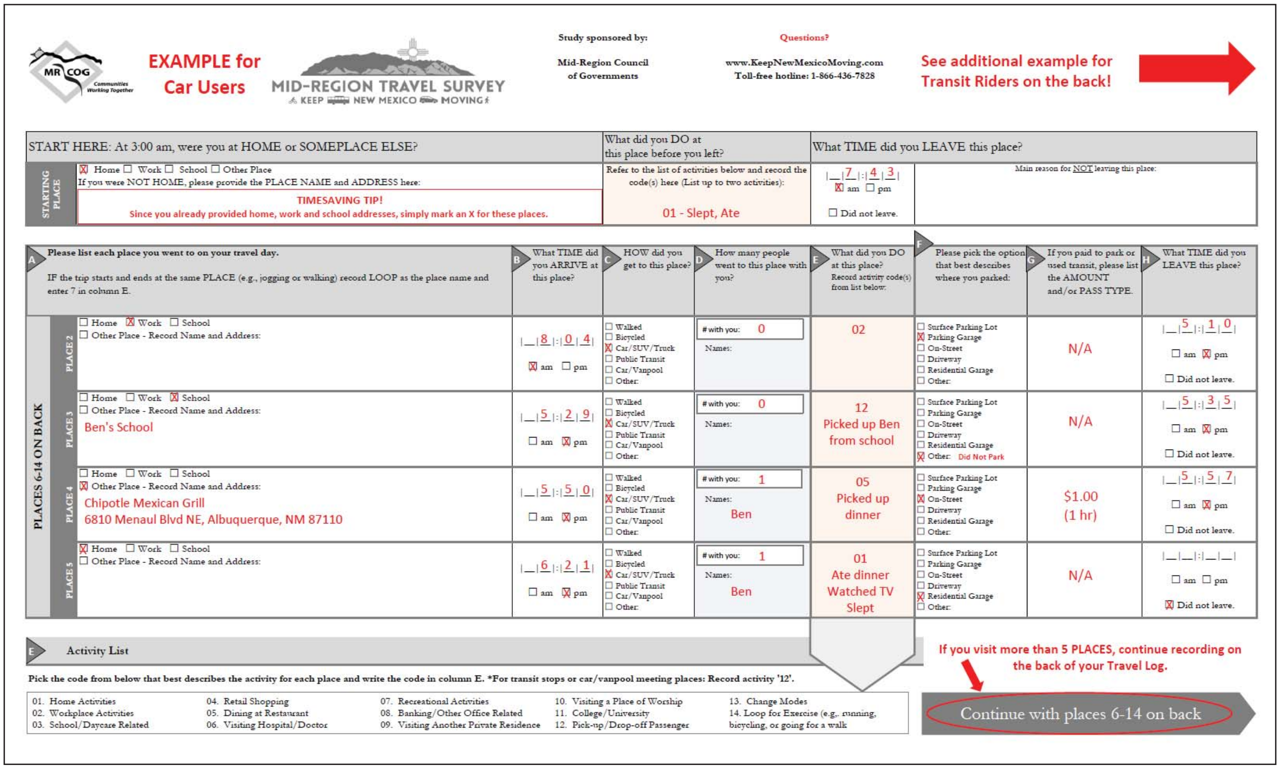
Pick the code from below that best describes the activity for each place and write the code in column E. *For transit stops or car/vanpool meeting places: Record activity '13'.

01. Home Activities	04. Shopping	07. Recreational Activities	10. Visiting a Place of Worship	13. Change Modes
02. Workplace Activities	05. Dining at Restaurant	08. Banking/Other Office Related	11. College/University	14. Loop for Exercise (e.g., running, bicycling, or going for a walk)
03. School/Daycare Related	06. Visiting Hospital/Doctor	09. Visiting Another Private Residence	12. Pick-up/Drop-off Passenger	

Continue with places 6-14 on back

Source: Westat, 2014. Reproduced with permission of Westat, Inc.

Figure 2-24b. (*Continued*)



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EXAMPLE for Car Users

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Questions?
www.KeepNewMexicoMoving.com
Toll-free hotline: 1-866-436-7828

See additional example for Transit Riders on the back!

START HERE: At 3:00 am, were you at HOME or SOMEPLACE ELSE?	What did you DO at this place before you left?	What TIME did you LEAVE this place?	
STARTING PLACE: [X] Home ☐ Work ☐ School ☐ Other Place If you were NOT HOME, please provide the PLACE NAME and ADDRESS here: TIMESAVING TIP! Since you already provided home, work and school addresses, simply mark an X for these places.	Refer to the list of activities below and record the code(s) here (List up to two activities): 01 - Slept, Ate	|__|7|:|4|3| [X] am ☐ pm ☐ Did not leave.	Main reason for NOT leaving this place:

	A. Please list each place you went to on your travel day. IF the trip starts and ends at the same PLACE (e.g., jogging or walking) record LOOP as the place name and enter 7 in column E.	B. What TIME did you ARRIVE at this place?	C. HOW did you get to this place?	D. How many people went to this place with you?	E. What did you DO at this place? Record activity code(s) from list below:	F. Please pick the option that best describes where you parked:	G. If you paid to park or used transit, please list the AMOUNT and/or PASS TYPE.	H. What TIME did you LEAVE this place?
PLACE 2	☐ Home [X] Work ☐ School ☐ Other Place - Record Name and Address:	|__|8|:|0|4| [X] am ☐ pm	☐ Walked ☐ Bicycled [X] Car/SUV/Truck ☐ Public Transit ☐ Car/Vanpool ☐ Other:	# with you: 0 Names:	02	☐ Surface Parking Lot [X] Parking Garage ☐ On-Street ☐ Driveway ☐ Residential Garage ☐ Other:	N/A	|__|5|:|1|0| ☐ am [X] pm ☐ Did not leave.
PLACE 3	☐ Home ☐ Work [X] School ☐ Other Place - Record Name and Address: Ben's School	|__|5|:|2|9| ☐ am [X] pm	☐ Walked ☐ Bicycled [X] Car/SUV/Truck ☐ Public Transit ☐ Car/Vanpool ☐ Other:	# with you: 0 Names:	12 Picked up Ben from school	☐ Surface Parking Lot ☐ Parking Garage ☐ On-Street ☐ Driveway ☐ Residential Garage [X] Other: Did Not Park	N/A	|__|5|:|3|5| ☐ am [X] pm ☐ Did not leave.
PLACE 4	☐ Home ☐ Work ☐ School [X] Other Place - Record Name and Address: Chipotle Mexican Grill 6810 Menaul Blvd NE, Albuquerque, NM 87110	|__|5|:|5|0| ☐ am [X] pm	☐ Walked ☐ Bicycled [X] Car/SUV/Truck ☐ Public Transit ☐ Car/Vanpool ☐ Other:	# with you: 1 Names: Ben	05 Picked up dinner	☐ Surface Parking Lot ☐ Parking Garage [X] On-Street ☐ Driveway ☐ Residential Garage ☐ Other:	$1.00 (1 hr)	|__|5|:|5|7| ☐ am [X] pm ☐ Did not leave.
PLACE 5	[X] Home ☐ Work ☐ School ☐ Other Place - Record Name and Address:	|__|6|:|2|1| ☐ am [X] pm	☐ Walked ☐ Bicycled [X] Car/SUV/Truck ☐ Public Transit ☐ Car/Vanpool ☐ Other:	# with you: 1 Names: Ben	01 Ate dinner Watched TV Slept	☐ Surface Parking Lot ☐ Parking Garage ☐ On-Street ☐ Driveway [X] Residential Garage ☐ Other:	N/A	|__|__|:|__|__| ☐ am ☐ pm [X] Did not leave.

PLACES 6-14 ON BACK

E. Activity List

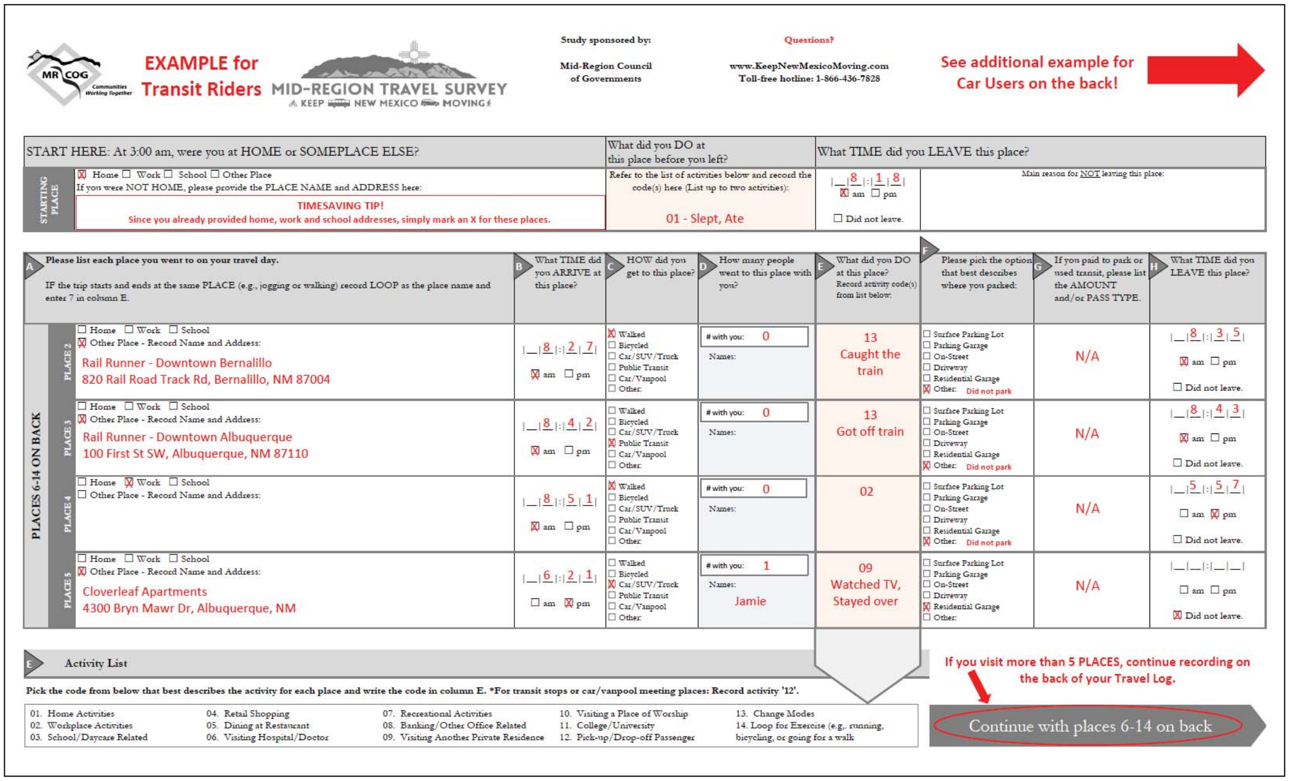
Pick the code from below that best describes the activity for each place and write the code in column E. *For transit stops or car/vanpool meeting places: Record activity '12'.

01. Home Activities	04. Retail Shopping	07. Recreational Activities	10. Visiting a Place of Worship	13. Change Modes
02. Workplace Activities	05. Dining at Restaurant	08. Banking/Other Office Related	11. College/University	14. Loop for Exercise (e.g., running, bicycling, or going for a walk
03. School/Daycare Related	06. Visiting Hospital/Doctor	09. Visiting Another Private Residence	12. Pick-up/Drop-off Passenger	

If you visit more than 5 PLACES, continue recording on the back of your Travel Log.

Continue with places 6-14 on back

Figure 2-24c. (*Continued*)



EXAMPLE for Transit Riders

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See additional example for Car Users on the back!

START HERE: At 3:00 am, were you at HOME or SOMEPLACE ELSE?	What did you DO at this place before you left?	What TIME did you LEAVE this place?	
STARTING PLACE: [X] Home [ ] Work [ ] School [ ] Other Place If you were NOT HOME, please provide the PLACE NAME and ADDRESS here: TIMESAVING TIP! Since you already provided home, work and school addresses, simply mark an X for these places.	Refer to the list of activities below and record the code(s) here (List up to two activities): 01 - Slept, Ate	|__|8|:|1|8| [X] am [ ] pm [ ] Did not leave.	Main reason for NOT leaving this place:

	A. Please list each place you went to on your travel day. IF the trip starts and ends at the same PLACE (e.g., jogging or walking) record LOOP as the place name and enter 7 in column E.	B. What TIME did you ARRIVE at this place?	C. HOW did you get to this place?	D. How many people went to this place with you?	E. What did you DO at this place? Record activity code(s) from list below:	F. Please pick the option that best describes where you parked:	G. If you paid to park or used transit, please list the AMOUNT and/or PASS TYPE.	H. What TIME did you LEAVE this place?
PLACE 2	[ ] Home [ ] Work [ ] School [X] Other Place - Record Name and Address: Rail Runner - Downtown Bernalillo 820 Rail Road Track Rd, Bernalillo, NM 87004	|__|8|:|2|7| [X] am [ ] pm	[X] Walked [ ] Bicycled [ ] Car/SUV/Truck [ ] Public Transit [ ] Car/Vanpool [ ] Other:	# with you: 0 Names:	13 Caught the train	[ ] Surface Parking Lot [ ] Parking Garage [ ] On-Street [ ] Driveway [ ] Residential Garage [X] Other: Did not park	N/A	|__|8|:|3|5| [X] am [ ] pm [ ] Did not leave.
PLACE 3	[ ] Home [ ] Work [ ] School [X] Other Place - Record Name and Address: Rail Runner - Downtown Albuquerque 100 First St SW, Albuquerque, NM 87110	|__|8|:|4|2| [X] am [ ] pm	[ ] Walked [ ] Bicycled [ ] Car/SUV/Truck [X] Public Transit [ ] Car/Vanpool [ ] Other:	# with you: 0 Names:	13 Got off train	[ ] Surface Parking Lot [ ] Parking Garage [ ] On-Street [ ] Driveway [ ] Residential Garage [X] Other: Did not park	N/A	|__|8|:|4|3| [X] am [ ] pm [ ] Did not leave.
PLACE 4	[ ] Home [X] Work [ ] School [ ] Other Place - Record Name and Address:	|__|8|:|5|1| [X] am [ ] pm	[X] Walked [ ] Bicycled [ ] Car/SUV/Truck [ ] Public Transit [ ] Car/Vanpool [ ] Other:	# with you: 0 Names:	02	[ ] Surface Parking Lot [ ] Parking Garage [ ] On-Street [ ] Driveway [ ] Residential Garage [X] Other: Did not park	N/A	|__|5|:|5|7| [ ] am [X] pm [ ] Did not leave.
PLACE 5	[ ] Home [ ] Work [ ] School [X] Other Place - Record Name and Address: Cloverleaf Apartments 4300 Bryn Mawr Dr, Albuquerque, NM	|__|6|:|2|1| [ ] am [X] pm	[ ] Walked [ ] Bicycled [X] Car/SUV/Truck [ ] Public Transit [ ] Car/Vanpool [ ] Other:	# with you: 1 Names: Jamie	09 Watched TV, Stayed over	[ ] Surface Parking Lot [ ] Parking Garage [ ] On-Street [ ] Driveway [X] Residential Garage [ ] Other:	N/A	|__|__|:|__|__| [ ] am [ ] pm [X] Did not leave.

PLACES 6-14 ON BACK

E. Activity List

Pick the code from below that best describes the activity for each place and write the code in column E. *For transit stops or car/vanpool meeting places: Record activity '12'.

01. Home Activities	04. Retail Shopping	07. Recreational Activities	10. Visiting a Place of Worship	13. Change Modes
02. Workplace Activities	05. Dining at Restaurant	08. Banking/Other Office Related	11. College/University	14. Loop for Exercise (e.g., running, bicycling, or going for a walk
03. School/Daycare Related	06. Visiting Hospital/Doctor	09. Visiting Another Private Residence	12. Pick-up/Drop-off Passenger	

If you visit more than 5 PLACES, continue recording on the back of your Travel Log.

Continue with places 6-14 on back

Figure 2-25. Travel Survey Instrument, Ames, Iowa

Ames Area MPO metropolitan planning organization

Regional TRAVEL SURVEY

One of the first considerations for planning the future of a region is the need for adequate transportation. Because of the time it takes to implement and the investment required, long range transportation planning is vital to successfully shaping the future of any region. We would like your help today in shaping the future of the Ames Region. Thank you for taking time to complete the survey. When you are finished, please return your completed survey in the postage-paid envelope addressed to ETC Institute, 725 W. Frontier Circle, Olathe, KS 66061.

1. **How many operating vehicles (cars, trucks, motorcycles/mopeds, vans) do you have in your household?**
   _____vehicle(s)

2. **Please select all the choices that best describe you. (Check ALL that apply)**

___(1)	Employed outside the home	[Answer Q2a-2c]
___(2)	Student (K-12)	[Answer Q2b-2c]
___(3)	Student (University)	[Answer Q2b-2c]
___(4)	Operate home-based business	[GO TO Q3]
___(5)	Not currently employed	[GO TO Q3]
___(6)	Retired	[GO TO Q3]

2a. In which city do you work? _____

2b. What method of transportation do you normally use to go to work/school?

___(01) Car/truck–drive alone
___(02) Carpool
___(03) Vanpool
___(04) Walk
___(05) Taxi
___(06) Bicycle
___(07) Public transit (bus/train/shuttle) (CyRide)
___(08) Motorcycle/moped
___(09) Park and Ride
___(10) Other: _____

2c. How many miles is your place of employment/school from your home?
_____ **miles**

3. **On a typical weekday, how many one-way trips do you normally make using the following types of transportation?** Please count all trips completed, including return trips to your home. If you make multiple stops on your way, please count each destination you visit as a separate trip. For example, if you stop at a gas station on the way to work, this would count as two trips.

(A) Drive a car/truck alone . . . . _____ trips

(B) Carpool . . . . _____ trips

(C) Vanpool . . . . _____ trips

(D) Ride the bus/shuttle . . . . _____ trips

(E) Ride a motorcycle/moped . . . . _____ trips

(F) Walk (to a destination) . . . . _____ trips

(G) Ride a bicycle . . . . _____ trips

Source: City Ames, 2014

Figure 2-25. *(Continued)*

4. Perceptions of Current Transportation Issues **Please rate your satisfaction with the following:**		Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied	Don't Know
A.	Ease of north/south travel in the Ames area	5	4	3	2	1	9
B.	Ease of east/west travel in the Ames area	5	4	3	2	1	9
C.	Ease of traveling from your home to city parks and recreation facilities	5	4	3	2	1	9
D.	Ease of traveling from your home to work	5	4	3	2	1	9
E.	Ease of traveling from your home to shopping areas in Ames	5	4	3	2	1	9
F.	Ease of traveling from Ames to other cities in Iowa	5	4	3	2	1	9
G.	CyRide (public transit in Ames)	5	4	3	2	1	9
H.	HIRTA (public transit in Story County, including Ames)	5	4	3	2	1	9
I.	Availability of "on street" bicycle lanes	5	4	3	2	1	9
J.	Availability of "off street" shared use paths/trails	5	4	3	2	1	9
K.	Availability of pedestrian walkways	5	4	3	2	1	9
L.	Availability of parking	5	4	3	2	1	9
M.	Neighborhood traffic safety	5	4	3	2	1	9
N.	Traffic safety on major streets	5	4	3	2	1	9
O.	Flow of traffic on area streets during peak times of day ("rush hours")	5	4	3	2	1	9
P.	Flow of traffic on area streets at non-peak times	5	4	3	2	1	9
Q.	Condition of roadways	5	4	3	2	1	9
R.	Traffic signal operations (signal timing, signal progression, etc.)	5	4	3	2	1	9
S.	Neighborhood "cut-through" activity from traffic in the Ames area	5	4	3	2	1	9
T.	Speeding traffic on neighborhood streets	5	4	3	2	1	9

5. **Which THREE of the items in Question 4 do you think are the MOST IMPORTANT Transportation issues?** [Write in the letters below using the letters from the list in Question 4 in the priority of their importance to you].

1st:_____ 2nd:_____ 3rd: _____

6. **Overall, would you rate the transportation system in the Ames Area as excellent, good, average, or poor?**
   ___(1) excellent
   ___(2) good
   ___(3) average
   ___(4) poor
   ___(9) don't know

7. **Do you feel that congestion at rush hour in the Ames Area is better or worse than rush hour congestion in other cities of comparable size that you have visited?**
   ___(1) Better
   ___(2) Worse
   ___(3) Same
   ___(9) Don't know

8. Parking in the Ames Area **Please rate your satisfaction with the following:**		Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied	Don't Know
A.	Parking availability in residential areas	5	4	3	2	1	9
B.	Parking availability in the downtown area of Ames	5	4	3	2	1	9
C.	Parking availability on campus	5	4	3	2	1	9
D.	Parking availability in Campustown	5	4	3	2	1	9

Figure 2-25. ***(Continued)***

PUBLIC TRANSIT IN THE AMES AREA

9. How would you rate the availability of public transit in Ames?

___(1) excellent
___(2) good
___(3) average
___(4) poor
___(9) don't know

10. Transit Availability in the Ames Area **Please rate your satisfaction with the following:**		**Very Satisfied**	**Satisfied**	**Neutral**	**Dissatisfied**	**Very Dissatisfied**	**Don't Know**
A.	Availability of information about public transit services	5	4	3	2	1	9
B.	Destinations served by public transit	5	4	3	2	1	9
C.	Distance to the nearest public transit stop from your home	5	4	3	2	1	9
D.	The frequency of bus service	5	4	3	2	1	9
E.	Hours and days transit service is provided	5	4	3	2	1	9

11. Which of the following are reasons that you <u>do not</u> use public transit (CyRide) more often? (check all that apply)

___(A) Service is not available near my home.
___(B) Service is not offered to destinations I visit frequently.
___(C) I don't know how to use the service (need information about routes/fees/schedules).
___(D) I had a bad experience with the service (treated poorly, arrived late, did not feel safe).
___(E) It takes too long to get to destinations compared to travel by car.
___(F) The service is confusing to use.
___(G) Service is not offered at the time I need it.
___(H) It's too expensive.
___(I) Buses do not come by stops frequently enough.
___(J) The bus is too crowded when I need to take it.
___(K) I just prefer to drive.
___(L) Other: ___________________

12. How close of a walk (in minutes) would a public transit stop need to be located for you to consider using public transit instead of a car?

___(1) 5 minutes
___(2) 10 minutes
___(3) Other___________

13. How frequently (in minutes) would a bus or other form of public transit need to be scheduled to arrive at stops for you to consider using public transit instead of a car?

Every ______ minutes

<u>BICYCLING IN THE AMES AREA</u>

14. Have you ridden a bicycle in the Ames area during the past year?

___(1) Yes [answer Q14a-f]
___(2) No [skip to Q15]

14a. How safe do you feel bicycling on major streets?

___(1) Not very safe
___(2) Safe
___(3) Very safe
___(9 Don't know

Figure 2-25. ***(Continued)***

14b. Have you ridden a bicycle using an on-street bike lane during the last year?
___(1) Yes
___(2) No

14c. How safe do you feel bicycling in an on-street bike lane?
___(1) Not very safe
___(2) Safe
___(3) Very safe
___(9) Don't know

14d. Have you ridden a bicycle on a shared-use path or trail during the last year?
___(1) Yes
___(2) No

14e. How safe do you feel bicycling on a shared-use path or trail?
___(1) Not very safe
___(2) Safe
___(3) Very safe
___(9) Don't know

14f. What is the primary reason why you ride your bike?
___(1) To commute to school, work, personal business, or shopping trips
___(2) For recreational (fitness, leisure) use
___(3) Both (if both, give the approximate percentages for commuting and recreation)
what percentage of your biking travel is for commuting? _____%,
what percentage is for recreational biking? _____%

WALKING IN THE AMES AREA

15. Have you walked along streets in the Ames area during the past year?
___(1) Yes [answer Q15a-d]
___(2) No [skip to Q16]

15a. How safe do you feel, walking along major streets?
___(1) Not very safe
___(2) Safe
___(3) Very safe
___(9) Don't know

15b. Have you walked on a shared-use path or trail or sidewalk during the last year?
___(1) Yes
___(2) No [skip to Q15d]

15c. How safe do you feel walking on a shared-use path or trail or sidewalk in the area where you live?
___(1) Not very safe
___(2) Safe
___(3) Very safe
___(9) Don't know

15d. What is the primary reason for your walking travel?
___(1) To commute to school, work, personal business or shopping trips
___(2) For recreational (fitness, leisure) use
___(3) Both (if both, give the approximate percentages for commuting and recreation)
what percentage of your walking travel is for commuting? _____%,
what percentage of your walking travel is for recreational purposes? _____%

Figure 2-25. ***(Continued)***

ROADWAY ISSUES

16. Several intersections in the Ames Area are listed below. Which TWO do you think should receive the top priority for improvement over the next 5 years? (check up to two items)

___(1) South Walnut/Clark & Lincoln Way
___(2) South 16th & Duff
___(3) Grand Avenue & 13th Street
___(4) Franklin & Lincoln Way
___(5) Grand Avenue & 24th Street
___(6) Lincoln Way & Duff Avenue
___(7) Stange Road & 13th Street
___(8) Welch Avenue & Lincoln Way
___(9) Other:_______________

GENERAL QUESTIONS

17. For each of the following system enhancements, please indicate whether you would be very supportive, somewhat supportive, or not supportive. Please recognize that there is an increased cost to some of these elements.

System Enhancements Please rate your support for the following:		Very Supportive	Supportive	Neutral	Not Supportive	Don't Know
A.	Having dedicated lanes for bikes on major city streets in the Ames Area	4	3	2	1	9
B.	Limiting the number of access driveways to retail and commercial locations to improve traffic flow along major roads in the region	4	3	2	1	9
C.	Developing major roads in future growth areas that are designed to let traffic flow at least 45-50 miles per hour	4	3	2	1	9
D.	Increase investments in technologies, such as variable message signs that inform drivers about traffic conditions and/or sensors that adjust the timing of traffic signals to maximize traffic flow	4	3	2	1	9
E.	Widening existing roads and building new roads to relieve congestion	4	3	2	1	9
F.	Adding more turn lanes at critical intersections to improve traffic operations	4	3	2	1	9
G.	Installing red light running cameras for enforcement	4	3	2	1	9
H.	Installing high-tech traffic control equipment to give buses priority through signalized intersections	4	3	2	1	9
I.	Support of internet based real time travel information	4	3	2	1	9
J.	Getting access to the interstate on the north side of town	4	3	2	1	9

18. Establishing a vision for updates to long range transportation is vital to shaping the future of the Ames area. How important are each of the following statements? For each one, please rate them by choosing a number between 1 and 5, where 5 means it is "very important" and 1 means "not at all important."

Importance of Various Issues to Transportation Improvements		Very Important	Important	Neutral	Not Important	Not at all Important
A.	Developing a safe and connected multi-modal network, including bikes, pedestrians, transit and autos	5	4	3	2	1
B.	Fostering livability and sustainable development	5	4	3	2	1
C.	Delivering solutions that preserve and enhance the environment and the community	5	4	3	2	1
D.	Supporting area economic opportunities	5	4	3	2	1
E.	Maximizing the benefits of transportation investments	5	4	3	2	1
F.	Addressing community health and quality of life	5	4	3	2	1
G.	Protecting environmental resources	5	4	3	2	1

Figure 2-25. ***(Continued)***

19. Transportation improvements are critical, but also costly. The funding for transportation improvements can come from several sources. Which of the following sources of funding would you most support? For each one, please rate them by choosing a number between 1 and 4, where 4 means you are "very supportive" and 1 means "not supportive."

Sources for Funding Transportation Improvements **Please rate your support for the following:**		**Very Supportive**	**Supportive**	**Neutral**	**Not Supportive**	**Don't Know**
A.	Increase the gas tax	4	3	2	1	9
B.	Use of tolls	4	3	2	1	9
C.	Increase vehicle registration fees	4	3	2	1	9
D.	Apply a usage fee so that the more you drive, the higher the fee	4	3	2	1	9
E.	Apply a road impact fee for new developments	4	3	2	1	9
F.	Sales tax increase	4	3	2	1	9
G.	Apply a congestion fee so that when you drive in rush hour, the fee is higher	4	3	2	1	9
H.	Property tax increase	4	3	2	1	9

20. Which THREE of the funding sources in Question #19 do you most support? [Write in the letters below using the letters from the list in Question 19 in the priority of their importance to you].

1st:_____ 2nd:_____ 3rd:_____

To ensure our survey is representative of the community, please provide the following:

21. How many persons in your household (including yourself), ages 16 and older, are dependent on public transit or rides from friends/relatives because they do not have a car or do not drive? _____ persons

22. How many persons in your household (counting yourself), are?

Under age 5 _____
5–9 years _____
10–14 years _____
15–19 years _____
20–24 years _____
25–34 years _____
35–44 years _____
45–54 years _____
55–64 years _____
65+ years _____

23. Would you say your total Household income is:

_____(1) Under $30,000
_____(2) $30,000 to $59,999
_____(3) $60,000 to $99,999
_____(4) $100,000 plus

24. Which of the following best describes your race? (Check all that apply)

_____(1) African American/Black
_____(2) American Indian
_____(3) Asian/Pacific Islander
_____(4) White/Caucasian
_____(5) Other: _____

25. *Are you currently a student* at Iowa State University?

___(1) Yes
___(2) No

26. Your gender:

___(1) Male
___(2) Female

This concludes the survey. Thank you for your time!

Please Return Your Completed Survey in the Enclosed Postage Paid Envelope Addressed to:
ETC Institute, 725 W. Frontier Circle, Olathe, KS 66061

Reported response rates for various household survey methods vary by the data collection strategy employed by the planner. In general, response rates for the three major survey types are about 90 percent for face-to-face interviews, 50 percent for telephone surveys, and less than 30 percent for mail-back surveys.

Once the interviews have been completed, the travel data are coded by origin and destination. Each trip end (origin or destination) is coded to the zone where it occurred. The data are then expanded to the full sample by a zonal factor that is calculated by dividing the total number of dwelling units in the zone by the actual number of interviews successfully completed. Other factors are used to convert the data to an average weekday. Further adjustments are made by determining the total number of trips crossing screenlines established in the study area. The survey results are compared to the screenline counts and correction factors are developed.

Workplaces and Major Trip Generators. Surveys of travel patterns and trip rates of major traffic generators can obtain targeted information about the non-home end of a trip. The surveys can involve intercept or cordon counts of people entering, leaving, and accumulated within the activity center by mode and time of day. They may also include interviews with a sample of the visitors or workers. Survey forms are distributed to employees at their place of work and are usually administered as self-completed forms.

Transit Surveys. On-board transit surveys are usually distributed to passengers as they board a bus or train. Forms are completed by passengers and deposited in a collection box or returned by mail. Response rates range from 15 to 40 percent, varying by type of rider. In some cases an interviewer using a handheld computer or tablet can conduct the survey interactively to increase the quantity and quality of responses.

Internal Truck and Taxi Surveys. A separate survey instrument is used to collect information on the movements of trucks and taxis. Vehicles are grouped into classes for which separate analyses are desired (large trucks, small trucks, taxis). For each vehicle class, a sample size is selected based on the market share of the vehicle class to all commercial vehicles in the study area.

Information for taxis is obtained on garage address, description of vehicle, and trips made on a given day. Trip information includes origins and destinations; time of start and end of trip; and number of passengers (for taxis).

Truck surveys may be conducted in urban areas to determine local trip-making patterns. Other truck surveys are conducted to allow analysis of long-distance trips. The former are often done as trip diaries. The latter are often intercept surveys.

Survey accuracy is checked by comparing travel patterns across screenlines with actual ground counts on an hour-by-hour basis. Transit ridership as determined from surveys should also be compared with transit agency records and transit line ridership. Work trips to and from major employment centers can be compared with estimates of the number of people employed in the zone. Allowance should be made for absenteeism.

G. Parking Needs Studies

The objective of most parking studies is to establish existing and future parking needs by comparing parking supply and demand. The studies obtain information on, (1) parking supply characteristics, such as the number, location, and cost of spaces, or who provides the spaces; (2) occupancy turnover and use of spaces; (3) parker characteristics, including when, where, why, and how long people park and where they are going; and (4) parking space demands and needs for existing or new developments. Parking studies often result in recommended facility locations, conceptual designs, costs and revenues, and financing plans (see chapter 11 for more information).

The key study steps include: (1) defining the study area, (2) conducting a parking space inventory, (3) determining parking occupancies (accumulations), (4) computing parker durations (length of stay) and parking space turnover (parkers per space per day), (5) obtaining basic characteristics of parkers (purpose, fee paid, destination), and (6) comparing parking supply and demands. Step 5 involves interviews with parkers and is normally done as part of a comprehensive parking study. Alternately, a more limited parking study can be performed in which parking demands are obtained by applying demand data for similar land uses, or by prorating the peak parking accumulation based on the distribution of floor space or employment among areas.

1) *Study Area Definition*. The first step in a parking study is to clearly define the study area. This area should include the traffic generators of concern and surrounding areas within a reasonable walking distance. It should include areas of current problems along with areas that might be affected by growth and change. Each block in the study area should be uniquely identified. Parking analysis zones may include these individual blocks (or groups of blocks) and then be aggregated to districts. Block faces can be numbered from one to four clockwise around the block, with the number one block face being on the north side of the block. Off-street facilities should be keyed to blocks and can be numbered from five up.

2) *Parking Space Inventory*. The existing on-street and off-street space supply should be inventoried by type of space. Curb spaces are usually classified by type of parking permitted—unrestricted spaces; truck, taxi, or bus loading zones; time-limit parking zones; and metered spaces by time limit. Off-street facilities and spaces are classified by type (lot or garage), availability (open to general public or restricted) and ownership (public or private).

3) *Peak Parking Occupancies*. Parking occupancy (or parking accumulation) studies determine the number of parking spaces occupied at various times of the day and identify the periods of peak use. Observations of curb and off-street space usage are made at regular intervals throughout the day. Curb space occupancy of parked vehicles should be done by block face. The number of occupied legal parking spaces, as well as commercial vehicles in loading zones and illegally parked or double-parked vehicles, should be counted. In small study areas, the observer can obtain these data by walking through the targeted sites. In larger study areas the observer may drive. Often there is both a driver and an observer present to count and record the information. Using two people in the car allows more area to be covered. In more modern parking garages, where sensors identify the number of parking spaces available, surveillance sensors can be used to determine space occupancy.

   It may be difficult to observe parking occupancy at large parking areas with frequent evening operations, such as those found around stadiums and regional shopping centers. In these cases, counts of vehicles entering and leaving by time period are necessary. Figure 2-26 shows how parking utilization is represented in a typical parking study.

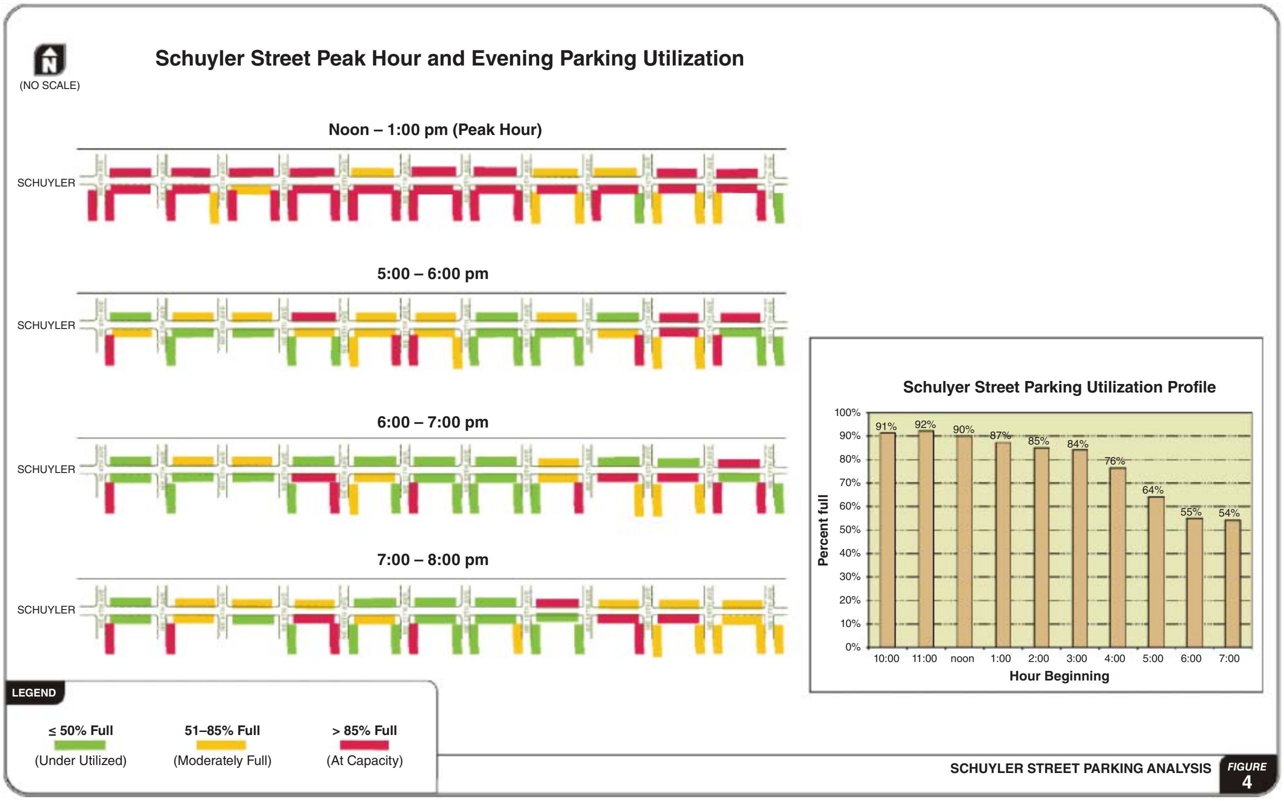
4) *Parking Durations and Turnover*. Parking durations (the time parked at a given parking space) and turnover (the number of vehicles parked in that space throughout the study period) are useful in parking management activities. They provide a basis for changing time limits or rates, focusing on enforcement, and removing curb parking. Information can be obtained by recording license numbers throughout the study period.

5) *Parker Characteristics*. Characteristics of parkers are obtained at the parking location either by parker interviews or by postcard mail-back surveys. The interviews are designed to obtain information on where people park, trip purpose and frequency, trip origin, primary destination, length of time parked, parking fee paid, arrival and departure times, and distance walked from parking space to primary destination. The data are used to calculate the parking demand of an area on a block-by-block basis. Occupancies, durations, and turnovers can also be obtained at the same time. Interviews are sometimes conducted at representative samples of curb and off-street parking facilities. To reduce costs, an area may be subdivided and the interviews spread over several days.

Surveys of visitors and employees at specific major generators, such as office buildings, shopping centers, hospitals, and industrial plants, provide important ancillary information about travel modes, trip origins, travel attitudes, and pedestrian flows. Employee information is usually obtained by employers and visitor information is usually obtained through direct interviews. Where offices constitute most of the space in a mixed-use development (such as in the downtown), restaurant and retail shops may draw workers for their patrons. Estimating the proportions of primary and secondary destinations requires direct interviews with patrons. The interviews should obtain information on trip purpose, travel mode, and whether the destination is primary or ancillary; they can be conducted at entrances to a trip generator.

Chapter 11 provides more detail on parking studies.

Figure 2-26. Example of Parking Utilization, Portland, Oregon



Source: Kittleson, Inc., 2005

V. MODAL STUDIES

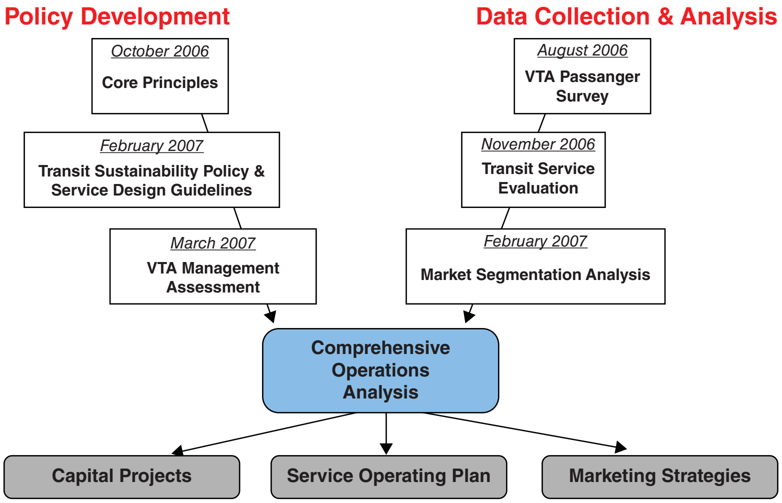
Transportation planning often focuses on specific modal issues, such as transit service planning, parking studies, pedestrian and bicycle analyses, and freight movement. Each of these topics is covered in more detail in other chapters of this handbook. However, some of the important data collection issues associated with these studies are discussed below.

A. Transit Studies

Transit studies usually focus on the quality of existing services and help establish the need for service improvements. They also include operations planning for a given route, comprehensive operations analysis, short-range transit development programs, and major transit investment studies. The studies develop information used to analyze the extent of usage, problems of traffic flow and safety, riding patterns, and traveler attitudes. Data are collected for a sampling of routes and coach runs, recording boardings and alightings by stop by time of day.

Figure 2-27 illustrates a study design for a short-range transit operations study often called a comprehensive operations analysis (COA). Note the importance of both technical analysis and input from agency

Figure 2-27. Comprehensive Operations Analysis Study Design, Santa Clara Valley Transportation Authority, California



Source: Santa Clara Valley Transportation Authority, 2009

Table 2-12. Common Public Transportation Study Data Items, Uses, and Collection Methods		
Data Item	**Uses**	**Study Method**
Load at peak point or other key point	Scheduling, planning	Point check, ride check
Running time and delay	Scheduling, planning	Ride check, trail car
Schedule adherence at specified points	Scheduling, evaluation, control	Point check, ride check, trail car
Boardings	Scheduling, evaluation, planning, reporting	Driver study, ride check
Distribution of boardings by fare category	Planning, marketing	Driver study, ride check
Boarding and alighting by stop	Planning	Automatic data collection equipment, ride check
Passenger miles or kilometers	Evaluation, reporting	Automatic data collection equipment, ride check
Passenger characteristics and attitudes	Planning, marketing	Survey
Passenger origin and destination pattern along route	Planning, marketing	Special ride check, survey, inferred from automatic data collection equipment, point check, ride check

Source: Urban Mass Transportation Administration. 1985

leaders. Table 2-12 lists some of the common transit data items and the methods used to collect the necessary information. Additional details on transit studies are described in chapter 12.

1. Transit Inventories

Inventories supply essential background information for a transit service analysis. Data include transit network maps; locations of all shops, transfer points, and garages; schedules indicating frequency and hours of service on each route and travel times between various points in the network; a list of the rolling stock supplying the service showing its capacity, age, and condition; and the list of fares.

2. Service Coverage

Service coverage analysis indicates how well the existing (or planned) route network covers the population within the transit area. Typically, areas within one-fourth to three-eighths of a mile of a bus route (or within one-half mile of a rail station) are delineated, and the population within these areas is estimated. The service area population within the specified walking distance is termed the *population coverage*. This concept can be extended to include coverage of employment. The proportion of the service area population within a given distance of a transit stop and also within a specified distance of a workplace represents a total coverage value.

3. Ridership Counts

These studies provide information on passenger boarding and alighting, vehicle loads, and schedule adherence. Such counts are useful in planning services, including the adjustment of routes and schedules, establishing bus stop locations, restricting turns along transit routes, adjusting street patterns and curb parking regulations, and developing transit priority measures, such as bus lanes and tragic signal priorities. Two major types of passenger counting strategies are common in the transit industry.

- *Point Checks*. Point checks obtain data on the number of passenger boardings and alightings and the loads on vehicles at one or more transit stops along the routes surveyed, usually the busiest stops. They may also include studies of dwell times and passenger service times. Point checks are conducted by individuals stationed at transit stops who count passenger movement when vehicles arrive. They may also collect data on transfers where multiple routes intersect.

- *Ride Checks*. Boarding and alighting checks can be performed along an entire transit route by direction of travel and time of day. This makes it possible to develop a profile of passenger loads by location and to compare these levels with the seats that are provided. Ride checks are conducted by individuals riding transit routes and making counts of passenger movement along the route.

4. Automated Ridership Profiles

Modern transit systems have incorporated automated sensors in vehicles and fare turnstiles that can be used to collect data on ridership. Often referred to as automatic passenger counters (APCs), these data provide reliable estimates of boardings and alightings, as well as a ridership profile along the entire route.

B. Pedestrian Studies

Pedestrian studies are used for a variety of purposes in transportation planning. They are used to establish safe-route-to-school maps for elementary children, establish the need for traffic controls, and adapt controls to better serve pedestrian movement. The studies provide a basis for sidewalk improvements, and they help justify pedestrian and transit malls, pedestrian skywalks, overpasses, tunnels, escalators, and moving belts. They are especially important in designing access to major pedestrian generators, such as urban stadiums, convention centers, and downtown developments that generate large pedestrian movements. They are also useful in designing access to and within transit stations and terminals and in developing plans for sidewalk amenities and public open spaces.

An aging population requires more emphasis on providing pedestrian facilities and in changing some of the parameters (such as walking speed) that are traditionally used in pedestrian analyses. The provision of special aids for handicapped persons (wheelchair ramps at intersections or to supplement stairs, audible traffic signals for the blind) has become an important aspect of the urban planning process.

Pedestrian studies include: (1) studying pedestrian volumes, speeds, and capacities; (2) establishing needs for traffic controls; (3) surveying pedestrian trip origins, destinations, trip purposes, and walking distances; (4) developing pedestrian trip generation rates; (5) obtaining pedestrian attitudes and perceptions; and (6) analyzing pedestrian behavior and space-use patterns. Detailed study procedures for obtaining and analyzing pedestrian volumes, walking speeds, needed gap sizes, and conflicts are contained in the ITE *Manual on Transportation Engineering Studies* [2010]. Chapter13 also provides more information on nonmotorized transportation.

Pedestrian volume and flow studies may be expressed in terms of volume (persons per hour), flow rate (persons per minute per meter or foot), spacing (square meters or feet per person), or walking speed (meters or feet per minute). Speed, flow rate, and density are interrelated. As flow rates on a sidewalk, crosswalk, passageway, ramp, or stairs increase, walking speed tends to decrease. After the flow rate reaches its maximum, density continues to increase toward a *jam density* or *crush density*, and flow rate and walking speed approach zero.

Most pedestrian counts are made manually. This can be labor-intensive, so the hours of data collection should be chosen carefully. Short-term sample counts may be used and then expanded to provide estimates for the period surveyed. Counts generally should be recorded in 5-minute intervals.

1) *Flow Rates and Capacities*. Pedestrian capacity depends on the effective walkway width. This effective width includes deductions of 6 inches (0.15 meters [m]) or more to account for buildings, curbs, window displays, and other street furniture (poles, parking meters, planters, bicycle racks, newspaper racks, benches, bus shelters). Pedestrian capacity and level of service (LOS) analyses are based on pedestrian spacing, the square footage of effective space per person. This is the reciprocal of density, pedestrians per square feet. LOS standards express spacing in terms of square feet per person per minute.

2) *Walking Speeds*. Pedestrian walking speeds vary by LOS or density by area and by groups of people. Studies have shown walking speeds ranging from about 2.2 feet (0.7 m) per second to more than 5 feet (1.5 m) per second. Many engineers have used 4.0 feet (1.2 m) per second in traffic engineering analyses. However, there is a growing tendency to use 3.3 feet (1.0 m) per second as a general value, and 3.0 feet (0.9 m) per second or 3.25 feet (1.0 m) per second for specific applications such as facilities utilized by elderly or handicapped people. Walking speeds below 3.0 feet (0.9 m) per second should not be used.

3) A special pedestrian walking speed study is sometimes desirable to define an appropriate value to be used in an area under study. Such a study should have a defined distance delimited along the path traveled by the pedestrian population under consideration. Individual pedestrians are timed as they pass through the "trap." A sample of approximately 100 pedestrians is sufficient. The sample should be collected during the timeframe of interest (for example, peak hour, noon, or afternoon). The data are plotted in a cumulative percentage curve. The fifth-percentile value is usually the appropriate value to use for traffic control and safety purposes.

4) *Door Counts*. Counts of people entering and leaving buildings, stores, off-street parking facilities, and transit terminals provide a basis for (1) establishing person-trip generation rates and (2) expanding sample interviews at the same locations. The counts should be made during the a.m. peak, noon time, and p.m. peak periods for developing trip rates. When keyed to interviews, they should normally be conducted from 7:00 a.m. to 6:00 p.m. Trip rates are obtained by relating the pedestrian volumes to the characteristics of the activity surveyed, such as floor space and employment (if only exiting pedestrians are counted, the surveys could be done from 10:00 a.m. to 6:00 p.m.).

C. Goods Movement Studies

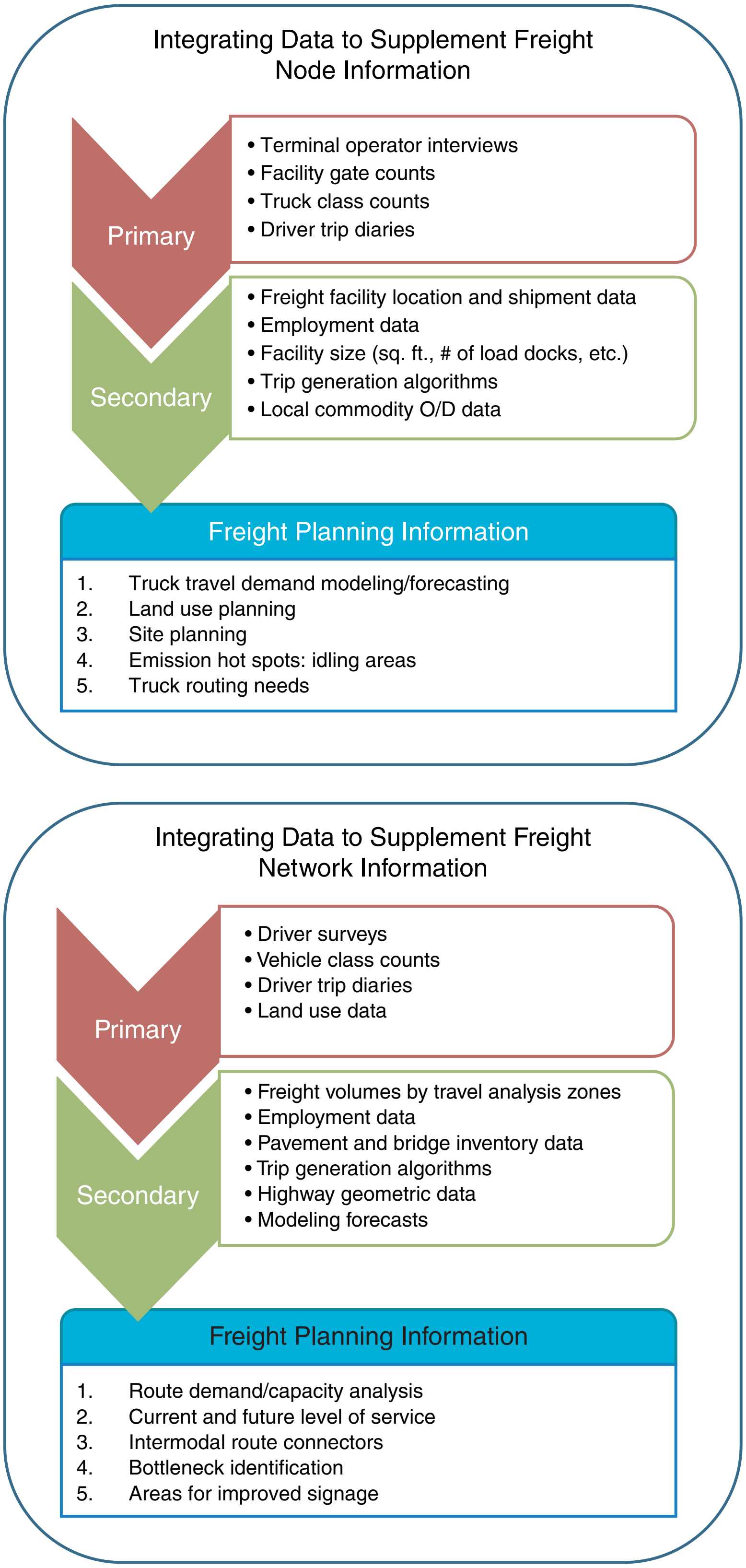
Goods movement involves the collection and distribution of raw materials and finished products. Freight is handled by truck, train, ship, and pipeline with small amounts of high-value cargo going by air. The scale, types, and patterns of goods movement vary widely; studies should be keyed to specific needs. They generally involve obtaining information on (1) types and magnitudes of commodities shipped, (2) modes of conveyance utilized, (3) origins and destinations, (4) shipment and terminal travel times, (5) loading and berthing requirements, (6) daily and hourly variations in shipments, and (7) frequency of shipments. Where trucks are involved, their number, type, weight, commodities carried, and use of roadways are important. Chapter 22 provides more detailed information on freight analysis.

At the local level, goods movement studies are usually undertaken in response to specific problems. Figure 2-28 shows the types of data that are used in transportation planning studies.

1. Intercept Surveys

Truck operators can be interviewed at a cordon line around an urban area, often as part of a comprehensive transportation planning study. The surveys should identify the volumes and types of commodities moving into and through an area, the destinations of these commodities, and the types

Figure 2-28. Freight Data and Uses for Transportation Planning at Freight Node and Network Levels



Source: Rhodes et al., 2012. Reproduced with permission of the Transportation Research Board.

of vehicles involved. The Port Authority of New York and New Jersey, for example, conducts commodity surveys of vehicles crossing the Hudson River and Verrazano Narrows Bridge on a periodic basis. Intercept interviews can be conducted at truck weight stations. Where these are located near the cordon line, there is usually space for trucks to pull out for interviews.

The following factors must be considered when conducting intercept surveys:

- *Type of Interview*. These can be conducted as brief one-on-one interviews, or where time is an issue, mail-back postcards can be distributed to willing participants.
- *Traffic control*. When conducted at businesses, data collectors are usually stationed at loading docks to conduct interviews while trucks are being loaded/unloaded to minimize the impact on traffic operations. At weigh stations, truck stops, and rest areas, drivers are directed to a defined area in which all interviews are conducted. Some interviews, however, are conducted at points along a road or at an intersection.
- In these instances, traffic control measures must be put into place to maintain efficient operations for all vehicular traffic. Coordination with law enforcement may be necessary if safety and traffic control assistance is needed. Traffic speeds may need to be reduced to ensure the safety of data collectors. Advanced warning signs also help improve safety for both the motoring public and those involved in the data collection process.
- *Data collection equipment*. Interviews can be conducted using a variety of equipment. The most common data collection tools include paper surveys and handheld computers. The surveys developed for driver interviews are designed to be easily completed in less than three minutes to minimize the impact on the participating commercial vehicle operators.
- *Sampling plan*. Most truck studies do not have the budget available to collect data on every corridor, for all periods of the day, week, and year. Therefore, a sampling plan must be developed to capture an adequate amount of representative data. Goals of the sampling plan should be to provide geographical coverage of the study area, to collect adequate time-of-day and time-of-year data, to capture both intra-regional (internal to internal) and inter-regional (internal to external, external to internal and external to external) trips.
- *Data expansion*. Recognizing that a 100-percent sample cannot realistically be gathered at most locations, it is necessary to expand the records collected to represent the full traffic stream. To represent the total truck traffic, expansion factors can be applied to the survey results. These expansion factors can be established by comparing the number of trucks surveyed during an hour to hourly count data provided by the jurisdiction or collected for the project.

2. Interviews

Interviews conducted with shippers, carriers, building owners, and managers/tenants at terminals can provide detailed information of goods movement characteristics and problems.

Building owner/manager/tenant interviews should obtain information pertaining to:

- Building use—floor space by use (for example, retail, warehousing, office), number of tenants, percentage occupied, number of employees, and so on.
- Delivery restrictions—restrictions imposed by the building owner relating to hours of delivery and types of vehicles.
- Delivery reception—location at which delivery and service vehicles park, off-street loading facility availability and utilization, location of freight elevators, and the like.
- Delivery variations—variations in deliveries by hour, day, or month.
- Enforcement—building actions taken to assure proper usage of the available loading space.
- Size and types of shipments.
- Origins and destinations of goods shipped or received.
- Procedures for handling mail and trash.
- Particular problems noted or experienced.
- Reaction to various alternative solutions.

Truck owners and operator interviews can obtain information on trip patterns. A sample could be selected from vehicle registration data; the percentage of total registered truck owners interviewed should range from 1 to 5 percent, depending on the truck classification. Information should be obtained on license owner and location where the vehicle is based, axle arrangement and body style, cargo specialty, commodities carried, trips and stops made, and related travel information.

Questionnaires can be distributed at for-hire truck terminals and followed up with in-depth interviews. The same procedures can be followed for major rail, marine, or air cargo terminals. Interviews could obtain information such as the following:

- A detailed description of the routine operation of the terminal, including hours of operation, workflow, volume fluctuations, and types of commodities carried in the areas served.
- A description of operational characteristics of the terminal, including capacity, number and types of trucks and rail cars served, and special equipment used.
- The types of records maintained at the terminal that might be used in a comprehensive goods movement survey, including shipment patterns and commodity characteristics.
- Particular problems noted or experienced.
- Reaction to various alternative solutions.

Businesses with heavy truck activity can be another great source of information on truck travel characteristics. Information from these establishments regarding the type of services provided, the number of trucks in operation during a typical weekday, and their fleet composition can be used to expand data collected through intercept surveys. These interviews can be conducted in person or via telephone.

By targeting key stakeholders in the trucking industry, planners can capture vital information about the movement of goods through an area. This data collection tool has two major components:

Defining Stakeholder List. To best understand how trucks move through an area, the stakeholder interview process must target individuals from a variety of industrial categories, business sizes, and geographic locations.

Developing Interview Guidelines. The types of questions asked during this process depend on the purpose of the study and the individual stakeholder being interviewed. The general form of these interviews should be free-flowing, in-person discussions that elicit insight from respondents. Topics of discussion often include supply chain structures, operational information, and the challenges/advantages of operating in and around the study area.

3. License Plate Capture

This method is generally used in combination with the previously described techniques. Video cameras are used to capture license plate information at multiple locations around the perimeter and within a given study area. Information collected at these sites are analyzed and compared against each other to generate travel pattern information. Travel times can be compared to determine whether or not stops were made between detection locations. The following are critical components of any video license plate capture assignment:

Site Selection. The purpose of the study usually determines the selection of data collection points. Generally, cameras would be placed at entry/exit points of the study area.

Camera Placement. Depending on the company conducting the data collection, video camera placement varies. Some data collectors place their equipment on overpasses, angled down to capture vehicles passing below. Recently, some companies have tried other techniques, such as placing cameras inside traffic barrels on the side of the road.

Data Processing and Transcription. The method used to process the license plate data can vary greatly depending on the magnitude of the project and the budget available. License plate collection can be as simple as setting up a camera and manually recording the license plate numbers from the video output at each collection location. The recorded data would then be compared between locations to analyze travel patterns. For larger-scale projects, the data processing can be accomplished by fully automated systems, which collect the license plate data, process it, and store it in a database for analyses.

4. Loading and Unloading Studies

Studies of loading deck operations are used to determine space requirements and geometric design criteria. These studies investigate occupancy and dwell times often by land use type. The information provides a basis for establishing desirable on-street and off-street loading space.

There is a growing body of information on goods movement at the national, state, and local levels. The reader is referred to the Transportation Research Board's *Guidebook for Understanding Urban Goods Movement*. [Rhodes et al., 2012] Many metropolitan areas have conducted freight or goods movement studies; an Internet search on "urban goods movement" will provide the reader with many examples of how such studies are conducted as well as data on freight flows for individual metropolitan areas.

5. Truck Weight Studies

Information on truck weights is collected for many purposes, including pavement design, revenue estimates, motor carrier enforcement, highway cost allocation, and other planning and engineering activities. Vehicle weights are reported by motor freight companies as part of their reporting requirements. The recipients of this information vary by state, but the state motor vehicle department is usually the agency that collects this information through the vehicle registration process.

Roadside weight checking is conducted with either permanent or portable scales, usually as part of an enforcement program. Following the changes in trucking regulations in the 1980s and the resulting changes to fleet mixes, truck size and weight studies are often conducted to evaluate the impact on types of trucks being used on pavement performance, geometric requirements, and changes in industry efficiencies. Depending on the analysis to be conducted, the data collection method should consider ADT, percent trucks, percent trucks by type, percent trucks by commodity, interstate versus non interstate trips, site suitability, and nearby alternate routes. Static scales are required to certify truck weights and to establish a legal basis for identifying violators. This requires special truck access to avoid any spillback on the main travel times. Weigh-in-motion (WIM) scales are used to determine if a truck is traveling within a reasonable range of legal weight limits. Information collected may include gross vehicle weight, axle weight, and tandem axle weight. WIM scales are often found at permanent truck weigh station sites, but they are used by some agencies in a roving mode.

6. Global Positioning System (GPS)–Based Data Collection

Recently, GPS technology has been used to improve the accuracy and amount of data collected in truck studies. In-vehicle devices can accurately combine time-coding and location data with user input about trip characteristics. All data collected by these units can then be easily input into geographic information system (GIS) maps, producing visual displays of route choices and travel patterns. This type of data is increasingly used in statewide and metropolitan freight studies. Chapter 22 on integrating freight concerns into the transportation planning process provides more detail on this new approach toward collecting data on truck movements.

VI. STATISTICAL CONSIDERATIONS

If cost and time were not important, traffic data collection would likely collect as much data as possible. However, as previously noted, substantial resources are often allocated to collecting the necessary data to conduct a variety of planning studies. Accordingly, data are often collected based on samples that have required levels of precision and error allowance. Statistical analysis methods are essential in this effort. They can address questions such as how to best characterize the distribution of travel times, speeds, or land uses; what sample sizes are needed at a specified level of accuracy to estimate shopper origins at a major activity center; or how to establish predictive relationships between land use and trip generation.

Transportation planners work with data and statistics on a variety of tasks, with the complexity depending on the application. It is beyond the scope of this chapter to present a detailed discussion of the statistical tools used by transportation planners. Interested readers are referred to [Washington et al., 2003; ITE, 2010]. However, statistical sampling is one area where transportation planners use statistics that merits some attention.

A. Sampling and Inference

Sample procedures make it possible to show inferences about a population. By sampling a small representative fraction of the entire population, it is possible to estimate characteristics that represent the population as a whole with enough accuracy to base decisions on the result with a reasonable level of confidence. Sampling procedures involve establishing confidence intervals, estimating sample sizes, and comparing various groups. They make it possible to address such questions as the following: How good are the results? What sample sizes are needed? Are the differences between two sample means or variances statistically significant?

The following principal steps in conducting a survey show how sampling is part of the effort.

1) Clearly state the objectives and reasons for the survey.
2) Define the population of interest to be sampled.
3) Identify the data to be collected.
4) Establish the desired degree of precision.
5) Determine the methods of measurement (for example, household telephone survey versus home interview survey).
6) Construct the sampling frame for the population to be sampled. This frame should cover the entire population to be sampled, and each individual element must appear only once on the list.
7) Select the sample design and sampling plan. This includes initial estimates of sample size and precision, as well as time and cost implications.
8) Pretest the survey instrument (questionnaire) and modify it as necessary.
9) Organize the fieldwork and collect the data.
10) Summarize, analyze, and interpret the data. Clearly indicate the amount of error that is expected in the most important elements.
11) Preserve the information assembled for future surveys. Quantifying key parameters, such as the variances, will prove useful in preparing future survey designs.

1. Types of Samples

The common types of probability sampling include: (1) simple random sampling, (2) stratified random sampling, (3) systematic sampling, and (4) cluster sampling.

1) *Simple random sampling*. This is the simplest and most widely used form of sampling. A simple random sample from an infinite population is selected in such a way that all observations chosen are statistically independent. A simple random sample from a finite population involves selecting n units out of the population, N, so that each individual element has an equal chance of being selected. In practice, a sample is drawn unit by unit. A table of random numbers might be utilized. For telephone surveys, random digit dialing procedures can be used.
2) *Stratified random sampling*. A stratified random sample is obtained by dividing the population into classes or strata and then selecting a random sample from each strata. It is useful where there are wide variations among strata and stratification would reduce overall sample size requirements for any given level of precision. It makes it possible to obtain data of known precision for certain subdivisions of the population (for example, travel times on freeways and arterial streets). Stratified random sampling is also commonly used in urban travel behavior studies where it is important to set minimum quotas for subgroups of individuals that appear infrequently in the population, are difficult to interview, and/or are important to model for policy analysis. For example, in urban travel studies, with stratification, it is common to oversample low-income households and current transit users.
3) *Systematic sampling*. A systematic sample draws every *k*th element of the sampling frame beginning with a randomly chosen point. For example, if the first unit is 13 and every 15th unit is chosen, then units 28, 43, 58, and so on would be selected. Systematic samples are easier to obtain than simple random samples in terms of time and cost. If spread more evenly over the population, this approach may be more precise than simple random sampling. However, systematic samples may give poor precision where periodicity in

the data exists. An example of this is the railway bill sampling because sequentially numbered forms are drawn from multiple supplies simultaneously, which increases the likelihood of low numbered forms.

4) *Cluster sampling*. Cluster sampling divides the population into a series of mutually exclusive classes that are usually defined based on convenience. Clusters are then selected for detailed study, usually by some random basis. Either a complete census or a random sample is obtained from each of the selected clusters. Results are then combined. Cluster sampling is useful when there are no reliable lists of elements in the population or because of the ease of constructing lists of sampling units and time-and-cost efficiencies. However, cluster sampling usually results in higher sampling errors than other kinds of surveys. For a given level of precision, stratified samples require the smallest sample and cluster samples require the largest.

2. Errors in Sampling

When estimates are made from a sample, it is not likely that the sample estimate will be exactly the same as that obtained from a complete census. The difference between the two represents the sampling error, if both the sample data and population data are obtained by identical methods. When probability samples are used, the amount of this sampling error can be determined.

Non sampling errors may exceed sampling errors, and they should be minimized by careful survey design and execution. They include errors associated with measuring a unit (for example, trying to estimate standees on a crowded subway train); errors introduced in editing, coding, and tabulating surveys; and failure to measure some units in the sample (for example, nonresponse to the survey).

Nonresponse errors include failure to survey particular units of the sample (that is, people who refuse to be interviewed, are not at home, or are unable to answer). In these cases, there is no assurance that the nonrespondents would respond similarly to those sampled. The nonresponse can be minimized by the method of survey (for example, direct interview versus mail back) and by call back. In estimating sample sizes, it may be desirable to *oversample* various segments of the population surveyed to compensate for nonresponse. While this will address the sampling error, it may not necessarily compensate for nonresponse bias. Table 2-13 shows typical response rates for surveys.

3. Household Travel Survey Recruiting and Sample Size Determination[2]

Since 2010, most regional household travel survey recruiting methods typically use an address-based sampling (ABS) approach. Under this design, the sample frames are selected from the United States Postal Service (USPS) Computerized Delivery Sequence File and are geocoded once the sample frame is generated and invitation letters are mailed. An ABS frame supports both simple and stratified random sampling. The fact that all samples are geocoded makes it possible to obtain surveys that are geographically representative or, through the use of Census geographies, develop targeted strata using data from sources such as the American Community Survey (ACS). Targeted strata include households with possessing certain characteristics of interest such as zero-vehicle, large, or minority households, for example.

Table 2-13. Response Rate Comparison to Surveys

Study	Year	Final Response and Participation Rate
Massachusetts Travel Survey	2010–2011	34.6%
ARC Regional Travel Survey	2011	5.9%–34%
CALTRANS HH Travel Survey	2011	5.5%
ARC Regional Travel Survey Pre-Test	2010	11%–31%
Central Indiana Full Study	2010	41%
Oregon Full Study – Region 4	2009	39%
Oregon Full Study – Region 2	2009	44%
Central Indiana Pre-Test	2008	10%–36%
Oregon 1-day Pre-Test	2008	15%–46%
Chicago Full Study	2007–2008	10%–31%
Chicago Pre-Test	2006	9%–29%

Source: Massachusetts DOT, 2012

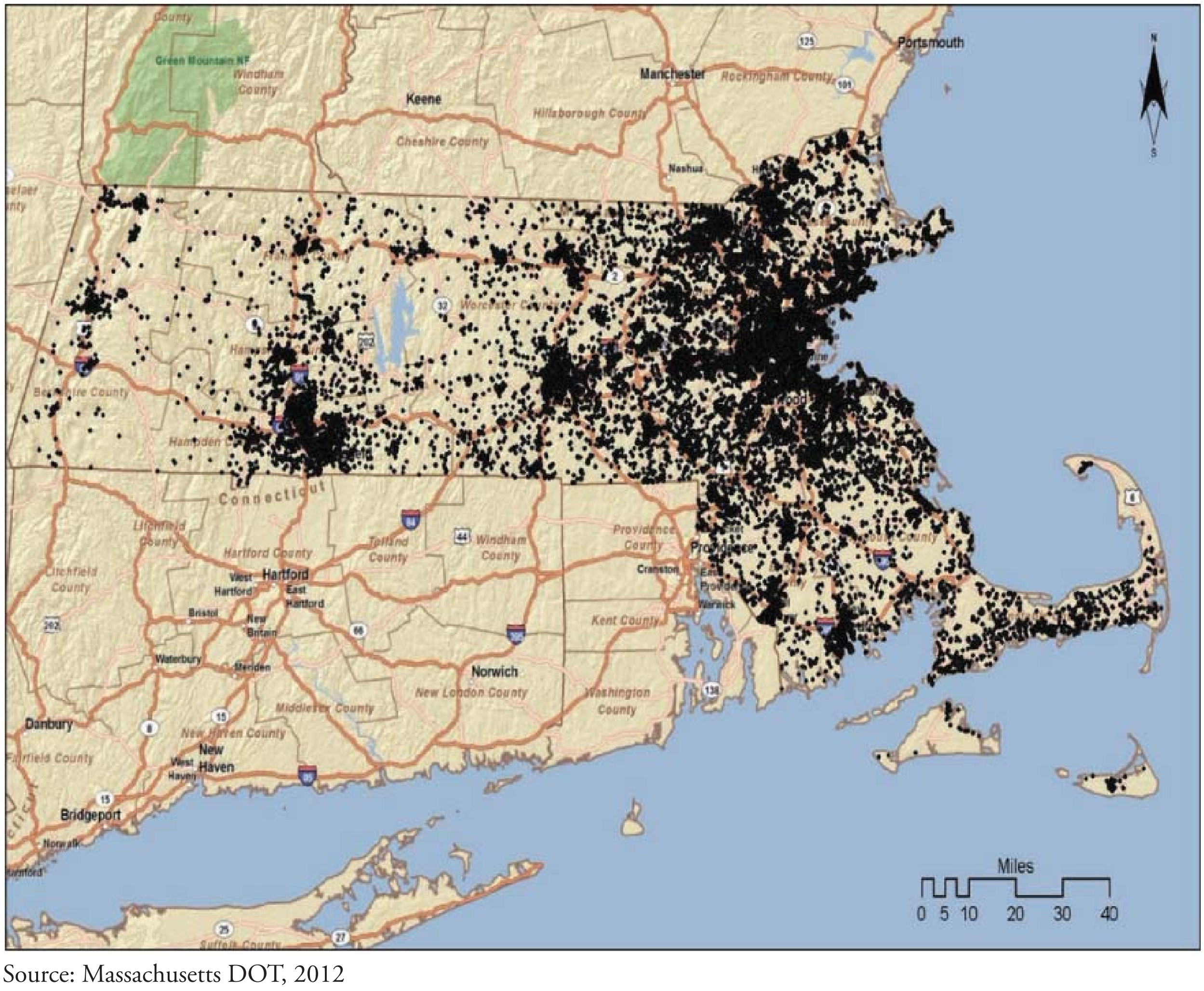
[2] This section was written by William Bachman, Westat, Inc.

Households are typically offered the opportunity to self-recruit using a web survey, and conduct a computer-assisted self-interview (CASI), or to call in and complete the survey by phone with a trained survey interviewer/data collector who uses a computer-assisted telephone interview (CATI). Reminder postcards are also sometimes mailed to reiterate the message encouraging participation on the original invitation letter and promote survey response. Once recruited and assigned a travel date, households again have a choice to report their travel (retrieval survey) via CASI, through a mobile device application, or by CATI.

A travel survey for the Massachusetts DOT provides a good example of how a geographically based sampling strategy is required to provide a statistically valid survey result. Figure 2-29 shows the households sampled in the state to obtain survey results. A geographic stratification scheme was used to ensure adequate representation of households by MPO regions and municipal density groups. A demographic stratification was also used to set demographic controls and monitor the performance of the sample against these controls. [MassDOT, 2012]

The determination of survey sample size and demographic stratification is entirely dependent on existing models or the development of more advanced models (for example, activity-based models) and/or other transportation planning activities. Traditional four-step models typically require a representative sample (that is, that closely matches U.S. Census distributions) of socio-demographic categories (household income, household size, vehicle ownership, etc.) as well as an even geographic distribution (see chapter 6 on travel demand modeling). More advanced models require significantly more complex sampling stratification to ensure that certain categories, such as transit riders, are adequately represented. For example, Asheville, North Carolina, conducted a travel survey in 2013 to support a traditional four-step model and the main survey objective was to ensure that enough surveys were completed for households that matched U.S. Census distributions. With those targets in mind, the survey team used U.S. Census data and local demographic information to recruit participants in the Asheville region. Recruiting invitations were

Figure 2-29. Households Recruited for Massachusetts DOT Survey



Source: Massachusetts DOT, 2012

Table 2-14. Sample Stratification Table: A Typical Example															
	Number of Workers														
	0			**1**			**2**			**3+**			**Totals**		
Hhld Size	**# of Hhlds.**	**% of Total**	**Survey Goal**	**# of Hhlds.**	**% of Total**	**Survey Goal**	**# of Hhlds.**	**% of Total**	**Survey Goal**	**# of Hhlds.**	**% of Total**	**Survey Goal**	**# of Hhlds.**	**% of Total**	**Survey Goal**
1	78,403	11.1%	777	109,598	15.5%	1,087	0	N/A	0	0	N/A	0	188,001	26.6%	1,864
2	62,293	8.8%	618	85,659	12.1%	849	82,855	11.7%	821	0	N/A	0	230,807	32.7%	2,288
3	***12,702***	***1.8%***	***126***	41,419	5.9%	411	44,695	6.3%	443	***12,195***	***1.7%***	***121***	111,011	15.7%	1,101
4+	***11,838***	***1.7%***	***117***	62,799	8.9%	623	69,285	9.8%	687	***32,296***	***4.6%***	***320***	176,218	25.0%	1,747
Totals	165,236	23.4%	1,638	299,475	42.4%	2,969	196,835	27.9%	1,952	44,491	6.3%	441	706,037	100.0%	7,000

mailed to participants and successful recruiting characteristics were monitored to ensure that adequate samples were collected in all category combinations and in all geographic areas.

In addition to a geographic (for example, by county, jurisdiction, modeling subareas) representation, planners want to have a representative sample relating to socioeconomic characteristics. Table 2-14, for example, illustrates a sampling stratification table for a household travel survey conducted in the Las Vegas region. The highlighted cells were combined, which is typical when the individual targets are small and it would be very difficult to achieve the goals (for example, a three-person household with three workers).

Travel surveys are sometime funded by multiple agencies resulting in more complex sampling requirements. To meet the needs of both the Michigan Department of Transportation (MDOT) and the Southeast Michigan Council of Governments (SEMCOG), a recent statewide survey required a sample plan that met both a statewide geographic distribution among 21 sampling areas as well as a sampling stratification with three variables specific to the SEMCOG region (vehicle ownership, household size, and number of workers). Other variables, such as travel mode, may be monitored to ensure that enough samples are collected to support the development of model algorithms.

VII. SUMMARY

Transportation planning depends on collecting and analyzing data, both on the transportation system and on system users. Understanding the basic characteristics of urban transportation systems is fundamental to discerning the challenges these systems face today and will likely face in the future. Similarly, knowing the underlying variables that influence urban travel, such as population characteristics and resulting travel patterns, is a basic foundation for analyzing the likely consequences of strategies to influence travel behavior.

This chapter presented an overview of the data collection and analysis procedures that are commonly used in transportation planning. Data are essential to the transportation planning process, and it is, thus, not surprising that a large portion of the budget for transportation planning studies is often devoted to data collection. Given the expense, transportation analysts often adopt different strategies for collecting or updating already collected data for use in a particular study. These procedures are often based on sampling techniques that collect data on representative samples of a target population. This means that the transportation analyst must understand sampling methodology and the appropriate use of different survey techniques.

In addition, both federal and state transportation agencies often have data manuals that guide the collection and analysis of data. It is beneficial to read these manuals for a particular jurisdiction prior to undertaking a data collection effort.

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Land Use and Urban Design[1]

I. INTRODUCTION

One of the major reasons often stated for investing in the transportation system is to promote economic development. The link between economic development and transportation is founded on the accessibility provided by transportation to the daily social and economic activities in a community. However, this accessibility influences more than just economic development. In a much broader sense, system accessibility influences all forms of interactions. In the context of this chapter, accessibility affects where industries and services locate, where people live, and how easy it is to access all of the supporting activities (for example, health care) associated with a modern community. In other words, a transportation system influences land use.

Over time, the transportation–land-use relationship also defines how a transportation system is used. Areawide, land-use patterns and associated trip-generating activities affect transportation network performance. For example, the concentration of office buildings around a freeway interchange (because of the excellent accessibility afforded by the proximity to the freeway) will likely lead to high levels of congestion on the interchange and adjacent road network. The high concentration of residential, commercial, and office development in downtowns encouraged by rail transit stations also results in heavy station boardings during transit peak periods. For individual land parcels, development characteristics influence how much traffic is generated and attracted to these specific locations. The position of buildings at a site, their relationship to the surrounding community, and the amenities provided to those who use the site (that is, urban design) can influence trip-making behavior.

Although transportation planning has historically viewed land use solely as an exogenous input in travel demand estimation (for example, how many trips are generated given land-use type and intensity of development?), land-use and urban design principles have emerged as effective tools that communities can leverage for improving mobility and accessibility. Transportation planners must be aware of fundamental land-use and urban design concepts, as they serve as the foundation for a comprehensive approach to community-building.

The Federal Highway Administration (FHWA) notes that, "at a minimum, the coordination of land use and transportation requires that those concerned with the well-being of a community (or region, state or nation) assess and evaluate how land-use decisions affect the transportation system and can increase viable options for people to access opportunities, goods, services, and other resources to improve the quality of their lives. In turn, the transportation sector should be aware of the effects the existing and future transportation systems may have on land-use development demand, choices, and patterns." [FHWA, 2013] This chapter is organized to provide the practitioner with the knowledge and tools to contribute such information to the decision-making process.

The following section describes those factors that influence land use and urban form. In particular, three major influences are described: (1) regional planning and the provision of infrastructure, (2) local government planning and development regulation, and (3) land owners, private developers, and financial lenders. The chapter then discusses the role that urban design and access management can play in development and transportation decision making. The following section examines current approaches to land-use modeling and the characteristics associated with both the models and their use in planning. The final section focuses on context-sensitive solutions (CSS) that depend on a combined land-use–transportation perspective for achieving both transportation and community development goals.

[1] The original chapter in Volume 3 of this handbook was written by Michael D. Meyer, WSP/Parsons Brinckerhoff.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

II. WHAT DRIVES DEVELOPMENT AND RESULTING URBAN FORM?[2]

The land-use and development patterns of metropolitan areas and individual communities are influenced by a variety of factors. For example, a study of the key influences that shaped Atlanta's regional development pattern from 1950 to 2000 identified the eight factors shown in Table 3-1. [Meyer, 2001] In some cases, the factors listed in this table are under the control of transportation officials (such as the provision of transportation infrastructure); for others, transportation officials exert little to no influence.

Different groups and individuals participate in or influence development-related decisions. In the private sector, these include developers, contractors, financial lending institutions, and individual and corporate buyers of real estate. In the public sector, the participants include elected and appointed community officials, local agency staff, state and regional transportation planning officials, transit authorities, local zoning and planning commissions, and local school officials, all of whom influence how the community development process occurs.

Many of the institutional and regulatory land-use frameworks found in U.S. communities exhibit common characteristics (such as similar zoning codes). However, in reality, every community is different, and community development patterns evolve under influences that are specific to the regional and market contexts found in a particular community. One must therefore understand not only the ordinances and regulations commonly used to influence the amount and type of community development, but also other factors that can have an impact on development patterns. Three major considerations are important in understanding the institutional and regulatory factors that shape community development: regional planning and provision of public infrastructure, local government planning and development regulations, and the major players in land-use transactions, that is, land owners, private developers, and financial lenders.

A. Regional Planning and Provision of Public Infrastructure

Although the strongest *governmental* influence on local land use comes from community comprehensive plans and development ordinances, the evolution of a community's development pattern occurs within a much larger economic, social, and political context (see, for example, [Brook, 2013; Congress for the New Urbanism and Talen, 2013; Gallagher, 2013; Katz and Bradley, 2013; and Montgomery, 2013]). Many communities are located in metropolitan areas that are implementing policies intended to influence community development patterns. This regional context for community development takes two major forms—(1) the metropolitan-wide policies or strategies aimed at managing and directing growth, and (2) the metropolitan-wide investment in transportation, sewers, water systems, and other infrastructure/services that are prerequisites for most types of development. Importantly, the metropolitan area planning approach to growth management is strongly influenced by the state and local planning environment, such as the use of impact fees, adequate public facilities ordinances, taxing districts, and other exactions used by local jurisdictions.

Metropolitan planning organizations (MPOs) and regional development agencies often adopt policies intended to influence how growth occurs. These policies focus on directing the shape and character of metropolitan development

Table 3-1. Factors That Influenced Development Patterns in Atlanta, 1950–2000
Racial Attitudes
Urban Redevelopment and Housing Policy
Zoning and Development Policy
Location and Quality of Public Schools
Dispersal of Employment Opportunities
Transportation Infrastructure — Highways
Transportation Infrastructure — Transit
Institutional Structure for Decision Making

Source: Meyer, M. 2001. "Historical Perspective on the Growth of Atlanta Since World War II." Paper prepared for the Atlanta Regional Commission, Environmental Justice Initiative, Atlanta, GA.

[2]Some of the material in this section originated in Meyer and Dumbaugh, 2005.

through actions such as targeting development away from suburban fringe areas, as well as encouraging the more efficient use of existing infrastructure, including roads and sewer systems. The types of policies actually employed vary from region to region, from Portland, Oregon's, growth management boundary and Minneapolis–St. Paul's, Minnesota, infrastructure phasing requirements to more market-oriented approaches, such as the use of impact fees and development exactions. Because such policies have a strong influence on when and if certain lands will be developed, they can be leveraged to encourage desired development outcomes, such as promoting the design of communities that support nonmotorized travel. [Daniels, 1999; Meyer and Dumbaugh, 2005]

Metropolitan transportation planning is just one of the many planning processes that considers development and land-use policies and strategies. As noted in chapter 1, the transportation planning process begins with an articulation of a vision, that is, what characteristics of quality of life, economic vitality, transportation system performance, and societal benefit accruing from public investment are desired by a community or region? The definition of this vision often comes from an extensive public participation process that encourages many different community stakeholders to develop statements regarding a desired future. Not surprisingly, given the importance of the built environment, these vision statements usually emphasize desired development patterns. For example, the following vision statement comes from the Puget Sound Regional Council (PSRC), the MPO for Seattle, Washington.

> *"Our vision for the future advances the ideals of our people, our prosperity, and our planet. As we work toward achieving the region's vision, we must protect the environment, support and create vibrant, livable, and healthy communities, offer economic opportunities for all, provide safe and efficient mobility, and use our resources wisely and efficiently. Land use, economic, and transportation decisions will be integrated in a manner that supports a healthy environment, addresses global climate change, achieves social equity, and is attentive to the needs of future generations."*
>
> *—Puget Sound Regional Council [2009]*

The corresponding transportation goal for this vision included: "The region will have a safe, cleaner, integrated, sustainable, and highly efficient multimodal transportation system that supports the regional growth strategy, promotes economic and environmental vitality, and contributes to better public health." Specific policies adopted to guide transportation investments included:

- Prioritize investments in transportation facilities and services in the urban growth area that support compact, pedestrian- and transit-oriented densities and development.
- Give regional funding priority to transportation improvements that serve regional growth centers, and regional manufacturing and industrial centers.
- Make transportation investments that improve economic and living conditions so that industries and skilled workers continue to be retained and attracted to the region.
- Design, construct, and operate transportation facilities to serve all users safely and conveniently, including motorists, pedestrians, bicyclists, and transit users, while accommodating the movement of freight and goods, as suitable to each facility's function and context as determined by the appropriate jurisdictions.
- Improve local street patterns—including their design and how they are used—for walking, bicycling, and transit use to enhance communities, connectivity, and physical activity.
- Promote and incorporate bicycle and pedestrian travel as important modes of transportation by providing facilities and reliable connections.

Another example of a vision statement comes from the Atlanta Regional Commission (ARC), which produced a policy framework to guide all regional planning efforts, including transportation planning. [ARC, 2015a] As shown in Figure 3-1, ARC's framework has defined three major areas for improving the region: developing and maintaining world class infrastructure, creating healthy livable communities, and supporting a competitive economy.

Figure 3-1. Policy Framework for Regional Planning by the Atlanta Regional Commission

Source: ARC, 2015a, Reproduced with permission of the Atlanta Regional Commission.

The policy goal and selected actions most relevant to transportation included: [ARC 2015a]

Goal: Ensure a comprehensive transportation network, incorporating regional transit and 21st century technology

- Promote transit and active transportation modes to improve access.
- Maintain and improve the economic viability and accessibility of key intermodal freight facilities.
- Prioritize data-supported maintenance projects over expansion projects.
- Promote system reliability and resiliency.
- Establish effective transit services that provide regional accessibility.
- Prioritize transit projects in areas with transit-supportive land use, plans, and regulations.
- Promote bicycle transportation by developing safe and connected route options and facilities.
- Promote pedestrian-friendly policies and design.
- Enhance and expand Transportation Demand Management (TDM) programs.
- Prioritize solutions that improve multimodal connectivity.
- Direct federal funding for road capacity expansion to the regional strategic transportation system, including the managed lanes system.
- Road expansion projects in rural areas should support economic competitiveness by improving multi-modal connectivity between centers.
- Implement a complete streets approach on roadway projects that is sensitive to the existing community.
- Promote and enhance safety across all planning and implementation efforts, including support for the state strategic highway safety plan.
- Coordinate security and emergency preparedness programs across transportation modes and jurisdictions.
- Maintain and expand transportation options that serve the region's most vulnerable populations.
- Improve connectivity around transit stations and bus stops for all users.
- Increase funding for Human Services Transportation (HST) and Medicaid transportation services.
- Increase access to areas with essential services, including healthcare, education, recreation, entertainment, and commercial retail.
- Provide safe and reliable access to freight land uses and major intermodal freight facilities.
- Promote the use of information technologies to foster the most efficient movement of freight.
- Preserve industrial land uses in proximity to existing freight corridors.
- Pursue the application and use of advanced technologies.
- Encourage the application of passenger information technologies.
- Encourage development, redevelopment, and transportation improvements to consider impacts on neighborhoods and communities.
- Promote and support urban design standards that enhance elements of accessibility and livability.
- Plan for the impacts of extreme weather events on community services and infrastructure, including system resiliency.
- Foster improved access to cultural assets.

As can be seen in this list, planning concerns span a range of issues that are important to the future of communities. Where transportation investment fits into these larger visions very much influences the types of strategies and actions that will surface at the end of the process.

Unless local communities align their own plans, policies, and regulations to support a regional vision, the vision will not be realized. Portland, Oregon, for example, has established a strong alignment between regional policies and local government actions. In Denver, Colorado, the *Mile High Compact*, a regional policy that encourages nontraditional development patterns, has been adopted by many of the region's communities. In this case, the region's MPO grants extra priority for transportation investment to projects in communities that have adopted this policy.

Although metropolitan plans and policies can provide an overarching context for local decisions, the strongest *regional* influence on land use, and on the decisions leading to development, comes from the actual changes made to those infrastructure systems that provide the basic necessities of modern societies. With urban areas expanding dramatically during the twentieth century, governments at all levels recognized the need for metropolitan-wide efforts to coordinate the provision of critical infrastructure. The federally-mandated metropolitan transportation planning process is an example of such an effort. Others include regional efforts to put in place water systems and waste disposal sites and to handle societal needs that transcend individual community boundaries, such as helping the elderly population. This handbook, in essence, focuses on the how transportation system investment decisions can be informed by the transportation planning process.

B. Local Governmental Planning and Development Regulation

Local governments are most often the closest service and infrastructure provider to community residents. In the United States and in many other western countries, local comprehensive plans, zoning ordinances, and subdivision regulations are used to guide the levels and types of community development. As per state constitutions, local governments are given the responsibility for establishing the regulations and controls that oversee development decision making within their jurisdictional boundaries. For example, one of the most influential tools for influencing the substance and style of community development (and the one most jealously guarded by local officials) is the local zoning code. It is through this code that the community vision of what it wants in terms of development patterns is expressed in a way that holds the force of law. Table 3-2 shows other types of tools that local officials have at their disposal for influencing community development. In some instances, communities utilize all of the tools shown in the table, whereas in others, only a few are available.

Schools are also an important community investment that influences development patterns, especially in fast-growing communities that attract young families. The planning for school facilities is not often part of the larger community comprehensive planning process, but is an independent activity undertaken by local school boards. In most of these efforts, professionally accepted (and defined) methodologies, analysis tools, and data collection strategies serve as the foundation for the resulting plans and investment programs.

The following sections discuss in more detail some of the land-use planning tools available to communities.

1. Comprehensive Plans

Most local governments and communities produce community-specific comprehensive plans that lay out the desired future for the community along with the infrastructure and policy support needed to achieve it. In many states (for example, California, Florida, Georgia, and Washington), local comprehensive plans are required by state law. Community comprehensive plans often have a high level of detail and focus more on community-specific strategies than regional plans.

Comprehensive plans serve three major functions. First, comprehensive plans reflect what a community desires in terms of future development. In some sense, they thus represent a vision of a desired future. Second, the plan guides public policy and private developer decisions. In other words, what steps must be taken or adopted to assure that the community development plan becomes a reality? Finally, the enabling legislation for most zoning codes and other types of regulatory approaches requires the adoption of a benchmark (a plan) that can be used to judge the desirability and legality of community actions. For example, the standard zoning enabling acts adopted by many states in the early twentieth century often noted that zoning "shall be in accordance with a comprehensive plan." Many of the legal challenges to zoning decisions are often decided on the interpreted consistency between the recommended action and the community's comprehensive plan.

Table 3-2. Land Regulations and Implied Requirements of Plans		
Regulation Type	**Regulation Logic**	**Implied Plan Logic**
Zoning	Externalities (positive and negative)	Strategy to address interdependence due to irreversibility of investments and indeterminate adjustment process given imperfect foresight
	Infrastructure capacity	Strategy for expansion and design of capacity at build-out because of irreversibility and indivisibility
	Fiscal objectives	Policy for consistent and fair repeated decisions for the development community
	Information costs or errors	Policy to provide information that is a collective good or asymmetric between buyers and sellers
	Management of supply	Strategy to reduce infrastructure costs of spatial substitution of uses as technology changes given imperfect foresight
	Amenity protection	Strategy to protect scarce natural resources
	Development timing	Strategy of zoning for non-urban areas until land use is ready for more intense development
Official maps	Project rights-of-ways	Strategy to preserve design decisions by developer that have collective good external effects
Subdivision regulations	External effects of design decisions	Policies to achieve design decisions by developer that have collective good external effects
Urban service areas	Timing, resource lands protection, "optimal city size," depending on how changes in area are managed over time	Strategy of efficient infrastructure provision and interaction costs over time; policy of consistent and fair resource land protection; target design of city
Adequate public facilities ordinances	Timing	Strategy of efficient infrastructure provision and interaction costs over time
Development rights (for example, conservation easements, transferable rights)	Permanent allocation of land uses	Target design of pattern of uses, for example, resource lands and urban development
Impact fees	Timing, fiscal management, and distribution of costs among current and new residents	Policy for consistency and fairness; strategy for infrastructure financing

Source: From "Urban Development" by Lewis D. Hopkins. © 2001 by the author, reproduced by permission of Island Press, Washington, DC.

Although the specific requirements of the transportation component of a comprehensive plan will vary by state, the topics most often covered include: (1) an inventory of transportation facilities and services, (2) an assessment of the condition and performance of the current transportation system, (3) the identification of transportation problems or deficiencies with respect to the goals of the comprehensive plan, (4) an analysis and evaluation of prospective solutions to these problems, (5) the development of a recommended investment and operations strategy, and (6) (increasingly) the identification of alternative financing strategies for supporting the recommended strategies.

2. Zoning

Local governments' use of zoning and land-use ordinances to establish the design requirements for, and the physical context of, development projects is perhaps one of the most important influences on community development. [Merriam, 2005] While zoning and land-use ordinances are taken for granted by planners today, a look at the historical impetus for placing restrictions on the use of land provides some insight as to why newer, compact, mixed-use forms of development often come into conflict with locally adopted land-use regulations.

During the Industrial Revolution, millions of Americans flocked to cities in response to a substantial growth in employment opportunities. At the time, local governments did not yet possess a legal means to review the proposed use of a plot of land and effectively guide this population growth. Developers responded to the intense market pressures for new workforce housing by constructing tenements that were as cheap as possible (for example, exhibiting poor structural supports), having little to no ventilation, water, or sewage facilities. This unregulated development in response to industrialization resulted in myriad negative impacts to the health, safety, and general welfare of local communities. The modern era of land-use zoning in the United States began in the early twentieth century in reaction to deteriorating living conditions brought on by overcrowding in cities.

New York City adopted the first comprehensive zoning ordinance in 1916. The ordinance established three types of districts based on land use (residential, industrial, and commercial) and provided regulations for the physical layout of individual structures within a given land-use district. The objective of this ordinance was to create safe and quiet areas for family living, primarily by limiting density. This first zoning ordinance established several elements of zoning that were soon adopted in zoning ordinances in other cities: setback distances from the street, maximum building heights, maximum bulk or what is known today as Floor Area Ratio (FAR, the ratio of a building's total area to its footprint to the area of the entire lot), occupant density, minimum lot size, and permitted and/or allowed uses (residential, commercial and industrial). This ordinance codified two principles of land-use planning that until recently were accepted as characteristics of good practice—limit the intensity of development and separate land uses.

At the federal level, the Standard Zoning Enabling Act (SZEA) of 1924 sought to standardize land-use zoning nationwide. This act gave President Herbert Hoover the authority to establish an advisory committee to develop a "template" that allowed state governments to enact legislation giving municipalities the authority to zone. The primary tenets of the SZEA were:

1) *Grant of Power*: Promote the health, safety, morals, and general welfare of the community. This included the power to regulate the height, number of stories, size of structure (bulk), percentage of the lot that may be occupied, size of yards, density of population, and the use of buildings.
2) *Districts*: The local legislative body could divide the municipality into districts that were deemed best suited to carry out the act.
3) *Purposes in View*: The regulations were to be made in accordance with the comprehensive plan and designed to lessen congestion in the streets; secure safety from fire, panic, and other dangers; promote health and the general welfare; provide adequate light and air; prevent the overcrowding of land; avoid undue concentration of population; and facilitate the adequate provision of transportation, water, sewage, schools, parks, and other public requirements.

This basic template formed the framework for zoning enabling acts adopted with various modifications in states across the United States.

This initial concept of zoning was legally challenged in a 1926 U.S. Supreme Court case, *City of Euclid, Ohio v. Ambler Realty*. Ambler Realty argued that zoning regulations unconstitutionally diminished the value of its land by imposing use requirements. However, the Supreme Court ruled that zoning did have a "rational relationship to valid governmental interests in preventing congestion and in segregating incompatible uses." [Juergensmeyer and Roberts, 2003] The term "Euclidean Zoning" comes from this case. Ten years after the Euclid case, 1,246 municipalities in the United States had zoning ordinances. [Moore and Thorsnes, 2007]

Another important distinction in zoning is the manner in which states can delegate zoning power to municipalities. The first, commonly referred to as *Dillon's Rule*, prevailed in most communities until the mid-twentieth century. In this concept, local governments have only the powers specifically enumerated by the state. This considerably limited the ability of local governments to act on their own behalf. Today, Dillon's Rule has largely been rejected by most states in favor of *Home Rule*. In Home Rule states, municipalities have all the power necessary to perform their tasks unless that power has been specifically restricted by the state.

A typical zoning designation for different types of land uses in Atlanta, Georgia, is shown in Table 3-3. As indicated, zoning usually identifies the type of land use that can occur on a parcel "by right" and the level of intensity of development. Sometimes specialized zoning is necessary for an area where a large tract of land is involved. Driven by a desire to reverse suburban sprawl and establish more compact patterns of development, many urban areas are now beginning to promote density and the integration of multiple land uses by incentivizing more intense, mixed-use development, which runs contrary to the intent of the earliest zoning ordinances, as well as the content of many approaches to local land-use regulation still in use today. A planned unit development (PUD) designation, for example, allows a mix of land uses, flexibility in the placement of buildings, and the relaxation of development standards.

Table 3-3. Sample Zoning Codes from City of Atlanta	
Zoning	**Zoning District Name**
BL	Beltline overlay district
HBS	Historic building or site
HD-20G	West End historic district (example of several)
LBS	Landmark building or site
LD-20A	Cabbagetown landmark district (example of several)
LW	Live-Work
MRC-1	Mixed residential and commercial, maximum floor area ratio of 1.696 (example of 3 MRC designations)
MR-1	Multi-family residential, maximum floor area ratio of 0.162 (example of 8 different MR designations)
NC-1	Little Five Points Neighborhood Commercial (example of 5 different NC designations)
PD-H	Planned housing development (single-family or multi-family) (example of 3 planned unit designations)
R-1	Single-family residential, minimum lot size 2 acres (example of 10 single family residential designations, R-1 to R-5)
RG-1	General (multi-family) residential, maximum floor area ratio of 0.162 (example of 6 such designations)
O-I	Office-industrial
C-1	Community business
C-2	Commercial service
C-3	Commercial-residential
C-4	Central area commercial-residential
C-5	Central business district support
I-1	Light industrial
I-2	Heavy industrial
SPI-1	Special Public Interest District: Central Core (example of 17 special interest districts)

Source: City of Atlanta, 2015

An approved PUD plan fixes the nature and location of uses and buildings on the entire site. Cluster development is a form of PUD in which buildings, usually residences, are grouped together to preserve open space or environmentally sensitive areas, such as wetlands.

Overlay districts are another strategy to provide opportunities for special development or urban design treatments in a particular area (see Beltline overlay designation in Table 3-3). An overlay district keeps the underlying zoning requirements for targeted parcels, but provides owners and developers with the ability to adopt special allowances. A good example of an overlay zone is found in Portland, Oregon, with its "Light Rail Transit Station Zone." [Portland Metro, 2000] This overlay zone "allows for more intense and efficient use of land at increased densities for the mutual reinforcement of public investments and private development. Uses and development are regulated to create a more intense built-up environment, oriented to pedestrians, and ensuring a density and intensity that is transit supportive." Actions include prohibiting parking garages within a specified distance of a station, reducing the minimum number of parking spaces required within 500 feet of a light rail alignment by 50 percent, and requiring streetscape landscaping at a very high level. Such an approach is tailored to foster walkable community environments.

Although zoning has been used extensively in the United States for decades, some argue that current applications of zoning regulations are detrimental to the development patterns best suited for today's market. For example, Levine [2005] argues that land development is one of the most regulated sectors of the U.S. economy, and conventional zoning actually gets in the way of market forces. He notes: "The design template for urban sprawl is written into the land-use regulations of thousands of municipalities nationwide."

Relaxing zoning regulations can facilitate improved mobility in a number of ways. First, allowing mixed residential and commercial uses increases traveler accessibility to a greater number of potential destinations, reducing trip lengths and increasing the potential for satisfying some of those trips by walking or bicycling rather than by automobile. Second, allowing higher residential densities in transit corridors can support more efficient transit services and reduce automobile mode share. Finally, relaxing minimum off-street parking space requirements can facilitate infill development by both reducing the land area and costs required for a single use. Conversely, other regulations can improve land-use efficiency. For instance, Moderately Priced Dwelling Unit (MPDU) requirements improve equitable access to housing. Transfer of Development Rights (TDR) programs allow by-right zoning on farmland to be transferred to more urban "smarter growth" locations that will have the effect of preserving farmland and reducing sprawl.

Form-based zoning codes recognize there is no longer a significant conflict between industrial and residential uses as there was when use-based zoning was originally adopted. As opposed to the Euclidean approach, which first rigidly defines the use of a plot of land and then provides general guidelines as to a building's potential form, a form-based code approach essentially prescribes the style and form of buildings and then allows the use to be flexible. By their very nature, form-based zoning codes facilitate mixed-use development, which is often difficult (and many times illegal) under current zoning laws. Instead of use-based zones, which segregate land uses and often increase the distance required to travel to different types of destinations, form-based zones allow for varying densities and the interspersing of different types of destinations next to (and even on top of) one another. This tends to decrease the distance required to travel to various services.

3. Zoning and Parking

Zoning standards typically establish minimum requirements or formulas for how many parking spaces must be provided for specific types of land uses. The intent of most local governments is to require property owners to provide sufficient off-street parking spaces so as to avoid spillover parking onto public streets or adjacent private property. Parking requirements, however, have come under increasing scrutiny in recent years from many who argue that minimum parking requirements often lead to too much parking. The report, *Recommended Zoning Ordinance Provisions* [Parking Consultants Council, 2007], recommends language to protect the city's interests while allowing flexibility to address the most common circumstances influencing parking demand. Some of the circumstances where flexibility in zoning requirements may be appropriate are:

- *Shared Parking*—In some cases, adjacent land uses generate parking demand at different times of the day, and thus in a shared parking program, parking capacity is shared over the day.
- *Captive Market*—A captive market is an employment location where nearby land uses can be readily accessed by walking or transit (for example, in a central business district). A captive market consideration is a component of shared parking effects; however, it does not require that parking be shared to achieve a reduction in demand.
- *Fees-in-Lieu*—It may be in the best interests of a city to develop public parking in a densely developed activity center, rather than have each property owner provide parking for each building. With the high cost of parking structures and the competing demands on city resources, a number of cities have asked developers to contribute to the costs of developing municipal parking facilities in lieu of providing the totally required amount of parking for their development site.
- *Off-Site Parking*—Many cities have added clauses in their zoning that allow for off-site parking to be substituted for on-site parking under certain conditions.
- *Ridesharing*—Ridesharing generally refers to various forms of carpooling, vanpooling, and subscription bus service associated with employees' trips to and from work. Properly formulated ridesharing programs can reduce both traffic and parking demand. Zoning credits for ridesharing programs are a particularly effective means of achieving transportation management goals. Ridesharing credits are also a means of adjusting parking requirements for any development site that runs a dedicated shuttle. The most common application is hotels that cater to those wanting convenient access to an airport. However, other development sites may also run shuttles and thus merit reduced parking requirements.
- *Transit*—For areas that are well served by public transit, it is reasonable to expect that some reduction in parking demand will occur due to visitors and employees using transit. In some communities, if a development site is within a certain distance of a regularly scheduled transit stop or station, the zoning code allows the developer to reduce the number of parking spaces required on site.

See chapter 11 for additional discussion on the relationship between zoning and parking requirements.

4. Subdivision Regulations

A common development trend that has emerged in urban areas within the United States and many other Western countries over the past 50 years is the division of large plots of land into smaller individual parcels, commonly referred to as "subdividing." Subdivision regulations provide guidance on what a community desires when land is subdivided like this for development purposes. Developers must submit plans to the relevant governmental body (such as a planning board or commission) for approval. This site plan review process covers things such as the size and shape of lots, street design, sewer and water connections, and environmental protection. The most important transportation components of the site plan review process include street layout, provision of sidewalks, access points to the subdivision, and proposed building footprints with respect to regional transit services (if transit services are available).

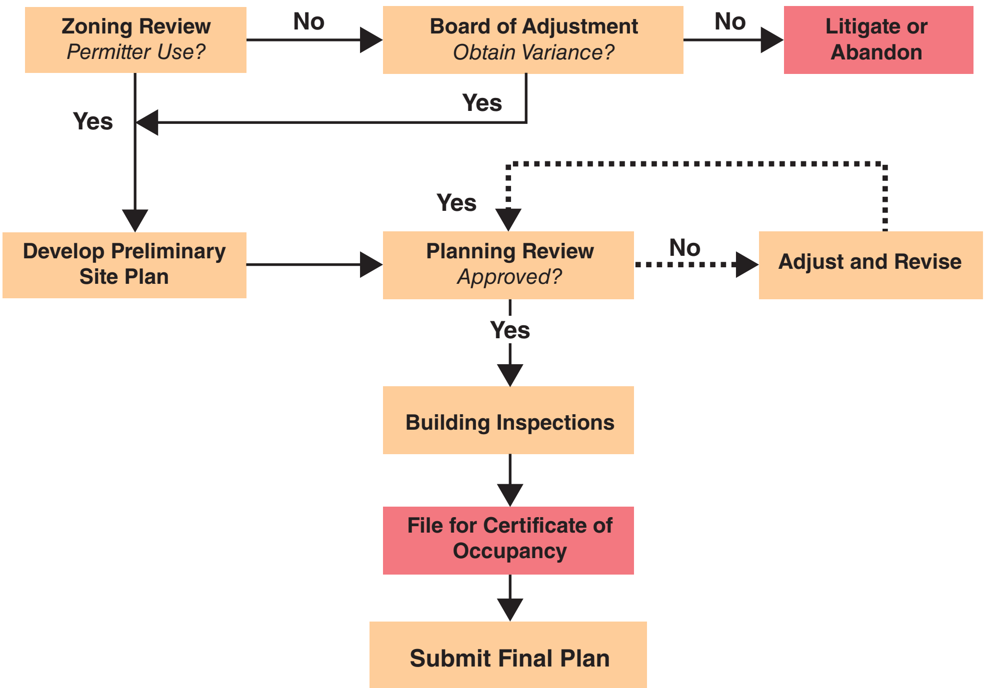
5. Development or Site Plan Review Process

The development or site plan review process provides an opportunity for communities to make sure development proposals are consistent with the zoning code and the comprehensive plan. This process is often based on checklists reviewed by community planners (and thus developers as well to anticipate what the planners will be looking for) to determine such consistency. Given that differences often occur between development characteristics and zoning requirements, the negotiation on what will be allowed, if anything, usually occurs during this review process. Figure 3-2 presents a typical site plan review process. It is during a process similar to that shown where the determination of what is "good for the community," and the potentially different interpretations from local citizens, is played out.

One of the common debates occurring during this process relates to the perceived value of additional growth in a community. Some view growth as a necessary ingredient to a vibrant and evolving community, whereas others consider such growth as adding additional burdens to community services. This difference of perspective has led to dramatic shifts in the elected representation on community boards and decision-making bodies, depending on which perspective is on the rise at any point in time.

It is important to note that both subdivision regulations and site plan reviews usually require a transportation impact analysis, certainly for larger proposed developments. Traditionally, this analysis focused almost exclusively on automobile access to development sites with little attention to other modes of travel. In many cities, the analysis has shifted to a multimodal accessibility perspective. Whereas road performance levels of service had been consistently applied everywhere in a region (for example, every intersection must operate at least at a level of service C), in many cities today, road performance thresholds can vary depending on the context and availability of alternative modes. Readers are referred to Broward County's (Florida) multimodal concurrency process: (http://www.broward.org/PlanningAndRedevelopment/ComprehensivePlanning/Documents/TransGOPS2014.pdf) and Montgomery

Figure 3-2. A Typical Community Review Process for Development Decisions



Source: Meyer and Dumbaugh, 2005

County's (Maryland) development guidelines (http://www.montgomeryplanning.org/transportation/latr_guidelines/latr_guidelines.shtm) as illustrations of how vehicle trip impacts can be exchanged for exactions that lead to more multimodal solutions. ITE's *Recommended Practice on Traffic Impact Analysis for Site Development* is a good reference on different traffic impact analysis approaches. [ITE, 2010a] See also chapter 19 on site planning and impact analysis.

6. Growth Management

Growth management concepts first appeared in the United States in the late 1960s and early 1970s in response to community concerns over human impacts on environmental resources. [Porter, 1997] In 1972, a landmark court case in New York established the legal foundation for communities to manage growth through the comprehensive planning process. In *Golden v. Planning Board of the Town of Ramapo*, the New York Supreme Court (upheld by the U.S. Supreme Court) stated that the uncompensated control of the timing and sequencing of residential subdivision development is legal for a "reasonable period of time" (defined in this case as 18 years or the life of the local comprehensive plan) with such a linkage tied to the provision of capital improvements. As noted by Freilich [1999] "the importance of this law is the recognition of the fundamental constitutional principle that techniques to handle growth over the next 15 to 20 years can be controlled by linking the proposed development with the planned extension of capital improvements over the lifetime of the comprehensive plan."

The following two definitions of *growth management* help identify the key factors that are part of a growth management strategy:

According to the U.S. Environmental Protection Agency (EPA), "growth management is a method of planning new development that serves the economy, the community, and the environment. It changes the terms of the development debate away from the traditional "growth or no growth" to "how and where should new development be accommodated?" [U.S. EPA, 2014] Smart growth answers this question by simultaneously achieving:

- "*Healthy communities* that provide families with a clean environment. Smart growth balances development and environmental protection—accommodating growth while preserving open space and critical habitat, reusing land, and protecting water supplies and air quality.
- *Economic development and jobs* that create business opportunities and improve the local tax base.
- *Strong neighborhoods* that provide a range of housing options, giving people the opportunity to choose housing that best suits them. It maintains and enhances the value of existing neighborhoods and creates a sense of community.
- *Transportation choices* that give people the option to walk, ride a bike, take transit, or drive."

According to ITE's recommended practice on smart growth and transportation guidelines, "smart growth is a complex mix of land use and transportation design" with the following five goals serving as its foundation:

- Pursuing compact, efficient land-use patterns to maximize transportation efficiency and improve the neighborhood environment.
- Providing multimodal mobility within developed areas.
- Providing accessibility within existing built-up areas.
- Making the most efficient use of transportation infrastructure.
- Supporting smart growth through pricing and sustainable funding. [ITE, 2003]

While growth management policies can have a profound effect on encouraging desired development objectives, in many regions, such development policies are not very influential; they simply state desired outcomes or visions of what a metropolitan area wants to look like, with very little policy linkage to individual community decisions on development proposals. A strong "home rule" proviso in many state constitutions that leaves development decisions to local officials is most often the reason for this weak linkage.

Interested readers should refer to ITE's report on growth management for a comprehensive discussion of how transportation actions can reinforce growth management principles. [ITE, 2003]

7. *Transit-Oriented Development (TOD)*

TOD is a form of managed growth, in this case, offering incentives for development to locate next to transit stops or stations. TODs are usually compact, mixed-use, pedestrian-oriented developments providing greater attention to civic uses of the space and treating the transit facility as the centerpiece of the entire development. According to Reconnecting America, Inc., one of leading nonprofit organizations advocating TOD development, the key characteristics of transit-oriented job sites are:

- Urban densities ranging from mid-rise buildings with 2.0–5.0 FAR to high-rise buildings with 4.0 or higher FAR, with the highest densities located in the closest proximity to transit stations and stops.
- Significant concentrations of workers in order to create the demand that will support convenience, retail, and personal services near the station, and help justify the provision of high-quality transit service.
- A variety of easily accessed transit services to provide a high-level of connectivity in business districts, ranging from local bus or streetcars to enhance local circulation, to light rail or bus to connect to nearby neighborhoods, to express bus and commuter rail to connect to neighborhoods further away.
- Limited parking, or pricing that limits parking demand, ideally in combination with financial incentives from employers to encourage transit ridership.
- A mix of businesses that are "transit-oriented," including shops and restaurants that allow workers to meet their needs without a car. [Reconnecting America, 2008]

Reconnecting America, Inc. notes several observations that make TODs an appealing development concept today and even more so in the future.

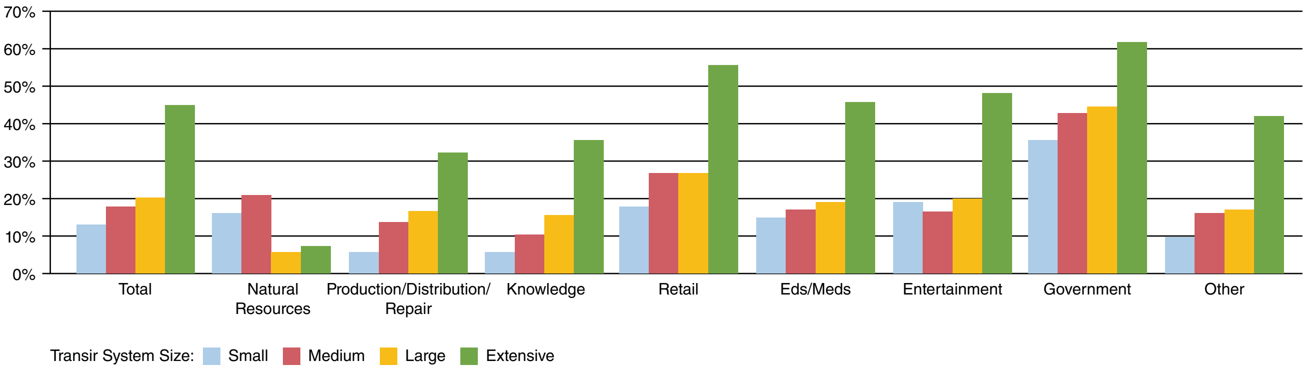
Demographics are promising for TOD: Aging Baby Boomers and young urban professionals are population groups attracted to TOD, and both groups are growing in the United States. In particular, these groups tend to desire "walkable" urban lifestyles.

Corridor-centered growth is increasing, in many cases served by transit: Corridor-centered growth is a development pattern that is found in many urban areas, often centered around development nodes either at highway interchanges or transit stations. TOD developments are natural elements of a corridor-centered growth pattern.

TOD-supportive industries are growing: As shown in Figure 3-3, some types of jobs are more transit-oriented than others, including jobs in the service, financial, and professional sectors. These employment sectors are also some of the fastest growing in the U.S. economy. From a land use and transportation planning perspective, these are the types of jobs (with corresponding firms and companies) that could be targeted for TOD developments.

TOD needs more than transit: Real estate development occurs in response to many different market factors, most importantly the monetary value of land parcels to potential buyers and tenants. For example, the economic recession of 2008 to 2010 caused much of the investment in land development to slow down in the United States. With a reviving economy after 2012, development once again began to occur in most major metropolitan areas. Developers began focusing on those parcels that had the greatest level of market attractiveness, with much of this development located in higher density, transit-oriented sections of center cities.

Figure 3-3. Share of Regional Jobs near Transit by Industry and Transit System Size, 2008



Source: Center for Transit-oriented Development, 2011

Active leadership is crucial for success: Public agencies, most often state governments and transit agencies, can facilitate TOD, using many different policy and financial tools. For example, leveraging other agency resources to improve station locations and working with developers and local governments to provide incentives to develop in these locations have been very successful. In some cases, transit agencies have bought land near transit stations and then worked with developers to build out the station area.

"Mobility hubs" are an emerging concept within TOD research and refer to transit stops or stations with frequent transit service, high development potential, serving as a critical point for trip generation or transfers within the transit system. This concept broadens the mobility emphasis to active transportation modes such as bicycling and walking, and promotes a total mobility perspective for higher density locations. Two examples of guidelines for promoting mobility hubs include:

- Metrolinx in Toronto, http://www.metrolinx.com/en/projectsandprograms/mobilityhubs/mobility_hub_guidelines.aspx.
- Virginia's Multimodal System Design Guidelines http://www.drpt.virginia.gov/activities/MultimodalSystemDesignGuidelines.aspx.

See Reconnecting America, Inc. for a series of reference documents on TODs and the steps necessary to make them happen (Reconnecting America, http://www.reconnectingamerica.org/what-we-do/what-is-tod/).

C. Private Developers and Financial Lenders

While government has a strong say in determining the policies that shape communities, private companies and investors are probably even more important for private development projects. Both for-profit and nonprofit developers, institutional lenders, and a host of other groups, including contractors, construction professionals, and engineers, are responsible for developing the buildings and neighborhoods that comprise a community.

1. Private Developers

Many landowners do not have the financial resources to develop their land. The individuals or companies having the financial means to do so are called private developers. Developers often buy large tracts of land or multiple parcels so that developments can be of sufficient size to attract clients. Because the attractiveness of a particular development site depends on many factors often outside the control of a developer, private development is a high-risk venture. What developers seek are relatively stable investments that can be relied on to generate a return on their investment.

In many cases, a "safe investment" is one that has been proven to be successful in the local market. Thus, although the site plan review process and the underlying zoning code can become the subject of disagreements over what should be allowed in a development proposal, some have suggested that zoning in fact promotes a market environment that minimizes development risk because all similar types of developments face the same constraints. However, the focus on "what has worked before" can also inhibit innovative land-use strategies and the adoption of new growth management concepts that better meet today's community challenges. For example, many urban communities have encouraged developers to consider higher densities, parking limitations, and a mixing of land uses that are not allowed by the zoning code. When developers generate proposals that attempt to satisfy the latest community desires, they often run into procedural and regulatory barriers designed to "protect" the community from developments that are "different" from the status quo.

When such differences are found in development proposals, the developer must request a variance to existing codes. The public nature of the zoning ordinance and development of the comprehensive plan provides opportunities for community residents to participate in any effort to grant a use variance. The zoning board or commission usually holds a public hearing and all those potentially affected by the change (for example, adjacent land owners) are notified of their opportunity to voice their opinion. This process can take many months.

As noted earlier, the site plan review process is often the step in the process where proposed changes from existing zoning ordinances or regulations are negotiated and accepted or rejected. Complex development projects that could potentially affect many different government agencies, such as transportation departments, school departments, fire and police departments, and so on, are provided the opportunity to comment on the changes, and in cases such as public safety, have the authority to reject the proposal. If the developer still wishes to proceed with the project, the proposal must be revised to respond to the objection(s) and resubmitted. There have been instances where navigating the site plan review process given agency objections has taken many years.

A study by Inman et al. [2002] surveyed more than 700 developers in the United States about their experience with the development process. Although dated, the survey results are still relevant today. A large majority of the surveyed developers perceived local zoning as the most challenging obstacle in getting approval for non traditional developments. The noted barriers included: local zoning regulations (43 percent), neighborhood opposition (17 percent), lack of market interest (15 percent), and financing (9 percent). Of the developers responding to the survey that had proposed alternative development strategies, but were required to modify their proposals, the following modifications were required: 82 percent had the density reduced by the community planning process, 47 percent had mixed-use characteristics reduced, 29 percent had the housing types changed, 33 percent had the share of mixed use development changed, and 19 percent had changes made in pedestrian or transit orientation. The authors noted the following:

> *"On the whole, the random sample of developers perceives considerable market interest in alternative development; believe that there is inadequate supply of such alternatives; view local government regulation as the primary obstacle to the further development of these alternatives; and indicate interest in developing more densely and mixed use than regulations allow, notably in inner suburban areas. Thus it appears that in the perceptions of developers, at least, it is hardly more planning intervention that would bring about greater alternative development forms in the United States context, but relaxation of restrictive land-use and transportation policies that are excluding these forms to begin with."*
>
> *—Inman, Levine and Werbel, [2002]*

2. Financial Lenders

Most developers rely on institutional lenders to provide the capital funds to support a development project. Thus, for example, if a developer is permitted by a local government to develop a parcel of land that does not meet all of the requirements of the zoning regulations, the institutional lender financing the project must agree to the variations as well. However, financial lenders look at each lending opportunity from the perspective of risk. [Gillham, 2002] Will a loan likely be repaid? Or in development terms, is the proposed development marketable (and thus profitable) given what has happened in the community and the development market in recent years? Most lending institutions rely on a development's consistency with local zoning ordinances as a litmus test for determining financial suitability.

One of the key issues in this regard has been the requirement for a minimum amount of parking at the development site. In some instances, communities and developers that have wanted to reduce the number of parking spaces in order to encourage more transit and nonmotorized transportation travel have run into opposition from lenders who took the position that minimum parking requirements reflect the needed parking capacity to make the development successful. This type of opposition has lessened in recent years as the development and lending communities have become more used to changing transportation requirements, especially in communities that have made a commitment to alternative modes of travel.

In summary, zoning and subdivision ordinances have a very strong influence on community development patterns and on the parcel-specific characteristics of a particular development. One of the implications of this is that nontraditional development proposals desired by community residents might face significant obstacles. Even if such proposals will eventually be approved, the time delay in seeking approvals for variances in existing ordinances could very well cause a developer to seek other alternatives, such as traditional market-tested, large lot, auto-oriented developments. And it is not just the developer that faces risks in additional costs and time delays associated with nontraditional developments. The financial lending institution could also be hesitant to accept a nontraditional development simply because the "community standard" as expressed in the zoning code is not being followed.

III. URBAN FORM

The previous sections identified the different factors that influence individual development proposals and ultimately the type of development that occurs on individual parcels of land. The cumulative effect of these individual development decisions over time results in a spatial development pattern referred to as urban form. In other words, the development patterns that over time define the physical, economic, and often socio-demographic characteristics of the individual communities are the same elements that, in the aggregate, shape a region. The role of transportation investment in influencing this evolution and vice versa has received a great deal of attention in recent decades. During the 1990s and early 2000s, for example, this attention produced books for the popular market critiquing urban form and in particular suburbanization (for example, see [Duany and Plater-Zybek, 1991; Hart and Spivak, 1993; Kay, 1997; Kunstler, 1997, 2013; Morris, 2005]).

In addition, more systematic studies of the relationship between land use and transportation have given particular attention to the resulting consequences on such things as air quality and public health. [Whitfield and Wendel, 2015] For example, the Urban Land Institute published *Growing Cooler,* one of the first examinations of the impact of different land-use patterns on the production of greenhouse gases. [Ewing et al., 2007] Specifically, the study tried to answer three policy questions:

1) What reduction in vehicle miles traveled (VMT) is possible in the United States with compact development rather than continuing urban sprawl?
2) What reduction in CO_2 emissions will accompany the reduction in VMT caused by more compact development patterns?
3) What policy changes will be required to shift the dominant land development pattern from sprawl to compact development?

Compact development was defined as denser development, enhanced land-use mix, an emphasis on population and job centers, and more pedestrian-friendly design.

The authors estimated that the use of compact development practices at a very high penetration level would result in a 20 to 40 percent reduction in VMT for each increment of new development or redevelopment, depending on the degree to which best practices are adopted. This led to an estimated 7 to 10 percent reduction in total transportation-related CO_2 emissions by 2050 relative to continuing sprawl. The authors also suggested that "dramatic" policy changes in land use at the state, regional, and local levels of government would have to occur for this level of CO_2 emissions reduction to take place. Indeed, it was the need for such dramatic policy changes that spawned serious critiques of this study. Simply put, many thought the study was misleading because the type of change necessary in land-use policies was unlikely to occur in the foreseeable future.

Soon after, a group of transportation professional organizations sponsored *Moving Cooler*, which was an effort to identify different "bundles of transportation and land-use strategies and their likely impacts on CO_2 emissions." [Cambridge Systematics, 2009] The *Moving Cooler* study found, not surprisingly, that more compact development patterns produced less travel and thus fewer CO_2 emissions. Transit and nonmotorized transportation improvements were more effective at reducing CO_2 emissions in areas with higher population densities. It also concluded that strategies to encourage the use of alternative modes (such as road pricing) would have a greater impact when applied in conditions where better alternatives exist (as would be found with increased transit investment and more compact land-use patterns).

In 2009, the Transportation Research Board published a study on the effects of the built environment on VMT, energy consumption, and greenhouse gas emissions. [TRB, 2009] Given the nature of the work, and the emphasis on facts and science underlying the conclusions, this report was much more circumspect than the two mentioned above. The conclusions included:

1) Developing more compactly, that is, at higher residential and employment densities, is likely to reduce VMT.
2) The literature suggests that doubling residential density across a metropolitan area might lower household VMT by about 5 to 12 percent, and perhaps by as much as 25 percent, if coupled with higher employment concentrations, significant public transit improvements, mixed uses, and other supportive demand management measures.
3) More compact, mixed-use development can produce reductions in energy consumption and CO_2 emissions both directly and indirectly.
4) Illustrative scenarios developed by the committee suggest that significant increases in more compact, mixed-use development will result in modest short-term reductions in energy consumption and CO_2 emissions, but these reductions will grow over time.

5) Promoting more compact, mixed-use development on a large scale will require overcoming numerous obstacles. These obstacles include the traditional reluctance of many local governments to zone for such development and the lack of either regional governments with effective powers to regulate land use in most metropolitan areas or a strong state role in land-use planning.

6) Changes in development patterns significant enough to substantially alter travel behavior and residential building efficiency entail other benefits and costs that have not been quantified in this study.

Additional studies and research will undoubtedly continue to study the relationship between transportation, land-use patterns, and the resulting impacts. The major conclusion from the three above studies is that transportation behavior and travel patterns can indeed be affected by land use and development patterns. The overall effect, however, will depend on how much the needed development design or strategy (for example, compact development) will penetrate the urban market.

Additional references useful to practitioners include National Cooperative Highway Research Program (NCHRP) Report 684, *Enhancing Internal Trip Capture Estimation for Mixed-Use Developments* [Bochner et al., 2011]; Transit Cooperative Research Program (TCRP) Report 95, chapter 15 on *Land Use and Site Design* [Kuzmyak et al., 2003] and chapter 17 on *TOD* [Pratt et al., 2007]; and the ITE *Recommended Practice on Traffic Impact Analysis for Site Development* [ITE, 2010a].

IV. URBAN DESIGN

Transportation planners and engineers often become involved in another planning effort called urban design. [Montgomery, 2013] Urban design is "concerned with the physical characteristics of the city and the implications of design and planning decisions for the public realm of the city. The urban design strategy must serve as an integrating tool, one that coordinates how various public and private development proposals, including transportation and public infrastructure, will affect the city physically." [City of Pittsburgh, 1998]

Urban design guidance and principles can take many forms. In some cases, communities provide illustrations or concepts of what development characteristics and associated amenities are desired in future development. As an example, Figure 3-4 shows the core development principles adopted as part of a corridor planning study for

Figure 3-4. Core Development Principles and Means of Applying Them, City of Madison, Wisconsin

East Washington Capitol Gateway Corridor

Core Development Principles

Implementation Techniques	Protect & Enhance Iconic View of Capitol	Respect & Strengthen Existing Neighborhoods	Establish Corridor as Employment Center Supported by Transit	Create Inviting & Vibrant Boulevard
Land Use		●	●	●
Bulk Standards (Height, Setbacks, Stepbacks)	●	●		●
Design Guidelines	●	●		●
Transportation and Parking		●	●	●

Source: City of Madison, 2008, Reproduced with permission of the City of Madison.

a major urban arterial road in Madison, Wisconsin, and the implementation techniques that could be used to apply them.

Table 3-4 shows the values articulated by a citizens steering committee for urban design concepts relating to the corridor's land use. Urban design standards for the corridor area (that would be incorporated into city development or site plan reviews) were developed simultaneously with the corridor plan.

Figure 3-5 illustrates some of the development and transportation concepts that were recommended for the corridor.

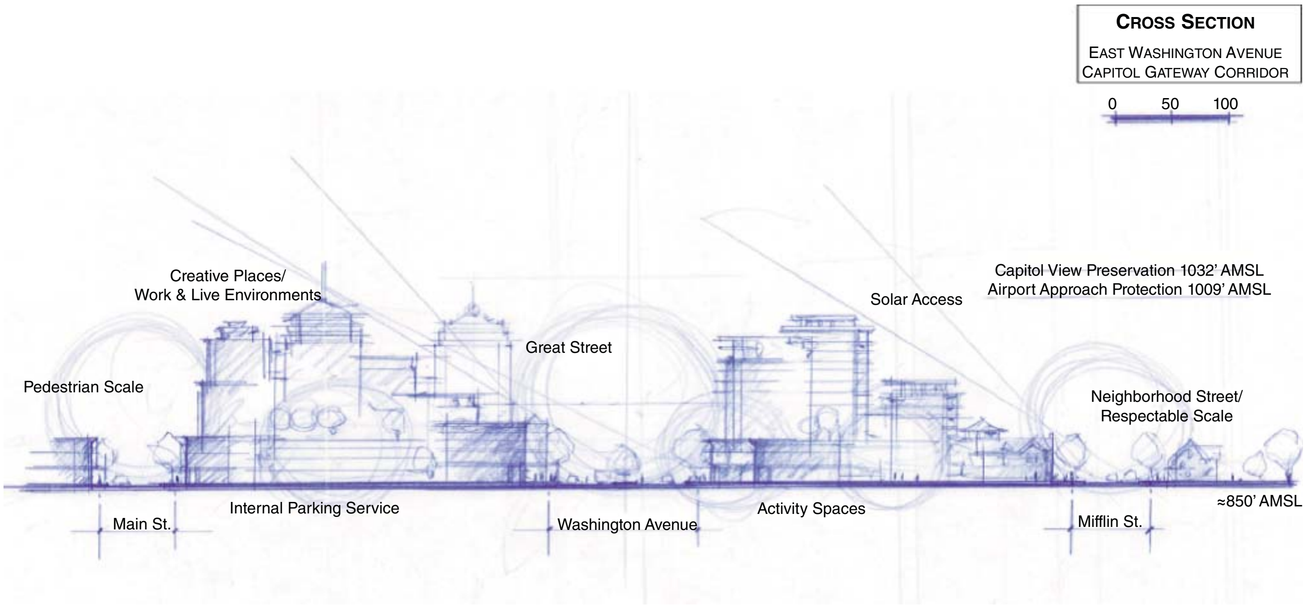
In other cases, urban design guidance takes the form of narrative descriptions of the principles and actions that should guide the "look" and "feel" of community places. [Eitler et al., 2013] For example, the Milwaukee, Wisconsin,

Table 3-4. Articulated Design Values as Part of an Urban Arterial Corridor Study, Madison, Wisconsin

Character of Development	• Fully utilize infrastructure/reduce urban sprawl • Provide vibrant mix of businesses • Protect neighborhood character • Enhance recreation open space • Create live-work environment
Identity	• Preserve and enhance attractiveness of area to the "new, creative workforce"
Building Facades & Architecture	• Create a dynamic skyline • Encourage high-quality development that is visually compatible with architectural context • Enhance pedestrian experiences through architectural design
Streetscapes	• Create pedestrian-scale environments and public spaces • Encourage visible building activity • Bury overhead utility wires • Encourage and support public art • Encourage energy-efficient and low-glare outdoor lighting • Emphasize grand entranceway
Neighborhood Character, Compatibility & Context	• Ensure compatibility along corridor with adjacent neighborhoods • Ensure development adjacent to public areas has attractive facades and bicycle and pedestrian connections
Employment	• Retain and attract high wage employment • Retain and attract businesses that provide meaningful employment to residents
Types of Businesses	• Provide incubator space • Provide post-incubator space • Attract light industrial and office businesses • Focus business development on job creation, family-supporting wages, and neighborhood-based businesses
Transportation	• Coordinate transportation options and land use • Establish an efficient and safe transportation corridor
Trucks	• Respect US-151 (the major arterial road) as a regional commuter artery
Parking	• Provide (public and private) parking for businesses

Source: City of Madison, 2008, Reproduced with permission of the City of Madison.

Figure 3-5. Development and Transportation Urban Design Concepts, City of Madison, Wisconsin



Source: City of Madison, 2008, Reproduced with permission of the City of Madison.

Department of City Development has adopted the following principles for urban design within the city. [City of Milwaukee, undated]

Principle #1: Neighborhood Compatibility
New development should be compatible with the pattern of its surrounding context. Development that adheres to this principle will:

- Relate to the physical character and scale of the neighborhood.
- Enhance linkages to surrounding uses, especially public services and amenities (schools, parks, mass transit).

Principle #2: Pedestrian Friendly Design
New development should be designed to create attractive, comfortable, and safe walking environments. Development that adheres to this principle will:

- Locate buildings to define street edges and corners.
- Enliven street frontages to enhance the pedestrian experience.
- Create memorable places for people.

Principle #3: Land-use Diversity
Diversity uses land efficiently, provides for neighborhood convenience, and contributes to unique urban experiences. Development that adheres to this principle will:

- Encourage a compatible mix of uses at the neighborhood scale.
- Identify opportunities for shared uses.

Principle #4: Transportation Diversity
The transportation system should be maintained and improved in ways that accommodate various modes of transportation balanced with needs for pedestrians. Development that adheres to this principle will:

- Create a balanced circulation system that accommodates mobility choice (pedestrians, automobiles, bicycles, and transit).
- Enhance public transportation by making it more comfortable and convenient to use.

As can be seen in these principles, transportation is often a part of urban design policies. The following transportation-related principles from the City of Minneapolis's urban design policy [City of Minneapolis, 2009] provide another example of the mutually reinforcing relationship among development, urban design, and transportation considerations:

Downtown

- The ground floor of buildings should be occupied by active uses with direct connections to the sidewalk.
- Integrate components in building designs that offer protection to pedestrians, such as awnings and canopies, as a means to encourage pedestrian activity along the street.
- Locate access to and egress from parking ramps mid-block and at right angles to minimize disruptions to pedestrian flow at the street level.
- Coordinate site designs and public right-of-way improvements to provide adequate sidewalk space for pedestrian movement, street trees, landscaping, street furniture, sidewalk cafes, and other elements of active pedestrian areas.
- Use skyways to connect downtown buildings and that:
    - Provide consistent and uniform directional signage and accessible skyway system maps near skyway entrances, particularly along primary transit and pedestrian routes.
    - Provide convenient and easily accessible vertical connections between the skyway system and the public sidewalks, particularly along primary transit and pedestrian routes.

Multi-Family Residential

- Medium-scale, multi-family residential development is more appropriate along Commercial Corridors, Activity Centers, Transit Station Areas, and Growth Centers outside of Downtown Minneapolis.
- Orient buildings and building entrances to the street with pedestrian amenities like wider sidewalks and green spaces.

Single-Family and Two-Family Residential

- New driveways should be prohibited on blocks that have alley access and no existing driveways.

Mixed-Use and Transit-Oriented Development

- Provide safe, accessible, convenient, and lighted access and way finding to transit stops and transit stations along the Primary Transit Network bus and rail corridors.
- Coordinate site designs and public right-of-way improvements to provide adequate sidewalk space for pedestrian movement, street trees, landscaping, street furniture, sidewalk cafes, and other elements of active pedestrian areas.

Commercial

- Enhance pedestrian and transit-oriented commercial districts with street furniture, street plantings, plazas, water features, public art, and improved transit and pedestrian and bicycle amenities.
- Require storefront window transparency to assure both natural surveillance and an inviting pedestrian experience.
- Maximize the year-round potential for public transit, biking, and walking in new developments.

Industrial

- Design industrial sites to ensure direct access to major truck routes and freeways as a way to minimize automobile and truck impacts on residential streets and alleys.

Public Spaces

- Emphasize improving public access to and movement along the riverfront.
- Develop public plaza standards that give specific guidance on preferred design and maintenance of seating, lighting, landscaping, and other amenities utilizing climate sensitive design principles.

These principles focus on the characteristic of buildings and sites as they relate to transportation options. Streets, sidewalks, and parking facilities are also often part of urban design guidance. Again, from the Minneapolis guidance, the following list presents the urban design-desired actions for streets and sidewalks:

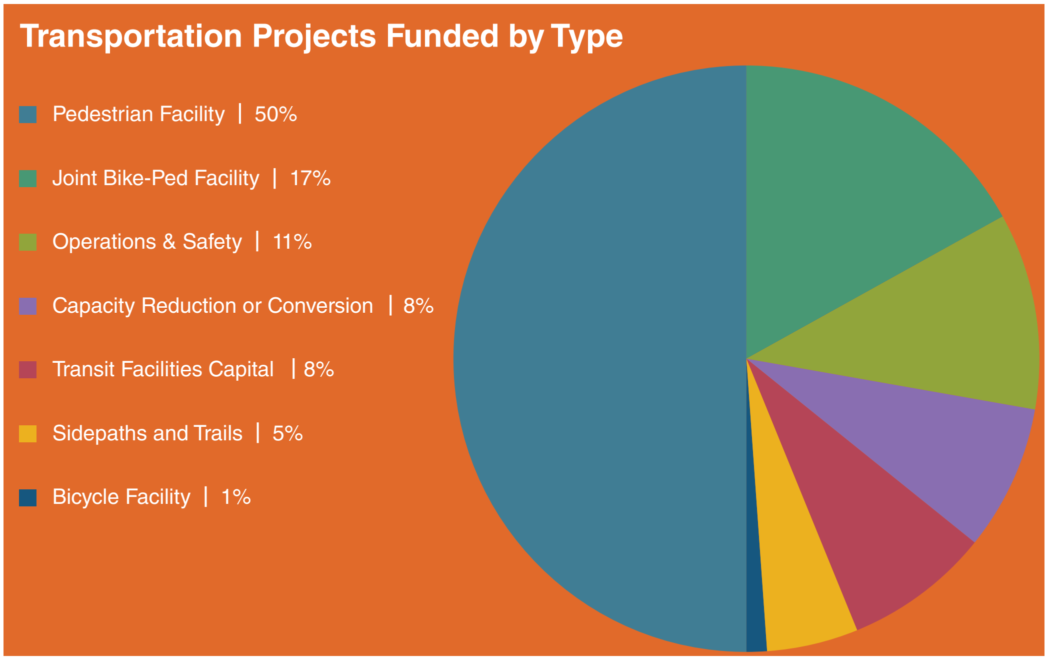
- Consider street variations as a last resort to preserve the network of city streets and arterials.
- Integrate and/or reuse historic pavement materials for streets and sidewalk reconstruction, where appropriate.
- Reduce street widths for safe and convenient pedestrian crossing by adding medians, boulevards, or bump-outs.
- Improve access management and way-finding to and from all streets, sidewalks, and other pedestrian connections.
- Explore options to redesign larger blocks through the reintroduction and extension of the urban street grid.
- Encourage wider sidewalks in commercial nodes, activity centers, along community and commercial corridors, and in growth centers such as Downtown and the University of Minnesota.
- Provide streetscape amenities, including street furniture, trees, and landscaping that buffer pedestrians from auto traffic, parking areas, and winter elements.
- Integrate placement of street furniture and fixtures, including landscaping and lighting, to serve a function and not obstruct pedestrian pathways and pedestrian flows.
- Employ pedestrian-friendly features along streets, including street trees and landscaped boulevards that add interest and beauty while also managing storm water, appropriate lane widths, raised intersections, and high-visibility crosswalks. [City of Minneapolis, 2009]

Urban design also focuses on public spaces. The American Planning Association (APA) defines a public space as "a gathering spot or part of a neighborhood, downtown, special district, waterfront, or other area within the public realm that helps promote social interaction and a sense of community. Possible examples may include such spaces as plazas, town squares, parks, marketplaces, public commons and malls, public greens, piers, special areas within convention centers or grounds, sites within public buildings, lobbies, concourses, or public spaces within private buildings." [APA, 2015] (Note that the importance of public space is recognized as one of the six core principles for roadway systems planning in ITE's *Recommended Practice for Planning Urban Roadway Systems* [2014]).

In the planning and urban design literature, planners often refer to "place-making," which means incorporating urban design concepts into a public (or private) space turning the location into a vibrant and economically sustainable "place to be." Transportation has a critical role in making this happen. For example, the types of transportation strategies as part of a public space include the availability and adequacy of sidewalks; sidewalk buffers, for example street trees, landscaping, on-street parking, and the like; bike lanes where feasible and the addition of bike share stations; urban design guidelines that address streetscape/pedestrian amenities; street trees that provide shade; and other walkability amenities. The concept of Complete Streets is a good example of how publicly provided transportation space can be made more appealing to a range of users (see chapter 9 on road and highway planning).

In recognition of the importance of place making, some MPOs have created funding programs for local cities and towns to develop master plans for targeted community areas where a mix of land uses and appropriate transportation strategies can be combined to create a special place. The Atlanta Regional Commission (ARC), for example, was one of the first MPOs to develop such a program. Called the Livable Centers Initiative (LCI), the program awards funding grants to local communities and nonprofit organizations to develop plans that (1) encourage a diversity of mixed-income residential neighborhoods, employment, shopping, and recreation choices in activity centers, town

Figure 3-6. Local Project Types Funded for Livable Centers Initiative Funds, Atlanta Regional Commission, 2014



Source: ARC, 2015b, Reproduced with permission of the Atlanta Regional Commission.

centers, and corridors; (2) provide access to a range of travel modes including transit, roadways, walking, and biking to enable access to all uses within the study area; and (3) develop an outreach process that promotes the involvement of all stakeholders. [ARC, 2015b]

Implementation funds are also available to those recipients where the plans have been formally adopted by the local government as part of comprehensive plans and/or who have taken steps to implement the recommendations, such as creating tax allocation districts or downtown development authorities. Figure 3-6 shows the distribution of ARC's transportation implementation funds with respect to the types of projects funded. It is interesting to note that the majority of funds were spent on pedestrian walkways and other connectivity measures. Given that, as of 2014, the ARC board had committed $500 million through 2040 for projects identified in LCI studies, the program can be considered quite a success. Just over $172 million in federal funds have been spent on LCI construction projects since 2000, with the total investment (including local matches) exceeding $235 million. [ARC, 2015b] Sixty-nine percent of all the new office growth in the region between 2000 and 2014 occurred in LCI-designated centers. The Houston-Galveston Area Council (H-GAC) has a similar "Livable Centers" program. [H-GAC, 2015]

It should be noted that some of the urban design principles listed above could very well conflict with engineering design practice or guidelines (for example, the use of trees to define a street space, or policies on turning lanes or two-way streets). In such cases, transportation officials usually enter into discussions with relevant officials to provide the transportation infrastructure and services that best support adopted urban design principles. This approach is called context sensitive solutions (CSS) and is discussed later in this chapter.

V. LAND-USE FORECASTING AND TRANSPORTATION PLANNING

For short-term analyses (3 to 5 years), transportation planners can usually take the current activity or land-use system as a given. In such cases, an inventory of the current land-use activity system for the study area is adequate to identify the number of trips to be generated from, or attracted to, a study area. In the long run (5 or more years), however, the urban land-use activity system clearly does change. Neighborhoods gain or lose population or employment of various types. New areas may be developed while older, developed areas may decline in quality, be renovated, or undergo redevelopment. As a result, travel demand patterns and transportation system requirements will also change.

Hence, long-range transportation planning must explicitly consider expected changes in the urban activity system in order to predict future travel demand.

The timeframe for forecasting land-use change varies by the type of planning study. *Comprehensive planning* usually considers "build-out" horizon years, often in the 30- to 50-year time horizon, and is applied area-wide. The *long range transportation planning* process most often uses a 20-year time horizon and is applied at the metropolitan or citywide levels. *Project planning* for the National Environmental Policy Act (NEPA) project development process uses horizon years of 20 to 25 years and is often done at the corridor or site level. *Air quality conformity/programming* focuses on horizon years of 6 to 20 years and occurs usually at the air basin or regional level. The timeframe for *site impact studies*, and the associated traffic impact analysis, will vary depending on local regulations and rules. Usually, the target years for projections include the year of development opening, 5 to 10 years beyond opening date, and full build-out (if the development site is part of a larger activity center).

A. Population and Employment Forecasting

In most cases, transportation planners are provided a population and employment control value often generated from state-level economic forecasts. In many states, it is expected that the population and employment forecasts will conform to this overall total forecast, although the distribution of such forecasts within the study area is left to the metropolitan or local planning agency.

Approaches for forecasting changes in population include the following:

- The *ratio-trend method*, which relates the population of a study area to the rising or falling ratio of that area's population to the population of a larger area, for which an accepted population forecast exists.
- The *cohort-survival method,* which adds the effects of net natural population increase and net migration to the existing population.
- The *economic-base method,* which gears population growth to a forecast of employment growth.
- The application of a *constant or gradually declining compounded annual rate or percentage increase* in population.
- A *constant absolute rate* of population increase per annum or per 5- or 10-year period.

Employment forecasts, which typically tend to be more difficult to perform, use techniques such as trend extrapolation, input-output analysis, and professional (usually economic) judgment. In the United States, the Federal Reserve Bank system provides employment forecasts for individual metropolitan areas, as does the Bureau of Labor Statistics.

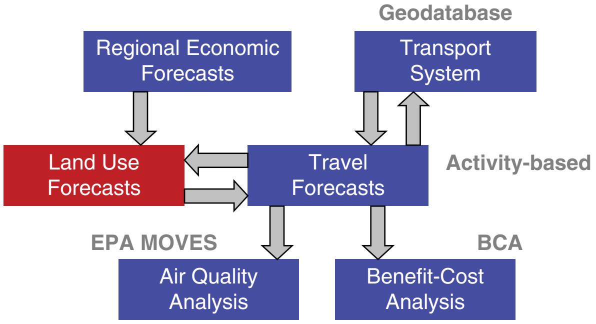
As an example of population forecasts for a large metropolitan area, the ARC notes that its process was "a multi-year effort, benchmarking and culminating into region plan updates. Several forecasting models are used and evaluated. In addition, several advisory meetings are held with local economists, dozens of engagement meetings are held with local governments and constituents over several iterations." [ARC, 2014a] ARC staff used the Regional Economic Models, Inc. (REMI) model to forecast population control totals, and then used another process to distribute the population throughout the region. The types of input data (or assumptions) for the ARC REMI model application included: population survival rates; population characteristics by race; birth rate; labor participation rates; equations that predicted economic output and employment by industry; unemployment rates; special populations such as those living in boarding houses, college dormitories, prisons, and mental institutions; fuel demand; migration; and economic and retired migrants. [ARC, 2014b] The forecasted regional total was then allocated to smaller districts.

B. Interrelationship between Land-Use Forecasts and Travel Modeling

Land-use forecasts provide two important inputs into predicting future transportation demand: (1) the future levels of population and employment (that is, what will be the future demand?) and (2) the distribution of land uses in the study area (that is, where will trips be coming from and going to?). Figure 3-7 shows the key components of a land-use forecasting model (UrbanSim) and its relationship to a travel demand model as used by the Puget Sound Regional Council (PSRC).

Several observations illustrate what is generally true of all land-use models and their relationship to travel demand modeling. First, accessibility is the major predictor of land use, that is, the more accessible a parcel of land, the more desirable it is for development. This accessibility comes from the travel demand model after it has run through its many steps, shown in Figure 3-7 as a two-way arrow (see chapter 6). There is, thus, a feedback loop from the demand model to the land-use model and, in fact, land-use models are often run through iterations with the updated demand model feedback in order to reach an equilibrium state. In other words, land-use patterns will affect travel times and costs, which in turn could affect land-use patterns, which in turn could affect travel times and costs, and so on.

Figure 3-7. Land-Use and Travel Modeling, Puget Sound Regional Council



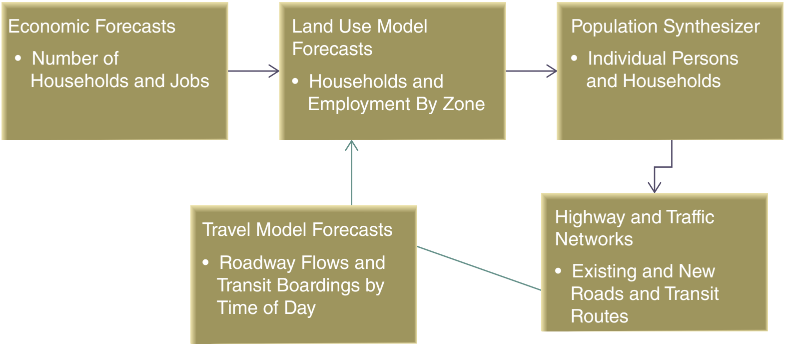
Source: Puget Sound Regional Council, 2012

Second, the land-use model has an exogenous input representing regional economic forecasts. In this case, a model other than the land-use model is used to forecast overall population and employment in the study area.

Third, a two-way arrow is also shown between the transportation network and travel forecasts. This represents the identification of projects and strategies as part of the planning process that will not only change the future transportation network but, over time, will affect land use as well.

Finally, the air quality emissions model and the benefit-cost analysis module are simply post-model analyses conducted to assess the air quality implications of the proposed plan and the benefits that will likely accrue.

Figure 3-8. Activity-Based Modeling and Land Use, Denver Example



Source: Denver Regional Council of Governments, 2010

Figure 3-8 shows another example from Denver, Colorado of the relationship between land-use forecasting and travel modeling. [DRCOG, 2010] In this case, the relationship between the two is simulated using an activity-based travel-demand model (ABM), which is one of the newer forms of travel demand models (see chapter 6). Instead of being based on trips like a traditional four-step model, ABMs represent the actual travel behavior of an individual over a specified period (for example, a day) and use travel tours to reflect the fact that many trips are made as a trip chain, with possibly many different intermediate stops. In this modeling framework, the location of future population is synthesized with a population synthesizer. In the Denver example, a forecast is developed of individual households and persons with detailed demographic characteristics for chosen year. The synthesizer uses two sets of control variables for household characteristics: regional-level controls and zonal-level controls (distributed with a land-use model). The synthesizer then distributes the households randomly within the zone it resides, and assigns socio-demographic characteristics that cumulatively match regional totals.

With regard to work location, the model takes all workers (as identified from the population synthesizer) and assigns them a regular work location zone and point. Characteristics of the worker and their home zone are used in combination with zonal characteristics to determine the desirability of any zone. For further information on the Denver model, see [DRCOG, 2010].

In sum, no matter what type of travel model is used, a strong linkage exists between land-use forecasts and the travel modeling process. Without having some sense of where households, people, and jobs will be located in the future, it would be very difficult to undertake travel demand modeling in a credible way.

C. Distributing Population and Employment Among Study Zones

Once the change in overall population and employment has been estimated, the planner next distributes these amounts to the traffic analysis zones in the study area. Transportation planning agencies use different types of land-use models, or in some cases, rely on economic data analysis and local development expertise to forecast future land-use patterns. Some models can be very comprehensive with numerous submodels and mathematical relationships intended to represent the very complex evolution of a community's development patterns. Others rely on simplifications, or simply focus on the most important variables.

At least three generations of land-use modeling efforts can be identified from the practice in Western countries: (1) experimentation in the 1960s with a variety of modeling methods, (2) the emergence of large-scale simulation models in the 1970s, and, (3) currently, operational models that have evolved over the past 20 years and that have built on and extended the earlier models.

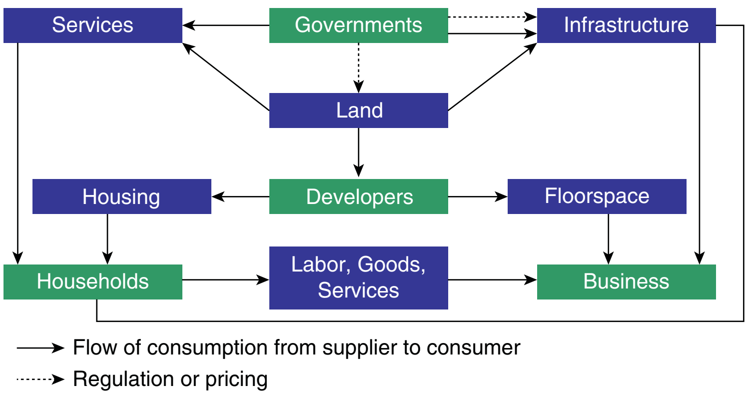
Of the various first generation models, the Lowry model has had by far the most enduring impact on the field. [Lowry, 1964] It is a heuristic model that iteratively allocates households to residential locations and retail or population-serving workers to employment locations, based on an exogenously supplied distribution of basic employment. Lowry models in various forms and of varying levels of complexity have been widely applied, although they are subject to a number of criticisms, including the lack of a dynamic structure and a lack of representation of urban land markets.

The key concept underlying the Lowry model is the definition of two classes of employment: retail and basic. Retail employment arises from all activities that are implicitly related to population and purchasing power. All activities for which a local market or service area can be identified for final products or services are in the category of retail employment. Major shopping centers and office complexes are example sources of retail employment. Basic employment is composed of everything else, that is, all those activities that are site-oriented in that their locations are dependent on factors other than the size and location of residence-oriented local market areas. Thus, for example, heavy industrial locations are considered to be sites of basic employment.

The model assumes that the basic employment in each zone of the urban area is exogenously determined. Given this base employment, the model allocates these workers to residential areas in the urban area using a work-to-residence distribution function. Then, given this residential distribution, the distribution of retail employment serving this population is similarly allocated using a resident-to-shop distribution function. These workers, in turn, must be allocated to residences, which then generate additional retail activity (employment) and so on. Thus, the model incorporates a multiplier effect in which each new employee (basic or retail) generates further retail employment, until the entire process converges to an equilibrium state.

The basic concept in the Lowry model (in a simplistic sense) and in more modern models is that key "agents" are making decisions that together over time result in land-use patterns. Figure 3-9 from the PSRC model, for example, shows four major "agents" that influence future population and employment locations—government, people or households, employers, and developers. In any given year of the land-use simulation model:

Figure 3-9. Land-Use Modeling, Puget Sound Regional Council



Source: Puget Sound Regional Council, 2012

- Developers use land to construct housing and nonresidential floor space demanded by households and businesses, which are also interacting in the labor market and in the markets for goods and services.
- Governments provide infrastructure and services, regulate, and, in some cases, alter prices for the use of land and infrastructure.
- Households, individuals, employers, developers, and governments are the key agents that respond to market forces.

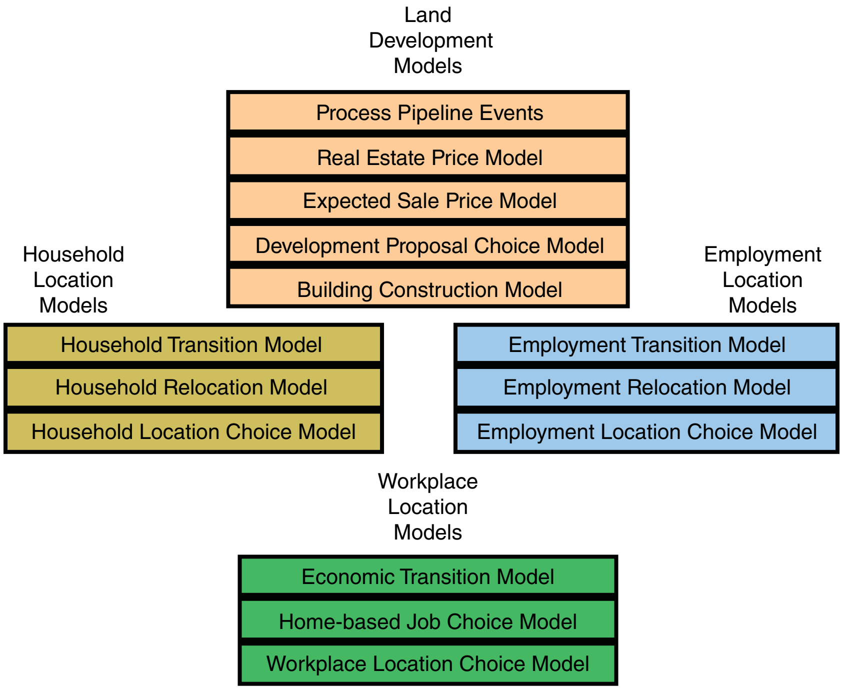
- Households make a cluster of interdependent long-term lifestyle choices, including when to move, neighborhoods to locate within, the type of housing to rent or purchase, and the number of vehicles to own. Individuals within households choose their labor force and educational status, their job mobility and job search, their daily activity schedule, their transportation mode, and route.
- Employers choose to start and close establishments, and choose site locations, size of employment, and types and quantities of real estate to rent or purchase.
- Developers choose to undertake real estate development projects, and the scale and locations of those projects.
- Governments set policies and make investments that affect the choices of other agents, and also make development choices regarding public facilities, including type, location, and scale of development. [PSRC, 2012]

These agents interact in a variety of ways to form future land-use patterns. For example, Figure 3-10 shows four models included within the modeling platform representing the decision process that occurs cumulatively within the overall model. Thus, for example, the model begins with a real estate price model, then proceeds to an expected sale price model, a development proposal choice model, and a building construction model. The intent of these models is to represent the availability of developable land and the corresponding land price. This then feeds into employer and household location decisions.

The basis for distributing population and employment among the zones in the study area—and one mathematically incorporated into land-use models—is the attractiveness of a particular location. The attractiveness of a location for a given activity depends on a wide variety of factors. For example, the attractiveness of a neighborhood as a residential location depends on characteristics such as: (1) the lot or house price, size, type, age, and quality of the available housing; (2) the quality and proximity of schools (if the household contains school-age children); (3) the availability of parks and other recreational facilities; (4) the extent to which the neighborhood is hazard-free (where hazards might include busy streets, noxious factories, and the like); and (5) the social-ethnic-racial composition of the neighborhood (and perceived trends in this composition). Similarly, the attractiveness of a location for a retail store depends on factors such as: (1) the availability of a suitable building for the store, (2) the location of the building relative to the street, (3) pedestrian flows and parking, (4) the rent for the building, (5) the expected market at the location for the goods being sold, and (6) the mix of retail stores currently located in the neighborhood.

In practice, the analysis is limited by the number of attraction attributes that can be specified and observed. The result is that surrogates, generally size variables (for example, total retail floor space in a zone as a measure of retail attractiveness

Figure 3-10. Models Representing Development Decision Making, Puget Sound Regional Council



Source: Puget Sound Regional Council, 2012 or total number of single-family housing units in a zone as a measure of residential attractiveness), are used in place of more specific behavioral variables.

Attractiveness is also influenced by *accessibility*, which typically provides the basis for the transportation component of urban activity or land-use modeling. Accessibility is generally defined as some aggregate measure of the size and closeness of activity opportunities of a given type to a particular location. For example, in characterizing the accessibility of a residential zone i to retail shopping opportunities, a common measure used is:

$$A_i = \sum_{j=1}^{n} F_j^{\alpha} e^{-\beta t_{i,j}} \qquad (3\text{-}1)$$

where,

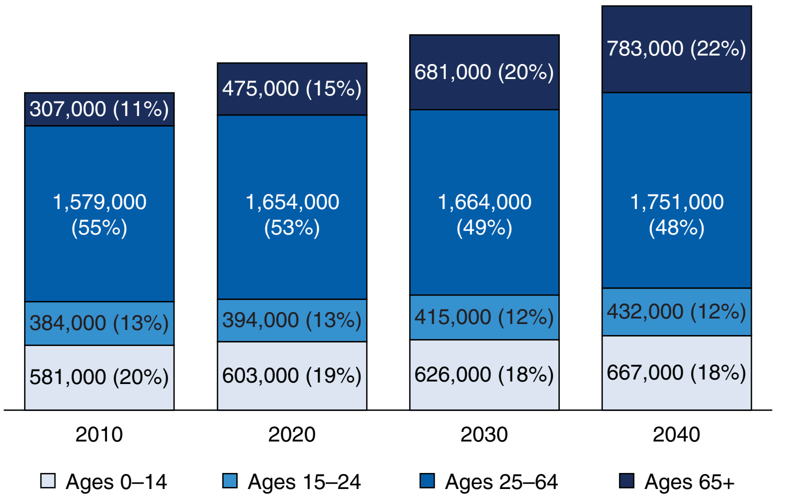
A_i = accessibility of zone i to shopping opportunities
F_j = amount of retail floor space in zone j
t_{ij} = travel time from zone i to zone j
n = number of zones with retail stores
α = parameter indicating the relative sensitivity of accessibility to store size ($\alpha > 1$)
β = parameter indicating the sensitivity of trip-making to travel time (the larger β is in magnitude, the less likely people are to travel long distances to shop)

As indicated in equation 3-1, it is assumed that location choice is positively correlated with accessibility. That is, it is assumed people would like to have more accessibility than less to shopping and employment opportunities, retail stores would like to be highly accessible to high-income households, and so on. The negative exponent to the travel time variable in equation 3-1 indicates that as the travel time between residential locations and shopping increases, the level of accessibility decreases. Similarly, the larger the value of F in the equation, the amount of retail space, the more desire there is for residents to travel to that location.

The output of land-use forecasting provides travel models with the expected location of population and employment sites in the study area for the target year, as well as interim years. The following list and Figure 3-11 from the Metropolitan Council (Met Council) in the Twin Cities, Minnesota note the typical information produced by a regional forecast.

- According to the latest regional forecast, the Twin Cities region will gain 783,000 residents over the next 30 years, bringing the total population of the region to 3.6 million in 2040.
- By 2040, the Twin Cities region will experience three major demographic shifts. The population will be, (1) more racially and ethnically diverse, (2) older, and (3) more likely to live alone.

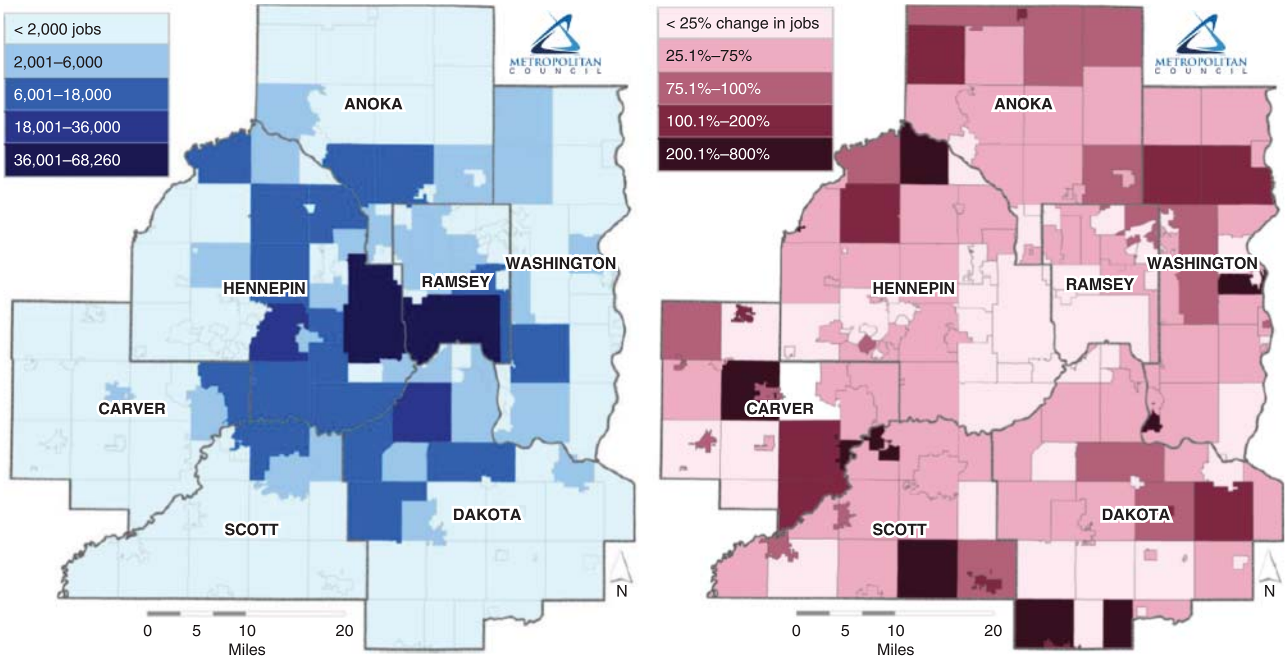
Figure 3-11. Population by Age Group, 2010–2040, Metropolitan Council, Minneapolis-St. Paul, Minnesota



Source: Metropolitan Council, 2015a

- Jobs and economic opportunity attract people to the Twin Cities region. The churn of people moving to and from the Twin Cities region is increasing the racial and ethnic diversity of the workforce and schools.
- The housing needs and preferences of older adults—residents over age 65—will significantly reshape the region's housing market.
- The Twin Cities region will add 468,000 jobs, bringing the total number of jobs to over 2 million by 2040. [Met Council, 2015]

Figure 3-12. Change in Employment, 2010–2040, Metropolitan Council, Minneapolis-St. Paul, Minnesota



Source: Metropolitan Council, 2015b

Figure 3-12 shows typical results of the distribution phase of land-use modeling, again from the Metropolitan Council. In this case, the figure shows the distribution of new jobs both on an absolute change basis and on a percentage basis.

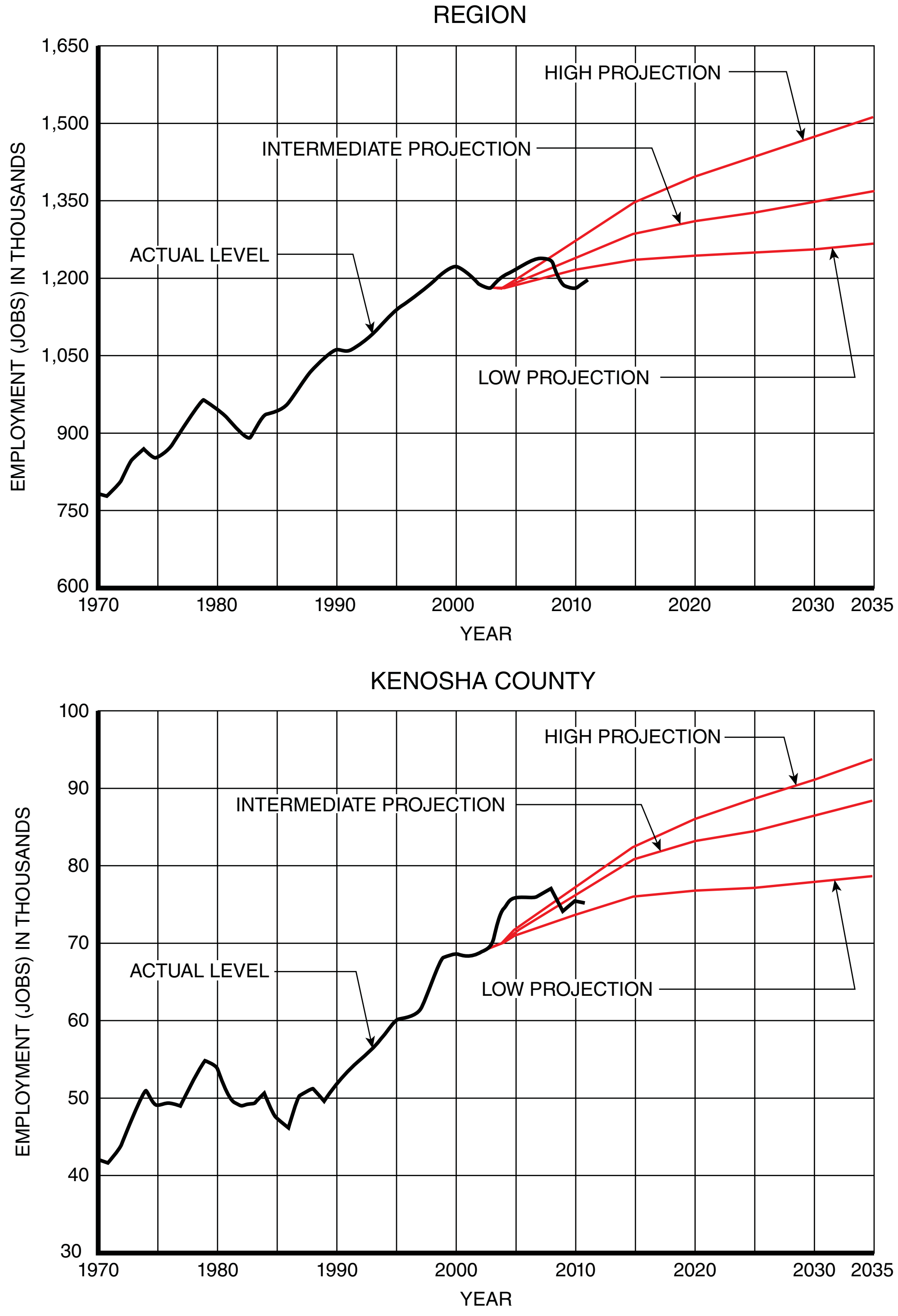
Figure 3-13 from the Southeastern Wisconsin Regional Planning Commission (SEWRPC), the MPO for the Milwaukee, Wisconsin, metropolitan area, shows another common characteristic of population/employment forecasting and land-use modeling. As shown in the figure, the forecasted employment is viewed from three scenarios, each representing different assumptions as to growth rates, state of the economy, and other variables that might make the Milwaukee area more or less attractive for population and employment. [SEWPRC, 2013] The figure depicts the projected changes in employment under each scenario for both the metropolitan region and one of the MPO member counties. Use of scenarios will be further discussed in the following section.

While it is beyond the scope of this chapter to describe in detail each of the land-use models available in practice today, this section has, nevertheless, provided a very brief overview of the major concepts as to how land-use forecasting is conducted. The transportation planner should be careful when considering a land-use model to understand: (1) the data requirements for each candidate model, (2) the amount of staff resources necessary to calibrate and use the model, (3) the underlying logic of the land development decision-making process embedded in the model, and (4) the level of integration to travel forecasting. In some cases, formal land-use models will make sense; in other situations, scenarios or expert panels might very well suffice to provide the information necessary to conduct transportation planning.

Land-use models are constantly evolving and are continuously being updated by model developers. Several papers and books provide more detailed comparisons of available land-use transport models (see, for example, see [Hunt, Kriger and Miller, 2005; Meyer and Miller, 2014; Waddell, 2011; and Zhao and Chung, 2010]). Thus, planners interested in the latest characteristics of a particular land-use model should examine the most recent documentation for that particular model to see recent enhancements. In particular, most MPOs provide documentation of their land-use forecasting methodology and assumptions. A representative set of documentation includes:

- Atlanta Regional Commission (ARC). 2014a. “Regional Forecasting (Socio-economic Allocation),” http://www.atlantaregional.com/info-center/forecasts/forecast-development.
- Denver Regional Council of Governments (DRCOG). 2010. “Focus Model Overview,” https://drcog.org/sites/drcog/files/resources/FocusOverview_WebVersion.docx.
- Metropolitan Council (Met Council, Minneapolis-St. Paul). 2015a. “The Regional Forecast to 2040,” http://www.metrocouncil.org/Data-and-Maps/Publications-And-Resources/MetroStats/Census-and-Population/Steady-Growth-and-Big-Changes-Ahead-The-Regional-F.aspx.

Figure 3-13. Forecasted Employment, Southeastern Wisconsin Region and Kenosha, Wisconsin



Source: SEWRPC, 2013

- Southeastern Wisconsin Regional Planning Commission (SEWRPC, Milwaukee). 2013. *The Economy of Southeast Wisconsin*. http://www.sewrpc.org/SEWRPCFiles/Publications/TechRep/tr-010-5th-ed-economy-se-wisc.pdf.
- Southern California Association of Governments (SCAG, Los Angeles). 2010. "Growth Forecast," http://rtpscs.scag.ca.gov/Documents/2012/final/SR/2012fRTP_GrowthForecast.pdf.

In addition, the FHWA manages a website that provides information on the latest developments in land use and transportation planning, which provides a good source of up-to-date information. The website can be found at: http://www.fhwa.dot.gov/planning/processes/land_use/.

VI. SCENARIO ANALYSIS FOR URBAN FORM

Instead of formal land-use models, many planning agencies use some form of a scenario-based approach or other subjective techniques to predict future land-use patterns. Land-use scenarios can represent different types of desired land-use patterns, for example, more clustering of development around transit stations, encouraging new development to locate in established cities and towns, or expecting infill development in more established communities in the region. Figure 3-14 shows a summary of the process used by a travel modeling effort from Fredericksburg, Virginia, that included land-use scenarios in the methodology.

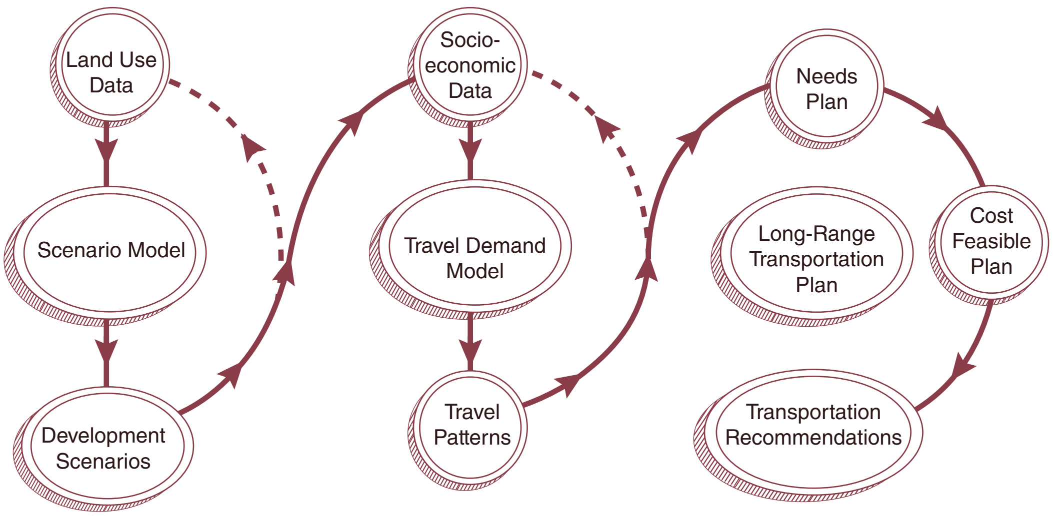
The project team established two focus groups, one with business and development interests (to identify factors that make land more attractive to development) and a second with chief planners and public works officials (to identify the effect of local land development policies and available infrastructure on future development patterns and intensities). Three citizen workshops were held to capture community values and attitudes toward growth in the region. An online survey captured residents' perceptions toward growth and long range planning. A project steering committee was established to provide direct oversight and counsel in the planning process. All of this input led MPO planners to prepare four alternative growth scenarios. Each scenario was sufficiently different to allow for real choices to be made on how the region could develop under one or more planning initiatives (see Figure 3-15). The four growth scenarios were identified as:

- Decentralized Growth
- Compact Centers & Growth Corridors
- Green Print Initiative
- Greater Jobs-Housing Balance

Table 3-5 shows how the different scenarios relate to the 24 performance measures identified by the planning study. As seen in the table, providing incentives for jobs and housing to be located closer together is found to be the most effective in meeting study objectives, a result which has been echoed in many other studies.

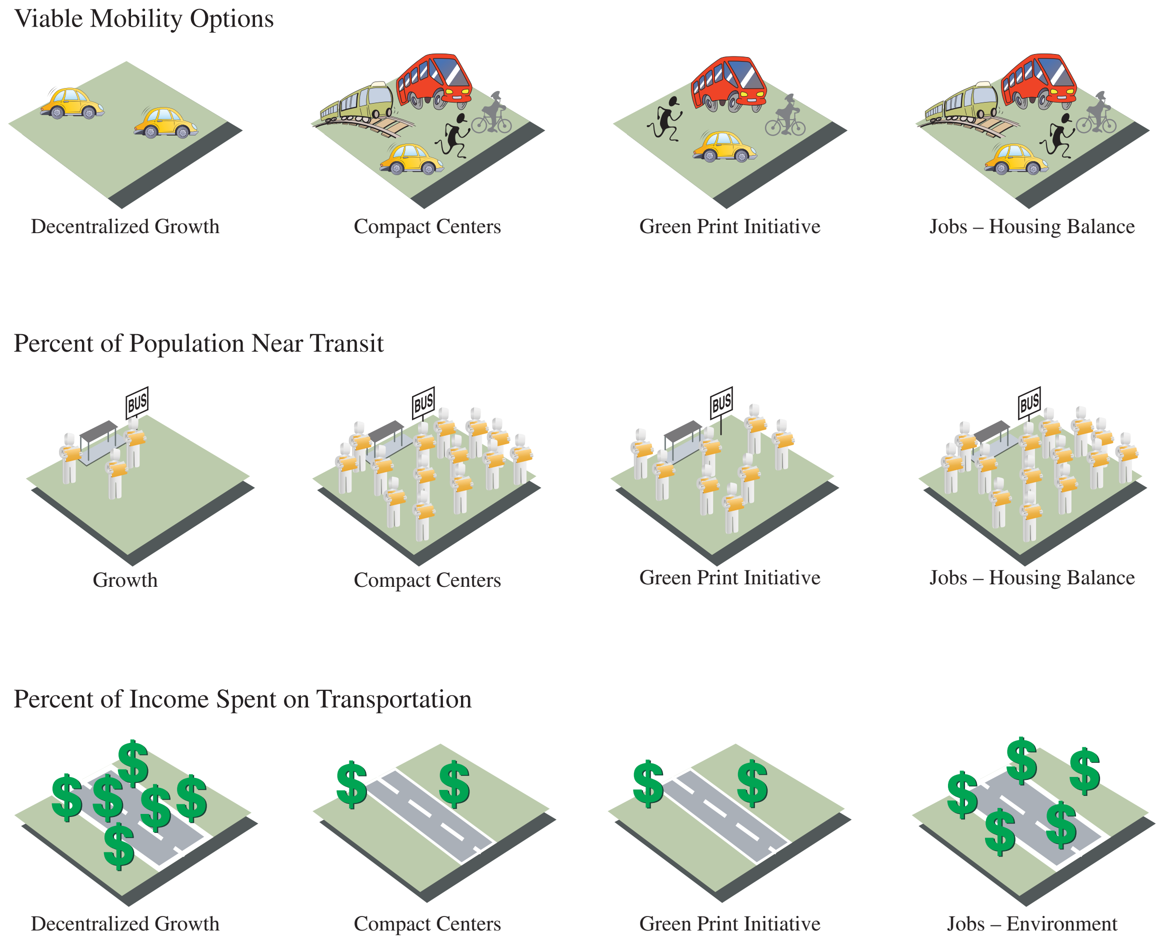
Figure 3-14. Use of Scenarios in Travel Forecasting, Fredericksburg, Virginia

General Process Diagram



Source: FAMPO, 2013

Figure 3-15. Scenario Characteristics, Fredericksburg, Virginia



Source: FAMPO, 2013

A 2005 review of scenario planning experience in the United States showed its widespread utilization among planning agencies. [Bartholomew, 2005] Tables 3-6 to 3-9 show different characteristics of the scenarios and their evaluation found in this review.

Scenario analysis shows the expected transportation implications for different types of land-use patterns, or of different population characteristics. [Zmud et al., 2014] Decision makers can adopt one scenario or a combination of scenarios as the desired future land-use pattern and can provide investment in transportation facilities and services that would best lead to such a future.

VII. HIGHWAY FACILITY-RELATED STRATEGIES

At a regional or community scale, land-use strategies can influence the amount of travel occurring in a transportation system and the flows occurring on the network. At the individual facility level, land-use considerations can also have an effect on road performance and safety. Two strategies, in particular, have been used by transportation planners and engineers to improve facility operations and design characteristics: access management and context sensitive solutions (CSS). Both of these strategies are discussed in detail in ITE's *Traffic Engineering Handbook* [Pande and Wolshon, 2016], as well as in chapter 9 of this handbook. The following sections provide an overview of both from the perspective of how land-use considerations are incorporated into project-level planning.

A. Access Management

Many different types of transportation and land-use strategies can be considered as part of the transportation planning process. It is beyond the scope of this chapter to describe each in detail. However, one strategy clearly links land

Table 3-5. Results of Land-use Scenarios, Fredericksburg, Virginia				
	Decentralized Growth	**Compact Development**	**Green Print Initiative**	**Job-Housing Balance**
MOBILITY				
Vehicle miles traveled per capita	o	○	ø	●
Vehicle hours traveled per capita	o	○	ø	●
% population near potential transit node	o	●	ø	●
Congested corridors	o	○	ø	●
% income spent on transportation	o	●	○	●
Viable mobility options	o	●	○	●
ENVIRONMENT				
Urban footprint	o	○	●	○
Agricultural land consumed	o	○	●	○
Eco-core land consumed	o	○	●	○
Amount of protected open space	o	○	●	○
GENUINE COMMUNITIES				
Housing mix	o	●	ø	●
Proximity to existing development	ø	●	○	●
Jobs-housing balance	o	o	o	●
REGIONAL COLLABORATION				
Consistency with local plans	o	○	ø	ø
Consistency with regional plans	o	○	ø	ø
Land use/transportation connection	o	●	ø	●
MAXIMIZING EFFICIENCIES IN PUBLIC INFRASTRUCTURE				
Demand for new parks	o	○	○	●
Demand for new schools	o	ø	ø	●
Demand for water	o	ø	ø	●
Demand for sewer	o	ø	ø	●
QUALITY OF LIFE				
Protection of Civil War battlefields	o	ø	●	ø
Jobs-housing balance	o	o	o	●
Amount of protected open space	o	○	●	○
Maintaining rural character	o	○	●	○
COMPOSITE GRADE		○	ø	●

● Most satisfies performance measures ○ Moderately satisfies ø Somewhat satisfies o Least satisfies

Source: FAMPO, 2012

Table 3-6. Types of Land-Use Patterns Examined in Scenario Studies (*n* = 225)	
Scenario Types	**Number of Scenario Studies**
Center, cluster, or satellite	58
Compact	43
Dispersed, fringe, or highway-oriented	39
Corridor	5
Infill or redevelopment	24
Other or undefined	36

Source: Bartholomew, 2005

Table 3-7. Variables Distinguishing Scenario Studies (*n* = 80)	
Variable	**Number of Scenario Studies**
Rate or amount of growth	20
Location of growth	73
Density of growth	76
Design of growth	25
Homo/heterogeneity of growth	50
Transportation system elements	40
Pricing/policy elements	12

Source: Bartholomew, 2005

Table 3-8. Types of Analysis Tools Used in Scenario Planning Studies (*n* = 80)	
Types of Tool	**Number of Scenario Studies**
Travel forecasting model	47
with transit/pedestrian-oriented development submodel	9
with a GIS scenario building tool	20
with a land-use allocation model	7
Sketch travel model	3
Sketch land-use/travel model	3
Land-use model only	4
GIS scenario building tool only	10
Economic model/analysis	6
Other/no data	13

Source: Bartholomew, 2005

Table 3-9. Indices Used to Evaluate Scenarios (*n* = 80)	
Measure	**Number of Scenario Studies**
Transportation	63
Auto ownership	5
Vehicle miles traveled	50
Vehicle trips	20
Average trip length	16
Vehicle hours of travel	24
Average peak hour speed	19
Other congestion	28
Mode shares	23
Transit ridership	27
Households served by transit	20
Other transportation measures	23
Land use	47
Amount of developed land	33
Amount of agricultural land converted	25
Other land-use measures	32
Sewer capacity	6
Water consumption	12
Fiscal cost	30
Air quality	33
Energy consumption	18
Greenhouse gas emissions	10

Source: Bartholomew, 2005

use, urban design, and transportation issues at the facility level, this being access management. It is a basic tenet of transportation engineering that site access should maintain the operational integrity of the surrounding road system. This can be best achieved by applying access management principles and designs.

Access management provides or (manages) access to land development while simultaneously preserving the flow of traffic (safety, capacity, and speed) on the surrounding road system. It consists of the systematic control of the location, spacing, design, and operation of driveways; median openings; interchanges; and street connections to a roadway. It also includes applications such as median treatments, auxiliary lanes, and the appropriate spacing of traffic signals. [ITE, 2010a]. An important access management objective is to ensure that the cumulative effects of a series of closely spaced, uncoordinated developments do not deteriorate safety and mobility on the surrounding road system.

Key elements of access management include defining allowable access for various types of roadways, establishing spacing of traffic signals and driveway connections, providing a way to grant variances when reasonable access cannot otherwise be provided, and establishing a means of enforcing standards. The degree of access control and management is determined by statute, deed, zoning, and operational and geometric design standards. Comprehensive statewide access management codes are found in several states including Colorado, Florida, Minnesota, New Jersey, Oregon, and South Dakota. [Committee on Access Management, 2003]

Access management codes and ordinances specify when, where, and how access can be provided to developments along a roadway. Access classification systems, an integral part of these programs, give the relevant access with spacing guidelines. They relate the allowable access to each roadway's purpose, importance, and functional characteristics. A functional classification system provides the starting point in assigning highways to access categories. Modifying factors include development density, driveway density, and geometric design features, such as the presence or absence of a median. Additional guidelines for access management are set forth in the *Access Management Manual*. [Committee on Access Management, 2003]

NCHRP Report 548, *A Guidebook for Including Access Management in Transportation Planning*, provides useful recommendations on how access management can be better integrated into the transportation planning process. [Rose et al., 2005] Specifically, this guidebook recommends the following steps for an effective access management program:

- Develop and apply an access classification system that assigns access management standards to roadways in accordance with their level of importance to mobility. This system generally parallels the roadway functional classification system.
- Plan, design, and maintain road systems based on this access classification system and related road geometry.
- Define the level of access permitted to each classification, which includes the following:
  - Permitting or prohibiting direct property access.
  - Allowing for full movement, limited turns, and median.
  - Designating the type of traffic control required such as signal, raised median, or roundabout.
- Establish criteria for the spacing of signalized and nonsignalized access, as well as access setback distances from intersections (corner clearance) and interchanges.
- Apply agreed-upon engineering standards that include appropriate geometric design criteria and traffic engineering measures to each allowable access point or system of access points.
- Establish policies, regulations, and permitting procedures to implement the listed components.
- Ensure coordination with and supportive actions by local jurisdictions exercising their land-use planning authority as well as their development permitting and review authority.

More detailed information on access management from an engineering perspective is found in ITE's *Traffic Engineering Handbook*. [Stover and Williams, 2016]

B. Context-Sensitive Solutions (CSS)

An important trend in project development in the past decade—and one that links closely to urban design and land-use issues—has been the increasing consideration of the context within which design occurs. [McCann, 2013] Referred to as context-sensitive design (CSD) or CSS (to reflect a broader perspective on potential problem solutions), this approach to design is defined by the FHWA as "a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources, while maintaining safety and mobility."[FHWA, 2006]

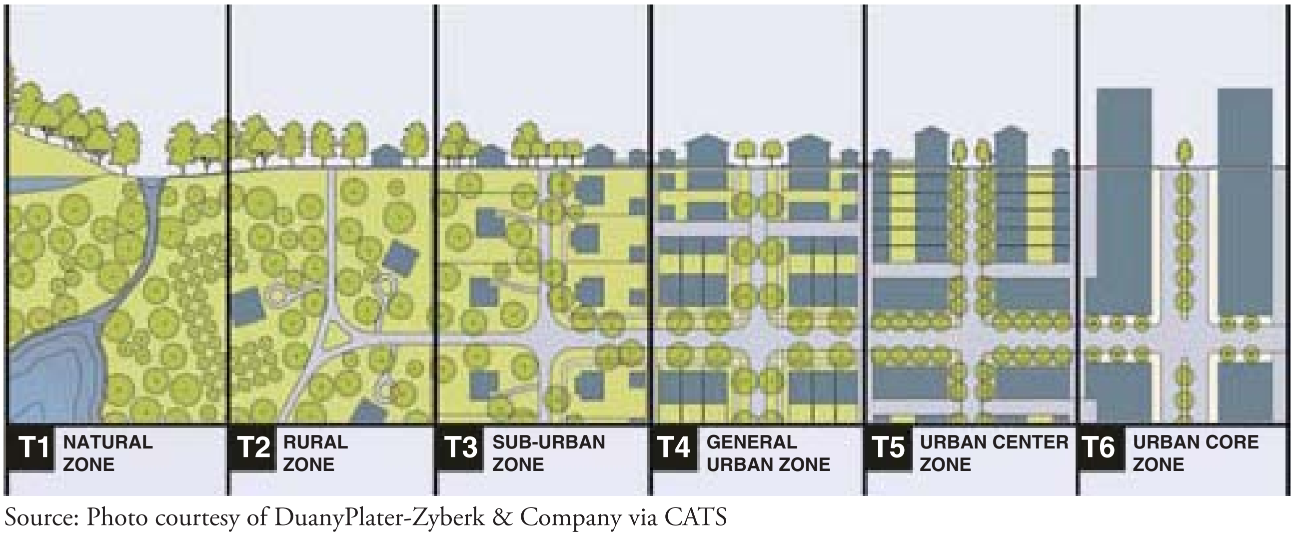
As noted in an NCHRP report, "CSD recognizes that a highway or road itself, by the way it is integrated within the community, can have far-reaching impacts (positive and negative) beyond its traffic or transportation function. The term CSD refers to as much an approach or process as it does to an actual outcome." [Neuman et al., 2002] This chapter uses the term CSS because much of the broad context for transportation facility design in urban areas is defined by the land use and community character surrounding the project. CSS is important to planning practitioners because it describes the best strategies of how to combine the principles or solve the conflicts of urban design and engineering design. Chapter 9 on road and highway planning also presents material on CSS.

Fundamental to CSS approaches is an urban planning concept called the urban-to-rural transect, developed by New Urbanist Andrés Duany. [Duany et al., 2009] As shown in Figure 3-16, the transect represents a transition in development environments ranging from open land to higher density development patterns. Importantly to transportation planners, this transition could also mean a different style of road design, transit service provision, and accommodation of pedestrians and bicyclists. Some communities and professional organizations (such as ITE) have developed guidance based on the transect as it relates to everything from functional classification to geometric design.

The Maryland State Highway Administration outlined the basic characteristics of a highway CSS approach, which included the following: [Maryland State Highway Administration, 1998]

- The project satisfies the purpose and needs as agreed to by a full range of stakeholders. This agreement is forged in the earliest phase of the project and amended as warranted as the project develops.
- The project is a safe facility for both the user and the community.
- The project is in harmony with the community and preserves environmental, scenic, aesthetic, historic, and natural resource values of the area.
- The project exceeds the expectations of both designers and stakeholders and achieves a level of excellence in people's minds.

Figure 3-16. Rural to Urban Transect and Linkage to Transportation



Source: Photo courtesy of DuanyPlater-Zyberk & Company via CATS

- The project involves efficient and effective use of resources (time, budget, and community) of all involved parties.
- The project is designed and built with minimal disruption to the community.
- The project is seen as having added lasting value to the community.

According to ITE's Recommended Practice *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach,*

> *"Applying the principle of CSS enhances the planning and design process by addressing objectives and considerations not only for the transportation facility, but also for the surrounding area and its land uses, developments, economic and other activities, and environmental conditions. With a thorough understanding of the CSS principles and design process, the practitioner planning or designing a thoroughfare seeks to integrate community objectives, accommodate all users and make decisions based on an understanding of the trade-offs that frequently accompany multiple or conflicting needs."*
>
> *[ITE, 2010a]*

At the thoroughfare *network planning level*, CSS concepts include:

- Multimodal network planning should be integrated into long-range comprehensive plans that address land use, transportation, and urban form.
- Network planning should address mobility and access needs associated with passenger travel, goods movement, utilities placement, and emergency services.
- Reserving right of way for the ultimate width of thoroughfares should be based on long-term needs defined by objectives for both community character and mobility.

For *street connectivity and spacing*, CSS concepts include:

- Networks should provide a high level of connectivity so that drivers, pedestrians, and transit users can choose the most direct routes and access urban properties. Connectivity should support the desired development patterns. Networks should provide intermodal connectivity to easily transfer between modes.
- Intersperse among arterial thoroughfares a system of intermediate collector thoroughfares serving local trips connecting neighborhood and subregional destinations.
- Expand the typical definition of collectors to recognize their role in connecting local origins and destinations to distribute trips efficiently, keep short local trips off the arterial system, and provide a choice of routes for transit, pedestrians, drivers, and bicyclists.
- Build network capacity and redundancy through a dense, connected network rather than through an emphasis on high levels of vehicle capacity on individual arterial facilities. This approach (having more thoroughfares rather than wider thoroughfares) ensures that the network and thoroughfare facilities can support other objectives, such as pedestrian activity, multimodal safety and support for adjacent development.
- Minimize property access directly onto arterials through design of a connected network of closely spaced arterial and collector thoroughfares and local street connections. With fewer driveway-type interruptions, arterial thoroughfares can perform more efficiently for vehicles and for pedestrians. Thus, network connectivity can provide a foundation for access management strategies to increase corridor capacity and accessibility.

With respect to CSS-related characteristics for choosing *performance measures*:

- Select transportation performance measures that reflect stakeholder objectives and priorities for the system or facility being planned or designed. Some of these might not be strictly transportation measures, but include economic development and other types of measures.
- Use performance measures that recognize all modes.

- Performance goals can vary for different parts of the network as long as direct comparisons are made to the same measures.
- Performance measures could include conventional measures of vehicle congestion, capacity and density, considered at a network-wide or corridor-wide level.
- To reflect walkability and compact development, consider measures such as a connectivity index, intersection density measures, and pedestrian environment measures.
- Selected performance measures should include measures of safety for all users.

For those desiring more information on how CSS principles and approaches can be incorporated into transportation planning and design, the ITE *Recommended Practice* is strongly recommended as an excellent source of information, as is the FHWA CSS toolbox website at http://contextsensitivesolutions.org/content/topics/misc/fhwa-toolbox/. In addition, the reader is referred to chapter 9 on road and highway planning.

For neighborhood street design and CSS principles, the reader is referred to ITE's *Recommended Practice on Neighborhood Street Design, Guidelines*. [ITE, 2010b] Neighborhood-level CSS project descriptions can be found at: www.contextsensitivesolutions.org.

VIII. SUMMARY

The connection between land use and transportation planning has been a fundamental relationship that has guided both the process of planning as well as the technical tools planners and engineers rely on. For many years, land-use factors were considered by transportation planners only as inputs into the modeling process. In recent years, however, land-use and urban design strategies have become important components of the tools that planners and elected officials can use to enhance community accessibility and mobility. This chapter has provided an overview of the land use–transportation relationship that is so important to the transportation planning process.

Information on future levels of population and employment and their location in a study area is a basic point of departure for conducting most transportation studies. In addition, transportation at the local level will be strongly influenced by the type and magnitude of development that will occur in compliance with local comprehensive plans and zoning ordinances. Given the importance of this land use–transportation relationship to successful transportation planning, it is important that the agencies or units within an agency responsible for land-use forecasting and transportation modeling work closely together to ensure that the transportation planning process has a strong foundation for estimating future travel.

The following lessons learned from a scan of U.S. land use–transportation studies provide some useful guidance on the steps that might be necessary to provide an integrated land use–transportation planning process:

- Individual methods developed for the coordination of transportation planning and land-use policies differ by community. Lessons and best practices can be shared, but ultimately, successful solutions should be the result of local needs and local processes and should respect local values.
- Planning efforts that fail to include sufficient public outreach and participation are unlikely to succeed. Any planning efforts—particularly innovative efforts—that move ahead without sufficient attention to public involvement and concurrence can generate discord and delay implementation.
- Physical design matters as much as good planning. Planning alone is not sufficient to create a successful development that integrates transportation and land use in a way that will attract new users and residents. The aesthetic appearance, the ease of use, and the connectivity of design are all important factors.
- The financial needs of a project and the levels of available funding should be tentatively calculated and then revisited throughout the planning process. Many multimodal transportation and infrastructure projects are completed in stages, with each component planned and financed independently. Such incremental projects lend themselves to the use of multiple sources of funding, each source dedicated to a different aspect of the project.

- The local development climate will strongly influence efforts to coordinate transportation and land-use planning. To be effective, planning should take into account the realities of the private- development environment, including issues of financing, demand, and timing. In these ways, public projects are linked to patterns of private development.
- Ideas should be presented in ways that make sense for a particular community. Creative planning efforts should find ways to present ideas—particularly contentious ideas—in locally acceptable language and context. The political and cultural environment varies by community, and planning projects should use a vocabulary that resonates in the community in which it will be used. [FHWA, 2003]

As noted in the resulting report, "Innovative planning ideas can move beyond established processes and regulations, requiring old policies to be revised and updated. New methods of planning and visioning, particularly those that are grounded in community participation, can present a challenge to established planning regulations. Innovative proposals may be stymied in their efforts to move ahead because of existing zoning and transportation policies, which are often geared toward large-lot, low-density, automobile-oriented development … With time, new and innovative planning processes must be integrated into the existing systems of planning in order to maintain the strength of the established planning processes while allowing for new methods to be explored." [FHWA, 2003]

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Environmental Considerations[1]

I. INTRODUCTION

It would be hard to find an issue that has engaged transportation planners more during the past 50 years than the potential impacts of transportation system performance and facility construction on the natural and built environment. Since the late 1960s and early 1970s, the transportation planning process at all levels has been guided by laws and regulations governing the impacts that need to be considered as part of decision making, and that often identify the methods of analysis to be used. In addition, the transportation planning process in the United States has been closely tied to the attainment of air quality goals in metropolitan areas whose air quality does not meet national air quality standards.

Many governments throughout the world have passed laws and created regulations to protect and enhance the environment. Specific rules guide their application to the development and operation of infrastructure, including transportation projects. While these laws and regulations vary by country and jurisdiction, this chapter references U.S. environmental laws and regulations to illustrate general principles and practices and to provide a framework for discussion. It also focuses on highway and transit project development processes, with the understanding that other types of transportation facilities, such as airports and maritime and port facilities, follow comparable processes.

Two scales of planning applications merit attention when discussing the relationship between environmental factors and transportation planning. The first is the broader transportation planning occurring at the statewide, metropolitan, or corridor level. This planning is often not project-specific (except for many corridor studies), and thus insufficient engineering is done to identify the types of environmental impacts likely to occur. The second type of planning, which is more closely related to project development, provides a much more detailed analysis of the likely consequences of project alignment and operating decisions. This planning usually includes sufficient conceptual engineering detail to determine the types and magnitudes of environmental impacts likely to be encountered during project construction and operation, as well as what might be needed to mitigate them.

An important policy discussion in recent years has been how to provide a closer linkage between the two scales of analysis, such that information produced in the planning process can be used in project-specific planning to avoid duplication of effort. (This approach is often referred to as environmental streamlining.) Both types of planning will be discussed in this chapter.

This chapter describes the role of environmental impacts and consequences in the transportation planning process. The intent is to discuss ways to incorporate environmental considerations in the planning process so that decisions made early in the process will remain valid for later environmental regulatory reviews and documentation. This chapter also discusses considerations for determining the appropriate level of detail for environmental analysis and documentation during planning. The second section provides an overview of the role environmental considerations play in transportation policy and decision making, followed by general principles that should guide them. The next several sections present more detailed information by impact category, followed by construction-related environmental effects. The final two sections describe how to assess and document mitigation strategies in the systems planning process.

II. ENVIRONMENTAL CONSIDERATIONS IN TRANSPORTATION PLANNING AND DECISION MAKING

As will be seen in subsequent sections, environmental considerations are found throughout the transportation planning and decision-making processes. The following paragraphs discuss four major concept/linkages that are found in

[1]The original chapter in Volume 3 of this handbook was written by Greg Benz, Senior Vice President, WSP/Parsons Brinckerhoff. Changes made to this updated chapter are solely the responsibility of the editor.

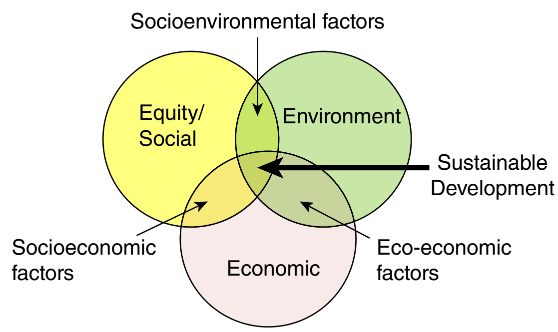
Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

most current practice: sustainability, environmental considerations at the systems level, environmental considerations in project development, and linking the latter two, as one progresses from systems planning to project development.

A. Sustainability

Sustainability, or sustainable development, has received increasing focus as a desirable societal goal since the mid-1980s, when a United Nations commission defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." [United Nations World Commission on Environment and Development (Brundtland Commission), 1987] This definition was further refined to include the Triple Bottom Line of economic development, social equity, and environmental quality, defined by the American Association of State Highway and Transportation Officials (AASHTO) as follows and shown in Figure 4-1.

Figure 4-1. Triple Bottom Line of Sustainability



- Economy—Support economic vitality while developing infrastructure in a cost-efficient manner. Costs of infrastructure must be within a society's ability and willingness to pay. User costs, including private costs, need to be within the ability of people and households to pay for success.
- Social—Meet social needs by making transportation accessible, safe, and secure; include provision of mobility choices for all people (including people with economic disadvantages); and develop infrastructure that is an asset to communities.
- Environment—Create solutions that are compatible with—and that can be an enhancement to—the natural environment, reduce emissions and pollution from the transportation system, and reduce the material resources required to support transportation. [AASHTO, 2009]

What sustainability means to transportation agencies, and in particular to the transportation planning process, will vary from one jurisdiction to another. [Booz Allen Hamilton, 2014] For example, an AASHTO report on sustainable transportation identified a range of actions shown in Table 4-1 that could provide a more sustainable transportation system.

Many transportation agencies have adopted a variety of policies and tools that support some elements of sustainability, such as context-sensitive solutions (discussed in chapter 3), Complete Streets, asset management, access management, congestion management systems, pavement management systems, environmental analysis for requirements of the National Environmental Policy Act (NEPA), economic analysis of transportation projects and system improvements, and a broadened approach to planning and to project development. Many of the building blocks for Triple Bottom Line sustainability are in place—but they need to be refined, expanded, fully embraced, and integrated.

The performance measures used by states and regions to monitor progress in achieving community goals and objectives can also reflect a sustainability theme. For example, the following transportation system metrics from the Maryland Department of Transportation are good examples of how sustainability can be incorporated into the capital program and operations of a transportation agency. [Maryland DOT, 2013]

Goals: Quality of Service; Connectivity for Daily Life

- Percentage of the Maryland State Highway Administration (SHA) network in overall preferred maintenance condition.
- Percent of roadway miles with acceptable ride quality.
- User cost savings for the traveling public due to incident management.
- Percentage of state-owned roadway directional miles within urban areas that have sidewalks and percent of sidewalks that meet Americans with Disabilities Act compliance.

Table 4-1. Sustainable Objectives and Transportation Options	
Sustainable Objective	**Examples of Options**
Reduce energy consumption	Traffic signal coordination/optimization Low-energy lighting Dedicated transit lanes Bike lanes Transit signal priority
Reduce consumption of material resources	Recycled aggregates Narrow traffic lanes Fewer luminaire poles/catenary lighting system Higher-strength concrete pavements Precast or modular construction elements
Reduce impacts to environmental resources	Rain gardens for storm water infiltration Diverse plant/tree selections Storm water infiltration basins in planter strips Porous pavement Wildlife crossings
Support vibrant urban communities	Noise-reducing pavement materials Public art Pedestrian refuges in medians Emergency vehicle access
Support sustainability during implementation	Reclamation of demolition materials Use of renewable fuels for construction equipment Use of locally obtained materials Access to affected businesses Minimize construction "footprint"

Source: AASHTO, 2009, Reproduced with permission of AASHTO.

- Percentage of state-owned roadway centerline miles with a bicycle level of comfort grade "D" or better and directional mileage of SHA-owned highways with marked bike lanes.
- Travel demand management and transit service quality.

Goal: System Preservation and Performance

- Percentage of the SHA network in overall preferred maintenance condition.
- Number of bridges and percent that are structurally deficient.

Goal: Safety & Security

- Number of bicycle and pedestrian fatalities and injuries on all Maryland roads.
- Number of high-crash locations.
- Annual number of traffic fatalities and personal injuries on all roads in Maryland.

Goal: Environmental Stewardship (including climate stewardship)

- Amount of transportation-related greenhouse gas emissions.

As can be seen in this list, many of the transportation-related sustainability metrics pertain to the natural environment, and do not reflect the other dimensions of sustainability, that is, economic development and societal equity. This is fairly common in the transportation field and is an area where further thought and research are necessary.

Sustainability presents an opportunity for transportation agencies to engage customers and elected officials in crafting management, policy, and public outreach approaches that emphasize triple bottom line (TBL) sustainability values. If done well, and with effective public engagement, sustainability provides an opportunity for increasing transportation agency credibility with the public and elected officials.

Those interested in knowing more about sustainability and transportation are referred to TRB, 2004; USEPA, 2011; FHWA, 2011; ITE, 2013; and the following websites:

- Sustainable Highways Initiative, Federal Highway Administration, http://www.sustainablehighways.dot.gov/.
- Transit's Role in Environmental Sustainability, Federal Transit Administration, http://www.fta.dot.gov/13835_8514.html.
- Sustainability, Center for Transportation Excellence, American Association of State Highway and Transportation Officials, http://environment.transportation.org/environmental_issues/sustainability/recent_dev.aspx.

Later sections discuss so-called "green" analysis tools that can be used to improve the sustainability characteristics of transportation projects.

B. Environmental Considerations at the Systems Level

Various types and levels of transportation planning support the development of a state's or region's transportation policy and plans. Transportation planning studies help decision makers select the most effective solution to an identified problem in the context of agreed-upon goals and objectives. The planning process should begin by identifying potentially contentious issues and resolving these issues prior to the more detailed project development/preliminary engineering and final design stages, where a major flaw could set back a project several years. A transportation study should examine an appropriate combination of transportation technologies, capacity enhancements, transportation control measures, optional alignments, and transportation system configurations in a given corridor, region, or subarea. The study should then evaluate these strategies in terms of transportation impacts, capital and operating costs, a range of environmental impacts (appropriate to the level of detail to which the strategies are defined), cost-effectiveness or cost benefit, and financial feasibility. The study should yield sufficient information for decision makers to determine which transportation strategies or plan alternatives best meet the goals and objectives. The level of environmental analysis in such planning reflects the scale and level of specificity associated with the study focus.

An example of the types of issues considered in a systems-level planning effort is found in the technical guidance for major capital investments from the Federal Transit Administration (FTA). This guidance notes that systems planning should give adequate consideration to systemwide and regional issues, including the interdependence of corridors in terms of travel demand, system design, and operations; the feasibility of various mode and alignment combinations in each corridor in terms of engineering, cost, operations, and environmental impacts; and the region-wide financial implications of various investment levels in each corridor.

Corridor-level transportation planning studies typically result in a set of strategies or projects in a metropolitan area's transportation plan, and often in a decision to proceed with more detailed project analysis. Such projects should be defined in terms of design concept and scope. There should be sufficient detail to enable the resulting regional plan, composed of many projects and strategies, to meet the requirements of various systems-level environmental analyses, such as regional air quality conformity analyses (see chapter 17 on corridor planning).

Figure 1-1 in chapter 1 offered a framework for transportation planning that represents the major steps in the planning process. Specifically, it suggests that transportation planning include efforts to understand the problems and challenges facing a community or region; establish a future vision; identify desired goals, objectives, and performance measures; conduct technical analysis of different alternatives; evaluate each alternative to develop a sense of which ones were more cost-effective; implement recommended actions; and monitor system performance. These steps are repeated through an iterative process to reflect new transportation challenges facing the jurisdiction. Table 4-2 shows possible linkages between environmental considerations and these major steps in a transportation planning process.

The Metropolitan Transportation Commission (MTC) of the San Francisco Bay Area provides a good example of how environmental considerations can be incorporated into systems planning. By state law, regional plans in California are

Table 4-2. Environmental Factors in Transportation Planning	
Planning Step	**Consideration of Environmental Factors**
Visioning	A community's vision should include explicit consideration of desired environmental characteristics. This could include targeted resources (for example, air or water quality), geographic areas (for example, wetlands or habitats), or a more general quality of life consideration. Some MPOs that have used scenarios as a means of better defining desired community visions have included "protection of environmental resource areas" as one of the scenarios. In such scenarios, economic development and consequent infrastructure provision for these areas are limited.
Goals and Objectives	In most cases environmental factors are found in some form in a planning goals and objectives set. This most often takes the form of a specific statement, such as a goal or objective that expresses the intent of "minimizing the impact on the environment" or a qualifying phrase that modifies a more important goal: "Maximize system performance in a way that minimizes environmental impacts."
Performance Measures	This is one of the newest elements of transportation planning; it puts in place a set of measures that is continuously monitored to identify the status of the transportation system and of its linkages to other factors. One type of measure or indicator that could be included in this set is related to environmental quality. For example, several jurisdictions include air-quality measures as part of their system measurement. Other indicators might relate to water quality, wetlands exposure, habitat reduction, historic and cultural resources, and archaeological sites.
Data/Analysis Methods	Given the importance of environmental considerations in the evaluation of plans and alternatives, data should be collected on environmental factors that are of concern to decision makers. Analysis capability using such data is needed to provide some sense of the environmental consequence of each alternative. At the systems planning level, the data and analysis methods might be very general, but they would presumably become more specific as the analysis occurs on detailed project or plan alternatives.
Alternative Improvement Strategies	The actions adopted as part of the transportation plan could include strategies targeted at enhancing environmental quality. Certainly, the actions that result from programs such as the Congestion Mitigation and Air Quality (CMAQ) initiative would relate to improving air quality. Projects could also relate to transportation enhancements, strategies to reduce single-occupant vehicle use, actions aimed at environmental enhancement (for example, brownfield developments), and water quality. At the systems planning level, where alternative plan configurations are considered, one scenario could be "environmental preservation," which might focus on actions such as minimizing development in river discharge basins.
Evaluation	The evaluation process is, in essence, a synthesis that brings together all the information that has been produced as part of the analysis. The evaluation criteria structure how the information is presented to decision makers, and thus are important in raising decision-maker awareness of environmental issues. The evaluation criteria should include measures that relate to the environmental impacts of proposed alternatives.
Plan	The transportation plan should reflect the results of the goals setting, analysis, and evaluation. As such, the plan should provide an explicit linkage to the environmental consequences of the proposed set of projects or of the selected alternative, if such was the focus of the study. In those cases where plan alternatives must be analyzed from an environmental perspective, the plan might include a section that shows the results of this analysis.
Transportation Improvement Program (TIP)	The transportation improvement program (TIP) reflects the types of projects that are recommended in the transportation plan. Therefore, it is likely that several projects aimed at enhancing environmental quality will be found in the TIP.
Implementation of Projects/Strategies	The implementation of projects and strategies will include the project development process as well as the mitigation strategies that are necessary as part of project implementation. Thus, project implementation could very well include, for example, context-sensitive solutions, environmental mitigation, and efforts to minimize or avoid serious environmental impacts.
System Operations	The performance of the transportation system, otherwise known as system operations, will naturally include an emphasis on the ability of the transportation system to satisfy demand. However, it is important that the monitoring of system operations should also keep track of the consequences of such operation on the natural and human environment.

Source: Amekudzi and Meyer, 2005, Reprinted permission from the Transportation Research Board.

Table 4-3. 2035 Transportation System Performance Goals, Metropolitan Transportation Commission, San Francisco Bay Area, California

E's	Goals	Performance Objectives
Economy	Maintenance & Safety	**Improve maintenance:** *Local streets & roads:* maintain pavement condition index of 75 or better *State highways:* distressed lane-miles no more than 10% of system *Transit:* average asset age no more than 50% of useful life and average distance between service calls of 8,000 miles
	Reliability	**Reduce delay:**
	Freight	20% per capita from today
Environment	Clean Air	**Reduce vehicle miles traveled and emissions:**
	Climate Protection	*Vehicle miles traveled:* 10% per capita from today *Fine particulate matter:* 10% from today *Coarse particulate matter:* 45% from today *Carbon dioxide:* 40% below 1990 levels
Equity	Access	**Improve affordability:**
	Livable Communities	10% reduction from today in share of earnings spent on housing and transportation costs by low- and moderately low-income households

Source: MTC, 2013, Reprinted permission from Metropolitan Transportation Commission.

subject to an environmental impact review and a general environmental assessment of the overall program of projects, which are then implemented through a series of later actions. In addition, new performance-based criteria have been introduced into the assessment. Interestingly, the overall evaluation of the region's transportation plan was based on the sustainability framework described in the previous section. [MTC, 2013] Table 4-3 shows the performance goals and the metrics that guided the development of the regional transportation plan. In the environmental impact statement (EIS), each impact area was analyzed according to: (1) environmental setting, (2) criteria of significance, (3) method of analysis, (4) summary of impacts, and (5) impacts and mitigation measures. An assessment of the impacts was then made, with possible findings focusing on:

- Significant unavoidable impacts
- Significant irreversible environmental changes
- Cumulative impacts
- Impacts found to be not significant. [MTC, 2009]

As seen in Table 4-4, it is often difficult to identify mitigation measures at the systems planning level because many of the environmental impacts are project-specific, which is not the level of detail found in systems planning. For a systems-level assessment, the planner should identify the geographic areas of environmental sensitivity (for example, protected populations, wetlands, protected habitats, noise-sensitive receptors, etc.), describe the types of mitigation measures that should be considered, and establish processes ensuring that such mitigation will occur and be monitored. Other chapters in this handbook provide more detailed descriptions of how environmental factors are incorporated into transportation planning (see, for example, chapter 15 on state transportation planning, chapter 16 on metropolitan transportation planning, and chapter 17 on corridor planning).

Amekudzi and Meyer [2005] examined how environmental factors were considered in transportation systems planning by state DOTs and metropolitan planning organizations (MPOs) in the United States. They found:

- The most-considered environmental factors in transportation planning are air quality, land use, socioeconomic considerations, and environmental justice.

Table 4-4. Example Environmental Noise Assessment of Systems Plan, Metropolitan Transportation Commission, San Francisco Bay Area, California		
Impact	**Mitigation Measure**	**Significance after Mitigation**
Construction of the proposed Transportation 2035 Plan projects has short-term noise impacts on surrounding areas	None required	Less than significant
Transportation 2035 Plan projects could result in noise levels that approach or exceed the FHWA Noise Abatement Criteria or could cause noise levels to increase by 3 dBA or more when compared to existing conditions.	As project sponsors prepare the environmental review document of their individual project pursuant to California Environmental Quality Act (CEQA)/NEPA and prior to environmental certification, project sponsors shall consider adopting appropriate measures that would minimize or eliminate cumulatively considerable environmental impacts pursuant to CEQA/NEPA. MTC shall be provided with status reports of compliance with mitigation measures pursuant to MTC Resolution 1481, Revised. Mitigation measures to reduce noise impacts that shall be considered by project sponsors and decision makers may include, but are not limited to, those described below: Adjustments to proposed roadway or transit alignments to reduce noise levels in noise sensitive areas. For example, below-grade roadway alignments can effectively reduce noise levels in nearby areas. Techniques such as landscaped berms, dense plantings, reduced-noise paving materials, and traffic calming measures in the design of their transportation improvements. Contributing to the insulation of buildings or construction of noise barriers around sensitive receptor properties adjacent to the transportation improvement.	Less than significant
Implementation of the proposed 2035 Transportation Plan could result in increased noise and ground-borne vibration related to transit operations.	The above mitigation measures are considered appropriate for bus transit noise impacts. In addition to those mitigation measures, the following additional measures are provided to reduce impacts as they relate to rail transit: Design approaches to reduce noise and vibration impacts of rail transit, such as vibration isolation of track segments, use of continuously welded track to minimize wheel noise, resilient wheels, vehicle skirts, wheel truing, rail grinding, undercar absorption, or vehicle horn loudness and pitch adjustments. Operational changes to reduce noise impacts of rail transit, such as assisting local jurisdictions in pursuing Quiet Zones.	Less than significant
The proposed 2035 Transportation Plan, combined with traffic related to projected regional population and employment growth, could result in a cumulatively considerable increase in overall noise levels along some travel corridors.	Mitigation measures listed above could help to reduce this cumulative impact.	Significant cumulative impact

Source: MTC 2009, Reprinted permission from Metropolitan Transportation Commission.

- The most widely used tools for considering environmental factors in transportation planning were data trend analysis, geographic information systems (GISs), environmental impact–specific models, overlay maps, and focus groups.
- There was general agreement that only part of the data needed for considering environmental factors in transportation planning was currently available.
- The most readily available types of data within agencies relate to air quality, socioeconomics, noise, energy consumption, storm-water runoff, and erosion.
- The most readily available types of data from outside agencies relate to environmental justice, hazardous wastes, historic properties, water quality, biological effects, and climate.
- The majority of states and a minority of MPOs use performance measures that include environmental factors in transportation planning.
- Departments of Transportation (DOTs) and MPOs have a relatively high level of interaction with each other and with environmental resource agencies, the governor's office, environmental advocacy groups, and public interest groups in the transportation planning process.
- Competing priorities and a lack of appropriate planning analysis tools were identified by DOTs, MPOs, and environmental resource agencies as the most significant obstacles to considering environmental factors in transportation planning. Lack of data and lack of regulations were perceived as less important obstacles.
- A majority of DOT and MPO respondents had promoted environmental factors being considered prior to the project development stage.
- The majority of DOTs, MPOs, and environmental resource agencies believed that the most important benefit of considering environmental factors prior to project development is that it results in better decisions. MPOs noted that an equally important benefit was shortening the time to reach project implementation.

This report further noted that issues relating to regional air quality, watersheds, wetlands, wildlife habitat, and environmental justice are often initially considered during system planning in order to determine resource agency requirements and assess cumulative effects. These potential impacts are further considered in project-specific anlayses and refinements.

Another perspective on environmental considerations at a systems level relates to the current focus on measures to monitor transportation systems performance. NCHRP Report 809, *Environmental Performance Measures for State Departments of Transportation,* recommends environmental performance measures for state DOTs. [Crossett et al., 2015] Five categories of such measures were recommended:

Air Quality—Change in statewide motor vehicle emissions for nitrous oxides, volatile organic compounds (hydrocarbons), and particulates.

Energy and Climate—Statewide on-road gasoline consumption per capita and state DOT fleet alternative fuel use as percent of total fuel use.

Materials Recycling—Annual percent by mass of all roadway asphalt pavement materials composed of reclaimed asphalt pavement (RAP) used by the state DOT.

Storm Water—Percent of state DOT-owned impervious surface for which storm-water treatment is provided.

Wildlife and Ecosystems—Self-administered ecosystems self-assessment tool (ESAT) composed of 41 questions that evaluate performance across all aspects of state DOT programs relevant to wildlife and ecosystems.

C. Environmental Impacts in Project Development

In systems planning, project priorities are identified in the context of state, regional, or corridor plan goals and policies; the problems being solved; and the relative effectiveness of alternatives or strategies to solve them. Note that although the term "alternative" is used in both transportation planning and the NEPA process, it has somewhat different meanings in the different contexts. In transportation planning, the term "alternative" is usually applied to various system concepts and strategies to address the needs or problems identified. When used in a NEPA sense, the term "alternative" brings with it the expectation that details are available to allow an assessment of more precise project impacts. This more specific definition is important for environmental resource agencies that are responsible for approving (or not objecting to) the recommended actions from environmental reports. The term "strategy" is used throughout this chapter to distinguish a planning strategy from a NEPA alternative.

For system-level planning, projects are defined with a general design concept (for example, limited-access freeway) and scope strategies—expected transportation mode, project termini, number of lanes or tracks, degree of access control, general alignment, station footprints, and so forth. Project-level planning is much more detailed and refined, focusing on geometric alignment, detailed design concepts and standards, environmental protection, and project phasing. Satisfying federal, state, and local environmental laws and requirements is typically accomplished during the project-level analysis and refinement stage.

Project planning and engineering are typically performed in conjunction with a detailed analysis of environmental impacts, the specification of mitigation measures, and documentation to fulfill jurisdictional (federal, state, and local) environmental protection laws and requirements. It is at this stage, if federal funds or actions are involved, that NEPA becomes an important planning context.

NEPA is arguably the most important U.S. environmental law influencing how transportation projects are planned and designed. Although this law targets project-specific effects, its intent and philosophy on infrastructure make it an important foundation for the consideration of environmental impacts during the transportation planning process as well. Therefore, transportation planners and engineers need to know the important principles and requirements of this law.

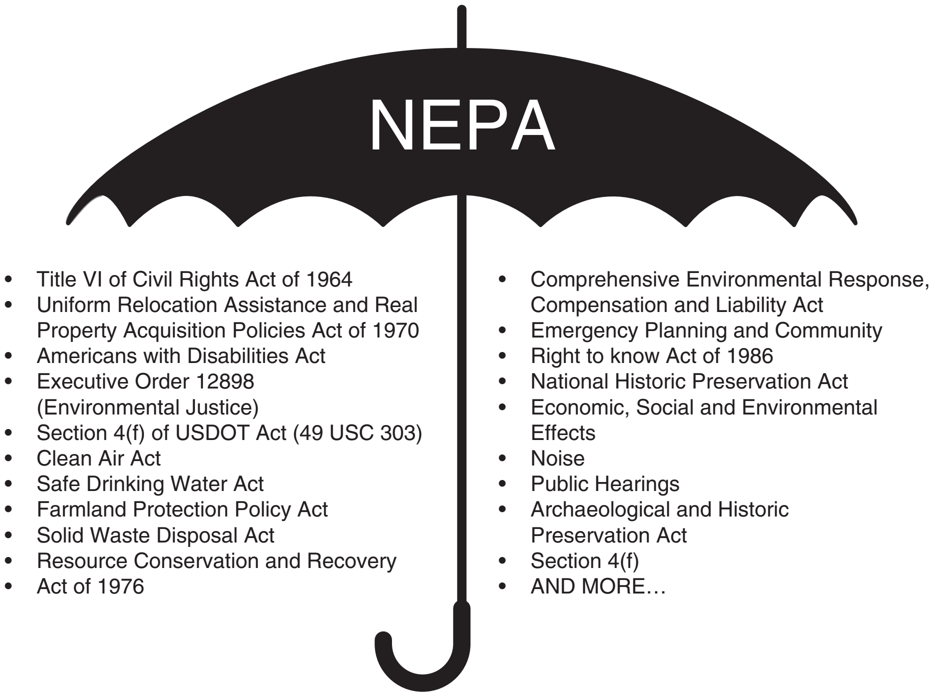
NEPA was enacted to "prevent or eliminate damage to the environment, stimulate the health and welfare of Man, and enrich the understanding of ecological systems and natural resources important to the nation." NEPA mandates that environmental factors be considered when federal actions are involved in a project, such as providing project funding or issuing a permit. The act calls for an assessment of alternatives, opportunities for public involvement, and coordinated agency action. Subsequent legislation and regulations have created a well-established process and standard of practice for fulfilling NEPA requirements, especially for transportation projects. Various other laws and executive orders require consideration of specific natural, cultural, and human resource impacts, and of the policies relating to them, including endangered species, historical and archeological resources, air, water, floodplains, wetlands, parklands, environmental stewardship, and environmental justice. In this context, the terms "environment" and "environmental resources" encompass the natural, cultural, and man-made environments.

NEPA provides an umbrella for addressing all relevant environmental laws and requirements during the development of transportation projects (see Figure 4-2). While the NEPA process provides a means to consider a host of environmental issues, other laws, executive orders, and regulations often have their own requirements and issues that must be addressed during project development. NEPA and other major laws relevant to environmental impacts are discussed in greater detail in chapter 2.

As noted by FTA,

> *"The NEPA process begins far earlier than the design and technical analysis of a particular project. Metropolitan and statewide transportation planning identifies transit needs and mobility problems and proposes solutions that reflect consideration of broad socioeconomic and environmental factors (such as regional air quality). If State or local agencies expect to seek FTA funding assistance for implementation of a resulting project, FTA must gauge the appropriate level of assessment and review of environmental impacts . . . . major proposed actions involving substantial new construction with off-site or long-term impacts usually merit a detailed review that is done with appropriate public involvement and documented in a formal environmental impact statement.*
>
> *The more detailed NEPA reviews are grounded on the notion that alternative solutions are available for meeting identified transportation needs. The formal review process requires the transit agency to develop and evaluate a range of reasonable alternatives, in addition to the proposed project, in order to determine the best option for addressing transportation problems, respecting the community, and protecting the environment."*
>
> *[FTA, 2014]*

Figure 4-2. The NEPA Umbrella



Source: *Linking Planning and NEPA: Executive Seminar Course Instructors' Manual*. Washington, DC: National Highway Institute, 2003.

The NEPA process leads to three possible analysis efforts:

- *Environmental Impact Statement (EIS)*—When the proposed action will have a significant impact on the environment, an EIS is required.
- *Environmental Assessment (EA)*—An EA is prepared when there is uncertainty as to the significance of the impacts of the project.
- *Categorical Exclusions (CE)*—Actions that do not individually or cumulatively have a significant social, economic, or environmental effect are excluded from the requirement to prepare an EA or EIS (http://www.environment.fhwa.dot.gov/projdev/tdmpdo.asp).

Which direction a NEPA process takes is dependent upon an initial assessment of the likely significance of expected impacts. Readers are referred to FHWA's *Environmental Guidebook* for further guidance on how NEPA applies to road projects (http://environment.fhwa.dot.gov/guidebook/results.asp?selSub=91). More specific information on project-level environmental impacts as they should be considered during project development is presented in the rest of this chapter.

D. Linking Environmental Considerations of Systems Planning and Project Development

Success in linking the environmental considerations of systems and project planning depends on several factors: the extent to which collaboration/involvement among the different transportation and environmental agencies has occurred in systems planning, the degree to which planning leads to early consensus on project purpose and need, the complexity of design concepts and scope, and how planning starts to address environmental regulatory requirements. Success can be measured by the extent to which early planning decisions survive in later project development phases where NEPA-related effects are examined in greater detail. The following principles can lead to such success:

Environmental considerations should inform the transportation decision-making process, while the transportation planning process should inform the environmental compliance process.

Although decision makers do not necessarily need to know all of the details when making system-level or even project/concept-level decisions, they do need reliable estimates of expected costs, benefits, and environmental impacts. If environmental factors are not considered seriously in the transportation planning process, decisions made at this point in the process may have to be revisited during subsequent project-level planning. For example, problems and needs identified during the planning process can serve as the basis for the purpose and need statement required by NEPA environmental documentation or other environmental processes (see chapter 1). Having an unsupported or poorly defined purpose and need statement is a primary cause of successful legal challenges to transportation projects. A well-supported and documented problem statement emerging from the transportation planning process provides a sound basis for the purpose and need statement that can be used later in the NEPA project development process.

Another important linkage between the planning process and environmental considerations occurs in the development and screening of alternatives and investment strategies. In a typical transportation planning process, a large number of strategies are narrowed to a number of feasible strategies through the analysis and evaluation process. The criteria for screening and refinement should include environmental (for example, socioeconomic, natural, and cultural) considerations along with mobility and other defined transportation-specific concerns, including engineering and operational feasibility, safety, cost, and affordability. The environmental measures are typically defined at a very high level, but with enough information to make decision makers aware of the expected consequences of various investment strategies.

Documenting the methodologies used, the mitigation strategies considered, and the decisions reached in planning can have distinct benefits in later stages of project development and implementation. Environmental or cultural resource agencies may not be part of the early planning process when screening and refinement steps are determined. Clear and reliable documentation can provide a record of considerations and the decisions made for use later in the process. Even if these agencies were involved early in the process, a project developed over a long period may involve different agencies or responsible officials at different points in time, again suggesting the need for good documentation.

Appropriate parties and stakeholders, especially environmental resource and regulatory agencies and others with environmental interests, should participate in, or at least be aware of, the decisions made.

An effective planning process involves more than a simple technical consideration of environmental issues. Because of the breadth and diversity of issues typically addressed in a transportation planning process, a wide range of stakeholders should participate when decisions are made. This leads to a broad-based understanding and acceptance of decisions relating to different decision points in the process, from identifying a problem statement to recommending a course of action. These parties could include transportation providers and policy/funding agencies, land use and planning entities, environmental resource and regulatory agencies, community and economic development interests, political bodies, and members of the public. The goal is to have balanced input and a consideration of issues so that decisions are based on the broadest range of perspectives from a community.

Environmental resource and regulatory agencies have statutory roles in reviewing and approving project-level analyses and disclosure documentation for specific resources, and/or issuing permits required for construction and/or operation of a project. Federal, state, and local environmental resource and permit agencies should thus have early involvement in a transportation planning study when some of the most fundamental decisions are being made. They should be an integral part of the cooperative and collaborative process in establishing a problem statement, defining the range of strategies to be studied, identifying the factors to be addressed, and adopting a work program with an agreed-to level of detail for study elements, particularly the environmental analysis. Having environmental resource agencies involved at the beginning of strategy development helps introduce relevant environmental impact avoidance strategies early in the process so that strategy development and screening decisions do not have to be revisited later. This can happen only if the resource agencies are part of the NEPA documentation review and permit processes.

It can be challenging, however, to get environmental resource and permitting agencies to participate in the planning process—particularly in the early stages. These agencies may have limited staff and funding that are fully committed to addressing projects further along in the development process. Nonetheless, it is worth securing the early involvement of these agencies given the benefits described above. One important benefit is that it will make their job—and that of transportation planners and engineers—easier and more effective throughout the rest of the planning process and in later project development stages. Numerous strategies have been used to encourage the early involvement of environmental resource agencies, including having a standard operating procedure for resource agency participation, providing resources for such participation, and initiating the formal environmental impact analysis/documentation process earlier in the planning process, thereby triggering formal resource agency involvement.

Environmental Stewardship

Environmental stewardship is an emerging concept. At one level it involves protecting the environment through the avoidance, minimization, and mitigation of environmental impacts, or through compliance with environmental laws and regulations. But it also has a larger aim. Environmental stewardship strives to improve environmental conditions and enhance the quality of life wherever possible. It encourages partnerships that promote ecosystem conservation and address public priorities such as mobility and safety.

A transportation project often provides an opportunity to address enhancement opportunities—unrelated to that transportation project—that can be viewed as mitigating or offsetting adverse effects. Incorporating context-sensitive design is one means of accomplishing environmental stewardship. The intent is to develop a project that is in harmony with its surroundings; maintains safety and mobility; and preserves scenic, aesthetic, historic, and environmental resources. Examples might include a recreational trail along a roadway or transit corridor, the restoration of a stream beyond project boundaries, and the use of indigenous materials or architecturally sensitive features in the design of structures or sound barriers. Context-sensitive design goes beyond strict design features and can include the use of materials and construction techniques, operational practices, and maintenance techniques that are environmentally sustainable.

The rationale or basis for early planning decisions should be well documented to inform later stages of the project development process.

Even within a highway or transit agency itself, a multidisciplinary, multidepartmental group of stakeholders is often needed throughout the planning and project development process. Typically, different agency units provide leadership at different stages. A planning office may have responsibility for the initial planning work, with a project development office assuming the lead for the preliminary engineering and environmental phase. The project may then pass to a design group at a headquarters location or to a district or regional office, and subsequently to construction and operations and maintenance groups. Because many of these groups often lead later phases of project development, they need to be informed of earlier decisions (and commitments) so they can understand the rationale for project designs and mitigation strategies. This can be done by participating in the planning process, or through formal transmittal documents that accompany a project as it proceeds through project development and that describe agreements and consensus on project characteristics.

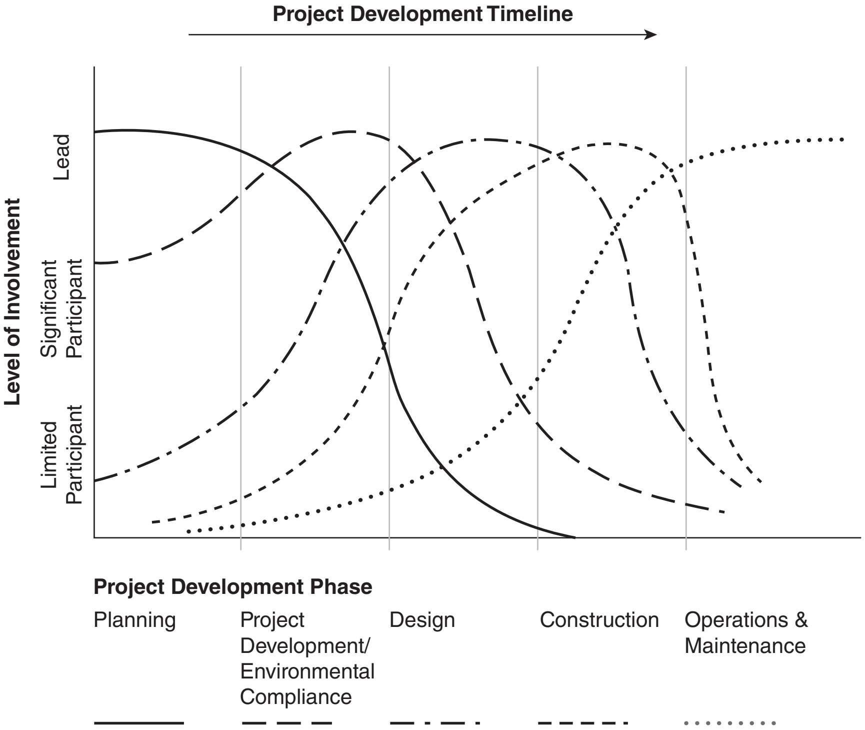
Figure 4-3 illustrates how one transportation agency envisions the involvement of multiple departments. The early planning stages are led and principally staffed by the planning unit, with significant involvement from the project development and environmental groups. The design, construction, operations, and maintenance departments have a limited role in the early stages, primarily informing the process and contributing to decision making from the perspective of designers, builders, operators, and maintainers. As project development progresses, other units assume the lead, and the roles and levels of involvement of the units increase or diminish as appropriate.

Several years can elapse between a decision made during a planning process and subsequent project development and implementation. Agencies and stakeholder participants may change, and different agency units and consultants may be involved in subsequent phases. Federal or local policies and priorities, planning assumptions and forecasts, and existing conditions can and often do change. It is important to remember that an effective planning process cannot rely on institutional memory. It needs solid documentation.

The planning process should include a public engagement program in which issues identified by the community influence the purpose and need of the project and definitions of prospective strategies.

It is worth noting that, although study and project participants may change, the affected communities and the issues that matter to them often remain relatively stable. A clear and thorough record of comments received from the public, and the respective responses, shows that issues have been vetted by the responsible authorities. In addition, thorough documentation of the environmental considerations, analysis methods, and results, as well as the development, screening, refinement, and evaluation of strategies, is required to satisfy legal and regulatory obligations. Without documentation, there is a risk that earlier decisions made in the planning phase may have to be revisited or the process repeated due to legal challenges, causing delays, extra costs, and stakeholder frustration.

Figure 4-3. Roles and Level of Involvement during Project Development Timeline



Based on unpublished Florida Department of Transportation diagram

Source: Florida Department of Transportation, Office of Policy Planning (unpublished and undated), Reprinted with permission of the Florida Department of Transportation.

Environmental streamlining—that is, using information produced in the planning process for the environmental analysis to minimize repetition and delays—has received a lot of attention from transportation officials in recent years. A Council on Environmental Quality (CEQ) NEPA Effectiveness Study [1997] found that the NEPA process was too long and had high costs; agencies often made decisions before hearing from the public; and the process was initiated too late for it to be fully effective. FHWA [2002] found that it typically took anywhere from 9 to 19 years to complete a federally financed new highway construction project. Five to 10 years were required for planning, preliminary design, and environmental review.

The aim of environmental streamlining is thus to:

- Improve timeliness of the environmental process.
- Improve interagency cooperation.
- Recognize constraints on time and resources (human, financial, etc.).
- Resolve issues early.
- Provide for mediation of process stumbling blocks.
- Improve project management.
- Foster environmental stewardship.

It is implemented by:

- Establishing a coordinated review process between the transportation agency and other involved agencies.
- Emphasizing concurrent reviews to save time and avoid formal dispute-resolution processes.

- Allowing local environmental review processes to be included in the coordinated review process.
- Enabling funding by a nonfederal agency to affected federal agencies to meet expedited time limits.
- Fulfilling responsibilities as trustees of the environment for succeeding generations, moving toward a cost-effective and environmentally sustainable future.
- Integrating environmental values with partners within all transportation work as a core business value.

Streamlining can be implemented via memoranda of understanding (MOU), training, memoranda of agreement (MOA) and programmatic agreements, information sharing, use of delegation authority, and other administrative flexibility actions and initiatives such as pilot programs to demonstrate the feasibility of streamlining strategies.

III. GENERAL PRINCIPLES REGARDING ENVIRONMENTAL CONTENT AND LEVEL OF DETAIL

The intensity or importance of an adverse or beneficial impact is related to its context. For example, the loss of a few houses or businesses in a small community or neighborhood might be considered more significant than the loss of the same number in a larger community or neighborhood. The small community context makes an impact much more significant than a similar impact in a larger urban area.

Another way to gauge intensity is through social acceptability. An unavoidable loss of several businesses might be considered an acceptable consequence of a project where there are mitigating benefits. On the other hand, impacts to public health and safety or to unique or unusual settings or environments, as well as impacts that generate a high degree of public controversy, might be deemed unacceptable to policy- or decision-making bodies. Unacceptable impacts are sometimes referred to as *fatal flaws*. This means that, notwithstanding the benefits of the project, a particular impact or accumulation of impacts can be so undesirable that it renders a specific strategy or even the overall action unacceptable. In some circumstances, there may be laws or regulations that enforce or set a standard for the acceptability of an impact.

The following paragraphs discuss some important issues to consider when establishing the overall approach to environmental assessment for transportation system and project planning.

A. Types of Impacts

Transportation systems can affect the environment in many ways. Not only are transportation professionals interested in potential impacts close to or adjacent to a facility, but in a broader sense, they are also interested in the significant effects transportation systems have on the health, economic success, and quality of life of a community. For example, the following vision of a sustainable transportation system, offered by the Oregon DOT, shows the range of impacts and strategy types that might be considered as part of the environmental context for transportation system performance:

> *" By 2030, Oregon's transportation system supports people, places and the economy. We travel easily, safely and securely, and so do goods, services and information. Efficient vehicles powered by renewable fuels move all transportation modes. Community design supports walking, bicycling, travel by car and transit wherever appropriate. Our air and water are dramatically cleaner, and community sensitive and sustainable transportation solutions characterize everything we do.*
>
> *Oregonians and visitors have real transportation choices and transfer easily between air, rail, motor vehicles, bicycles and public transportation; while goods flow just in time through interconnected highway, rail, marine, pipeline and air networks. Our communities and economies—large and small, urban and rural, coastal and mountain, industrial and agricultural—are connected to the rest of Oregon, the Pacific Northwest and the world. Land use, economic activities and transportation support each other in environmentally responsible ways.*
>
> *We excel in using new technologies to improve safety and mobility. We maximize the use of existing facilities across traditional jurisdictions and add capacity strategically. Public/private partnerships respond to Oregonians' needs across all transportation modes. Transportation system benefits and burdens are distributed fairly, and Oregonians are confident transportation dollars are being spent wisely. By 2030, Oregonians fully appreciate the role transportation plays in their daily lives and in the region's economy. Because of this public confidence, Oregonians support innovative, adequate and reliable funding for transportation . . . ."*
>
> *[Oregon DOT, 2008]*

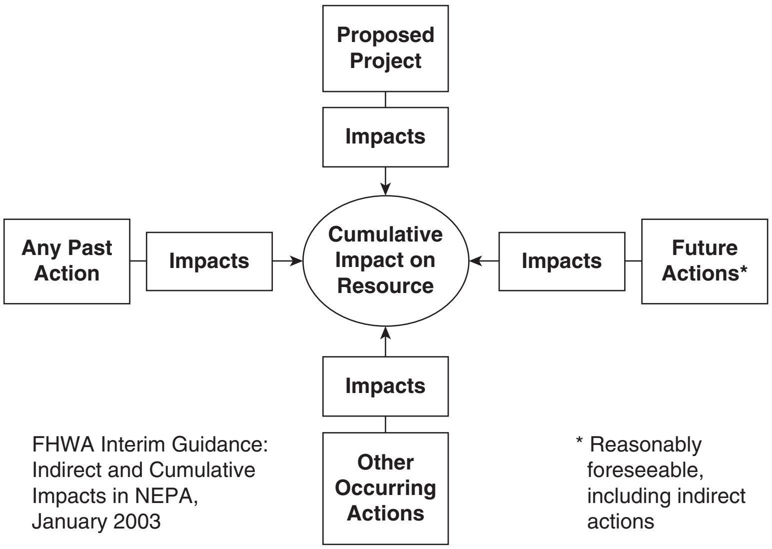
The Oregon DOT produces periodic progress reports indicating the level of achievement ODOT is making with regard to these sustainability goals (see ODOT, 2012).

The environmental consequences of a transportation project can take several forms. Direct impacts are the most obvious and tend to receive the most attention. These occur as the direct result of the *construction of the project* (for example, house or store displacements or loss of habitat) and of *facility operation* (for example, noise or ground vibration). Secondary impacts occur as a consequence of a direct impact. Typically, secondary impacts occur later or at some distance from the project, but they can still be reasonably foreseen. For example, a direct impact of a transportation improvement that improves access to adjacent land is residential or commercial land development. The secondary impact of the transportation investment occurs when this development produces its own set of environmental consequences, such as local road congestion, pollutant emissions, or community disruption. These secondary impacts should be covered in the environmental analysis and in the planning-level evaluation of transportation projects. In recent years, secondary impacts have also been examined in systems-level planning, albeit at a very broad level.

In certain situations, combined or cumulative impacts—those that result from the incremental consequences of an action when added to past occurrences, other actions, or reasonably foreseeable future actions—will generate an overall impact of such magnitude that it should be presented and considered in the evaluation. [CEQ, 1997] For example, the loss of a relatively small amount of wetlands as the result of a single project may in itself appear inconsequential, but the combined effect of a number of seemingly small losses could result in a significant loss and degradation of the wetlands resource (see Figure 4-4). Another way to consider cumulative impacts is to examine the project-related impact in the context of similar impact-generating activities currently occurring. For example, a traffic-generated noise impact on a given neighborhood may not be considered a serious adverse effect by itself, until it is placed in the context of current and expected traffic-related noise generation from other traffic sources. In the larger context, these impacts can have more severe consequences than would appear when they are considered individually. Where appropriate, the environmental analysis and strategies evaluation should include a discussion of cumulative impacts.

Most environmental concerns are limited to the effects of a particular project, such as the noise impacts from an increased number of passing vehicles. However, some impacts may need to be addressed programmatically. For instance, the impacts of a particular project on a watershed or on regional air quality may need to be addressed on a regional or programmatic scale during a regional planning process where the cumulative effects of a number of projects and actions are considered.

Figure 4-4. Cumulative Impacts



Source: Federal Highway Administration. 2014. *Questions and Answers Regarding the Consideration of Indirect and Cumulative Impacts of NEPA*. Washington, DC: FHA. Accessed February 9, 2016, from https://www.environment.fhwa.dot.gov/guidebook/qaimpact.asp.

B. Appropriate Level of Detail

The purpose of environmental analysis during the planning process is to identify any major environmental or design concerns that are likely to affect the selection of a preferred investment strategy, or that might relate to environmental regulations (such as for air quality) or permitting requirements (such as for wetland permits). This will likely include, at a minimum, the identification of environmentally-sensitive areas within the study boundaries. An initial scoping process should define the appropriate level of social, economic, and environmental analysis for a planning study, along with the approach toward interagency coordination and public engagement.

The level of analysis should be sufficient enough to identify and evaluate all differentiating characteristics of the project concepts and scopes under consideration. As noted previously, it is important to have environmental resource agencies involved at the beginning to help establish the level of detail for the environmental analysis and the strategies to be considered, including avoidance and minimization strategies and future no-build conditions. Resource agencies would also be valuable participants in screening strategies to make certain that environmental factors are appropriately considered. As will be discussed later, benefits and impacts can be assessed subjectively and/or they can be quantified and monetized (if possible and desired).

Commitments to specific mitigation measures are not usually made at the systems planning level. However, it is important to clarify the degree to which different types of mitigation strategies have been successful in avoiding or minimizing environmental impacts in the state or region. At the systems planning level, it is also desirable to have a sense of the costs associated with environmental mitigation strategies.

The level of detail in environmental analysis should reflect the complexity associated with different types of projects and strategies, with explicit consideration given to the risks and uncertainties related to the likelihood and magnitude of a possible impact. In cases where mitigation strategies would be costly, a more comprehensive study would normally be undertaken. In cases where the strategies and the extent of the impacts are likely to be less costly, a more general approach may be appropriate.

Most importantly, efforts made during a planning study should include close coordination of the inventory, analysis, and findings with agencies having jurisdiction over the various environmental resources. The planning study should document this coordination and should demonstrate the concurrence of the relevant agencies in the early findings.

The approach is very different for environmental analysis at the project planning level. Whereas in systems planning proposed projects are described in general terms, project planning focuses on very specific alignments and design characteristics. Thus, environmental analysis in project planning is much more detailed than that found at the systems level. According to federal transportation law, the appropriate steps for environmental analysis in project planning include:

- Review by a qualified professional of existing environmental resource inventories, supplemented with additional data collection where necessary, and resource planning studies done by/for the resource agencies.
- Preliminary analysis of the nature and severity of likely impacts, with cross references to other sections of the environmental analysis.
- Review of possible changes in the design or alignment of the strategy to avoid the impact (including costs and other implications).
- Identification of potential measures to mitigate the impacts.

Most of the material found in the rest of this chapter provides information on the data and tools that can be used to conduct environmental analysis at the project planning level.

C. Extent of Impact

Determining the spatial extent of potential impacts, often referred to as the impacted area, is an important part of determining the significance of an impact. For systems planning, the impacted area could be very broad, such as the regional air basin for a metropolitan area; or it might be limited, such as noise impacts to particular land parcels adjacent to busy freeways. The spatial aspect of environmental impacts is reflected in the types of tools used to analyze them. In the preceding illustrations, for example, analysis of regional air quality impacts usually relies on travel network modeling that estimates the flows of traffic in a region, and thus the concentration of motor vehicle–related air pollutants in an air shed that could be hundreds of square miles in area. Noise impacts, on the other hand, can be estimated with facility-specific models that target areas close to high-volume roads.

Impacts of concern should be identified early in the planning process. Several approaches can be helpful in doing this, including looking at prior studies to determine which environmental concerns were studied; consulting relevant agencies and groups; inviting citizen and stakeholder input; and/or actively engaging environmental agencies for their input. Of all the available reports on environmental conditions and impacts for an area, the most useful might be other environmental studies (EISs or environmental assessments) or area planning studies (including resource planning studies).

The process of identifying impact areas should allow the study sponsor to use the knowledge and expertise of the groups most familiar with the study area and those who know the specific laws, regulations, and rules that apply to these impacts. Field reconnaissance, especially in cooperation with other concerned agencies, is usually an excellent method of identifying impact areas. As the planning study progresses, additional areas of concern may be identified through the development and analysis of strategies, additional data gathering, and public and agency involvement.

D. Role of Travel Demand Forecasting and Traffic Analysis

The analysis of current and future travel behavior and of transportation system performance is at the core of a transportation planning study—especially estimating the effect that various transportation improvements will have on both. Changes in traffic flows and transit operations, in particular, are a key analysis link between the travel forecasting activities of a planning study and many of the social, economic, and environmental analysis topics discussed in the remainder of this chapter. Travel forecasting and system-modeling methods are addressed in chapter 6, and later chapters address methods for evaluating a range of actions and strategies.

Given the link between pollutant emissions, energy consumption, and the use of motor vehicles, air quality impacts are dependent on changes in travel demand and system performance, as is energy consumption. The analysis of noise, safety, and associated neighborhood/community impacts usually requires some level of site-impact analysis. Travel-forecasting results often have to be developed at a level of detail needed for environmental analysis. This is often a challenge. The computer models that serve as the foundation for most statewide and metropolitan transportation planning today were not developed to predict environmental consequences and are often unable to do so reliably. In many cases, post-processing modules have been added to the modeling regimen to accomplish this task. Although these models may not be the best approach for producing good estimates, they are usually the only approach available to transportation planners and engineers for making such assessments, and they are recognized as such in federal planning and environmental regulations.

The following sections describe the scope and appropriate level of detail for the social, economic, and environmental analyses that can be part of a planning study. They also describe the technical tools and methods typically used for such analyses. The list of environmental topics is not meant to be exhaustive, but rather representative of topics addressed in most planning efforts. It is important to note at the outset that many federal, state, provincial, and local planning agencies, as well as environmental resource agencies, publish regulations, rules, and guidance on the legal requirements for conducting an environmental study. The rules and guidance often change to incorporate new laws, or reflect different perspectives from those of new policy makers. At the very beginning of a study, the planner should contact the most relevant environmental resource agencies to obtain the most recent guidance.

IV. LAND USE AND ECONOMIC DEVELOPMENT IMPACTS

Transportation planning has for decades addressed the interaction between transportation investments and land use and development patterns. This interaction involves both the effect of land use on travel patterns and the influence of transportation investment decisions on land use development (see chapter 3).

Transportation planning takes existing and projected land-use patterns into account in almost every type of planning study. Knowing the future distribution of population and employment is fundamental to predicting future travel demand. At the project level, analyzing the consequences of transportation investment on land use has generally focused on the direct impacts of facility construction, such as land acquisition or the creation or elimination of a particular land-use activity. At the systems level, there is increasing interest in indirect or secondary impacts and/or cumulative impacts on land use that result from changes in accessibility brought about by transportation investments. An example of an indirect or secondary impact would be land development that capitalizes on the improved accessibility of a new highway interchange. A transportation improvement can also bring about an induced change in land-use activity or density, such as joint development around a transit station, that would not have occurred without the investment. Given the strong linkage between land use and transportation investments, land-use implications will likely be a critical topic in many transportation environmental studies.

Many regional land-use policy and planning issues are more appropriately considered at the metropolitan level. Thus, for example, a study that is looking at the implications of alternative future land-use scenarios on both regional environmental indicators and transportation system performance will necessarily have to be conducted at the metropolitan level. In most cases, this will entail using a land-use model or some other analysis tool to assess such consequences. The reader is referred to chapter 3 on land use for a discussion on how planning agencies carry out these types of analyses.

This section focuses instead on the interactions between land use and transportation at the corridor or subarea level. This impact category, required as part of environmental impact statements, is important because of the concerns often raised by local citizens and elected officials about the short- and long-term land-use effects of changing the transportation system.

In many cases, land use is not the purview of the transportation agencies involved in a study. This is true almost everywhere in the United States. For example, state DOTs do not have land-use authority, although through their access-permitting process and role in environmental review, they can certainly exert influence. Local governments are responsible through comprehensive planning and zoning regulations for land-use and development decisions, at least as they concern public authority. Therefore, it may be appropriate to involve as part of the collaborative planning process those agencies or levels of government with responsibility for, or jurisdiction over, land-use and development policies, planning, and decision making. It also may be beneficial to invite input from other stakeholders who have an interest in land use and may be affected by the planning process, such as developers and major landowners.

The following should be taken into account when addressing the land-use and development environmental effects of a transportation strategy:

- Under NEPA and similar environmental regulatory review requirements, federal agencies are required to consider the effects of proposed projects and alternative courses of action when federal action is contemplated. Most federal guidance includes the consideration of impacts on land use and economic development, even though the federal government does not have a role in such local decisions.
- Project sponsors often cite urban development benefits as an important reason for considering a major investment in transportation. In such cases, the magnitude of these benefits may need to be estimated to determine how the expected benefits and other related outcomes compare to the costs and impacts, and whether other strategies might bring about the desired benefits with less cost and/or impact.
- In some cases, cities or community groups may be concerned about the effect a strategy might have on neighborhoods and communities. For example, they may oppose changes in land use that would bring increased activity to quiet neighborhoods or would increase the volume of local traffic. A development impact analysis can help show whether these concerns are valid and, where necessary, foster agreement on appropriate mitigation measures.
- Strategies that have economic development benefits can often be financed, at least in part, through value-capture techniques, or they may be built through public/private partnerships that rely on capturing a strategy's development benefits. Preparing estimates of these future benefits or revenues can be an essential part of the financial planning work done for the planning study. This would include identifying those property owners most likely to benefit from increased property values (note that the dollar increase in property values should not be considered a benefit in the analysis; see chapter 7).

The discussion that follows is meant to provide guidance on the appropriate level of detail for different land-use and economic development impacts. It presents an overview of the linkage between transportation and land development, and identifies a framework and technical approach for assessing the magnitude and incidence of these impacts where appropriate.

A. Land-Use Impact Analysis

The analysis should separate development that is likely to be induced by a transportation project or strategy from development that would normally occur in the real estate market. Realistically, given the large number of factors that can influence development and the difficulty inherent in forecasting the causal outcomes of these factors, the best the analyst can often hope to achieve is an informed estimate. The steps for a land-use analysis as part of an environmental study include the following:

1. Identify Land-Use Markets

Land-use impact analysis can occur at different geographic levels, such as a region, corridor, subarea, or specific site. All levels of analysis should be consistent, meaning the sum of all land-use changes predicted at the local level should add up to the regionally defined control total for expected population and employment.

Impacts on Regional Development. As discussed earlier, regional land-use and development issues are typically addressed at the metropolitan level and primarily set the land-use planning context for corridor/subarea analyses. In most cases, transportation planning agencies do not have strong influence over local development decisions, although there are some metropolitan areas, such as Portland, Oregon, where regional agencies have been given strong land-use authority. Where corridor/subarea transportation investment strategies affect regional land-use patterns, such as providing increased transportation accessibility to different sectors of the region, such impacts should be considered in the environmental assessment. In addition, in many instances, corridor and subarea studies rely on the regional travel demand model and zonal system established for regional forecasting. Often, the zonal system is too aggregate for smaller-scale analysis, and these zones are then often subdivided to a higher level of detail (see chapter 6 on travel demand forecasting and chapter 17 on corridor planning). This finer level of detail on land-use and development patterns should be shared with the MPO so that its zonal system can be updated.

Impacts on Corridor or Subarea Development. Transportation investments are more likely to redistribute regional growth that was going to occur anyway than generate new development in the region. For example, strategies serving a healthy business district may provide the added transportation capacity needed for additional growth to occur at that location rather than in a suburban location. Such distributional effects will likely occur if inferior access conditions currently restrict one part of the region from growing as rapidly as other parts (although location decisions are also influenced by tax policies, access to the labor market, and incentives provided by local governments).

Where new development is anticipated, the analysis should indicate the extent to which the corridor/subarea growth will come from other parts of the region (if possible). It is important that regional decision makers understand that overall corridor/subarea-level impacts tend to be a zero-sum game when looked at from a regional perspective; regional equity and other implications of these impacts should be taken into account.

Impacts on Local Development. A transportation investment is likely to have the most noticeable land-use impacts in areas immediately adjacent to stations, interchanges, or other points of new or significantly increased accessibility. Because of the linkage between development and transportation accessibility, standard transportation evaluation or performance measures can be used to compare strategies in terms of their potential to produce local land-use changes. For systems planning, all of the strategies' potential to cause local development might be compared using the following outputs of the travel-forecasting process:

- Percentage of the region's population and/or employment within *x* minutes of the site by automobile and by transit.
- Changes in transit, highway, and other modal travel times, weighted by mode share. For this purpose, the denominator of the logit model can serve as the analysis variable (see chapter 6 on travel demand forecasting).

The methods for evaluating the indirect and induced impacts of transportation investments continue to evolve. These techniques range from those that are largely qualitative in nature, focusing on interviews and expert knowledge, to relatively quantitative approaches, such as linked land-use and transportation-forecasting model systems.

Integration of highly structured transportation and land-use modeling systems represents the most sophisticated means available for understanding or simulating an interaction of transportation and land use. This approach suits metropolitan area studies for the very largest of the major investment strategies. For investment strategies whose scale is less likely to make a measurable impression on overall regional allocations of households and jobs, other techniques can be employed to simulate transportation and land-use interaction (see chapter 3 on land use).

A technique that is well-suited to the latter is conducting a series of highly structured interviews with experts in relevant fields, to elicit their expert opinions on the likely land-use outcome of a major transportation investment. When the interviews are formally structured with a process of feedback to participants through a series of confidential interviews, the technique is known as a Delphi process. The Delphi process was first applied to land-use forecasting in the 1970s. With the renewed interest in land-use issues, this technique may be appropriate for application in investment studies.

Regardless of the level of sophistication, analyzing the interaction between transportation and land use addresses the same issues and requires systematic data collection and evaluation. Analysts should review all techniques to analyze these relationships and determine which can be used most effectively in their jurisdiction, given available data, resources, and outside recommendations.

2. Examine Past Land-Use Trends

The land-use analysis continues with the identification of past land-use trends in the area, defined to include those areas both directly and indirectly affected by a specific strategy. Analysts typically accumulate data on the rates and characteristics of land consumption for a period of 10 to 20 years, or the period that has passed since the last major improvement to the transportation facility. These are defined as the conversion of open or agricultural land to residential, commercial, office, and industrial use. Data on population/households and employment growth for the area can be assembled and evaluated to understand the role that transportation, in general, and current facilities and services, in particular, have played. The analysis would include identifying major development sites and/or employment centers, large-scale residential developments, and other uses that, from a land-use and transportation point of view, are key determinants of travel behavior in the corridor.

It may be prudent to look at nontransportation factors as well, such as regional growth rates, quality of schools, crime, and others. These factors may be the dominant determinants of land-use development, with transportation investment factors playing a relatively minor role. At this point in the analysis, existing and future land-use conditions and trends in the corridor may indicate that land use might not be a major factor in the development and evaluation of the strategies, and thus may not require an in-depth analysis in the transportation study.

3. Analyze Current Land-Use Conditions

The next step is to develop an inventory of current land uses in the study corridor, site, or subarea. Depending on the study's resources, this inventory may be based on existing sources, or there may be a need to collect new data. The data will most likely be in a GIS format. Methods for developing a land-use conditions inventory can include the use of aerial photography, records from local tax assessors, purchased data, or reports from commercial and residential real estate brokerage firms and/or other public or private data sources, such as other planning studies and resource agency plans. The inventory should define the amounts and locations of the principal land-use types in the study area.

The analyst should assess the likelihood of existing land uses remaining stable over the timeframe of the study. Evidence of any trends of economic decline or revitalization should be noted. These are easily identified from relative changes in land or real estate values, as compared with those in other similar local areas.

The inventory should also include information about the location of vacant parcels that could now be more desirable given the transportation investment, including underutilized or nonconforming parcels. Underutilized parcels are defined as those that have not yet been developed to the densities permitted by existing zoning or plans. Nonconforming parcels are those that do not conform to existing permitted uses. These may also be underutilized.

An assessment of the effectiveness of existing land-use policies should be undertaken if these policies are included as part of the transportation study. If the study includes an assessment of different land-use scenarios, it is essential to have a good sense of existing land-use conditions.

4. Evaluate Land Use–Transportation Linkages

Building on the evaluation of past trends and current conditions, the analyst should next examine the characteristics of proposed transportation strategies as they relate to land use, including an analysis of the likely consequences of increased accessibility and mobility resulting from the strategies. Some investments represent dramatic change in accessibility; others represent only incremental changes. The analyst should evaluate area sites that will be particularly sensitive to such changes.

Accessibility is defined as the extent to which a strategy makes or enhances connections between geographic areas or portions of a region as well as across modes. Mobility is defined as the ease (for example, speed) with which movement can occur. While these two terms are interrelated, it is important to separate them to complete the land-use impact analysis (see chapter 3 on land use).

Finally, the analyst could coordinate this evaluation with the travel forecasting activities and attempt to answer such questions as: To what extent is the strategy largely a peak period facility or service? To what extent does it serve various non-work trip purposes? The answers to these questions may lead to a better understanding of likely land-use impacts.

5. Estimate and Evaluate Future Land-Use Demand

The next step in the framework is to evaluate how different strategies will affect the demand for various types of land based on the analysis of changes in accessibility and mobility. This part of the analysis is accomplished by addressing questions such as the following:

- In what parts of the study area will the largest land-use effects occur? In addition to these primary impact areas, where will there be lesser impact? (These secondary areas will tend to be distant from a fixed route or guideway system, or have other constraints in which a change in transportation infrastructure affects land-use demand, for example, zoning or environmental constraints.)
- What types of land uses will be demanded in the market? The study would typically include a traditional taxonomy for land uses in the study area, for example, single/multifamily residential, industrial, or office. Land-use categories are defined by local ordinances and codes; however, the changing needs of residents, employees, and employers are leading to more interest in mixed-use development. In addition, the extent of land consumption (through requirements such as floor area ratios and parking requirements) associated with various land-use categories is only partly determined by market conditions. Land consumption is also a function of local ordinances and permitted densities. Thus, past land consumption trends may not be the only determinant of future demand.
- Are the demands resulting from a change in transportation infrastructure likely to be one-time changes or permanent changes? What is the likely timing of these land-use changes by type?
- Will the changes present net growth in the region, or will the changes cause a redistribution of population that, without the strategy, would have gone to another part of the metropolitan region? The answer to this question depends in part on the extent to which the transportation strategy represents a substantial increase in accessibility to new markets for businesses.
- Will future land-use demands result in the same or a different mix of land uses than currently found in the corridor? For example, will the area be more or less attractive for residential development? Retail development? All types of development?

6. Evaluate Land Supply

Because the interaction of land supply, travel demand, and local/regional development policy influences regional growth, it is very useful to evaluate the various determinants of land supply in the study area, as well as how each determinant may be affected by transportation strategies. For example, to what extent will the strategy itself use land that is otherwise developable? To what extent will the right-of-way needed affect the usefulness or marketability of adjacent parcels? These issues are traditionally addressed in a land-use impact analysis; they are considered direct impacts of the strategies.

In addition, the analyst may want to review existing zoning and comprehensive plan designations to understand the opportunities and constraints within which future development will occur. The supply of land affected by the transportation strategy will be shaped by these zoning and planning designations. Traditionally, for example, areas zoned for residential development—even though not yet fully developed—have an established character, which may not be easily changed despite demands for other uses.

7. Produce Findings and Conclusions

Comparing and contrasting the way the supply and demand for land and its uses are influenced by transportation strategies allow the analyst to assess direct, indirect, and induced effects of transportation investment, and the supporting data for those conclusions. This final step in the land-use analysis documents the steps taken in the analysis and provides evidence to support any recommendations or conclusions that result. The results are incorporated into the evaluation component of the transportation study (see chapter 7 on evaluation) or as the evaluation results of an environmental study.

In summary, by systematically addressing a series of land use–related issues and questions, the land-use analysis can contribute meaningfully to the strategy evaluation and impact assessment process. The approach described in this section can be applied to any kind of major transportation investment, both to individual modal elements or to multimodal strategies and plans. The key concepts are the links between changes in accessibility to a site, area, or corridor; the availability and suitability of land and sites in that vicinity; and the potential effects of existing or potential land-use policies, ordinances, or strategies that apply to the affected area.

B. Consistency with Planning and Zoning

The analysis should examine whether the forecasts for development are consistent with adopted local comprehensive plans and zoning. To the extent that the results of the land-use impact analysis lead to forecasts for levels or types of development inconsistent with current plans, there is an opportunity, or perhaps an imperative, to address and resolve these issues. Although the process for this resolution may evolve beyond the transportation planning study, the issues, opportunities, and conflicts should be clearly identified as part of the study process. Further, the planning process may provide an opportunity to bring about interjurisdictional and interdisciplinary coordinated and collaborative planning.

C. Impacts on Services and Tax Base

Changes in development can increase the tax base of an affected jurisdiction(s), but may also increase the demand for public services, such as schools and law enforcement. These effects should be explicitly considered in the analysis. Where the fiscal impacts of changes in development are thought to be an issue, local governments should be brought into the study process. Such estimates should take into account the type of development expected to occur, the kinds of public services normally required for such development, and the possible need for new capital facilities to provide these services.

D. Impacts on Transportation Systems

To the extent that strategies may lead to secondary and cumulative land-use impacts, their effect on transportation system performance should be explicitly considered. If the land-use analysis has identified new development in certain locations, it will be possible to estimate the travel demand and behavior associated with the new developments on these sites. The traditional travel-demand forecasting process can then be employed to determine the effects of this travel behavior on the performance of the transportation system. Where trip generation and distribution lead to the overloading of local street, highway, transit, or nonmotorized system capacity, mitigation measures may be necessary to increase system supply and/or manage travel demand (see chapter 6 on travel demand modeling).

E. Economic Impacts

Another important impact of the construction and operation of new transportation facilities or services is the effect on employment and local economic activity. Calculating the local employment impact is straightforward and relies on standard factors, which should be readily available from local economic development reports or from the economics or planning departments of local universities. Once a strategy's capital cost has been estimated, the temporary employment due to construction can be calculated using an estimate of person-years of employment per million dollars for this type of construction. In addition, permanent employment opportunities will be created to operate the expanded system. Estimates of permanent employment can be derived from the operating cost developed during the cost analysis. Both the temporary and the permanent effects of this direct employment can then be assumed to multiply the economic impacts as the direct wages and salaries are spent in the local area to generate indirect employment. These multipliers have been calculated for most local areas.

Four types of employment impacts are usually considered in an economic impact study: temporary and permanent direct employment, and temporary and permanent indirect employment. Such employment impacts can be included in the environmental justice analysis that examines social equity consequences of transportation investment (see next section).

The effects of spending large sums of money on the construction and operation of a new transportation facility are not limited to employment, even though most of this money is eventually spent on wages and salaries. Of interest to local governments, some of this money also is spent on local taxes.

V. SOCIAL AND COMMUNITY IMPACTS

Transportation systems affect the social environment of a community in numerous ways, both during and after construction. Social environment is defined as the surrounding community's interpersonal interactions that are within an impact area of a particular facility or service. Potential adverse social impacts include household or business displacement and relocation, reduced neighborhood cohesion, deterioration in the quality of neighborhoods and lifestyles, and reduced access to vital community facilities and services. Beneficial impacts could include improved access to employment and services, increased economic development, and improved infrastructure. As appropriate, these impacts should be assessed during a planning study. Where adverse impacts are anticipated, possible mitigation measures should be identified, as is required in the United States for highway and transit actions covered by NEPA, the joint FHWA and FTA EIS regulations, and Executive Order 12898 on Environmental Justice.

The lead and collaborating agencies should jointly identify the social issues that need to be considered in the study. The most useful way to identify potential social impact issues is through public outreach. Beginning with the study initiation process and continuing throughout the planning study, a public participation program provides opportunities for interested citizens and groups to express their views on the likely effects of the strategies being considered. This input provides valuable perspectives on potential effects and helps to assess the severity of impacts and possible mitigation measures. Experience reveals that various social indicators, such as neighborhood mobility and stability indices and social interaction analysis, are generally less useful than straightforward public involvement for identifying and assessing realistic social impacts and mitigation options.

Local agencies should avoid making judgments on the significance of social impacts, since this is largely a matter of perception. Instead, impacts should be quantified where possible, identifying the number of displaced households, for example. The planning study should carefully describe the impacts and public views about their significance, while avoiding judgment. The analysis of social impact should also identify groups likely to be affected, as called for in Executive Order 12898 on Environmental Justice. Where social impacts are anticipated, the documentation should use maps displaying neighborhood boundaries, and present a socioeconomic profile of each neighborhood. This information may then be used to assess the distribution of investment benefits and impacts among various jurisdictions, transportation users, and socioeconomic groups.

A. Community Disruptions

The physical construction of transportation projects frequently requires land, often causing households, businesses, and public facilities to be displaced. These impacts need to be identified and assessed to the degree possible for each strategy. An important measure is the number of individuals, families, businesses, and facilities that would be displaced. The availability of comparable replacement housing—and the significant effects on the neighborhoods the displaced individuals are likely to relocate to—should also be examined. Planning studies often determine the characteristics of the families to be displaced (race, income, tenure, age, family size), as these may have a bearing on the severity of the effects of displacement and the availability of suitable replacement housing. However, data availability and privacy issues may limit this information to what is available from the census data.

The level of displacement is normally determined by using aerial photographs and conceptual engineering drawings. While specific properties (defined by land ownership) to be taken for each alternative may not be known, there should be a fairly accurate estimate of the number of dwellings and businesses that would be displaced. For residential displacements, the community profile provides information on the characteristics of the neighborhood, and thus the likely racial and socioeconomic characteristics of those to be displaced. Where businesses are to be displaced, the study should try to identify the types of jobs likely to be affected and whether these might remain in the community.

Where displacement occurs, families and businesses must be compensated for the cost of the property taken and for relocation costs. Such compensation should be included in the capital cost of each strategy and should include the cost of land and structures, the purchase of business enterprises, relocation expenses, and rent supplements as may be necessary. Guidance on right-of-way acquisition and relocation assistance requirements is given in various federal and local governmental programs.

B. Noise and Vibration

Many types of transportation investments have the potential to increase noise and vibration levels in a community. Sources of transportation noise include vehicle operating noise, noise caused by diverted or increased traffic due to a highway or transit improvement, and noise and vibration generated by fixed-guideway transit facilities. (Note that noise and vibration are treated here as part of the social and community effects category, primarily due to their potential disruptive impacts on quality of life and social interaction.)

A major source of vehicle noise is the vehicle itself. This includes exhaust noise from diesel buses or truck engines, the whine of the electric traction motors of rapid transit cars, and the noise from air moving through cooling fans. In addition, tire noise made by rubber-tired vehicles can be substantial at high operating speeds. For rail systems, several types of noise are generated by steel wheels on steel rails, depending on the type and condition of the running surfaces. The guideway structure can also act as a noise source when it vibrates under moving vehicles. Some types of equipment continue to run while the vehicle is stationary (fans, radiators, dynamic brakes, and air-conditioning pumps); thus, the noise persists at traffic signals and in transit stations or storage yards. In transit facilities, noise is generated by ventilation fans (in stations, subway tunnels, and power stations), chiller plants, and maintenance equipment and operations.

Vibrations include those traveling through the ground and those perceived visually, such as by the swaying of signs as trains pass by. For people living near a maintenance facility or a transit or truck route, vibration can be a substantial irritant.

The purpose of a noise impact analysis is to determine and report important changes in noise impact on a community associated with a strategy. The potential for adverse noise impacts is the greatest when noise-sensitive receptors are located in the study area or when the community is located in an environment that is already exposed to high noise levels. Noise-sensitive sites are placed into three categories:

- *Category 1*—Low-density residential areas far from noise sources: buildings and parks where quiet is an important element.
- *Category 2*—Residential buildings, or buildings with overnight sleeping accommodations such as homes, hospitals, hotels, and motels.
- *Category 3*—Institutional land uses with primarily daytime use, including schools, places of worship, libraries, auditoriums, and active parks.

To determine whether a detailed noise analysis is needed, a phased approach is often used, with attention given to the type of strategy, its noise-producing characteristics, and the proximity of noise-sensitive receptors. The level of detail in a noise analysis depends on the level of detail required to evaluate different types of strategies—generally the degree and location of impacts, and the type, effectiveness, and cost of potential mitigation.

The three levels of analysis in this phased approach are described in greater detail in the FTA's *Guidance Manual for Impact Analysis of Transit Noise and Vibration Impact Assessment*. [Hanson et al., 2006] The first phase of all analyses should include a screening to determine whether a noise impact analysis is needed. Noise- and vibration-sensitive land uses, characteristics of strategies that would generate noise, and any potential noise problems should be identified. This can be done by conducting walking or windshield surveys, by reviewing current land-use maps, or by inspecting recent aerial photographs of the study area. If no noise-sensitive land uses are present, no further noise assessment is necessary in the planning study. When noise-sensitive land uses are present, however, this early screening phase can help determine whether further noise analysis is needed. Table 4-5 provides examples based on project type and distance from receptors. The distances noted in the table can be used to locate noise-sensitive land uses in the aforementioned three categories. If none of the listed land uses are found to be within the distances noted in Table 4-5, the proposed alternatives would not substantially increase noise. Therefore, no further analysis would be needed for the planning study.

Another common portrayal of noise standards is shown in Table 4-6 from the Federal Highway Administration. In this case, noise levels are specified for different types of activities, and estimated or measured levels are compared to standards. If noise levels are expected to exceed the standards, some form of abatement will be necessary.

A general assessment analysis provides more detailed information and covers a narrower study area than the screening-level analysis. It is used to examine strategies where environmental evaluation is needed before engineering details are available, as is the case for most planning studies. This phase picks up where the screening-level analysis ends, that is, after sensitive land uses within noise-impact corridors have been identified. During the general assessment phase, existing noise levels at these land uses are estimated. Future noise levels can then be estimated,

Table 4-5. Screening Distances for Transit Noise Assessments	
Type of Project	**Screening Distance (ft) from Right-of-Way or Property Line**
Fixed Guideway Systems	
Commuter Rail Mainline	750
Commuter Rail Station	300
Rail Transit Guideway	750
Rail Transit Station	300
Access Roads	100
Low and Intermediate Capacity Transit	100
Steel Wheel	750
Rubber Tire	500
Yards and Shops	2000
Parking Facilities	250
Access Roads	100
Ancillary Facilities	
Ventilation Shafts	200
Power Substations	200
Highway/Roads	750
Bus Systems	
Busway	750
Bus Facilities	
Access Roads	100
Transit Mall	250
Transit Center	450
Storage & Maintenance	500
Park & Ride Lots	250

Source: Hanson et al., 2006

taking into account factors such as vehicle types, speed, traffic volume, and the distance between the noise source and the listener or receiver. This requires the use of travel demand models to estimate future traffic volumes.

Ambient noise levels are compared with projected noise levels to calculate the increase in noise due to a strategy. An inventory of noise-affected receivers within an estimated corridor of the strategies can be prepared. The resulting inventory of affected receivers can also be used for comparing noise impact among strategies. A detailed analysis is used for assessing noise impacts where the formal environmental documents are prepared in conjunction with preliminary engineering. This type of analysis provides much more detail about one or more NEPA alternatives, including site-specific information about noise and vibration impacts on individual receptors, along with prescribed mitigation measures based on the extent to which the criteria are exceeded.

Transportation noise can affect a community in two basic ways. It may be loud and frequent enough to increase the cumulative noise significantly, or it may be objectionable even if it is intermittent or of short duration. Noise-impact assessment involves two components used to determine whether either type of noise impact will occur. An absolute criterion compares the predicted noise from a strategy or an alternative to a standard; it predicts interference from a particular noise source to the exclusion of other sources. The absolute criterion is used for rail rapid transit strategies and bus options on highways. The relative approach involves comparing projected noise levels to existing ambient levels. In this approach transportation noise is not considered in isolation but is integrated with the overall community noise level. The impact is assessed according to the contribution of transportation noise to the overall noise level. The relative approach can always be used. For rail strategies, the absolute criterion is based on the maximum level of a single vehicle pass-by (L_{max}), while the relative criterion is based on the change in peak-hour equivalent noise level (L_{eq}).

Table 4-6. Roadway Noise Abatement Criteria (Hourly A-Weighted Sound Level, Decibels)				
Activity Category	**Activity Criteria**		**Evaluation Location**	**Activity Description**
	L_{eq}	L_{10} **(h)**		
A	57	60	Exterior	Land on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	67	70	Exterior	Residential
C	67	70	Exterior	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings.
D	52	55	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.
E	72	75	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A to D or F.
F	No noise analysis required			Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical) and warehousing.
G	Mitigation is not required, but expected noise levels must be provided to local officials.			Undeveloped lands that are not permitted.

Source: FHWA, 2010a

The assessment of vibration impacts is usually performed in tandem with the noise assessment. At the planning level, this assessment is usually limited to identifying vibration-sensitive buildings. Vibration impacts are assessed on buildings rather than on general categories of land use. Vibration-sensitive buildings, however, may not be evident from land-use surveys. The type of business or industry housed in the structure must be identified to determine if vibration-sensitive processes are in use, such as hospital, laboratory, and recording studio activities. If no vibration-sensitive buildings are identified, no further vibration analysis is needed. If there are such buildings, further analyses may be necessary during preliminary engineering, when data on subsurface conditions are used to assess vibration levels.

When conducting a planning study where different investment strategies are still under consideration, potential mitigation is discussed only in general terms, that is, the possible need for mitigation and the feasibility and cost of various options. Later, when a specific project has been identified, specific mitigation measures should be described and commitments given to implement them, generally during the NEPA/preliminary engineering phase. The final environmental document should contain a complete description of mitigation measures to be implemented as part of the proposed project.

An excellent source of federal and state information on noise analysis is found on AASHTO's Center for Environmental Excellence website: http://www.environment.transportation.org/environmental_issues/noise/docs_reports.aspx.

C. Neighborhood Cohesion

Neighborhood cohesion refers to a social attribute that indicates a sense of community, shared civic responsibility, social interaction within a limited geographic space, and interdependence that serves an assimilating function for a number of other localized social purposes. The planning study should identify potentially affected neighborhoods that exhibit a strong sense of cohesiveness and that have attributes making the community unique. If cohesiveness is defined explicitly, it may be possible to obtain some empirical evidence to judge the degree of cohesion and thereby gauge the impacts of proposed projects on the neighborhood. Public engagement is likely to prove a good technique for identifying and assessing potential impacts. Impacts on community cohesion can be mitigated by adopting facility alignments that follow natural neighborhood boundaries or by proposing strategies that enhance the cohesion of the neighborhood.

D. Neighborhood Quality

Transportation investment strategies could also affect the overall quality of a neighborhood. Such effects may be reflected in changed property values, for example, or in the increased or decreased satisfaction residents derive from living in the neighborhood. Eventually, existing residents might be replaced by new residents with different lifestyles. Such impacts are difficult to predict, let alone quantify, yet they may be of considerable importance to those residing in the community.

Economic and environmental analyses performed as part of the planning study can help reveal the likelihood of any impacts on neighborhood quality and lifestyles. The assessments of noise and aesthetics, for example, should help reveal potential changes in neighborhood quality. Similarly, the economic development analysis may show that a strategy greatly increases a neighborhood's accessibility, and that this could in turn enhance prospects for redevelopment. Such redevelopment may be viewed as a positive impact of the project, but existing residents may prefer that their neighborhood not be changed. The public involvement program should help the study determine the extent to which community residents are concerned about impacts on neighborhood quality and lifestyles.

E. Access to Community Facilities and Services

Transportation investments may increase or reduce access to community facilities such as hospitals, schools, police and fire stations, shopping, places of worship, and other community-important centers. Access may be reduced if the roadway or guideway facility requires the acquisition of community facilities for right-of-way, or if the roadway/guideway creates a barrier between residents and the facilities. Such impacts should be considered both during the construction stage and for the permanent facility. Potential reductions in such access, particularly for school-age children and the elderly, would be considered a negative impact needing assessment and mitigation.

The impact on access to facilities is normally examined by identifying the location of community facilities and the areas they serve. Roadway/guideway projects that follow service area boundaries tend to have little, if any, impact on access to community facilities; those that create a physical barrier through a service area would have an impact. In such cases, the study should try to determine how many people would be affected by reduced access, and whether this barrier would create special problems for them. Potential mitigation measures might be explored, including changes in alignment, the construction of strategically located pedestrian crossings, or increased transit service by social service agencies. The public engagement program, once again, is the most useful technique for assessing likely impacts and evaluating potential mitigation measures.

F. Environmental Justice

Executive Order 12898 ("Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations") calls for federal agencies to identify and address "disproportionately high and adverse human health or environmental effects" on low-income and minority populations. The key aspect of this requirement is considering how federal action—or in the case of a planning study, the strategies—will affect low-income and minority groups in the study area and the region. In other words, who benefits? who pays? and who receives adverse or beneficial impacts? According to the FHWA, three major principles guide environmental justice analyses:

- Avoid, minimize, or mitigate disproportionately high and adverse human health and environmental effects, including social and economic effects, on minority and low-income populations.
- Ensure the full and fair participation of all potentially affected communities in the transportation decision-making process.
- Prevent the denial of, reduction in, or significant delay in the receipt of benefits by minority and low-income populations. [FHWA, 2000]

While environmental justice issues are often raised to some extent in planning documents in the United States, project-specific environmental analysis will consider it in more detail. The impacts and benefits accruing to specific low-income and minority populations in neighborhoods and communities should be highlighted. The planning study report's summary of environmental impacts—a cumulative impacts discussion and/or the evaluation chapter and equity discussions—should be compiled and a comparison made between the impacts/costs to identified low-income and minority populations versus the general population.

When a planning study is part of a larger regional planning process, the environmental justice analysis can support a broader system-level assessment of how the investment decisions and priorities will affect low-income and minority populations. GIS tools in particular are very useful in identifying environmental justice impacts in a study area. See chapter 7 on evaluation for more discussion on environmental justice analysis.

G. Public Health/Active Living

Chapters 1 and 2 describe the important role for transportation in the evolution of communities and in the quality of life of their residents. The physical characteristics of the transportation system are a factor in the health of a community's residents. Over the past 10 years, several agencies and groups have begun to examine this relationship more closely, for example, how can one encourage more exercise through active living? [Raynault and Christopher, 2013] Air quality regulations (see Section VI) have as their major focus the reduction of hazardous pollutants causing serious health issues for those sensitive to different emissions (for example, those with asthma). However, the more recent interest in public health focuses on urban form and how transportation does or does not encourage physical activity.

According to the Centers for Disease Control, a more active lifestyle (for example, exercising) can have the following benefits:

- Control weight.
- Reduce risk of cardiovascular disease.
- Reduce risk for type 2 diabetes and metabolic syndrome.
- Reduce risk of some cancers.
- Strengthen bones and muscles.
- Improve mental health and mood.
- Improve ability to do daily activities and prevent falls, if you're an older adult.
- Increase chances of living longer. [CDC, 2014]

Several transportation planning programs have embraced the concept of active transportation and have integrated such strategies into the transportation planning process. [Dannenberg et al., 2014] The Nashville, Tennessee, MPO, for example, has set aside funding for its active transportation program, with special focus on pedestrian and bicycle facility investments (see http://www.nashvillempo.org/plans_programs/tip/ATP.aspx). Portland, Oregon, has been a national leader in non-motor vehicle transportation for decades and Portland Metro, the region's MPO, has developed a Regional Active Transportation Plan (ATP) that "will make it easier to walk, ride a bike, or take public transportation to your destination. The plan identifies a vision, policies and actions to complete a seamless green network of on- and off-street pathways and districts connecting the region and integrating walking, biking and public transit." [Portland Metro, 2008] In San Francisco, the Metropolitan Transportation Commission (MTC) established the following performance measures for health and equity used in the regional prioritization process: premature deaths from exposure to particulate emissions, injuries and fatalities from collisions, and average daily time per person spent walking or biking for transportation. In addition, the MTC has recognized the important relationship between transportation and land use by trying to promote transit-oriented developments throughout the region. In San Diego, SANDAG, the MPO, awarded local community grants for activities related to pedestrian paths, sidewalks, connections to transit, food access, and urban agriculture. Interestingly, SANDAG also developed a health assessment module for its activity-based travel demand model. [Raynault and Christopher, 2013]

Several chapters in this handbook provide more detailed information on the analysis tools that can be used to assess the effectiveness of active transportation strategies. See, for example, chapter 3 on land use and urban design, chapter 12 on transit planning, chapter 13 on pedestrian and bicycle planning, chapter 14 on travel demand management (TDM), and chapter 19 on site planning and impact analysis. See also NARC [2014].

H. Historic, Cultural, and Parkland Resources

Transportation investments to be built with federal funding assistance are subject to two legal requirements dealing with potential impacts on historic, cultural, or open-space resources. While the specific provisions of the two laws are somewhat different and are generally treated separately, the work involved in addressing each requirement during a planning study is sufficiently similar to allow combined discussion here.

Section 4(f) of the U.S. Department of Transportation Act requires a finding by the U.S.DOT Secretary of Transportation that no prudent and feasible alternative exists to any federal action that has negative impacts on subject properties, and that all possible planning has been done to minimize harm. Subject properties include significant publicly owned parklands, recreation areas, open spaces, wildlife and waterfowl refuges, and historic sites.

Section 106 of the National Historic Preservation Act requires that federal agencies identify and assess the effects of expenditures of federal funds on historic sites, districts, buildings, and archaeological sites. The provision requires agencies to afford the Advisory Council on Historic Preservation an early opportunity to comment on proposed actions having potential impacts on historic properties and to mitigate these impacts to the extent possible. Subject properties are defined to include those on or eligible for the National Register of Historic Places.

The federal transportation agencies most affected by these laws, FHWA and FTA, must be satisfied that the stipulations are met before any funding assistance is given to transportation projects. As with many other technical areas, it is important to identify the appropriate level of detail required for the planning study, distinguishing it from the level of detail more appropriately done later during project development.

Identifying all potentially affected properties in the corridor or subarea is an important first step in the analysis of possible Section 4(f) and Section 106 impacts. For the diverse types of properties covered by the 4(f) requirement, it is necessary to consult with local, state, and federal agencies having responsibilities for parklands, recreation areas, open spaces, and similar properties. For historic properties, well-developed sources of information often exist. These include the U.S. National Register, state historic registers and other listings, and the files of the State Historic Preservation Officer (SHPO). In most cases, a survey by a historic preservation professional is needed to ensure the inventory is complete and meets Section 106 requirements. This survey uses, at a minimum, the standards of eligibility for the National Register to examine sites not currently listed on the register or those already identified as eligible.

The analysis of potential direct or indirect impacts is the second step in the 4(f) and 106 processes. Direct impacts include the physical taking of the property or parts of the property, while indirect impacts include effects that impair the use of the property for intended purposes. Indirect impacts usually involve noise, visual intrusion, or obstruction of access to the property. Thus, the analysis must consider the current uses of the properties and examine possible constraints on these uses caused by a project. Further, in considering indirect impacts, the scope of the analysis must be broad enough to include not only properties that may be physically taken in whole or in part, but also sites adjacent to and within view of the right-of-way. In some cases, the scope will include sites on access roads to station sites that might experience significant increases in traffic volumes. The processes conclude with determinations by the responsible agencies that proposed actions satisfy statutory requirements.

For the 4(f) requirement, the final NEPA document includes a 4(f) statement that:

- Presents the inventory and description of potentially affected properties.
- Discusses the likely nature of the impacts on these properties.
- Examines alignment variations and other design alternatives for the project that might avoid the impacts.
- Identifies mitigating actions that will be taken to minimize the adverse impacts, where these design avoidance options are not judged prudent and feasible.

Since the FHWA/FTA Administrators have been delegated the authority to verify the Department's finding that the Section 4(f) requirements have been met, this finding is made concurrent with approval of the final NEPA document. The U.S. Department of the Interior reviews and comments on the draft Section 4(f) statement prior to FHWA/FTA approval. See FHWA [2012d] for more detail on how to conduct a Section 4(f) analysis.

Federal legislation in 2005 amended the original law creating Section 4(f) requirements to simplify the processing and approval of projects that have only *de minimis* impacts on lands protected by Section 4(f). A *de minimis* impact is "one that, after taking into account any measures to minimize harm (such as avoidance, minimization, mitigation, or enhancement measures), results in either:

1) A Section 106 finding of no adverse effect or no historic properties affected on a historic property; or
2) A determination that the project would not adversely affect the activities, features, or attributes qualifying a park, recreation area, or refuge for protection under Section 4(f)." [FHWA, 2012d]

A use of Section 4(f) property having a *de minimis* impact can be approved by FHWA without the need to develop and evaluate alternatives avoiding the use of the Section 4(f) property.

For Section 106 requirements, findings of adverse effects must be sent to the Advisory Council on Historic Preservation. Mitigation measures are stipulated in a memorandum of agreement (MOA) among the SHPO, FHWA/FTA, and the grantee and the council, if it chooses to participate in the MOA.

The general recommendation regarding level of effort in this area parallels those of other technical areas. The work during a planning study should be sufficient to identify considerations that may be significant in selecting a preferred strategy. In effect, the purpose is to identify any likely problems in meeting the 4(f) and 106 requirements for each strategy. Thus, actual completion of the requirements is not necessary and, given the number of strategies and degree of uncertainty typical of a planning study, may not even be possible. This general guideline provides substantial latitude for determining the level of effort, depending on the degree of potential impacts in the corridor or subarea, the amount of existing information, and the degree and nature of local concerns.

Most important, efforts during the planning study should include close coordination of the inventory, analysis and findings with the SHPO and other agencies with jurisdiction over subject properties. The planning study should document this coordination and demonstrate the collaboration.

VI. NATURAL RESOURCE IMPACTS

Transportation projects can have significant impacts on the natural environment, resulting in subsequent impacts on communities and individuals (such as the impacts on air quality and water quality). A planning study should identify the impacts of each strategy as well as their significance. Most planning studies, for example, will consider potential impacts on water quality. Some will also examine impacts on wetlands, floodplains, and aesthetics. Occasionally, detailed studies of endangered species, coastal zones, toxic waste disposal, ocean dumping, navigable waterways, and other factors will be undertaken. Special rules, regulations, and permits apply to many of these impact areas. State and local legislation and ordinances may contain additional requirements. Many of these topics will not apply to a particular strategy or study area and can be eliminated from further consideration after an initial step of determining to what extent such impacts might be relevant to the study.

The requirements for analyzing and dealing with each type of impact are beyond the scope of this overview. However, there are numerous FHWA, FTA, and state/local resource agency documents on assessing impacts of transportation options on the natural environment, which should be consulted.

In cases where the sponsoring agency has identified possible impacts beyond the analysis resources or capabilities of local staff, outside assistance should be obtained. In many cases, specialized consultants are retained. Other governmental, nonprofit, or private organizations and individuals may also be able to provide support. The following federal agencies (and their local and state equivalents) might be useful: Army Corps of Engineers, Environmental

Protection Agency (EPA), Fish and Wildlife Service (FWS), and Coast Guard. Further assistance may be obtained through federally sponsored training courses and manuals.

A. Air Quality

The EPA has established National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to human health and public welfare. NAAQS exist for the following pollutants, known as criteria pollutants: carbon monoxide (CO), small particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and lead (see Table 4-7). Transportation-related pollutant emissions can be of concern primarily at a local level, such as CO emissions at intersections, or at a regional scale, such as ozone levels. Geographic areas that violate one or more of these standards are called nonattainment areas. States, in cooperation with local planning and environmental agencies, produce state implementation plans (SIPs) showing how these standards will be attained and maintained. Transportation control measures (TCMs) can be part of the set of strategies that will help achieve the standards.

Air quality assessments performed during planning address the potential impacts of each strategy from three perspectives: changes in regional pollutant emissions, changes in localized emissions, and the conformity of these changes with adopted air quality implementation plans. Formal conformity determinations will be made later, when the chosen alternative is added to the plan and TIP. For the purposes of a planning study, relative comparisons among the strategies for air quality and conformity impacts are all that is normally needed.

Table 4-7. National Ambient Air Quality Standards (NAAQS), United States

Pollutant		Primary/Secondary	Averaging Time	Level	Form
Carbon Monoxide		Primary	8-hour	9 parts per million (ppm)	Not to be exceeded more than once per year
			1-hour	35 ppm	
Lead		Primary and Secondary	Rolling 3-month average	0.15 μg/m^3	Not to be exceeded
Nitrogen Dioxide		Primary	1-hour	100 parts per billion (ppb)	98th percentile, averaged over 3 years
		Primary and Secondary	Annual	53 ppb	Annual mean
Ozone		Primary and Secondary	8-hour	0.075 ppm	Annual fourth highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution	$PM_{2.5}$	Primary	Annual	12 μg/m^3	Annual mean, averaged over 3 years
		Secondary	Annual	15 μg/m^3	Annual mean, averaged over 3 years
		Primary and Secondary	24-hour	35 μg/m^3	98th percentile, averaged over 3 years
	PM_{10}	Primary and Secondary	24-hour	150 μg/m^3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide		Primary	1-hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		Secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

Source: Environmental Protection Agency. "National Ambient Air Quality Standards (NAAQS)." Accessed Feb. 24, 2016, from http://www.epa.gov/air/criteria.html.

The level of analysis needed to address air quality impacts and the types of pollutants addressed will depend on the significance of local air pollution problems. A quantitative analysis is needed when a transportation project or strategy is located in a nonattainment area or could cause violations of one or more of the NAAQS. This includes highway investments with added single-occupancy vehicle capacity, transit investments with major parking facilities, downtown bus options (especially in areas where background concentrations are already high), and any proposal where there is the potential for adverse effects on sensitive receptors, including hospitals, parks, convalescent or nursing homes, schools, and residential neighborhoods.

Even though rail projects are electrically powered and the vehicles are nonpolluting, transit stations with parking for a large number of cars can be indirect sources of air pollution. Increased traffic near stations and at parking lots during peak periods may create hot spots or cause local increases in certain air pollutants in much the same way as various types of roadway improvements. Measures such as ramp metering can reduce congestion on major freeways but can create hot spots at the queues at metered ramps. Hot spots can also occur in queues at toll plazas. Tunnel ventilation exhaust facilities also need to be considered. Projects such as bus storage and maintenance facilities, downtown terminals, transit malls, and other projects that concentrate bus activity in populated areas can also negatively affect local air quality.

Comparing estimated air pollution levels with the NAAQS is one of the procedures used to determine whether an investment is likely to have an adverse effect on air quality and, if so, the severity of its effect. In areas that also have state air quality standards, a more restrictive standard may be used. Another procedure is to estimate a potential project's effects on total emissions in an area, known as an emission burden analysis.

Some federal standards are expressed as hourly averages, while others are annual averages. The NAAQS for CO, for example, is expressed as short-term 1-hour and 8-hour standards. The standard for NO_2, however, is expressed as an annual arithmetic mean. This makes it more difficult to assess the effects of operations during the short period of greatest use. Although no short-term standard exists at the federal level for NO_2, several states have adopted them. These can be used as a basis for gauging the air quality effects of some projects.

The primary criteria pollutants examined for diesel bus and truck activity are nitrous oxides (NO_x), which mostly represent the sum of nitric oxide (NO) and nitrogen dioxide (NO_2) hydrocarbons (HC), and small particulate matter. The effects of these activities on noncriteria pollutants, such as formaldehyde and benzene, might also be considered.

Ozone is a component of photochemical smog, which is produced by the action of sunlight on a combination of HC and NO_x. In metropolitan areas the major mobile-source factors affecting peak ozone concentrations are NO_x and HC emissions from motor vehicles and photochemical production of oxidants. Where gasoline-powered vehicles are the primary concern, the analysis focuses on CO. Most CO pollution and violations of standards are caused by motor vehicle emissions at hot spots or areas of heavy traffic congestion.

One of the most common ways of estimating pollutant emissions from the transportation system (called mobile sources) is to estimate some "activity factor," such as vehicle miles traveled, and multiply that factor by an emissions rate, for example, expressed in grams per mile. At a study level, the network demand model is the tool most often used to estimate this activity factor. For estimating emission rates, the EPA has developed or sponsored several models that can be used to estimate such rates. As listed on the EPA's website, these models include:

- "MOVES (MOtor Vehicle Emission Simulator) is EPA's current official model for estimating air pollution emissions from cars, trucks and motorcycles. In the future the model will also cover non-road emissions.
- NONROAD Model links to information on the NONROAD emission inventory model, which is a software tool for predicting emissions of hydrocarbons, carbon monoxide, oxides of nitrogen, particulate matter, and sulfur dioxides from small and large non-road vehicles, equipment, and engines.
- NMIM, or National Mobile Inventory Model, is a free, desktop computer application developed by EPA to help develop estimates of current and future emission inventories for on-road motor vehicles and non-road equipment. NMIM uses current versions of MOBILE6 and NONROAD to calculate emission inventories, based on multiple input scenarios that you enter into the system. One can use NMIM to calculate national, individual state, or county inventories.

- MOBILE Model links to information on the MOBILE vehicle emission factor model, which was EPA's official model for estimating air pollution emissions from cars, trucks, and motorcycles until it was replaced by MOVES.
- Fuel Effects on Vehicle Emissions links to information on test programs and modeling estimating the emissions impacts of changes in fuel properties and composition. Information on how fuel effects are applied in MOVES and NONROAD is available on the web pages for those models.
- OMEGA, the Optimization Model for Reducing Emissions of Greenhouse gases from Automobiles, estimates the technology cost for automobile manufacturers to achieve variable fleet-wide levels of vehicle greenhouse gas emissions.
- GEM, the Greenhouse gas Emissions Model, estimates the greenhouse gas emissions and fuel efficiency performance of specific aspects of heavy-duty vehicles. This model is a means for determining compliance with EPA's GHG emissions standards and NHTSA's fuel consumption standards . . . ." [U.S. EPA, 2013]

Given the long history and seriousness of the air quality challenge in California, the state's Air Resources Board has developed a menu of models that are used for environmental assessment in the state. For example, the Hotspots Analysis and Reporting Program Version 2 (HARP 2) is a software program consisting of three programs: Emissions Inventory Module (EIM), Air Dispersion Modeling and Risk Tool (ADMRT), and Risk Assessment Standalone Tool (RAST). The focus of this program tool is on emissions hotspots. The EIM allows users to create and manage a facility emission inventory database and calculate facility prioritization scores. The ADMRT performs atmospheric dispersion analyses and can calculate cancer and noncancer (acute and chronic) health impacts. The RAST calculates cancer and non-cancer (acute, 8-hour, and chronic) health impacts using ground level concentrations, uses point estimates or data distributions of exposure to calculate inhalation and multipathway risks, performs spatial averaging on concentrations and risk from various pathways and receptors, calculates population exposure, and calculates cumulative impacts for one or multiple facilities and one or multiple pollutants. [Air Resources Board, 2015]

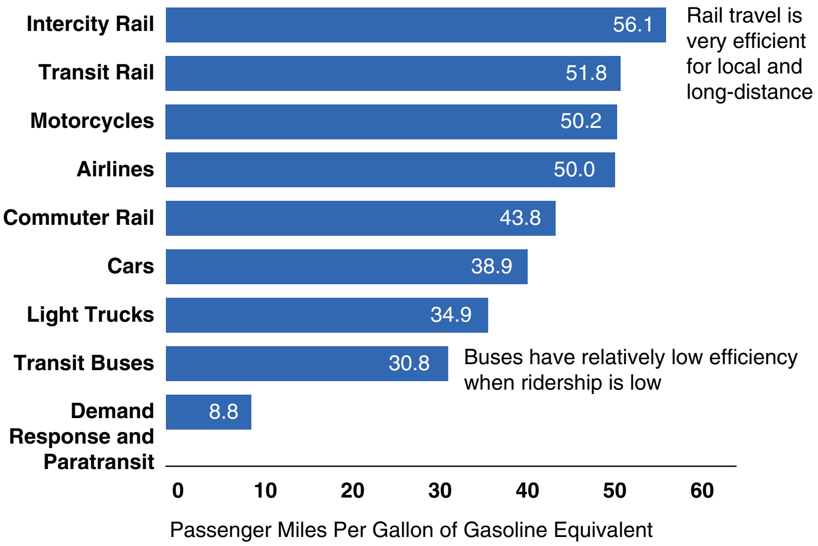
California has developed many other emissions models that are used for California studies and often in other parts of the United States. Interested readers are referred to Air Resource Board, "Modeling Software," http://www.arb.ca.gov/html/soft.htm for a detailed description of the models available.

Conformity — Conformity is defined in federal regulations as a transportation plan's, program's, or project's conformity to an SIP's purpose of eliminating or reducing the severity and number of NAAQ violations, and expeditiously meeting its standards. In addition, actions may not cause or contribute to new violations of air-quality standards, exacerbate existing violations, or interfere with timely attainment or required interim emissions reductions toward attainment. A federal conformity rule also establishes how FHWA, FTA, and the local MPO determine the conformance of highway and transit projects.

The MPO must develop tools to identify future investments planned in a nonattainment area and describe how these investments will assist in meeting the SIP's requirements. Transportation planning studies are used to determine transportation investment for corridors or subareas that could become part of an adopted plan and conforming TIP. Two approaches are suggested for evaluating regional conformity:

- A relative comparison of emissions strategies at the corridor level could be included as part of the planning study for NEPA purposes. While a full regional emissions model run would not be conducted for each strategy studied, a regional model run—including design concept and scope strategy—would be made before the plan is amended. The regional model run might cover a package of plan amendments, including not only the project resulting from the planning study but also other plan changes. This is the preferred approach in most planning studies.
- The regional emissions model could be run for each strategy in the study. Once the planning study is completed—and assuming that one of the strategies tested is proposed for inclusion in the plan—the regional emissions analysis would already have been done to support the conformity determination for the plan amendment. This assumes, however, that the project emerging from the planning study is the only amendment being made to the plan at that time.

Figure 4-5. Average Fuel Economy for Passenger Modes



Source: U.S. DOT, 2015

Since planning studies do not usually include sufficient information for a detailed hot-spot analysis, it may also be appropriate to conduct a project-level CO impact assessment of projects at typical locations. This will assess whether any of the projects raise serious air emission concerns, such as the existence of current CO problems, or to what degree any of the strategies will add to them. If an apparent problem arises, further analysis might be appropriate.

Planning study reports typically include an air quality section that discusses conformity in general terms and identifies any potential problems with strategies and how to resolve them. Once a project is in development, a supplemental hot-spot analysis is usually needed before completing the formal NEPA environmental analysis report.

Consultation—The air quality analysis methodology used in a planning study should be developed in consultation with state and local air pollution control agencies. The consultation process should ascertain which pollutants need to be addressed and the availability of data on existing pollutant concentrations and meteorological conditions. The state and local air pollution control agencies and MPOs should be consulted about the relevance of the SIP to the strategies being analyzed and the criteria for assessing conformity with the SIP.

B. Energy

Transportation vehicles have different fuel consumption rates, otherwise known as fuel economy. Figure 4-5 shows typical average fuel economy rates for passenger modes. In the past, the energy analysis for proposed transportation investments was typically much less sophisticated than air quality and noise analyses. Energy analyses for fixed guideway transit projects typically reveal no significant difference in operating energy usage among transit strategies, and any differences found appear to have little effect on project decision making. In addition, there are very little data on the energy requirements of transportation facility construction and operations. As a result, comprehensive energy assessments during transit corridor studies were not generally performed.

For highway projects, fuel or energy consumption was simply estimated by determining the average fuel consumed by vehicle type per mile traveled and then multiplying this rate by the number of expected vehicle miles traveled, as determined from the travel-demand model.

However, this lack of sophistication may change with more complex multimodal planning studies being performed and with increasing concerns about the cost, availability, and environmental issues associated with using various energy sources. These concerns may give rise to a consideration of the energy consumption of different fuel types among the strategies. Moreover, each strategy's energy requirements could be calculated if local officials or public involvement were to give transportation energy use high priority in decision making. It also seems likely that carbon-based emissions, those that contribute to global warming, will become increasingly important to many decision makers.

Table 4-8. Assessment of State DOT Strategic Directions Potentially Reducing Use of Energy: Lead Time and Qualifications		
Strategic Direction	**Lead Time**	**Qualifications**
Strategies to sustain or increase revenues		
Tolls or mileage-based user fees	5–10 years	
Fuel taxes	Immediate	
Registration fees	Immediate	
Beneficiary fees	5–10 years	Best in states with strong growth
General revenue sources	Immediate	
Increased use of private capital	5–10 years	Best in states with strong growth
Strategies to reduce costs		
Greater efficiency	5–10 years	
Reduced scope of responsibility	5–10 years	
Strategies to improve auto and truck travel		
Road expansion	10–20 years	Best in states with strong growth
Goods movement	10–20 years	Best in states with large ports or trade corridors
Congestion pricing	1–5 years	Best in states with large urban areas
ITS	>20 years	
Transportation system management	1–5 years	Best in states with large urban areas
Traffic safety	1-5 years	
Strategies to improve alternative modes		
Transportation demand management	1–5 years	
Public transportation	5–10 years	Best in states with large urban areas
Land use	>20 years	Best in states with strong growth
Strategies to promote energy efficiency and alternative fuels		
Vehicle feebates	1–5 years	
Carbon pricing	1–5 years	
Fuel mandates and programs	1–5 years	Form of mandate varies by state
Fuel production and distribution	5–10 years	Best fuel choice could vary by state
Agency energy use	5–10 years	

Source: Sorenson et al., 2014

Where energy analyses are performed, they should take into account the energy required to operate and build each investment strategy or alternative. Operating energy consumption is sensitive to many of the same variables as pollutant emissions—vehicle speed, operating mode, cold starts, and vehicle type (fuel, weight). These variables should be taken into account to get an accurate comparison between the options. Previous analyses have also considered the supply of energy in the region, including availability of alternative fuels and other factors, such as whether existing power plants could provide enough electrical power to operate a rail facility. Table 4-8 shows the results of a study, *Preparing State Transportation Agencies for an Uncertain Energy Future,* to gauge the likely timeframe for implementing different types of strategies to reduce energy consumption. [Sorenson et al., 2014]

The results of an energy impact analysis are normally presented in terms of the payback period for each strategy. The payback period is the time required for the operational energy savings, if any, to offset the energy consumed in building the facility. Planning study energy analysis could also be couched in terms of air emissions, particularly in nonattainment areas.

C. Water Quality

Water quality might be adversely impacted by dredging, discharging fill material or otherwise introducing pollutants into surface bodies of water, increasing runoff or altering surface drainage patterns, and affecting the water table by dewatering or contaminating subsurface waters. Unless projects or alternatives involve any of these activities, a water-quality assessment is not needed.

Wastewater generated by maintenance and storage facilities contains various pollutants, which unless treated and handled properly can be released into city storm-water systems. The environmental analysis should identify activities associated with the strategies that generate wastewater, such as steam cleaning, vehicle washing, and pavement runoff. Typical bus or truck garage effluent, for example, contains concentrations of oil and grease, detergents, chemicals, metals, and solid materials that pass into the sewer system. Storm-water runoff from parking areas and highways may contain harmful pollutants such as lead, zinc, and cadmium as well as de-icing salts. The potential for increasing runoff and corrective measures, such as reducing runoff or preventing pollutants from entering storm-water and groundwater systems, should be considered in the environmental analysis.

A National Pollutant Discharge Elimination System (NPDES) permit, required under Section 402 of the Clean Water Act, may be required if wastewater is discharged directly into the storm-water system. EPA issues NPDES permits and sets their pretreatment effluent limits. States and localities may also have their own limits and identified specific disposal sites. The environmental analysis should determine whether an NPDES permit is required and whether there are other local or state pretreatment requirements and permits.

Any strategy that involves the discharge of dredged or fill materials into U.S. waters must also comply with Section 404 of the Clean Water Act (33 U.S.C. 1344). These waters include:

- All waters that are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters that are subject to the ebb and flow of the tide
- All interstate waters, including interstate wetlands
- All other waters (such as interstate lakes, rivers, and streams) whose use, degradation, or destruction could affect interstate or foreign commerce
- Tributaries of such waters
- The territorial sea
- Wetlands adjacent to U.S. waters.

Generally, under NEPA, the selection and use of the sites, including the criteria for evaluating the impact of the dredged or fill material, are governed by EPA guidelines, but it is the Corps of Engineers' responsibility to ensure compliance with these guidelines and to issue the permits. EPA's guidelines for "Specification of Disposal Sites for Dredged or Fill Material," referred to as the 404(b)(1) guidelines, describe the contents of the permit application and the evaluation criteria (http://www.epa.gov/sites/production/files/2015-03/documents/cwa_section404b1_guidelines_40cfr230_july2010.pdf.

Four conditions must be satisfied before a determination can be made to permit the discharge of dredged or fill material:

- There can be no practicable alternative to the proposed discharge that would have a less adverse impact on the aquatic ecosystem, as long as that alternative does not have other significant adverse impacts.
- The proposed discharge cannot cause or contribute to a violation of any applicable state water-quality standard; any applicable toxic effluent standard or prohibition under Section 307 of the Clean Water Act; the Endangered Species Act of 1973; or Title III of the Marine Protection, Research, and Sanctuaries Act of 1972.
- No discharge of dredged or fill material can cause or contribute to significant degradation of U.S. waters.
- All appropriate and practicable steps must have been taken to minimize potential adverse impacts of the discharge on the aquatic ecosystem.

The District Office of the Corps of Engineers should be consulted as early as possible if it is thought that a permit may be required. This allows the information required for compliance with Section 404 to be integrated into the environmental planning process. Additionally, this information should be taken into account when developing the study work program. The permit itself does not have to be, and generally cannot be, obtained prior to FHWA's/FTA's approval of the formal NEPA environmental document (EA or final EIS). Generally, a planning study should focus on information that helps distinguish among alternatives.

These requirements need to be considered in developing, designing, and assessing the cost of alternative strategies during a planning study. Because water-quality impacts can normally be mitigated, the magnitude of the impacts on water quality is not usually a major factor in selecting a preferred option. The planning study does not normally include calculations to quantify the effects on water quality, only the cost of possible mitigation measures.

D. Navigable Waterways and Coastal Zones

The Rivers and Harbors Act of 1899 (33 U.S.C. 401 et seq.) requires that the Secretary of the Army issue permits for various activities. Section 9 of the act pertains to the construction of any dam or dike across any navigable waters of the United States, and Section 10 pertains to construction of any structure over, excavation from, or disposal of materials into navigable waters. Navigable waters mean those U.S. waters that are subject to the ebb and flow of the tide shoreward to the mean high watermark and/or those waters that are presently used, have been used in the past, or may be susceptible to use in transport for interstate or foreign commerce. Certain work performed, or structures constructed, in navigable waters require permits pursuant to both Section 9 and Section 10 of the Rivers and Harbors Act. A project involving dredging in navigable waters would require both a Section 10 and a Section 404 permit because Section 404 of the Clean Water Act pertains to U.S. waters, which include more than navigable waters.

During the planning study, the need for such permits should be determined for each option. Initial consultation with permitting agencies should occur to ascertain the specific requirements that must be satisfied if an option requiring a permit is chosen. These requirements should be described in the environmental section of the planning study report.

The U.S. Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.) requires consultation with the Fish and Wildlife Service (FWS) and the appropriate state wildlife agency when a project will impound, divert, channelize, or otherwise control or modify the waters of any stream or other body of water. Generally, if a permit is required under Section 402 or 404 of the Clean Water Act or Section 9 or 10 of the Rivers and Harbors Act of 1899, the consultation requirement will apply. Permit applications will be forwarded to FWS in later project development phases, to be reviewed according to the "Guidelines for the Review of Fish and Wildlife Aspects of Proposals in or Affecting Navigable Waterways" (http://environment.fhwa.dot.gov/guidebook/vol1/doc17g.pdf).

Consideration should be given to preventing wildlife damage or loss, and mitigating any effects caused by a project. If there is particular concern about these resources, it may be appropriate to send the planning study report to FWS for its review and comment, and to include an evaluation of how the actions may affect fish and wildlife resources. The discussion should include potential measures to minimize harm, such as features to reduce turbidity during construction, stabilizing the shoreline with plantings suitable for use by wildlife, or compensation for habitat that may be lost. FWS has issued a mitigation policy, which can be consulted when planning potential mitigating measures (http://training.fws.gov/courses/csp/csp3112/resources/Written_summaries_of_404_program/FWS_Mitigation_Policy.doc). The results of the coordination concerning potential mitigation measures should be included in the formal environmental document during the subsequent project development phase.

If an alternative will result in a project that directly affects the coastal zone of any state with an approved coastal zone management (CZM) program, the environmental analysis must consider whether the alternative will be consistent with the CZM plan. The Coastal Zone Management Act of 1972 (16 U.S.C. 1451 et seq.), as amended, established a voluntary program in which most of the 35 states with coastal zones currently participate. These states have Department of Commerce–approved plans and receive federal money and technical assistance to administer their programs.

The state agency managing the program, called the principal 306 agency, is usually the Department of Natural Resources or its equivalent agency. This agency should be consulted both for state procedures used to determine consistency with the CZM plan and for its opinion on whether proposed strategies under consideration are consistent with the state's program. The final environmental document prepared during subsequent project development should present the applicant's certification that the project is (or is not) consistent with the CZM program and the views of the state agency.

The U.S. Coastal Barrier Resources Act (16 U.S.C. 3501 et seq.) and the Coastal Barrier Improvement Act designate a protected network of undeveloped coastal barriers located on the Atlantic and Gulf coasts, called the coastal barrier resources system. Section 5 of this act prohibits federal expenditure for construction of any facilities, structures, roads, bridges, airports, and the like within the system. Exceptions can be made for some activities, such as the maintenance of existing channel improvements and related structures and the maintenance, replacement, reconstruction, or repair (not expansion) of publicly operated roads or facilities that are essential links in a larger network or system. Consultation with the Department of the Interior is required.

E. Climate Change and Extreme Weather

Many scientists estimate that over the next 50 to 80 years, Earth's climate is going to change dramatically due to the increasing levels of greenhouse gases that have entered the atmosphere and will continue to do so in the foreseeable future. This change is expected to occur over the long term (for example, gradual increase in sea levels) and over the shorter term (for example, more frequent and violent storms). Today, the United States has no requirement to include climate change impacts in federally supported environmental analyses (although there are proposals to do so); however, many other countries have such requirements, as do many state environmental laws (for example, California, Massachusetts, and Washington).

An important distinction is made between efforts to reduce greenhouse gases, called mitigation, and efforts to prepare for and respond to changing climatic conditions, called adaptation. As noted in a 2014 NCHRP report on climate change, adaptation can be defined as:

> *"Adaptation consists of actions to reduce the vulnerability of natural and human systems or to increase system resiliency in light of expected climate change or extreme weather events."*
>
> *[Meyer et al., 2014]*

Several guides and research reports are available for analyzing different aspects of both mitigation and adaptation. For mitigation, the most comprehensive guide is Strategic Highway Research Report (SHRP) 2 Report S2-C09-RW-2, *Practitioner's Guide to Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process* [PB Americas et al., 2013]. For adaptation, several national and state guides are available. Some of the more comprehensive include: [PIEVC and Engineers Canada, 2009; U.S. Army Corps of Engineers, 2011; Washington State DOT, 2014; ICF International, 2012; FHWA, 2012a,b,c, 2013; Meyer, Choate, and Rowan, 2012; and Meyer et al., 2014].

Table 4-9 shows the types of impacts that changing climatic conditions could have on roads and highways. Note that the expected impacts are focused not only on infrastructure design, but also on the operations and maintenance of transportation systems. Thus, although the focus of this chapter is on planning in a sense of infrastructure provision, some of the most important consequences of changing climatic conditions will likely be on the maintenance and operations functions of transportation agencies. This is especially true for extreme weather events. [Meyer, Choate, and Rowan, 2012]

It seems likely that interest in, and concern about, the impacts of climate change and weather on transportation systems will continue to grow. Several transportation agencies and organizations are keeping track of developments with respect to analysis tools and strategies that can be used to understand such impacts. Readers are especially referred to the following websites that will likely provide the most up-to-date information on how climate change and extreme weather events can be addressed by the transportation planning process.

- American Association of State Highway and Transportation Officials: "Transportation and Climate Change Resource Center," http://climatechange.transportation.org/.
- Federal Highway Administration: "Climate Change," http://www.fhwa.dot.gov/environment/climate_change/.
- U.S. Global Change Research Program: http://www.globalchange.gov/.

F. Impacts on the Natural Environment

The effects of major transportation investments on natural areas can be diverse and numerous. They may involve impacts on wetlands, floodplains, ground and surface waters, wildlife, plants, and other natural resources. Federal laws and executive orders prescribe the requirements that apply to each of these impact areas. In addition, specific

Table 4-9. Potential Impacts of Climate Change and Extreme Weather on Roads and Highways

	Climatic/ Weather Change	Impact to Infrastructure	Impact to Operations/ Maintenance
Temperature	**Change in extreme maximum temperature**	• Premature deterioration of infrastructure; • Damage to roads from buckling and rutting; • Bridges subject to extra stresses through thermal expansion and increased movement.	• Safety concerns for highway workers limiting construction activities; • Thermal expansion of bridge joints, adversely affecting bridge operations and increasing maintenance costs; • Vehicle overheating and increased risk of tire blow-outs; • Rising transportation costs (increased need for refrigeration); • Materials and load restrictions can limit transportation operations; • Closure of roads because of increased wildfires
	Change in range of maximum and minimum temperatures	• Fewer days with snow and ice on roadways; • Reduced frost heave and road damage; • Structures will freeze later and thaw earlier with shorter freeze season lengths; • Increased freeze-thaw conditions creating frost heaves and potholes on road and bridge surfaces; • Permafrost thawing leads to increased slope instability, landslides and shoreline erosion damaging roads and bridges due to foundation settlement (bridges and large culverts are particularly sensitive to movement caused by thawing permafrost); • Hotter summers in Alaska lead to increased glacial melting and longer periods of high stream flows, causing both increased sediment in rivers and scouring of bridge supporting piers and abutments.	• Decrease in frozen precipitation would improve mobility and safety of travel through reduced winter hazards, reduce snow and ice removal costs, decrease need for winter road maintenance, result in less pollution from road salt, and decrease corrosion of infrastructure and vehicles; • Longer road construction season in colder locations; • Vehicle load restrictions in place on roads to minimize structural damage due to subsidence and the loss of bearing capacity during spring thaw period (restrictions likely to expand in areas with shorter winters but longer thaw seasons); • Roadways built on permafrost likely to be damaged due to lateral spreading and settlement of road embankments; • Shorter season for ice roads.
Precipitation	**Greater changes in precipitation levels**	• If more precipitation falls as rain rather than snow in winter and spring, there will be an increased risk of landslides, slope failures, and floods from the runoff, causing road washouts and closures as well as the need for road repair and reconstruction; • Increasing precipitation could lead to soil moisture levels becoming too high (structural integrity of roads, bridges, and tunnels could be compromised leading to accelerated deterioration); • Less rain available to dilute surface salt may cause steel reinforcing in concrete structures to corrode; • Road embankments at risk of subsidence/heave.	• Regions with more precipitation could see increased weather-related accidents, delays, and traffic disruptions (loss of life and property, increased safety risks, increased risks of hazardous cargo accidents); • Closure of roadways and underground tunnels due to flooding and mudslides in areas deforested by wildfires; • Increased wildfires during droughts could threaten roads directly, or cause road closures due to fire threat or reduced visibility.

(*continued*)

Table 4-9. (*Continued*)

	Climatic/ Weather Change	Impact to Infrastructure	Impact to Operations/ Maintenance
	Increased intense precipitation, other changes in storm intensity (except hurricanes)	• Heavy winter rain with accompanying mudslides can damage roads (washouts and undercutting) which could lead to permanent road closures; • Heavy precipitation and increased runoff are likely to cause significant flood damage to tunnels, culverts, roads in or near flood zones, and coastal highways; • Bridges are more prone to extreme wind events and scouring from higher stream runoff; • Bridges, signs, overhead cables, tall structures at risk from increased wind speeds.	• The number of road closures due to flooding and washouts will rise; • Severe erosion at road construction project sites as heavy rain events take place more frequently; road construction activities will be disrupted; • Increase in weather-related highway accidents, delays, and traffic disruptions; • Increase in landslides, closures or major disruptions of roads, emergency evacuations and travel delays; • Increased wind speeds could result in loss of visibility from drifting snow, loss of vehicle stability/ maneuverability, lane obstruction (debris), and treatment chemical dispersion; • Lightning/electrical disturbance could disrupt transportation electronic infrastructure and signaling, pose risk to personnel, and delay maintenance activity.
Sea-level rise	**Sea-level rise**	• Higher sea levels and storm surges will erode coastal road base and undermine bridge supports; • Temporary and permanent flooding of roads and tunnels due to rising sea levels; • Encroachment of saltwater leading to accelerated degradation of tunnels (reduced life expectancy, increased maintenance costs and potential for structural failure during extreme events); • Loss of coastal wetlands and barrier islands will lead to further coastal erosion due to the loss of natural protection from wave action.	• Coastal road flooding and damage resulting from sea-level rise and storm surge; • Underground tunnels and other low-lying infrastructure will experience more frequent and severe flooding; • Increase in number of road accidents, evacuation route delays, and stranded motorists.
Hurricanes	**Increased hurricane intensity**	• Stronger hurricanes with longer periods of intense precipitation, higher wind speeds, and higher storm surge and waves are projected to increase; • Increased infrastructure damage and failure (highway and bridge decks being displaced).	• More frequent flooding of coastal roads; • More transportation interruptions (storm debris on roads can damage infrastructure and interrupt travel and shipments of goods); • More coastal evacuations.

Source: Meyer et al., 2014

agencies have been given responsibilities for protecting these resources. Analysis and coordination requirements are summarized in this section.

In a planning study, a generic process consisting of four steps is recommended for the analysis of natural areas.

1) Identify the location of natural areas (for example, floodplains, wetlands, wildlife or plant habitat, coastal zone, natural gas field, aquifer recharge areas) that may be affected by one or more of the strategies. In many instances, generalized boundaries of natural areas, particularly in metropolitan areas, have been mapped by responsible state and federal agencies at a level of detail sufficient for a planning study, and it is usually a simple matter to determine if the strategies pass through or close to them.
2) Identify the functions of the potentially affected natural areas. Functions may include flood control, aquifer recharge, species habitat, recreation, spawning areas, pollution abatement, and visual relief.
3) Determine the likely effect of the strategies on the functions of these areas.
4) Evaluate potential mitigation options if substantial effects are expected.

The impacts of transportation strategies on natural areas depend on the ecological functions of those areas. For example, the use of an existing transportation right-of-way through a wetland may not affect its functions. By contrast, filling in a wetland could have a major adverse impact on its ability to support its functions and values.

Wetlands are lowland areas that are inundated or saturated by surface or ground water at a frequency that, under normal circumstances, supports a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. One of their functions is that they are highly productive areas that provide habitat for many species of plants, fish, and waterfowl. Executive Order 11990, "Protection of Wetlands," requires federal agencies to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative.

For any transportation investment that may affect a wetlands area, DOT Order 5660.1A of August 24, 1978, "Preservation of the Nation's Wetlands," requires that an analysis be performed. Activities both upstream and downstream can affect wetland areas and should be studied for possible impacts. FWS, the Army Corps of Engineers, and state natural resources agencies should be contacted as soon as it is suspected that any strategies may affect a wetlands area.

The planning study should include an assessment of the effects on wetlands and associated wildlife resulting from both the construction and operation of the options under the study. It should also include potential measures to minimize possible adverse impacts and avoid, to the fullest extent possible, drainage, filling, or other disturbance of wetlands and the water resources supplying them. The hydrological resources; fish and wildlife; and recreational, scientific, and cultural uses of wetlands should be considered. Strategies that avoid new construction in wetlands should be studied, giving consideration to environmental and economic factors. If the preferred strategy requires new construction in wetlands, the analysis should demonstrate that there are likely no practicable alternatives to the use of the wetlands, and that all practicable measures to minimize harm will be considered. A specific finding attesting to these criteria must be included in a formal NEPA environmental document. This analysis should occur early in the planning process.

U.S. Executive Order 11988, "Floodplain Management," places special importance on preservation of floodplains, directing federal agencies to avoid conducting, allowing, or supporting actions on a floodplain. Maps of the Federal Insurance Administration, a branch of the Federal Emergency Management Agency (FEMA), should be consulted to determine if the proposed strategies are located within the 100-year floodplain. Flood insurance rate maps (FIRMs) are available for review at local zoning or planning commission offices or city halls. Regional FEMA offices can be contacted for assistance, but they do not maintain these maps. If a FIRM is not available for a particular area, a flood-hazard boundary map should be reviewed to get an indication of whether the strategies are clearly out of the floodplain or whether they may be located in a flood-prone area.

If any of the strategies is located within a floodplain, an initial analysis should be included in the planning study. The analysis should discuss any risk to, or resulting from, the strategies; the impacts on natural and beneficial floodplain values; the degree to which the strategies provide direct or indirect support for development in the floodplain; and potential measures to minimize harm or to restore or preserve the natural and beneficial floodplain values likely affected by the strategies.

During the planning study, the floodplain analysis should examine whether any of the strategies entail a significant encroachment. The planning document should explain that a floodplain finding would be required in the NEPA or detailed design processes if any of these strategies are chosen later in the project development process. It should also discuss any potential measures to avoid any significant encroachments or any support of incompatible floodplain development.

G. Endangered and Threatened Species

Section 7 of the U.S. Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.) requires FHWA/FTA, in consultation with FWS or the National Marine Fisheries Service (NMFS), ensure that projects funded do not jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. During study initiation/scoping, FWS or NMFS, and appropriate state agencies, should be contacted for information regarding any species listed (or proposed) as endangered or threatened that may be present in the study area. When a state has a third category of protected species, those that are considered rare, these too must be taken into account. Generally, marine species are under the jurisdiction of NMFS; all other species are under the jurisdiction of FWS. The lists of endangered and threatened wildlife and plants for FWS are contained in 50 CFR 17.11 and 17.12, with the designated critical habitats found in 50 CFR 17.95 and 17.96, and for NMFS, in 50 CFR 222.23(a) and 227.4.

The Section 7 regulation (50 CFR Part 402) sets forth a phased process that may involve early informal or formal consultation, depending on whether a proposed strategy may affect a listed species. Informal consultation includes all contacts between FHWA/FTA, the planning study, and FWS or NMFS that take place prior to formal consultation, including the initial request for information on endangered species in the study area. If it is determined during the planning that no listed species or critical habitat is in the study area, no further consultation is required. If listed or proposed species or critical habitat may occur within the project area, a biological assessment (as defined in the Section 7 regulations) should be conducted during the NEPA process to identify probable locations of listed species and determine the probable impacts of the project on the species and its habitat. [Lederman and Wachs, 2014]

VII. CONSTRUCTION IMPACTS

Earlier sections of this chapter dealt with the long-term effects of proposed transportation investment strategies and their operation. Construction impacts differ from long-term impacts in duration, type, and level of detail. Further, the intensity of the construction impacts may be at the other end of the spectrum from long-term impacts. For example, the immediate construction impacts of a subway line are usually quite severe, but over the long term, the system's operation usually has negligible adverse impacts and many beneficial effects. During construction, air quality is likely to be degraded because of impaired traffic flows and the operation of construction equipment, which could increase particulates (dust). At the same time, air quality could actually improve in the region during subway system operation because of improved traffic flow and reduced congestion as some travelers choose mass transit instead of driving.

A systems-level planning study will typically discuss the construction impacts in less detail than the long-term impacts. Detailed discussion of the construction impacts is usually contained in the formal NEPA environmental document, which presents the results of subsequent project development work on the preferred alternative.

Construction impacts can be divided into direct and indirect impacts. Direct impacts result from the construction itself and include air and noise pollution and temporary use of land, streets, and sidewalks. Indirect impacts during construction usually result from temporary land takings and include traffic congestion and delays, impaired access to buildings and civic or recreational spaces, and so forth. In many cases, especially when construction requires the closure of major streets, the indirect impacts can be quite substantial, such as reduced access to retail businesses. Although a detailed discussion of the construction impacts is not possible until an alternative is selected during NEPA analysis and preliminary engineering is performed, major impacts for the various strategies can generally be identified and should be noted in the planning study report. The differences among strategies should be highlighted.

The earlier that mitigation of potential construction impacts is considered, the easier it is to incorporate them into the planning and project development process. During the planning study, potential mitigation strategies should be identified, and all feasible options should be mentioned, at least generally. Although there are usually ways to minimize negative impacts during construction, if the construction impacts are severe, the study should mention the possibility of not building the project. Potential mitigation strategies include alternative construction techniques, use of alternative construction equipment, and scheduling to minimize impacts. This might include considering restrictions on construction activity at certain times of the day or even the year, such as during the Christmas shopping season or fish spawning season.

VIII. CONSIDERING MITIGATION STRATEGIES DURING THE SYSTEMS PLANNING PROCESS

The various social, economic, and environmental studies conducted during a planning study often reveal potential adverse impacts that will need to be mitigated. However, the analyses performed during a planning study are not normally detailed enough to evaluate fully the various potential mitigation options. It is not advisable, therefore, to make commitments to any specific mitigation measures until more is known about their likely effectiveness. At the systems planning level, it is sufficient simply to identify potential impact areas, potential mitigation options (with order of magnitude costs) for further study during preliminary engineering, and the views of the resource agencies and the public.

The supporting technical document (results report) on social, economic, and environmental impacts, as well as the planning study report, should clearly define those potential impacts that are expected to require mitigation. In addition, they should contain estimates of the range of costs that may be necessary to mitigate them. These costs are then factored into the cost estimate for the strategy. The information developed here will be important to policy makers who will have to make trade-offs in the selection of a preferred alternative during the subsequent NEPA analysis.

A. Documentation of Environmental Considerations during the Systems Planning Process

Documenting environmental factors considered during systems planning is key to successfully linking systems planning and project development, because documentation of the results is essential to avoid the need to restudy the same issues during subsequent NEPA efforts. While there may be no formal requirements for preparing methodology and technical results reports for social, economic, and environmental impacts during systems planning, such documents are often very useful in preparing the groundwork for subsequent project development efforts. A methodology report provides a means for gaining concurrence among the study participants—particularly the environmental resource agencies—on the key issues to be addressed; the level of detail of the analysis; and the methods, criteria, and data to be used. The results report similarly provides a means to document the details of the analysis beyond the summary level of presentation in the planning study report. The presentation of the methods, data, and criteria used for the planning study, and the actual results and interpretation of the findings, are invaluable for the review agencies in later phases and will greatly aid in the review process and help in streamlining the project development process. [FHWA, 2002]

If a methodology report on social, economic, and environmental impact assessment is being prepared, it should identify the specific impacts to be considered and the particular parts of the study area where these impacts are expected to be of concern. It should also explain the methods and criteria for assessing the impacts. The following could be included, as appropriate, for each area of concern:

- An assessment of data availability and the need for further data collection, such as air quality and noise monitoring.
- A description of the monitoring program, including monitoring sites.
- Models and/or analytic methods to be used to estimate the impacts of each strategy and of each alternative during the NEPA analysis, as well as the variables to be considered in the analysis.
- Key assumptions.
- A list of agencies and outside experts who will be consulted as part of the analysis.

See Amekudzi and Meyer [2005] for information on how environmental issues and factors can be considered more fully during transportation planning.

IX. SUMMARY

Transportation planners consider many different issues and public concerns in the course of a typical planning study. The impact of transportation on the human and natural environment is one of the most important issues from the perspectives of legal and regulatory responsibility and public interest. Many countries have a long legislative history of environmental protection, and major transportation projects cannot be planned and designed without seriously taking into account likely environmental impacts and how these can be avoided or mitigated. Increasingly, environmental concerns have taken on a broader context, with many groups—including transportation agencies—discussing things such as environmental stewardship and sustainability.

This chapter has provided an overview of the environmental factors that can be considered in the transportation planning process. At the systems planning level, much of this consideration will be at a fairly aggregate level, primarily because many of the specific environmental impacts will not be known until projects are in the preliminary design phase. As a project proceeds into project development, depending on the type of project and funding sponsors, environmental analysis and assessment requirements become much more specific. For example, what are the likely impacts on nearby community facilities, historic properties, wetlands, water quality, noise, and the like? As was described in this chapter, each of these impacts has its own requirements for environmental analysis and mitigation strategies. A primary intent of considering environmental factors in the transportation planning process is to identify what types of impacts might be considered later in the project development process, and what type of planning information would be useful in the project-specific environmental analysis.

Environmental concerns have been part of the transportation planning process for decades. It is highly likely that they will continue to be a major consideration in future transportation planning as well. In addition, new environmentally related issues, such as sustainability or climate change, will likely be added to the many other factors that transportation planners will be considering in decades to come.

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Transportation Finance and Funding[1]

I. INTRODUCTION

Traditionally, transportation plans did not include a discussion of the financial strategies or funding needed to implement the recommendations resulting from the study—this topic was considered to be outside of the planning process. Beginning in the 1970s, however, and especially with the requirement in the United States for metropolitan planning organizations (MPOs) to produce a transportation improvement program (TIP), transportation plans began to devote more attention to the different sources of funding needed for program implementation. With a declining trend of federal investment in transportation, states and metropolitan areas had to rely more on non-federal sources of funding, including public/private partnerships and contributions from a variety of sources. In addition, as maintenance budgets, which are wholly provided by state and local transportation agencies, increased due to a more extensive and aging infrastructure, state and local dollars were being stretched to meet both the capital and maintenance needs of the transportation system. Today, transportation planning is very much concerned with transportation finance and funding sources. Finding the means to invest in new transportation capacity while operating and maintaining the existing system is arguably the greatest challenge facing the transportation profession.

An important distinction needs to be made between finance and funding. Financial strategies are the mechanisms through which money is made available for transportation investment. Funding is the source of dollars used in the financial strategy. Thus, for example, debt financing or the borrowing of funds from the municipal bond market is a financial strategy. Gas tax revenues or toll receipts are the usual funding sources needed to repay the loan.

For many years, motor vehicle fuel use taxes have been the backbone of highway finance in the United States. For example, federal and state gas taxes were the primary sources of funding for building the interstate highway system and the state road networks. However, the U.S. environment for transportation finance began to change in the 1970s. For highways, transportation officials realized that gas tax revenues would not likely provide the level of funding necessary to expand and maintain the highway network. Many began to explore public/private partnerships, which promoted private investment in transportation projects. Others looked to explore other options for financing capital investment programs that became known as "innovative transportation finance."

For transit, the level of funding needed for the capital expansion of rail facilities was beyond the financial capability of most municipalities, and thus many turned to the federal government for support. In response, the federal government developed the "New Starts" program, whereby funding was provided for a portion of the capital cost of new projects. For the local match of these federal grants and to support locally supported services, transit agencies turned to sales tax revenues and bonding.

Today, states, metropolitan areas, and municipalities use a variety of financing strategies and funding sources to support both the capital investment needs and operations/maintenance costs of their transportation systems.

The next section describes some key finance and funding concepts and terms that are common across most transportation planning efforts. The chapter then introduces both traditional sources of transportation funding and some that are fairly new. This is followed by a discussion of finance strategies and the evolving nature of both public and private investments in the transportation system. An important step in the planning process from a financial strategy perspective is identifying future revenues as part of the capital investment program, as discussed in the following section. The final two sections discuss the importance of environmental justice analysis in developing an investment program, followed by a discussion of the likely finance and funding challenges facing transportation investment in future years.

[1] This chapter was written by Michael D. Meyer, WSP/Parsons Brinckerhoff.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

II. KEY CONCEPTS AND TERMS

Several key concepts and terms are important in understanding the substance and process of transportation investment programming and financial analysis. In some cases, these terms are specific to transportation, while in others they are generic terms used in all sectors. [BTS, 2014]

- *Capital Expenditure.* Capital expenditures include outlays for new equipment and infrastructure to improve or enhance capacity and quality with improvements lasting more than one year.
- *Discretionary Grants.* Funding grants from a government agency where the selection is at the discretion of the funding agency, usually based on proposals that describe the project's level of impact and benefit.
- *Enabling Legislation.* In the United States, state governments hold constitutional power to create lower forms of government. Every city, town, special-purpose authority, and even the federal government itself, is the creation of the states. For example, if a metropolitan area or state DOT wants to hold a referendum on a sales tax to be dedicated to transportation investment, it must first be "enabled" to do so by a state law.
- *Financial (or Fiscal) Constraint.* Limiting the amount of investment in a long-range plan or transportation improvement program (TIP) to the level of funding reasonably expected over the life of the document, usually 20 to 25 years for plans and 4 years for TIPs.
- *Formula Funds.* Funding allocated to jurisdictions based on a legislatively defined formula. Formula funds can be targeted at capital investment, rehabilitation, and operational needs.
- *Impact Fees.* Fees charged to developers related to the infrastructure improvements necessary for a proposed development and related to the expected trip generation. Such fees are usually defined by local governments, and reflect the number of trips generated per development size (for example, per acre) or density (for example, per dwelling unit).
- *Operation and Maintenance Expenditure*. Recurring payments to cover the cost of administration, operation, and normal maintenance and repair of transportation infrastructure and facilities.
- *Public/Private Partnerships.* Formal or informal relationships among government agencies and private entities that spell out the responsibilities of each in financing a transportation project.
- *Regionally Significant Project.* A project serving regional transportation needs of significant scale to be typically included in transportation demand modeling for air-quality emissions analysis and identified individually in the program document.
- *Risk Analysis.* A systematic process to understand the nature of and deduce the level of risk associated with a project. It provides the basis for risk evaluation and decisions about how risks are treated in a project proposal, and feeds into the determination of value for money on a project being considered as a public/private partnership procurement.
- *Transportation Improvement Program (TIP).* A capital program listing the committed investments in a metropolitan area (or a STIP for a state) over a specified period of time, usually 4 or 5 years. In other countries, this is often called a capital improvement plan or a capital investment plan.
- *TIP Amendment.* Any change to a regionally significant project, including an addition or deletion; major changes to cost, initiation dates, or design concepts or scopes; a major change to a program fund amount; and the addition of a year into the S/TIP.
- *Trust Fund.* An account established by law in a treasury department to hold tax receipts and earmarked for defined projects and/or programs.
- *Unconstrained Needs.* The level of funding needed for transportation improvements and associated operations, maintenance, and rehabilitation that require funding above and beyond assumed revenues. These needs are identified through the planning process.
- *User Charge or Fee.* A cost assigned to users of a good or service reflecting the use of that service. User charges, either direct or indirect, are collected on a periodic or occasional basis in the form of license fees and

excises, and usually paid at the time infrastructure services are consumed, as with the payment of fuel taxes and tolls.

- *Year-of-Expenditure (YOE) Revenues or Costs.* Dollar values that have been escalated to the year that dollars are expended or generated, based on escalation factors appropriate for specific revenue sources. These estimates are needed to make sure that future revenues are adequate to cover expected costs when they occur.

III. SOURCES OF TRANSPORTATION FUNDING

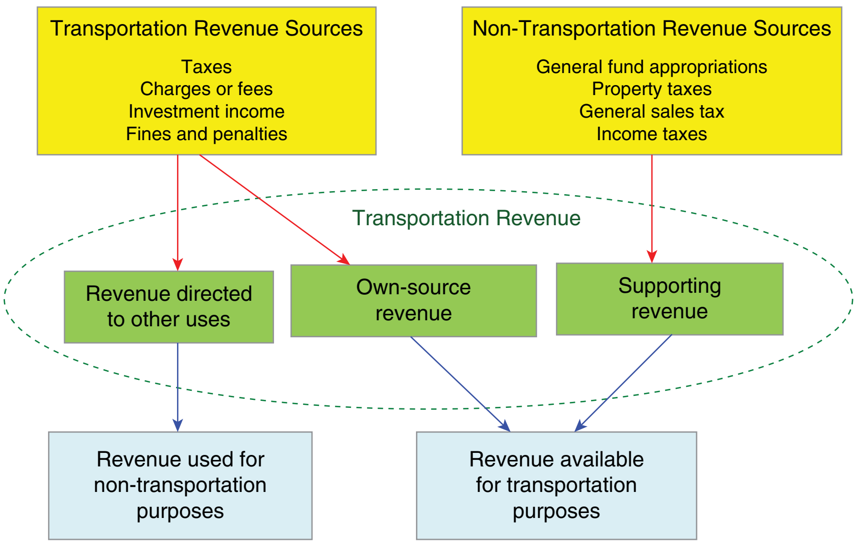
Transportation funding comes from many different sources. Revenues can come from a federal/national government, state/provincial government, local, and municipal governments, private funds, and a whole host of other agencies and organizations that choose to invest in the transportation system. For example, the Puget Sound Regional Council (PSRC), the metropolitan planning organization (MPO) for the Seattle metropolitan area, lists 31 different sources of funding for the region's transportation system. [PSRC, undated] The PSRC's long-range transportation plan also lays out the challenge facing many metropolitan areas today:

> *"It is critically important that the region deliberately moves forward in developing new ways to pay for transportation projects and programs. Limited public financial capacity for transportation infrastructure investment has encouraged transportation professionals and regional policy makers to discuss the potential benefits associated with reforming the way society pays for and finances transportation. The future of the fuel tax as a road finance approach is limited. Advances in vehicle technology and the erosion of purchasing power due to inflation have demonstrated the need to find other ways to pay for transportation investments. Business leaders, national experts, and state legislators are all coming to similar conclusions—traditional tax-based financing measures will not, by themselves, be sufficient to meet the region's transportation investment needs."*
>
> *[PSRC, 2014]*

Figure 5-1 shows in general terms the types of revenue sources available for transportation purposes. As shown, revenue can come from dedicated transportation sources such as gas taxes or fees and nontransportation sources such as property and sales taxes. Figure 5-2 shows typical transportation expenditures.

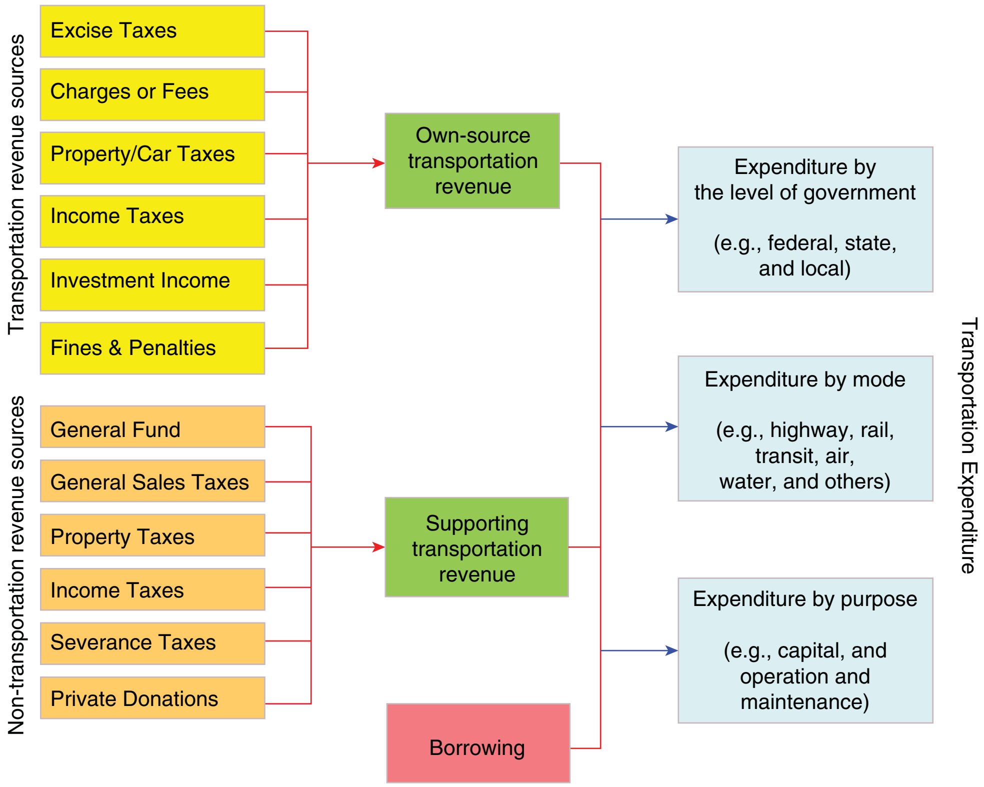
It is noteworthy that the United States is one of the few nations with a revenue source dedicated to transportation in the form of the motor fuel tax. In other countries, transportation investment is part of the general budget for the country, state/province, or municipality and thus competes with other demands for budgetary resources. Experience

Figure 5-1. Sources of Transportation Revenues, United States



Source: BTS, 2014

Figure 5-2. Typical Transportation Expenditures, United States



Source: BTS, 2014

has shown that transportation investment in such an environment often becomes embroiled in the politics of the budgetary process, more so than usual.

The following paragraphs describe some of the major sources of transportation funds used today in the United States as part of a typical investment program.

A. Motor Fuel and Excise Taxes

In the United States, motor fuel taxes are the primary source of funds for transportation investment. This falls within a more general category of user fees, in that those who use the system (for example, by using the highway network) pay for its use (for example, through motor fuel taxes). The use of motor fuel taxes began in earnest when the interstate highway system was approved in the mid-1950s. Two federal laws were passed, one to authorize the construction of an interstate highway system and the second to pay a federal share of this system with revenues collected from a federal gas tax. The gas tax receipts were to be deposited in the U.S. Treasury in a special account called the Highway Trust Fund, and these funds were to be dedicated to the construction of the system on a partial state and partial federal cost distribution. The maintenance and operations of that system were the responsibility of the states. Although a few states had used motor fuel taxes for road investment prior to the federal legislation, many more now established their own state highway trust funds for the deposit of their state gas tax receipts. In most cases, the state constitution limited the use of these trust funds to highway construction; the funds could not be used for investment in other modes. Some states have changed these restrictions, and others have developed yet another trust fund for investment in any mode of transportation.

Some states have also established other restrictions on the use of their trust fund dollars. For example, the Michigan Transportation Fund (MTF) is the primary means of distributing state transportation revenues in Michigan, with the two main sources of MTF funding being state motor fuel taxes and vehicle registration fees. [MDOT, 2014] By law, after miscellaneous transfers and deductions of funds, the funds that remain are distributed to the Michigan DOT (39.1 percent), counties (39.1 percent), and cities and villages (21.8 percent). The state constitution also provides that not more than 10 percent of motor fuel taxes and vehicle registration fees may be used for public transportation programs and must be placed in what is called the Comprehensive Transportation Fund (CTF). For the CTF, motor

Table 5-1. Federal Motor Fuel Tax Rates, 2015, United States			
		Distribution of Tax	
Type of Excise Tax	**Tax Rate (cents)**	**Highway Account**	**Mass Transit Account**
Gasoline[1]	18.3 per gallon	84%	16%
Diesel[1]	24.3 per gallon	88%	12%
Gasohol[1,2]	18.3 per gallon	84%	16%
Liquefied petroleum gas	13.6 per gallon	84%	16%
Liquefied natural gas	11.9 per gallon	84%	16%
M85 (from natural gas)[1]	9.15 per gallon	84%	16%
Compressed natural gas	48.54 per thousand cubic feet	80%	20%

[1]In addition to these rates, a 0.1-cent per gallon tax is levied and deposited in the Leaking Underground Storage Tank Trust Fund.

[2]Other rates apply to gasohol blends containing less than 10 percent ethanol or blends made with methanol.

Source: AASHTO, 2015c, Reprinted with permission of AASHTO.

vehicle–related sales tax revenue is also deposited in the trust fund, but not more than 25 percent of the state general sales tax on motor vehicle–related products can be used for comprehensive transportation purposes. This is an example of how different sources of funding—for example, motor fuel taxes, registration taxes, and sales taxes—can be combined legislatively into programmatic support for transportation investment with legislatively imposed constraints on their use.

Table 5-1 shows the current federal motor fuel tax structure in the United States for different fuel types. The website of the American Association of State Highway and Transportation Officials (AASHTO) [2015a] lists all of the state gas taxes.

Federal and state gas tax revenues support different funding programs where the funds are dispensed to achieve specific program goals, such as safety, economic development, congestion relief, air quality improvement, and the like. There are too many of these programs to list here, but the U.S. DOT websites and most state transportation improvement programs list the different programs that are supported with motor vehicle–related taxes and fees. See [American Road and Transportation Builders Association, undated; North Central Texas Council of Governments (NCTCOG), 2013; and National Surface Transportation Infrastructure Financing Commission, 2009], for descriptions of federal funding programs.

B. Vehicle Miles Traveled (VMT) Fees or Mileage-Based User Fees

One of the deficiencies of motor fuel taxes (from a transportation funding perspective) is that as vehicles become more fuel efficient or even operate without petroleum-based fuel (for example, electric vehicles), the consumption of motor fuel will decline, taking motor fuel tax revenue with it. However, at least in the foreseeable future, such vehicles will still need to use the highway infrastructure, thus contributing to the rehabilitation and maintenance needs of the system. One way of ensuring every motorist pays his or her fair share is to charge vehicles for the use of the highway network, most often defined as a VMT fee. As noted by FHWA, "as opposed to tolls, which are facility-specific and not necessarily levied strictly on a per-mile basis, these fees are based on the distance driven on a defined network of roadways." [FHWA, undated] The general idea is that global positioning system (GPS) technology or some other means would be used to identify how far a vehicle has been driven since the last fuel or energy "fill up." The owner of the vehicle would then be charged for the level of use of the road network. This concept has been piloted in Oregon and in other countries, especially for heavy-duty trucks.

One of the key issues with adopting this approach has been the perception by some that it relies too much on technologies that monitor travel, thus potentially infringing on personal freedom. However, with vehicles becoming more fuel efficient while at the same time the demand for transportation funding increases, it seems likely that some form of distance-based tax or fee will be one of the ways of raising the necessary investment dollars. The reader is referred to the FHWA website on innovative finance [FHWA, undated] and the Oregon DOT website ORe*GO*, http://www.myorego.org/. Agrawal et al. [2016] provide a good overview of public perceptions of vehicle miles traveled fees.

C. Tolls

Tolls are not new to the United States or to other countries. Even in colonial times, toll roads in the now United States were a very common way of supporting the expansion of the road network. In the mid-twentieth century, many states turned to toll roads (turnpikes) to fund the expansion of the long-distance road network in their state. However, with the advent of the interstate highway network in the mid-1950s, interest in toll roads faded. Over the past 20 years, toll roads have made a comeback simply because of the declining level of funding available to state DOTs to expand the highway network. [AASHTO, 2015b] In particular, highway-oriented public/private partnerships, discussed in the next section, depend on a source of funding to pay the concessionaire for the road capital outlays and operations/maintenance costs. In almost every case, the source of funding is toll revenues.

As of 2013, 42 states, the District of Columbia, and Puerto Rico had some form of tolling authorization or facility; 28 states and Puerto Rico had toll facilities operated by statewide entities; 14 states had toll facilities operated by regional entities; 20 states and Puerto Rico had privately operated toll facilities; and 9 states and the District of Columbia authorized tolling, but had no state or regional toll facilities. [FHWA, 2013]

Tolls have been used in many different ways over the past decade. For example, the concept of managed lanes has been implemented in many cities of the world, with the number of projects increasing in recent years, usually with electronic toll collection. The added element to managed lanes is that not only can electronic tolling raise revenues for the transportation agency, but the prices for use of the lane can be varied by time of day and vehicle occupancy to encourage alternative mode use or driving during less congested times. There are several different versions of the managed lane concept:

1. High-Occupancy Toll (HOT) Lanes

In this managed lane concept, single occupant vehicles can use the managed lane during peak periods for a price that often varies by the level of congestion in the lane. The more congested the lane, the higher the price. The driver is thus trading off faster travel times versus higher costs. A major criticism of this concept is that it favors those who can afford to pay the cost of a fast trip, leaving those who cannot relegated to the congested lanes. Studies have shown, however, that in numerous HOT lane operations, many of the users are in fact lower-income drivers who want to arrive at work or some other destination on time. Many metropolitan areas such as Atlanta, Dallas, San Francisco, Seattle, and Washington, DC, are investing heavily in managed lane capacity for their freeway system.

Some examples of HOT lane projects in the United States include:

- SR 91 Express Lanes (Orange County, California).
- I-15 FasTrak (San Diego, California).
- Katy I-10 QuickRide (Houston, Texas).
- I-25 HOT Lanes (Denver, Colorado).
- I-394 MNPASS (Minneapolis, Minnesota).
- I-85 (I-75 under construction) (Atlanta, Georgia).
- SR 167 (Seattle, Washington).

One of the key decisions with high-occupancy toll lanes is whether to use a flat rate for the lane use charge, or a dynamic pricing scheme whereby the price varies by usage. Table 5-2 shows an analysis from Seattle on how revenues and speeds would vary with different pricing schemes. Note that the biggest difference is total revenue and revenue generated per vehicle miles traveled (VMT).

2. Express Toll Lanes

As with HOT lanes, express toll lanes are situated next to regular highway lanes. The difference from the HOT lane concept is that with an express toll lane all personal automobiles using them pay a toll—there are no exceptions made for high-occupancy vehicles (HOV), thus reducing the revenue loss potential due to violations. However, transit vehicles and/or registered vanpools would usually be allowed to operate for free. While these lanes typically represent added highway capacity, existing toll-free lanes also could be converted to toll lanes. Express toll lanes also could be

Table 5-2. Estimated HOT Lane Performance under Dynamic and Static Pricing Schemes, Seattle				
Scheme	**Performance Category**	**6:00 A.M.**	**7:00 A.M.**	**8:00 A.M.**
Dynamic	Total revenue per hour	$1,123,521	$821,921	$518,524
	Revenue per VMT	$6.54	$4.49	$3.36
	Total travel time cost per hour	$7,255,610	$5,596,997	$3,831,644
	Travel time cost per VMT	$3.77	$2.71	$1.97
	Average HOT lane speed (mph)	60.01	60.01	60.08
	Average general purpose lane speed (mph)	38.4	34.3	37.8
Static	Total revenue per hour	$368,092	$503,497	$311,984
	Revenue per VMT	$2.52	$3.22	$2.11
	Travel time cost per hour	$2,993,879	$3,813,598	$2,680,838
	Travel time cost per VMT	$1.55	$1.85	$1.38
	Average HOT lane speed (mph)	60.14	60.08	60.14
	Average general purpose lane speed (mph)	39.3	35.1	38.9

Source: PSRC, 2014

located adjacent to traditional toll roads, but employ variable pricing (based on time of day and/or congestion levels) to maintain free-flowing traffic.

3. Truck-Only Toll (TOT) Lanes

Truck-only toll (TOT) lanes are similar in concept to HOT lanes, but are dedicated to commercial vehicles. Most proposals have the lanes next to regular freeway lanes, but separated with some form of barrier. TOT lanes have been studied in Los Angeles on two freeways heavily utilized by trucks accessing the Ports of Los Angeles and Long Beach. The preliminary Los Angeles region studies found that urban TOT lane facilities might not be desirable because of the predominance of short truck trips, limited travel time savings during off-peak periods, and significant construction costs and geometric constraints related to adding lanes in an urban environment. In addition, one could expect opposition from the trucking industry, whose position is often that they have already paid for the roads through gas taxes (see Table 5-1). The often large costs associated with providing such a lane, especially in an urban environment, are also financially challenging to most DOTs. A public/private financing partnership for such a lane only works if all trucks use the lane, thus possibly encountering industry opposition.

D. Cordon or Area Pricing, and Parking Charges

Cordon or area pricing is a relatively new concept, although one of the earliest applications in Singapore started in the mid-1970s. The basic concept is that vehicles are charged a fee to enter a highly congested area. The concept was implemented in central London in 2003 where a flat toll of £8 is charged to enter or drive within the tolled area during normal business hours. Tolls could be paid over the phone or via the internet. Enforcement occurs via numerous cameras located throughout the zone. The success of the London scheme has been attributed to improvements made to the public transportation system prior to implementation, where the revenues generated by the pricing scheme have gone to support this new service. In other words, a reasonable alternative to auto use had to be in place before the pricing scheme occurred.

A similar concept was implemented in Stockholm, and smaller implementations have been tried in Durham (UK) and Rome. Cities that are considering some form of pricing to access targeted zones during congested hours include Los Angeles, San Francisco, Bogota (Colombia), and Santiago (Chile). New York City was considering a congestion charging scheme as part of a federal demonstration program, but political considerations stopped the initiative before it could start.

Parking pricing is another policy tool that can help reduce road congestion. It is generally much easier to implement a parking pricing strategy than to apply area-wide toll strategies, but parking pricing faces political challenges common to most proposals that increase the cost of travel. In addition, pricing may only influence the driving behavior of a small group of employees, in that many employers subsidize employee parking. Other aspects that need to be considered are the likely effects of parking pricing on business attractiveness and the cost equity implications to those using the parking spaces.

Parking pricing strategies have been implemented in the following cities to discourage parking in central business districts (CBDs):

- *Boston*—A parking freeze in downtown Boston and two other neighborhoods limits the growth in the supply of off-street parking. A Resident Permit Parking Program restricts unmetered, on-street parking to CBD residents.
- *California Cities in Air Quality Nonattainment Areas*—A parking "cash out" program provides employees the option of receiving either a free parking space or a cash payment equal to the value of that space.
- *Canada, Sweden, and Australia*—Employer-provided parking is treated as a taxable fringe benefit (this applies to all cities in these countries).
- *San Francisco*—A 25 percent ad valorem tax has been imposed on all commercial, off-street, and nonresidential parking transactions.
- *Washington, DC*—Government employees are required to pay for parking that formerly was free.

See chapter 14 on travel demand management for other examples of programs designed to influence demand, and to raise funds in the process.

E. Value Capture

This funding mechanism takes advantage of increasing land values that often accompany new transportation accessibility to land, whether highways or transit. In other words, those who benefit from public investment can be charged for these benefits (a similar argument is used for the motor fuel tax). The term "value capture" means recouping some of this value to help pay for the transportation (or other) investments necessary as a precursor to the development. Vadali [2014] examined the effectiveness of many different ways of doing this and began by identifying the following tools.

- *Impact Fees*—One-time charges collected by local governments from developers to finance new infrastructure and services associated with the new development. Usually codified in local ordinances that link the level of development impact (for example, number of dwelling units or square feet) to the size of fee.
- *Special Assessment District*—An additional fee assessed on properties near a new highway or transit facility that is expected to benefit from such proximity. Typically, a vote of the district is needed for fees to be applied to an improvement. In addition, the revenues raised must be targeted to improvements in the district.
- *Sales Tax District*—Similar in concept to a special assessment district, the sales tax district requires those benefiting from a transportation investment to pay a limited sales tax instead of a property tax.
- *Negotiated Exaction*—A negotiated, one-time charge similar to impact fees, but not determined a priori by a formula or impact ratios. Exactions can take the form of in-kind contributions to local road networks, parks, or other public goods as a condition of development approval, or they can be requested in the form of in-lieu fees.
- *Air Rights*—A form of joint development in which development rights above or below highway or transit facilities are used to generate and capture an incremental increase in land value.
- *Joint Development*—Development of a transit facility and adjacent private real estate whereby a private partner either provides the facility or makes a financial contribution to offset its construction costs.
- *Land Value Tax*—A tax imposed on the value of land benefiting from transportation infrastructure.
- *Tax Increment Financing*—A mechanism allocating any increase in total property tax revenues accruing from new access to improvements in a designated district.
- *Transportation Utility Fees*—Utility fees assessed on the basis of characteristics of travel demand, such as traffic volumes.

Table 5-3. Applicability of Value Capture Mechanisms to Transportation		
Tool	**Conceptual Basis and Benefit or Levy**	**Basis Applicable Purpose**
Impact Fees	• New development to pay for facility use. • One-time developer charges when permits are issued. • Levied before and after an improvement.	Cost recovery
Special Assessment District	• Local benefit accruing to all property due to transport access. • Annually levied property owner charges in the service area before and after an improvement.	Capture of project expansion benefits
Sales Tax District	• Local benefit accruing to all property due to transport access. • Annually levied sales in the service area before and after an improvement.	Capture of project expansion benefits
Negotiated Exaction	• One-time ad hoc developer agreements before or after the improvement (discontinuous spot treatment).	Capturing opportunity for value creation and cost recovery
Air Rights	• Air space utilization above, below, under, and nearby/adjacent highway right-of-way for public and private benefit via transfer of rights and joint development. • One-time developer-related opportunity typically after an improvement (on-site developments—discontinuous spot treatment).	Capturing opportunity for value creation and cost sharing and revenue sharing with private sector
Joint Development	• Public and private partnership in relation to land (works with air rights or by itself). • One-time developer-related opportunity typically after an improvement (on- and off-site developments).	Capturing opportunity for value creation and cost sharing and revenue sharing with private sector
Land Value Tax	• Land value capitalization due to access, incentivize development. • Annually levied property owner changes before and after an improvement—taxes on value of land and a separate tax on value of buildings.	Capture of project expansion benefits
Tax Increment Financing	• Increment in property values due to capitalization of access and amenity values. Annually levied property owner charges before and after an improvement.	Capture of project expansion benefits
Transportation Utility Fees	• Public good nature of transport. Annually levied property owner charges before and after an improvement. This charge has been used only for defraying operating expenses as opposed to capital costs of projects.	Cost recovery—operating and maintenance costs

Source: Vadali, 2014, Reproduced with permission of the Transportation Research Board.

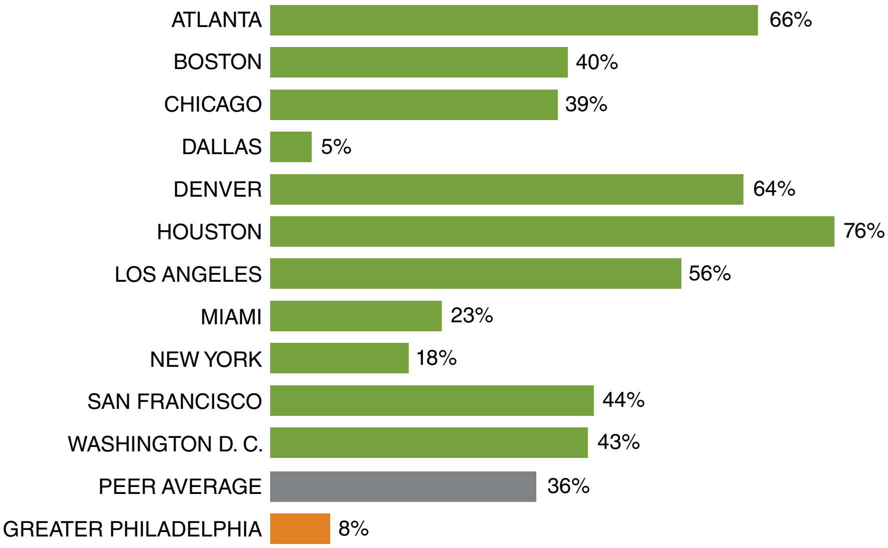
Table 5-3 shows the conceptual basis for each of these tools and the reason for its application.

Each of these tools has received considerable attention in the literature. It is beyond the scope of this chapter to repeat that analysis here. For useful references, see American Planning Association, 2015; Dye and Merriman, 2006; MacCleery and Peterson, 2012; Municipal Services Research Center (MSRC), 2015; Reconnecting America, 2015; Thomas, 2014; and Vadali, 2014.

F. Other Taxes

A variety of other taxes are used to support transportation investment, especially at the local level. California is using a carbon-based tax to raise revenues for some transportation projects. Other common sources of transportation-related

Figure 5-3. Percent of Transit Capital Program Coming from Local Sources, Selected U.S. Cities



Source: DVRPC, 2013

tax revenues include: vehicle license/registration fees, weight fees/taxes, fines and forfeitures, property leases and air rights, advertising (for transit, mainly), and development agreements. Figure 5-3 shows how important local revenues can be for transportation investment. This figure comes from the Delaware Valley Regional Planning Commission (DVRPC), the MPO for the Philadelphia metropolitan area, and was created to illustrate the disparity between Philadelphia's support for transit and peer areas. [DVRPC, 2013] As shown, local support for transit in many U.S. cities varies significantly across the peer systems, but in many it is a significant portion of total investment in the transit system.

Over the past two decades, many metropolitan areas and cities have come to rely on the generation of local tax revenues to support transportation investment. This reliance is a major difference from the 1960s and 1970s where federal and state funding was by far the major contributor to the investment program. [Goldman and Wachs, 2003] The sources for local funding for transportation include: local motor fuel taxes, local motor vehicle registration fees, local option sales taxes, local income/payroll/employer taxes, local severance taxes, value capture, tolls, and fares. [AASHTO, 2015d] Some of these funding sources have been described earlier and thus will not be repeated here. Sales tax revenues, however, deserve some attention.

Local Option Sales Tax—This tax has become a common strategy for raising funds for transportation. There are several reasons for this:

- A sales tax produces high revenue for a low marginal tax rate, although it is susceptible to retail sales declines during recessions.
- It has a favorable public perception because individuals of comparable means pay similar amounts of tax—despite its being regressive.
- It is considered fair from a modal perspective whereby, for example, bike/pedestrian and transit projects can be funded by users who pay the sales tax, which is not the case when it is funded with motor fuel tax revenues.
- Sales tax expenditures are a better reflection of ability to pay than is income or wealth.
- A sales tax is an attractive way to exact revenue from nonresident users of local transportation facilities. [Goldman and Wachs, 2003]

The importance of the sales tax for both transit capital and operations/maintenance support is shown in Table 5-4. The data are from the National Transit Database (NTD) and report the funding statistics as of 2009, the last year this type of data was collected by NTD. As shown, the sales tax is by far the largest contributor to transit capital and operations/maintenance revenues.

Table 5-4. Sales Tax Revenue Contributions to Transit Capital and Operations, United States, 2009		
Source	**Amount ($2009)**	
Capital Investments		**Percent of Capital**
Gas Tax	$38,017,00	1.5%
Income Tax	$15,775,000	0.7%
Property Tax	$135,782,000	5.9%
Sales Tax	$2,009,438,000	83.7%
Other	$201,796,000	8.2%
Total	$2,400,808,000	100%
Operations/Maintenance		**Percent of O&M**
Gas Tax	$158,956,000	2.4%
Income Tax	$81,238,000	1.2%
Property Tax	$717,386,000	10.7%
Sales Tax	$5,294,354,000	78.8%
Other	$463,822,000	6.9%
Total	$6,715,756,000	100%

Source: Federal Transit Administration (FTA), 2010

Sales taxes, almost always subject to public referenda as enabled by state legislation, will vary from one locale to another. For example, in some cases, the referendum raises revenues for both highway and transit investment. In others, it focuses only on transit projects or only on road projects. In most referenda, a simple majority (50% plus 1) determines the outcome. In California, local tax referenda for specific projects typically require a two-thirds majority. Increases in general taxes, as well as statewide bond measures, require a simple (50%) majority. Yet, even in California, most of the referenda pass. In 2005–2006, the California Legislative Analyst's Office estimated that of the $9.4 billion in local transportation revenue, about one-third, $3.1 billion, came from local option sales taxes. Local revenue was nearly half of the $20 billion spent on transportation in California that year. [AASHTO, 2015d]

It seems likely that with declining federal transportation revenues, metropolitan areas and cities will continue to rely on sales tax revenues for their investment needs.

IV. TRANSPORTATION FINANCE STRATEGIES

The term "financial strategy" is often used to denote two concepts in transportation. First, it is considered the mechanism by which funds are made available for transportation investment. Second, it is also the term used to describe the combination of different funding sources that together represent the investment strategy for a region or state. Table 5-5 shows a typical representation of the latter. This financial strategy, the level of funding that is expected to be available in the San Diego metropolitan area from 2010 to 2050, includes a wide range of funding sources. [San Diego Association of Governments (SANDAG), 2011] As shown, the funding sources include revenues from local, state, and federal governments. In addition, there are the more traditional sources of funds, such as gas taxes and transit fares. There are funds from local sales tax referenda, called TransNet, as well as San Diego's share of statewide tax referenda (for example, Propositions 1A and 1B). There are funds from nontraditional sources such as impact fees and public/private partnerships. Finally, there are revenues from bonds (for example, TransNet bond proceeds).

The San Diego example is most likely one of the more complex financial strategies found in the United States, given the myriad of funding sources; however, it does illustrate how different sources of funds can be packaged to develop an overall financial strategy for a region. Another unusual aspect of this example is that the financial strategy spans 40 years, a longer time span than most financial plans. More common to other metropolitan areas is that by far the majority of funding comes from local sources (see Figure 5-4).

Most of the innovation in transportation investment planning over the past 20 years has come in the many different financing strategies being used around the world. Usually described under the umbrella of "innovative transportation finance," new mechanisms and tools are now available for investment in the transportation system (see, for example, [Kramer et al., 2015; CPCS et al., 2015; and FHWA, *Project Finance,* undated]. As noted by the FHWA, the innovative nature of today's finance is that it: (1) enables new ways for existing revenue to be used to finance highways and transit,

Table 5-5. Major Revenue Sources/Revenue Constrained Scenario, San Diego					
	Revenue Sources Estimated Revenues (in millions of Year of Expenditure [YOE] dollars)				
Local	**FY 2010–2020**	**FY 2021–2030**	**FY 2031–2040**	**FY 2041–2050**	**FY 2010–2050**
TransNet	$2,997	$4,593	$7,002	$10,656	$25,248
TransNet (Bond Proceeds)	$2,849	$2,178	$1,259	0	$6,286
Developer Impact Fees	$292	$342	$376	$427	$1,437
Transportation Development Act (TDA)[1]	$1,457	$2,233	$3,405	$5,181	$12,276
City/County Local Gas Taxes	$1,190	$1,321	$1,649	$2,084	$6,244
General Fund/Miscellaneous Local Road Funds	$5,194	$6,435	$8,648	$11,622	$31,899
Future Local Revenues	$793	$2,296	$3,501	$5,328	$11,918
Toll Road/POE Funding (SR 11, Otay Mesa East POE, SR 125, SR 241, I-5, I-15)	$1,197	$79	$0	$4,591	$5,867
Public Private Partnerships/TODs	$340	$264	$470	$144	$ 1,218
FasTrak® Net Revenues[2]	$18	$87	$176	$301	$582
Passenger Fares	$1,398	$2,371	$4,530	$6,642	$14,941
Prior Year Funds in RTIP	$707	$0	$0	$0	$707
Subtotal	$18,432	$22,199	$31,016	$46,976	$118,623
State					
State Transportation Improvement Program (STIP)/Traffic Congestion Relief Program (TCRP)	$624	$1,380	$2,231	$3,611	$7,846
Proposition 42 (Local Street and Road)	$506	$573	$708	$873	$2,660
State Transit Assistance (STA) Program	$153	$324	$435	$584	$1,496
State Highway Account for Operations/Maintenance	$2,168	$3,208	$5,176	$8,367	$18,919
Proposition 1B/1A/Other	$1,287	$2,614	$2,853	$2,894	$9,648
Other State Managed Federal Programs/FSP	$229	$244	$388	$618	$1,479
High-Speed Rail	$0	$0	$0	$16,644	$16,644
Prior Year Funds in RTIP	$561	$0	$0	$0	$561
Subtotal	$5,528	$8,343	$11,791	$33,591	$59,253
Federal					
Federal Transit Administration (FTA) Discretionary	$906	$1,108	$2,533	$3,382	$7,929
Federal Transit Administration Formula	$1,122	$1,882	$3,675	$6,661	$13,340
Congestion Mitigation and Air Quality (CMAQ)/Regional Surface Transportation Program (RSTP)	$819	$1,216	$1,980	$3,225	$7,240
Other Federal Highway Administration (FHWA)	$259	$301	$490	$798	$1,848
Federal Railroad Administration (FRA) Discretionary	$312	$367	$470	$602	$1,751
Corridors and Borders Infrastructure/Other Freight Funds	$328	$560	$867	$1,351	$3,106
Prior Year Funds in RTIP	$736	$0	$0	$0	$736
Subtotal	$4,482	$5,434	$10,015	$16,019	$35,950
Grand Total Revenue Sources	**$28,442**	**$35,976**	**$52,822**	**$96,586**	**$213,826**

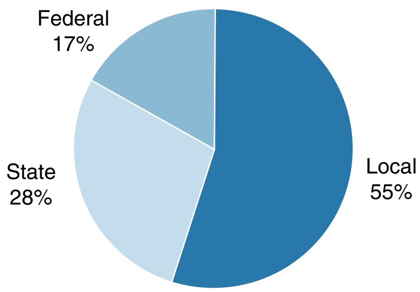
[1]Revenues come from general retail sales tax.

[2]Revenues come from tolls.

Source: SANDAG, 2011, Reproduced with permission of SANDAG.

(2) utilizes financing mechanisms such as debt finance, (3) utilizes fund management techniques, and (4) establishes new institutional arrangements. [FHWA, *Project Finance,* undated] Figure 5-5 shows some of the tools that can be used, especially in conjunction with federal funding programs, to capitalize a transportation project. Notice that many of the tools relate to debt financing and public/private partnerships. Public/private partnerships are so important to today's transportation financial picture that they are discussed separately in the section that follows.

Figure 5-4. Major Revenue Sources, San Diego Financial Strategy, 2010–2050



Source: SANDAG, 2011, Reproduced with permission of SANDAG.

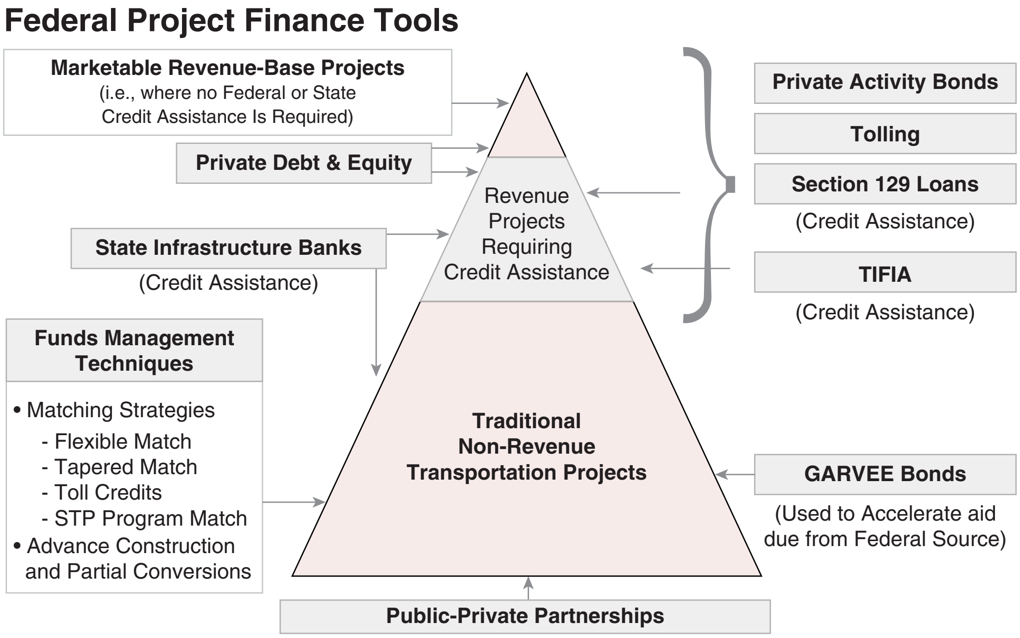
Some of the other financing strategies being used more regularly by transportation officials include debt financing and advance construction.

Many states use debt financing as a source of funds where the state constitution allows it. Debt financing is very similar to a homeowner's mortgage policy. The government borrows money from the municipal bond market at very low interest rates, and then has to pay back the principal with interest over a set number of years. The advantage of debt financing (sometimes called bonding) is that governments can close large investment gaps with the influx of capital funds, or for similar reasons accelerate the construction of a capital program. In the case of megaprojects, those costing $1 billion or more, debt financing is often the only way a government agency can construct the project, given that there is very little likelihood that $1 billion is available in the short term for the project.

The major disadvantage is that the principal and interest have to be paid back over many years. Some states that have heavily invested in bond financing have found themselves many years later allocating a large percentage of their yearly gas tax revenues to paying off the debt, leaving themselves unable to handle other transportation problems that have occurred since the debt was incurred. Accordingly, governments often establish criteria that dictate how much debt the state or city can sustain. Some of the common benchmarks include:

- Debt per capita.
- Debt as a percent of personal income.
- Debt as a percent of taxable property.
- Ratio of debt service expenditures to total revenues.
- Ratio of debt service expenditures to all expenditures.
- Debt service coverage by pledged revenues. [Henkin, 2009]

Figure 5-5. Federal Project Finance Tools, United States



Source: FHWA, *Project Finance*, undated

The key to a successful debt financing strategy is establishing a stable revenue source(s) to pay back the principal and interest. A variety of ways have been developed to do this both for direct borrowing by the government agency and for paying private investors for their borrowing of funds to construct a project. [Henkin, 2009]

- *Availability Payments and Performance Payments*—Public agencies compensating private companies or consortia for their project development and operations activities with annual availability payments that depend on facility performance and availability. Frequently, the public agencies first offer milestone payments when construction is complete and then offer annual payments for each period that the facility is available at a specified performance level.
- *Certificates of Participation (COPs)*—Tax-exempt bonds issued by states usually secured with revenue from an identified source. COPs enable governments to finance capital projects without technically issuing long-term debt.
- *Federal Credit Assistance*—Federal credit, provided through the Transportation Infrastructure Financing and Innovation Act (TIFIA) program and the Railroad Rehabilitation Infrastructure Financing (RRIF) program, providing direct loans (often on a subordinate basis with flexible repayment terms) and other finance assistance to large-scale transportation projects with identified revenue streams.
- *Grant Anticipation Borrowing*—The ability to securitize anticipated federal or state grant proceeds to generate funds for capital outlays. These debt obligations, commonly known as Grant Anticipation Revenue Vehicle (GARVEE) bonds for highways and GANs (grant anticipation notes) for transit, allow debt to be issued without necessarily pledging the credit of the issuer.
- *Private Activity Bonds (PABs)*—Allowing private entities to take advantage of the government ability to issue tax-exempt debt based on the investment purpose of the bond proceeds, but subject to a series of limitations.
- *Shadow Tolls*—Public agencies paying a fee to a private concessionaire for each vehicle that uses a facility. This approach provides incentives to the concessionaire for prompt and on-budget completion and quality performance. Because shadow tolls are not based on user fees, the public agency will need a source of revenue for payments.
- *State Infrastructure Banks (SIBs) and Other Revolving Loan Funds (RLFs)*—A lending organization capitalized (funded initially) with federal grants and state matching funds. Loans from contributed funds can be lent to projects at low interest rates and with favorable terms, with repayments being recycled into subsequent rounds of loans.
- *Tax Anticipation Notes*—Short-term municipal bonds issued in anticipation of future revenues generated from the project. These are sometimes referred to as revenue anticipation notes.

Another strategy being used by state DOTs is advance construction. This allows a state or local agency to initiate a project using nonfederal funds while preserving the eligibility for future federal aid. Eligibility means the FHWA has determined that the project listed in the STIP technically qualifies for federal aid; however, no present or future federal funds are committed to the project. After an advance construction project is authorized, it may be converted to regular federal aid funding, provided that federal funds are available.

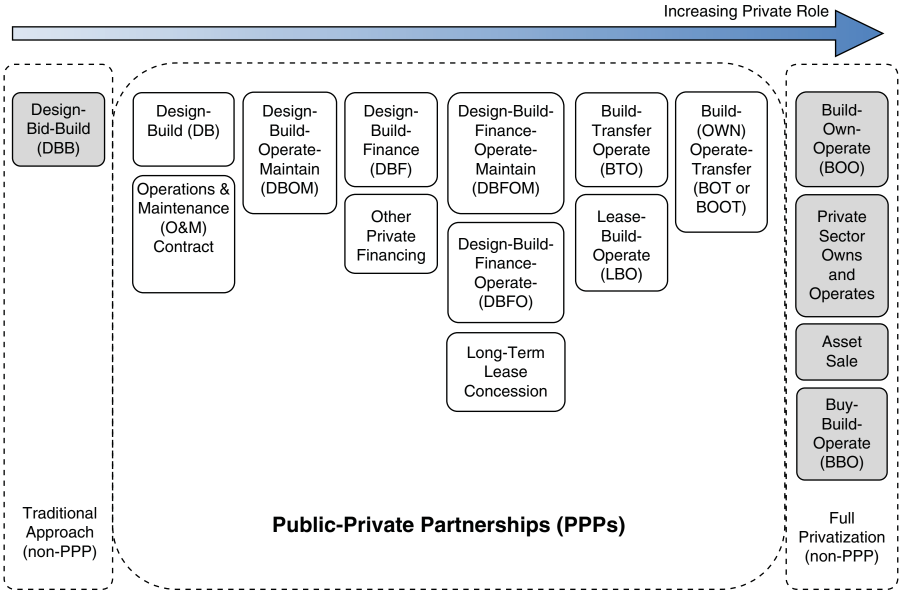
Much of what is considered innovative finance has focused on public/private partnerships, also known as P3s. Because of their importance to innovative finance strategies, the next section focuses on different types of P3 strategies and their potential.

V. PUBLIC/PRIVATE PARTNERSHIPS

The U.S. DOT defines a public/private partnership in the following manner:

> *"A public-private partnership is a contractual agreement formed between public and private sector partners that allows more private sector participation than is traditional. The agreements usually involve a government agency contracting with a private company to renovate, construct, operate, maintain, and/or manage a facility or system. While the public sector usually retains ownership in the facility or system, the private party will be given additional decision rights in determining how the project or task will be completed."*
>
> *[USDOT, 2004]*

Figure 5-6. Project Delivery Models along a Continuum of Private Sector Involvement



Source: Zhao, 2010

P3s differ from traditional public project development in that a private entity or consortium is responsible for more than one phase of the development process. [Gilroy and Poole, 2012] Figure 5-6 shows the many different types of P3 arrangements that could exist. The primary ones include:

> *Design-Build (DB):* The simplest form of P3 is design-build procurement. In this procurement model, a single private contractor is responsible for designing and building a project. The design-builder assumes responsibility for the majority of the design work and all construction activities, together with the risks associated with providing these services, for a fixed fee.
>
> *Design-Build-Finance (DBF):* In a design-build-finance structure, the design-builder takes on the additional responsibility of financing the project. The design-builder arranges financing for the project and is repaid over an agreed upon period, often upon completion of the project.
>
> *Design-Build-Finance-Operate-Maintain (DBFOM):* In this procurement strategy, a private entity (usually a consortium of companies) assumes responsibility for designing, building, financing, operating, and maintaining a project for an agreed upon period. While the public agency retains ownership of the project and must manage the project, the private partner assumes the long-term operations and maintenance risks of the project. The operations and maintenance period of the contract effectively acts as a warranty, enhancing the private partner's incentives to design and construct a quality facility that can be managed efficiently over a long period." [FHWA, 2012a]

Table 5-6 shows the major benefits of P3s as seen from a public sector perspective. The major distinction among the different forms of P3s and thus their benefits is the degree to which risk is transferred to other parties. Risks should be anticipated and should be transferred to those best equipped to manage the risk. Private firms take on the risks of some or all of the financing, designing, constructing, operating, and/or maintaining a transportation facility in exchange for future revenues. The distinguishing characteristic among the different forms of P3s is the degree of responsibility and risk that is transferred to the private sector. [FHWA, 2012a]

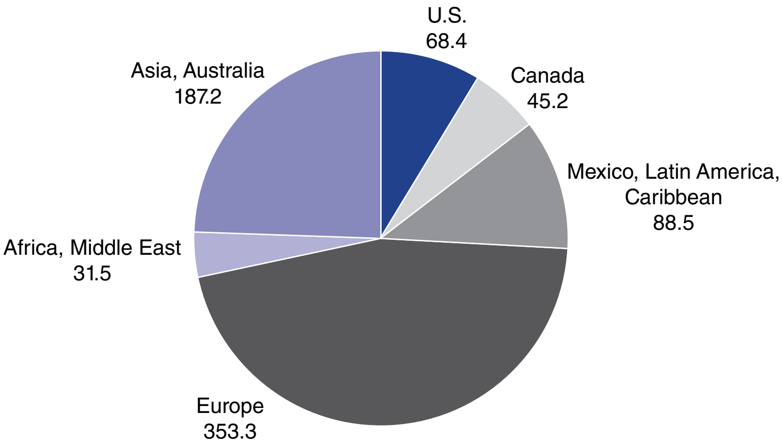
P3s have an important role in the development and delivery of transportation and infrastructure projects in many countries (see Figure 5-7). A Congressional panel examined this experience and made the following observations. [Committee on Transportation and Infrastructure, 2014] The panel found that successful P3s have several common elements, including leveraging the strengths of the public and private sectors, appropriate risk transfer, transparent and flexible contracts, and alignment of policy goals. Unlike most other countries, the United States possesses a robust municipal bond market of approximately $3.7 trillion, of which a significant portion is for infrastructure financing.

Table 5-6. Benefits from Public/Private Partnerships	
Benefit	**Description**
Increased capacity to finance projects	Using private equity and debt to help finance a project lessens the amount of public funds required in the short term to support a project. In addition, the private partners may be less risk-adverse than the public sector, allowing them to leverage greater upfront capital from anticipated project revenue than the public sector can. By accessing private financial resources, P3s can free up public funds to be used on other worthwhile transportation projects that may not be suitable for P3 delivery.
Accelerated infrastructure provision	P3s may provide public agencies access to upfront capital needed to complete major projects that is not subject to annual budget constraints or public debt caps.
Improved reliability of project delivery	Many P3s create incentives for the private sector to design and construct a project more efficiently. Several studies have found that P3 projects are more likely to be completed on time and on budget than projects using traditional procurement methods.
Improved allocation of resources over the project life cycle	In P3s where the private sector is responsible for operating and maintaining the asset, the private sector has a strong incentive to minimize operations and maintenance costs over the life of the project by improving quality of initial construction.
Transfer of selected risks to the private sector	Public sponsors can transfer risks, such as construction and financial risks, to the private sector.

Source: FHWA, 2012a

The panel found that the existence of a municipal bond market is a major reason why the U.S. P3 market has not grown as quickly as in other countries (which do not offer tax-exempt municipal bonds) and why the potential for P3s in the United States is limited.

Figure 5-7. Public/Private Partnerships Worldwide, Nominal Total Costs, 1985–2011, $ Billions



Source: Istrate and Puentes, 2011

The panel's work concluded that, in certain circumstances, "a well-executed P3 can enhance the delivery and management of transportation and infrastructure projects beyond the capabilities of government agencies or the private sector acting independently. The panel's work highlighted that the participation of the private sector in financing a project can bring discipline and efficiency to project delivery, which is too often lacking in the traditional public procurement process." [Committee on Transportation and Infrastructure, 2014]

Many state DOTs have established guidelines or criteria for when a P3 project makes sense for the state. Virginia's guidelines for P3 participation are a good example of such guidelines. The state's P3 policy had the following objectives:

- Create investment opportunities, which increase the quality of transportation services in Virginia.
- Administer a fair and competitive project development and procurement process that encourages innovation, private sector investment and creates long-term value for the Commonwealth.
- Achieve cost efficiencies throughout the life of a project using appropriate transfer of risk.
- Establish reliable and uniform processes and procedures to encourage private sector investment.
- Facilitate timely delivery of P3 projects within established laws and regulations.
- Promote transparency and accountability coupled with informed and timely decision making.
- Foster efficient management of Commonwealth financial and organizational resources. [Commonwealth of Virginia, 2014]

Table 5-7. Screening Criteria for State DOT Involvement in P3s, Virginia	
Level Project Screening Criteria	
Project Complexity	Is the project sufficiently complex in terms of technical and/or financial requirements to effectively leverage private sector innovation and expertise?
Accelerating Project Development	If the required public funding is not currently available for the project, could using a P3 delivery method accelerate project delivery?
Transportation Priorities	Is the project consistent with the overall transportation objectives and missions of the Commonwealth and the Agency? Is the project consistent with priorities identified by the appropriate transportation plans and programs, such as SYIP, STIP, and MPO plans and programs? Does the project adequately address transportation needs?
Project Efficiencies	Would the P3 delivery method help foster efficiencies through the most appropriate transfer of risk over the project lifecycle? Is there an opportunity to bundle projects?
Ability to Transfer Risk	Would the P3 delivery method help transfer project risks and potential future responsibilities to the private sector on a long-term basis?
Funding Requirement	Does the project have the revenue generation potential to partially offset the public funding requirement, if necessary? Could a public agency pay for the project over time, such as through an availability payment, as opposed to paying for the entire cost upfront?
Ability to Raise Capital	Would delivering the project under the PPTA help free up capital from other sources for other transportation priorities within the Commonwealth? Is the project consistent with federal requirements and potential agreements for federal funding and/or approval for P3 projects?

Source: Commonwealth of Virginia, 2014

Table 5-7 shows the criteria used in Virginia for a high-level scan of the feasibility of a P3 project. [Commonwealth of Virginia, 2014] As seen, the criteria range from how complex the project is to the distribution of risk associated with the project.

P3s can also pose significant legal and practical challenges. Thomas [2014] notes several issues that may arise for transit projects, but in reality are present for all transportation projects:

- *Federal and Local Legal Issues*—P3s currently involve several major exceptions to standard federal laws and regulations. In addition, local laws may restrict or impact P3s. Care must be taken to ensure that the P3 framework complies with FTA requirements and other applicable legal provisions.
- *Insurance Issues*—P3s may involve complex insurance arrangements and project-specific policies.
- *Labor Issues*—If a P3 includes a private entity performing transit operations or other related work, labor issues may need to be addressed by the partners.
- *Performance Metrics*—Most P3 agreements have contractual performance metrics that the concessionaire must satisfy with respect to the service being provided. These criteria are critical for the public partner in that they ensure a desired level of service; they also help define the risks assumed by the private partner in service provision (for which costs are usually assigned in the bid price).
- *Risk Issues*—P3s may involve a private entity serving as a concessionaire, but retain fare-setting power with the public entity. Such arrangements can raise issues regarding revenue risk allocation.
- *Tax and Financing Issues*—To obtain financing and favorable tax treatment, the private entity may need to demonstrate ownership of the asset being developed by the P3, yet the public entity needs to maintain continuing control of the project (among other reasons, to qualify for federal funds).

Excellent examples of how states and other agencies are viewing P3 arrangements can be found in [Rall et al., 2010; Istrate and Puentes, 2011; and Commonwealth of Virginia, 2014]. In addition, many guides are available on the steps that are necessary for developing a successful P3. Those interested are encouraged to visit the FHWA Office of

Innovative Program Delivery, which provides numerous guidelines and tools to assess the benefits and costs of P3 projects (see http://www.fhwa.dot.gov/ipd/).

VI. INVESTMENT PROGRAMMING AND REVENUE ESTIMATION

The previous sections discussed the different funding sources and financial strategies that are typical in the United States and in many other countries. An important challenge for transportation officials is matching the needs established by the planning process with the level of revenues that are reasonably expected over the lifetime of the transportation plan. The term for this is "programming," which in simple terms, is deciding which projects to fund and when to build them.

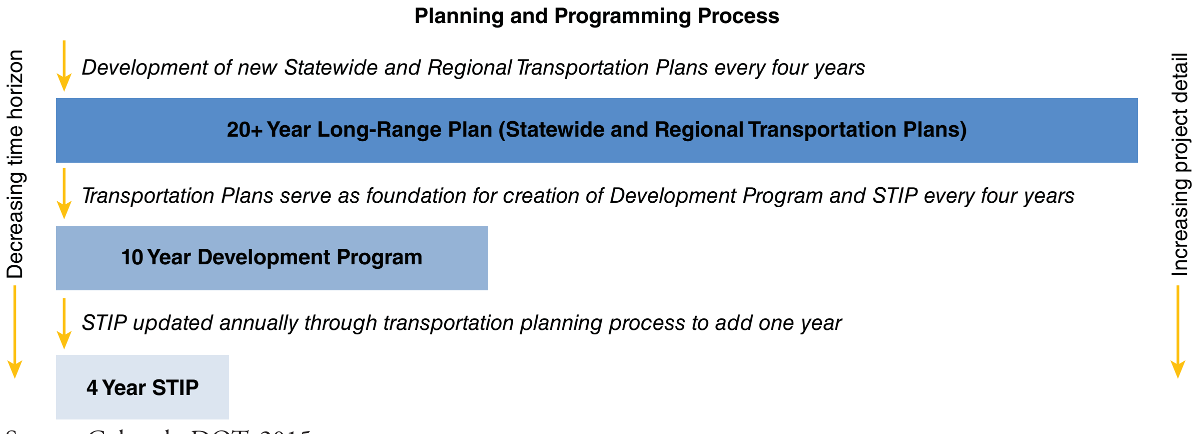
Figure 5-8 shows a typical relationship among the different planning and programming processes as adopted by the Colorado DOT. [Colorado DOT, 2015] The level of detail of projects is much greater during the programming process (the statewide transportation improvement program—STIP), as indicated in the figure.

There is a variety of ways that the programming process can be organized. The Minnesota DOT (MnDOT), for example, has both a decentralized and centralized programming process. A majority of the expected federal highway and transit funds is "targeted" to Area Transportation Partnerships (ATP) for the selection of federally funded projects in the STIP. ATPs are groups established by MnDOT in regions consisting of local officials, freight and passenger interests, MnDOT representatives, and other public representatives. This process is decentralized; ATPs have the responsibility for project selection. Federal funds that are not targeted to the ATPs are used for major statewide bridge and corridor projects that are solicited and awarded centrally. Wholly funded state projects are selected by the eight MnDOT district offices through their district planning processes. [MnDOT, 2015]

As an example of the program development at an MPO level, the Puget Sound Regional Council (PSRC) reviews all projects submitted for inclusion in the capital program to ensure the following:

- Consistency with the region's development and transportation plan.
- Consistency with local comprehensive plans.
- Funds are available or reasonably expected to be available.
- Consistency with the region's air quality conformity determination.
- Consistency with federal and state requirements such as functional classification.
- Consistency with PSRC's project-tracking policies. [PSRC, 2015]

Figure 5-8. Relationship between Planning and Programming Processes, Colorado



Source: Colorado DOT, 2015

In addition, PSRC makes sure that the region's financial strategy does the following:

- Reflects the impacts of the economic downturn on transportation finance (both revenues and expenditures).
- Makes the case for the development of new funding over the plan implementation period.
- Adds specificity to the funding assumptions contained in the financial strategy of the previous plan (for example, tolling, regional funding).
- Prioritizes projects using evaluation measures articulated through the VISION 2040 policy.
- Identifies projects that may not be ready for implementation prior to the planning horizon due to financial constraints or other project readiness limitations.
- Develops an illustrative list of projects (unprogrammed) that are not covered by the plan's financial strategy, and are not part of the plan's air quality determination. [PSRC, 2015]

The most important programming documents in the United States for transportation investment are the statewide transportation improvement program (STIP) and the transportation improvement program (TIP) for metropolitan areas (when talking about both generically, this chapter uses the term S/TIP).

A. State/Transportation Improvement Program (S/TIP)

By federal law, every state and MPO in the United States must produce a state transportation improvement program (STIP) or a metropolitan transportation improvement program (TIP). Although the primary intent of the TIP is to identify project priorities, it can serve other purposes as well. For example, the TIP for the Denver Regional Council of Governments (DRCOG) is intended to achieve the following purposes:

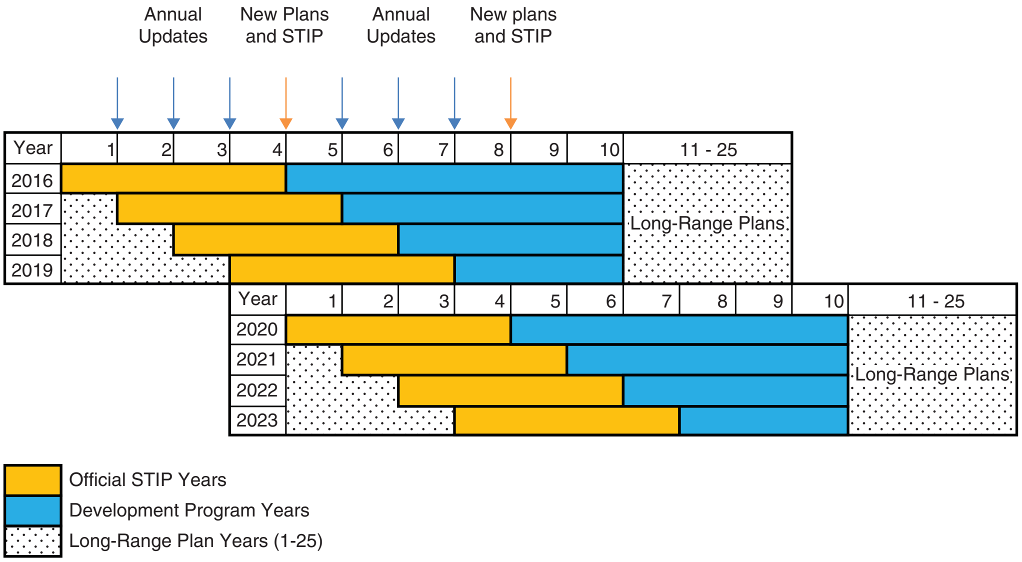
- Serve as a short-range implementation tool to address the goals of the regional long-range transportation plan.
- Provide continuity of current transportation improvement projects with those identified in previous TIPs.
- Identify transportation projects recommended for implementation by transportation mode, type of improvement, funding source(s), and geographic area.
- Estimate the costs of projects proposed for federal funding. The project allocations are to be consistent with the federal funds reasonably anticipated to be available for such projects in the area.
- Establish a prioritization of projects to effectively utilize federal funds as they become available.
- Identify and implement transportation improvements which will maintain the system; improve safety; improve air quality and reduce greenhouse gas emissions; reduce vehicle miles traveled (VMT) and congestion; and enhance the transportation system. [DRCOG, 2015a]

The Metropolitan Transportation Commission (MTC) in the San Francisco Bay area also notes that the TIP is multimodal, covers a four-year period, identifies future commitments of funding and signifies that a project may move ahead to implementation, shows estimated project costs and schedules, must reflect realistic revenue and cost estimates, and can be amended as new projects are added or existing projects are modified. [MTC, 2014a]

Figure 5-9 illustrates the concept of a continual "rolling over" of the S/TIP. Every year or two, depending on when the S/TIP is updated, a new year of investment is added to the capital program to take the place of the year that has just passed.

It is important to note that the S/TIP development process is subject to the same public participation rules as the transportation planning process, and thus requires opportunities for public input and for coordination with Tribal Nations and other transportation agencies (for state DOTs, in particular, there must be close coordination with MPOs). In addition, in those areas subject to Clean Air Act rules concerning nonconformance with air-quality standards,

Figure 5-9. Rolling Four-Year State Transportation Improvement Program, Colorado



Source: Colorado DOT, 2015

MPOs are required to show conformity of their TIP with the State Implementation Plan (SIP) for air quality before the TIP can be adopted (see chapter 4 on environmental analysis).

Projects can come from a variety of sources. At the metropolitan level, the rules state that projects programmed in the TIP must come from the long-range transportation plan or other planning products. Thus, a major challenge to MPOs is to prioritize the projects that surface from the planning process for inclusion into the TIP. DVRPC, for example, uses the following screening criteria for choosing road projects for its TIP: [DVRPC, 2013]

- Does the project serve the region's identified population and employment centers?
- Are there significant environmental issues that will be impacted by a project, as measured by DVRPC's Environmental Screening Tool?
- Is the project located in a Congestion Management Process (CMP) Priority Subcorridor?
- What is the reduction in regional vehicle hours of travel (VHT) associated with this project?
- What is the average annual daily traffic multiplied by the peak-period volume-to-capacity (V/C) ratio within the project limits?
- What is the daily truck traffic on the facility?
- How far has the project advanced?

Transit system expansion projects were evaluated with the following criteria:

- Does the project serve areas that will support a high level of transit service, as measured by DVRPC's Transit Score Index?
- Does the project serve environmental justice communities with additional transit needs, as identified by DVRPC's Degrees of Disadvantage (DoD) analysis?
- What is the potential for transit-oriented development?
- What is the status of the project?
- Is the project located in a CMP Priority Subcorridor?
- What is the project's anticipated farebox recovery rate?

System preservation and operational improvement projects were prioritized using asset management system condition data, use (vehicle and truck volumes, or transit ridership), detour length (for bridges), age, TIP status, speed impacts (for pavement), and functional class.

Readers are referred to DRCOG's priority criteria [DRCOG, 2015b] for an example of an extensive numerical approach to project prioritization; see also chapter 7 on evaluation.

At a state level, projects can come from the statewide transportation plan, as well as from many other sources. The following example from the Oregon DOT (ODOT) gives a sense of the breadth of involvement and range of project sources that could characterize a STIP development process.

Oregon categorizes STIP projects into two broad types: "Fix-It" projects, which maintain the existing transportation system, and "Enhance" projects, which improve the system. [ODOT, 2015] State-level plans provide an important source of projects. In ODOT's case, these include:

- *Oregon Transportation Plan (OTP)*—Policy and system investment analysis for the state's transportation infrastructure.
- *Oregon Freight Plan*—Summary of freight conditions and needs related to the state's transportation systems along with goals, policies, and strategies.
- *Oregon Highway Plan*—Policies and performance standards for the state highway system.
- *Oregon Bicycle and Pedestrian Plan*—Analysis of statewide conditions, system and facility standards, and strategies.
- *Oregon Public Transportation Plan*—Goals, policies, and strategies for the state's public transportation system.
- *Oregon Transportation Safety Action Plan*—Strategies for improving the safety of Oregon's transportation system.
- *Oregon Rail Plan*—Goals, objectives, and system needs for freight and passenger rail in Oregon.
- *Oregon Aviation Plan*—Policies and investment strategies for Oregon's public-use aviation system for the next 20 years.
- *Intelligent Transportation Systems Strategic Plan*—Strategies to increase the efficiency of existing transportation infrastructure.
- *Statewide Congestion Overview*—Analysis of congestion problems and recommended solutions.

Other sources for projects originate from a management system database. The Oregon Transportation Management System (OTMS) is used to monitor the condition of transportation assets such as pavement or bridges. Most rehabilitation and reconstruction projects in the STIP are developed from the OTMS. For example, all pavement preservation, bridge, and safety projects are developed using information from the management system. The most important management systems include:

Bridge Management System (BMS)—The Bridge Management System for bridges on and off federal-aid highways tracks inspection data and uses mathematical models to forecast future bridge conditions. It helps decision makers identify cost-effective solutions and prioritize investments.

Intermodal Management System (IMS)—The Intermodal Management System provides information about intermodal freight and passenger facilities and connections. The focus is intermodal exchanges, such as rail to truck, marine to rail freight movements, or passenger rail to highway exchanges. The system monitors information about general freight traffic on highways, main rail lines, and marine waterways.

Pavement Management System (PMS)—The Pavement Management System helps decision makers find cost-effective ways to maintain pavements in a serviceable condition. The PMS includes a pavement database, which contains current and historical information on pavement condition, pavement structure, and traffic. It is a forecast tool that estimates future pavement conditions and helps identify and prioritize pavement preservation projects.

Public Transportation Management System (PTMS)—The Public Transportation Management System collects and analyzes information about public transportation operations, facilities, equipment, and rolling stock. The system monitors the condition and cost of transit assets and the cost of transit operations. PTMS identifies needs and helps decision makers select cost-effective strategies for providing operating funds and maintaining transit assets in serviceable condition.

Safety Management System (SMS)—The Safety Management System consists of the Information Safety Management System (ISMS) and the Project Safety Management System (PSMS). The ISMS includes sources of data used by the PSMS and the overall monitoring and administration of ODOT's Roadway Safety Program. The PSMS includes processes, procedures, and tools to address critical safety issues for project scoping, design, and construction.

Traffic Monitoring System for Highways (TMS-H)—The Traffic Monitoring System for Highways monitors person and vehicular traffic data. It involves a systematic process for the collection, analysis, summary, and retention of highway- and transit-related data over time and is used to forecast future conditions on the highway system. [ODOT, undated]

In addition to ODOT plans and information sources, state projects in urban areas can come from metropolitan area transportation plans and rural transportation plans (including small communities). Outside of metropolitan areas, three planning processes are used to develop the source documents for projects listed in the STIP—ODOT facility plans, local transportation system plans, and local public transportation plans. Facility plans include corridor studies and other facility-specific plans, such as access management plans for interchanges, interchange area management plans, and expressway management plans. Given that Oregon is home to several federal parks and federal facilities, as well as Tribal Nations, the Oregon DOT STIP also includes projects from Federal Land Management agencies (for example, the U.S. Forest Service) and Tribal Area plans.

As can be seen from this description, STIP development relies on a wide range of inputs, not only those from the state DOT's own planning process.

Figure 5-10 shows a typical project description that would be found in an S/TIP, in this case from the DRCOG. The figure shows the expected level of funding over the lifetime of the TIP, the source for that funding, the agency responsible, and an annotated history of the development of the project. Usually, S/TIPs present additional information on the distribution of funds across modes and program types, and often by geographic area. Figures 5-11 and 5-12 illustrate this kind of information.

One of the important inputs into programming is the estimation of future costs and revenues. From earlier sections, one can the large variety of funding sources and financial strategies that can be considered as part of a capital program. For each of these, the state DOT and the MPOs must estimate what level of funding will be generated over the lifetime of the plan or program. This is even more important when one considers the requirement that long-range plans and programs be financially constrained. The next sections discuss ways of doing such estimation.

B. Estimating Revenues

In order to estimate future revenues, planners must know the underlying funding sources and the factors that influence the amount of revenue generated. Some revenues will relate to future economic activity, largely unrelated to transportation system performance. For example, a sales tax is more affected by the state of the economy than it is by the level of travel. Other revenues are directly related to the use of the transportation system, such as revenues from gas taxes, tolls, or transit fares.

In Seattle, for example, the PSRC had to forecast new transportation revenues for:

- Fuel tax increases.
- Sales tax on fuels.
- Motor vehicle excise tax (percent of value).
- Sales tax increase for local transit.

- Sales tax increase for Sound Transit (the region's transit agency).
- New development or impact fees.
- Road levy (property tax).
- Employee tax.
- Vehicle license fee.
- Street utility fees.

Some of these revenue categories relate to expectations about the future demographics of the region, including population and employment, as well as the value of the vehicle fleet, volume of fuel consumption, the value of retail sales, and others. PSRC uses a regional economic model to forecast future regional economic and demographic

Figure 5-10. Example Project Page from a TIP, Denver Regional Council of Governments

2016–2021 Transportation Improvement Program (Approved TIP)

Title: **Region 1 Traffic Signals Pool** Project Type: **Safety**

TIP-ID: **2007–075** STIP-ID: **SR16684** Open to Public: Sponsor: **CDOT Region 1**

Project Scope

CDOT Region 1 Traffic Signal Pool. Specific projects will not be listed.

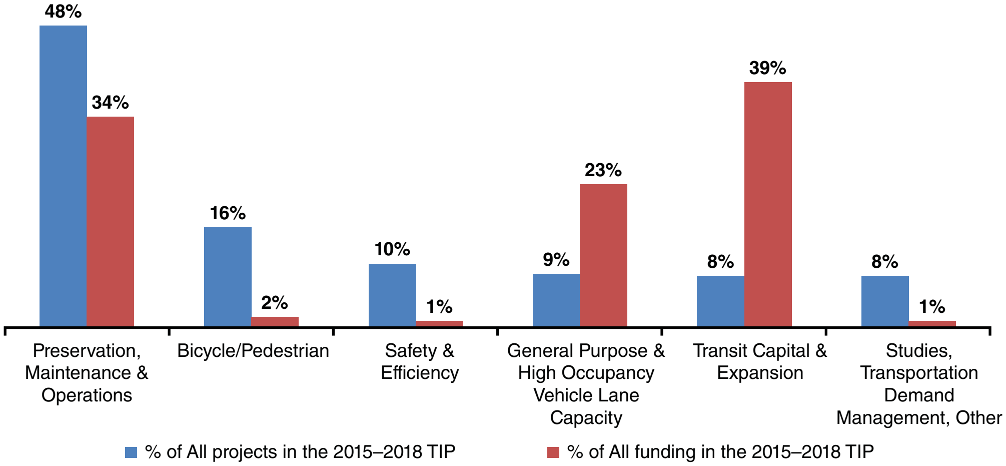
Affected County(ies)
Adams
Arapahoe
Broomfield
Denver
Douglas
Jefferson

Amounts in $1,000s	Prior Funding	FY16	FY17	FY18	FY19	FY20-21	Future Funding	Total Funding
Federal		$0	$0	$0	$0	$0		
State (Safety)		$1,050	$6,650	$5,000	$0	$0		
Local		$0	$0	$0	$0	$0		
Total	$2,341	$1,050	$6,650	$5,000	$0	$0	$0	$15,041

Date	Status	Description
05/04/2015	Proposed	Add the following projects and corresponding amounts to the pool for FY2016; SH-224 (E 74th Ave) at Dahlia St for $350,000; SH-287 (W 120th Ave) at Greenway Dr/Lamar St for $350,000; and SH-287 at W 10th Ave $350,000.
04/16/2015	Approved	Proposed for adoption into 2016–2021
08/21/2013	Amended	Add $245,000 in FY2014 and $255,000 in FY2015 of state Safety funds transferred from TIPID #1999-063. Increase total project funding.
04/06/2011	Adopted	Adopted into the 2012–2017 TIP
01/27/2011	Amended	Add $146,000 of state Safety funds to FY2011 and program to signal replacements at SH-74 and County Road 65. Increase total project funding.
02/23/2010	Amended	Add $122,000 of state Safety funds to FY 2010. Increase total project funding.
06/23/2009	Amended	Reduce state Safety funds in FY 2010 by $36,000. Decrease total project funding.
04/06/2009	Amended	Add $331,000 of state Safety funds to FY 2009. Increase total project funding.
08/15/2008	Amended	Reduce state Safety funds in FY 2009 by $58,000. Decrease total project funding.
03/19/2008	Approved	Adopted into the 2008–2013 TIP
06/14/2006	Approved	Adopted into the 2007–2012 TIP

Source: DRCOG, 2015a

Figure 5-11. Project Types in the 2015–2018 Regional TIP, Puget Sound Regional Council



Source: PSRC, 2015

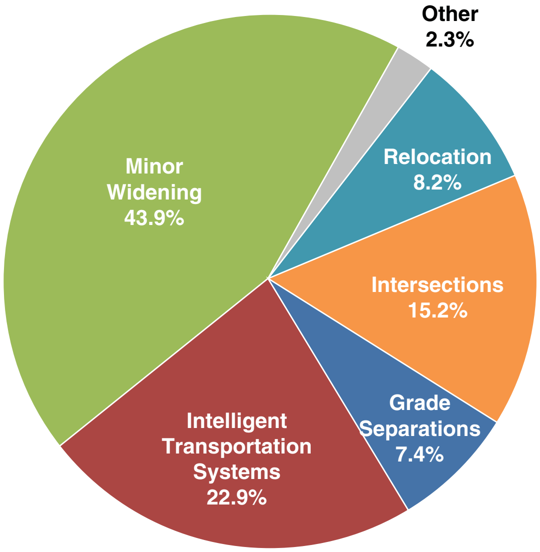
characteristics. These forecasts feed into tax-base forecasts leading to expected revenues (see Figure 5-13). For tolls, fares, and parking charges, PSRC uses its travel demand model to derive the revenue yield from various applications of a toll or fare policy. [PSRC, 2014]

The results of this financial analysis are shown in Tables 5-8 and 5-9 and Figure 5-14. These are typical presentations of revenue forecasting that one would see in MPO and, in some cases, state DOT financial plans. Table 5-8 shows the forecast of revenues related to those sources currently authorized, whereas Table 5-9 shows expected revenues from new sources.

Another example from the North Central Texas Council of Governments (NCTCOG), the MPO for the Dallas-Ft. Worth metropolitan area, again illustrates the assumptions that must be made when forecasting future revenues.

The following financial assumptions were used in the update of NCTCOG's long-range plan: [NCTCOG, 2013]

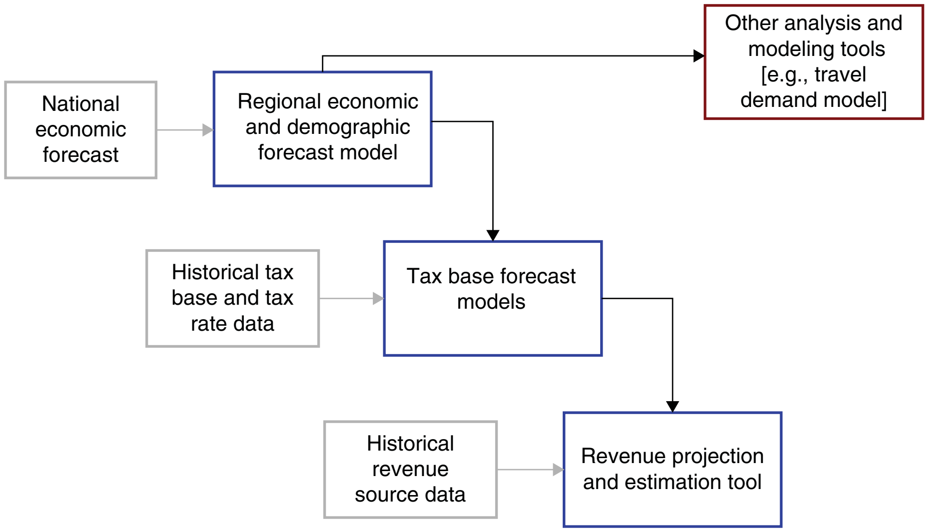
Figure 5-12. Project Selection Results for PSRC Funds, Safety and Efficiency Projects, Puget Sound Regional Council



Source: PSRC, 2015

- Beginning in 2015, the state fuel tax will be indexed (adjusted annually) to fuel efficiency. Because fuel taxes are assessed on a per gallon basis, as vehicles become more efficient they consume less fuel. This decreases the amount of revenue available for transportation improvements. Indexing to fuel efficiency allows existing revenues to be maintained into the future.
- Beginning in 2015, a $10 local option vehicle registration or mobility fee will be assessed within the 12-county Metropolitan Planning Area boundary.
- In 2020, both state and federal fuel taxes will be increased by 5 cents each.
- In 2025, an additional $10 local option vehicle registration or mobility fee will be assessed within the 12-county Metropolitan Planning Area boundary.
- By 2025, the state will have incrementally eliminated 80 percent of the diversions from the State Highway Fund. This does not include the portion of the gas tax that goes to fund education because this is protected by the state constitution.

Figure 5-13. Economic Modeling Leading to Revenue Forecasting, Puget Sound Regional Council



Source: PSRC, 2014

Table 5-8. Current Law Transportation Revenues by Source, Puget Sound Regional Council ($2008 millions)

Current Law Revenue Sources	2010–2020	2021–2030	2031–2040	2010–2040
State taxes on motor fuels	$5,260	$3,420	$3,040	$11,720
Registration and license fees (incl. weight)	$800	$490	$470	$1,760
Other state taxes and fees	$380	$380	$500	$1,260
Other taxes and fees for general funds	$6,450	$6,450	$6,100	$18,290
Property taxes (general or restricted)	$2,160	$2,160	$1,400	$5,080
Development and impact fees	$0	$0	$100	$100
Fares and operating revenues	$4,410	$4,410	$4,650	$13,410
Federal—FHWA	$1,860	$1,860	$970	$3,890
Federal—FTA	$2,630	$2,630	$1,250	$5,380
Sales-tax revenue (general)	$12,610	$12,610	$19,470	$46,290
Other transit revenue	$630	$630	$660	$1,610
Parking taxes	$250	$250	$140	$560
Property tax on motor vehicles	$670	$670	$0	$1,160
Port and Tribal contributions	$430	$430	$0	$630
Total Current Revenue	$38,540	$38,540	$38,750	$111,140

Source: PSRC, 2014

- In 2030, both state and federal fuel taxes will be increased by 5 cents each.
- Over the life of the MTP, toll roads, managed lanes, comprehensive development agreements, public-private partnerships, and other innovative funding options will be used to implement projects.
- Over the life of the MTP, the state will address pavement conditions, while the MPO will fund bridge replacements.
- Over the life of the MTP, regional transportation partners will continue to implement projects.
- Over the life of the MTP, there will be an increased reliance on local entities to fund projects locally.

Table 5-9. New Law Transportation Revenues by Source, Puget Sound Regional Council ($2008 millions)

Future New Revenues	2010–2020	2021–2030	2031–2040	2010–2040
Local Sources				
Road levy (property tax)	$ -	$1,800	$2,300	$4,100
Other local sources (parking, license, and impact fees)	$700	$3,600	$6,600	$10,900
Motor vehicle excise tax (cities and town)	$700	$2,100	$3,000	$5,700
Transit-Specific Sources				
Motor vehicle excise tax (transit)	$1,100	$3,100	$4,500	$8,600
Sales-tax increase for local transit	$ -	$1,900	$6,200	$8,000
Sales-tax increase for Sound Transit	$ -	$4,900	$8.300	$13,200
Tax increases supporting privately owned vehicles	$100	$200	$200	$500
Increases in transit and ferry fares	$100	$600	$1,000	$1,700
State Sources				
State fuel tax and bonding net proceeds	$3,100	$1,600	$1,600	$6,400
Other state sources (Natural Resources, Fish/Wildlife, etc.)	$300	$400	$500	$1,100
HOT Lanes and Facility Toll Revenues				
HOT and facility toll proceeds	$5,400	$5,500	$ -	$10,500
Highway system tolls	$ -	$ -	$47,300	$47,300
Fuel tax replacement	$ -	$5,600	$5,500	$11,000
Offsetting fuel tax	$ -	$ -	$(15,300)	$(15,300)
Total New Revenue	**$11,500**	**$31,300**	**$71,700**	**$114,000**

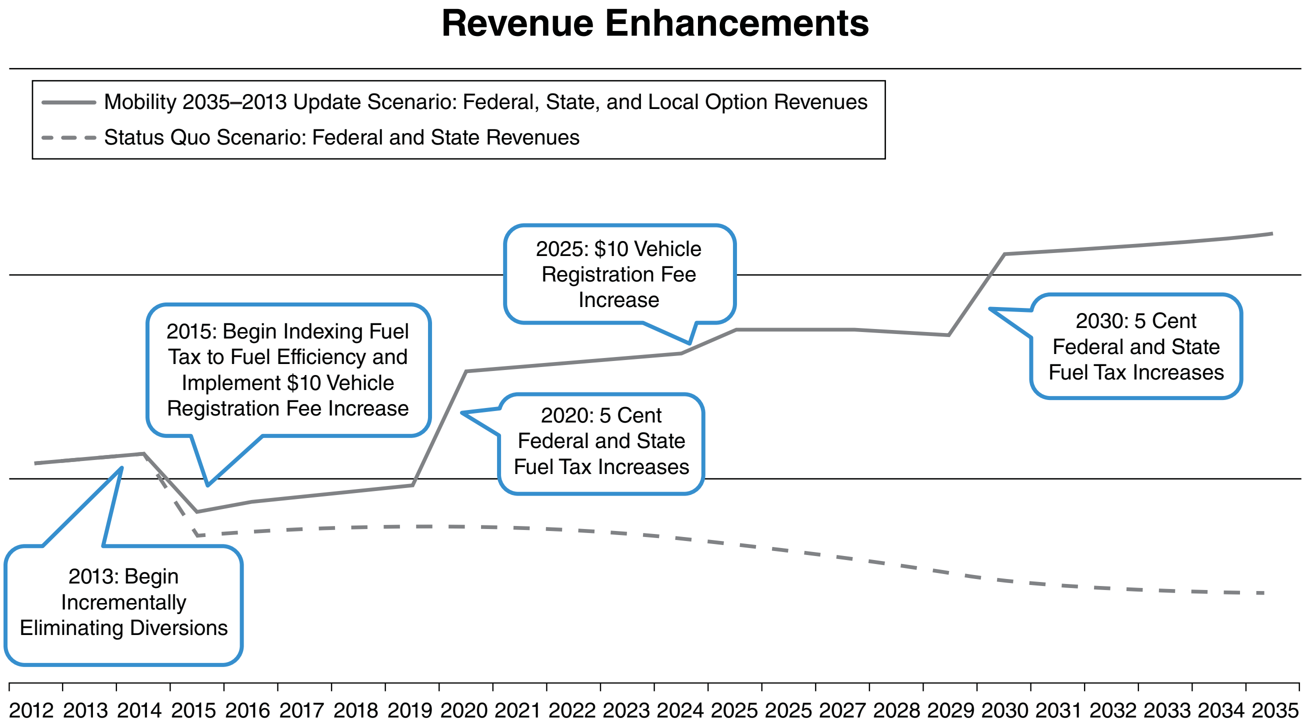
Source: PSRC, 2014

Figure 5-14. Distribution of Current and New Law Revenues, Puget Sound Regional Council

millions of $2008 constant

Source: PSRC, 2014

Figure 5-15. Impacts of Revenue Enhancements, North Central Texas Council of Governments



Source: NCTCOG, 2013

Another way of portraying the assumptions of new revenues is shown in Figure 5-15.

A revenue-forecasting model called Transportation Revenue Estimation and Needs Determination System (TRENDS) was used to forecast state and federal funds for the initial regional plan. [Ellis et al., 2011] The financial forecasts also included predicted revenue from the region's toll and managed lane system and local funds, as well as the revenues from the region's three transit systems. Three revenue scenarios were developed that reflected varying possibilities (see Table 5-10):

- *Status Quo*—This scenario represents a minimal level of investment that focuses on traditional transportation revenues as they exist today.
- *Statewide Enhanced*—This scenario represents the financial conditions that would exist if taxes or fees for transportation were increased at the state or federal level.
- *Statewide Enhanced + Local Option*—This scenario represents the most aggressive of the three funding options. In this scenario, the assumptions from the Statewide Enhanced scenario would be used with the addition of several local revenue initiatives. Local initiatives could be project-based (such as implementing a robust toll and managed lane system) and/or they could be tax- or fee-based (for example, an increase in vehicle registration fees). [NCTCOG, 2013]

After evaluating historic trends, the current state of transportation funding, and the plausibility of future funding, the MPO Board selected the $101.1 billion Statewide Enhanced + Local Option scenario to represent the financially constrained revenue forecast for the regional transportation plan.

As can be seen from these two examples, forecasting future revenues is based on historical trends and on reasonable assumptions about future revenue enhancements. The process can combine both economic forecasting and a

Table 5-10. Mobility 2035 Financial Scenario Assumptions, North Central Texas Council of Governments			
Funding Strategies	**Status Quo**	**Enhanced**	**Enhanced + Local Option**
State fuel tax per gallon	$0.20 (existing)	+$0.05 in 2020 and +$0.05 in 2030	Same as Enhanced
State fuel tax indexing	--	To fuel efficiency by 2015	Same as Enhanced
Federal fuel tax per gallon	$0.184 (existing)	+$0.05 in 2020 and +$0.05 in 2030	Same as Enhanced
Ave. vehicle registration fee	$60 (existing)	Same as Status Quo	+$10 in 2015 and +$10 in 2025
Toll roads, managed lanes and P3s	Currently funded facilities	Same as Status Quo	Additional facilities
Other assumptions	Regional partners continue to implement projects Reliance on local entities to fund projects locally	Status Quo plus: End 80% of diversions incrementally by 2025 Maintenance: TxDOT addresses pavement conditions MPO funds bridge replacements	Same as Enhanced
Total revenue ($B)	$74.9	$86.4	$101.1
Additional revenue from Status Quo		+11.5	+26.2

Source: NCTCOG, 2013

travel demand model for estimating future use of the transportation system. Changes that might need to be considered in the analysis include:

- Population change (should be compared with past trends and with statewide demographic control totals).
- Employment change (should be compared with past trends and with statewide economic growth control totals).
- Regional distribution of future population, employment, and land use.
- Demographic change (including automobile ownership, household income, household size, and multiworker households). [Kriger et al., 2006]
- Travel behavior change (including telecommuting, trip chaining, and Internet shopping).

Forecasting future revenues for a state transportation program often includes a similarly wide range of revenue sources. Wachs and Heimsath [2015], for example, surveyed state DOTs and found the following sources of revenue were forecasted by at least one state:

- Oil company gross receipts tax.
- Investment income and small revenue sources.
- Aviation fuel tax.
- Rental car surcharge.
- Off-highway sales tax on dyed diesel.
- Documentary stamp tax.
- Motor carrier surtax.
- Fuel tax transfers and refunds.
- Oversize/overweight permits.
- Damage to state property.

- Toll road lease proceeds.
- Miscellaneous permits and fees.
- Weight distance tax.
- Federal revenue reimbursements.
- 2% Special fuel excise tax on dyed fuel usage.
- Driver's license revenue.
- Truck regulation and enforcement fees.
- Projected unencumbered cash balances.
- Oil company—franchise tax.
- Contribution from Turnpike Commission.
- Vehicle code fines.
- Vehicle sales tax.
- Local participation.
- Interest on cash balances.
- Miscellaneous revenue.
- Dedicated taxes and fees.
- Ferry boat fees.
- Department of Motor Vehicle fees.
- Traffic violation fees.
- Airspace leasing.

They also found that the most common forecasting tools were: simple historical trend extrapolation, expert consensus, and econometric models, including econometric regression analysis.

Good references for revenue forecasting include [FTA, 2000; NCHRP, 2010; CRTPB, 2010; Wachs and Heimsath, 2015; and FDOT, 2013]. Kriger et al. [2009] is a good reference for the estimation of toll revenues.

C. Estimating Costs of Capital Projects

The project cost estimation responsibilities vary by agency role in project development. For example, state DOTs have primary responsibility for project planning, project development, construction, operations, and maintenance of the state highway system. Thus, highway capital cost estimates included in a regional TIP usually come from the state DOTs; the MPOs usually do not develop the estimates. However, cost estimates for other types of projects such as nonstate highways and pedestrian/bicycle projects are often prepared by MPO staff.

Cost estimates, especially for very large projects, have often been criticized because of "cost creep" once the project is under construction. There are many reasons why final costs might not reflect planning estimates, the most important being that detailed engineering has not yet been done during the planning process, so that specific project costs (such as environmental mitigation) are largely unknown at that point in project development. Anderson et al. [2007] suggest many reasons for discrepancies in project-level cost estimates, including:

Source Factor

Bias

Delivery/Procurement Approach

Project Schedule Changes

Engineering and Construction Complexities

Scope Changes

Scope Creep

Poor Estimation

Inconsistent Application of Contingencies

Faulty Execution

Ambiguous Contract Provisions

Contract Document Conflicts

Internal
Local Concerns and Requirements

Effects of Inflation

Scope Changes

Scope Creep

Market Conditions

Unforeseen Events

External
Unforeseen Conditions

Note that this list is for project-level costs where projects have advanced enough in the project development process to develop the details for more accurate cost estimates. Factors such as scope change and creep are not that relevant to planning level estimates because the specific project scope is not usually developed until after the plan.

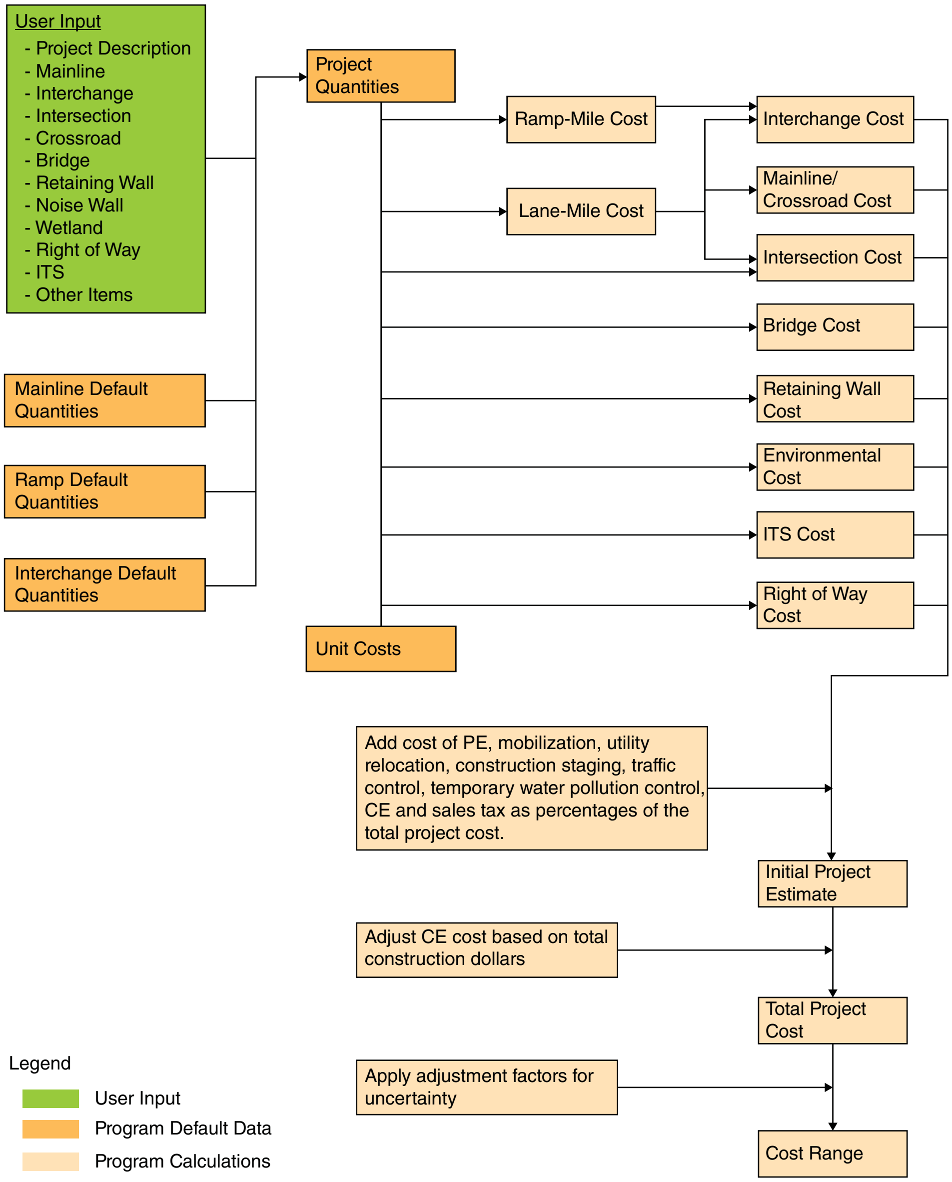
Figure 5-16 shows an approach used by Washington State DOT to develop planning cost estimates. [WSDOT, 2012] The approach simply multiplies unit costs by the expected quantities for a project cost element, and then sums across all component cost estimates to get a total cost. A similar approach is used for project-level cost estimation, but at a much more detailed level. [WSDOT, 2015] Most state DOTs have a cost estimation manual or policy that has been calibrated to the project cost histories in their state. MPOs often use these manuals when developing their own cost estimates.

One of the key characteristics of planning-level cost estimates is that insufficient project design has occurred to allow cost estimators to know with any certainty what the project cost is likely to be. In other words, there is a high level of risk associated with planning-level cost estimates. The way this is usually handled is to apply contingency factors, adding an "uncertainty" cost to the estimate. This contingency factor decreases as the project moves through project development and more detailed engineering is undertaken. Typical contingency ranges by phase are as follows:

- Planning and concept development phase—30 to 40 percent.
- Public involvement phase—25 percent.
- Semifinal phase—15 percent.
- Final review—5 to 10 percent.
- PS&E—0 percent. [Paulsen et al., 2008]

Transit capital cost estimation is similar in some ways to highway cost estimation, in that key standard cost categories are identified for each project, and then unit costs are applied where appropriate to estimate the category

Figure 5-16. Planning-Level Cost Estimation Procedure for Washington State DOT



Source: WSDOT, 2012

cost. [TransTech, 2003] The FTA has defined the cost categories for the cost estimation process, and allows two types of cost estimation: the "bottom up (deterministic)" and "top down (stochastic)" approaches. The "bottom up" approach totals the cost of each component of a category. The "top down" approach provides an order of magnitude cost based on data from projects that are similar in nature, where the cost is divided by a unit of measure and applied as a unit cost.

The FTA cost categories include:

Category 10: Guideway and Track Elements

Category 20: Stations, Stops, Terminals, and Intermodal

Category 30: Support Facilities: Yards, Shops, and Administrative Buildings

Category 40: Site Work and Special Conditions

Category 50: Systems

Category 60: Right of Way, Land, and Existing Improvements

Category 70: Vehicles

Category 80: Professional Services

Category 90: Unallocated Contingency

Category 100: Finance Charges

Two methods commonly used for estimating unit prices:

- *The Historical Bid Price Method* uses past unit price bids for similar work adjusted for time and project location and developed as a construction cost index. Bid unit costs are usually available from the state DOT. However, the timing of the bidding vis à vis the economy can also play a significant role in determining whether bids come in above, below, or at an engineer's estimate. External economic factors can cause the cost of constructing a traffic signal—a fairly standardized item—to vary by plus/minus 10 percent. When contractors are looking for work, they will submit lower bids to keep their forces and equipment busy.
- *The Time and Material* (also known as *Crew Price) Method* uses nationally recognized productivity, local labor, and equipment rates from a similar or the same database, and material or subcontract costs from the same database or as obtained by the estimating team for the project. [HDR, Inc. 2013]

As shown in Table 5-11, transit cost estimation also uses contingency factors to take into account the uncertainty of actual costs. Contingencies are allocated to specific project components as well as to the phase of project development.

Table 5-11. Transit Cost Contingencies

FTA Category	Description	Allocated Contingency Percentage
10	*Guideway and Track Elements*	
	–Guideway elements (except underground)	25%
	–Guideway elements (underground)	35%
	–Track elements	20%
20	*Stations, Stops, Terminals, and Intermodal Connections*	20%
30	*Support Facilities: Yard, Shops, and Admin Buildings*	20%
40	*Site Work and Special Conditions*	
	Demolition, clearing, earthwork	25%
	Site utilities, utility relocation	30%
	Hazardous materials, contaminated soil removal/mitigation, groundwater treatment	30%
	Environmental mitigation, for example wetlands, historic/archaeological, parks	30%
	Site structures including retaining walls, sound walls	25%
	Pedestrian/bike access and accommodation, landscaping	25%
	Automobile, bus, van access including roads, parking lots	25%
50	*Systems*	20%
60	*Right of Way, Land, Existing Improvements*	50%
70	*Vehicles*	10%
Unallocated Contingency Factors		
Planning	System planning	15%
	Alternatives analysis	10%
Design	Preliminary engineering	20%
	Final design	15%
	Construction	10%

Source: HDR, Inc. 2013

As the costs of projects continue to rise and the level of funding continues to decline, it will become even more important in the future to have a credible and effective capital cost estimation procedure.

D. Estimating Costs for Operations and Maintenance

Estimating future operations and maintenance (O&M) costs represents a particular challenge because of both unknown future labor rates and unknown future labor productivity rates. Accordingly, most estimates of future O&M costs are simply escalations of historic trends. For example, the PSRC considered the O&M component of system components as a program cost and assumed cost escalation at historic rates modified to reflect expected changes. City and county maintenance costs were estimated to grow at 2.7 percent in real terms over the 30-year planning period, while nonproject capital requirements were estimated to grow at 2.5 percent in real terms. Local transit operations were estimated to grow at, or slightly above, the rate of inflation, reflecting new cost control policies implemented since an economic downturn. Travel demand management, intelligent transportation systems (ITS), and toll system costs were also estimated programmatically through various detailed methods. [PSRC, 2014]

Transit O&M estimation is a bit different from the simple escalation approach, in that FTA and the transit industry have developed approaches and methodologies for estimating O&M costs, especially for future transit projects. The prerequisite for a transit O&M analysis is an operating plan, which outlines the expected fleet size, headways, and labor requirements. After a major transit facility is constructed, systemwide O&M expenses typically increase, requiring additional subsidies to continue operating and maintaining the transit system. [FTA, 2000] Fixed guideway projects, for example, often result in significant service realignments. The operating plan contains at least 5 years of historical data and 20-year forecasts of O&M expenses for the existing transit system and the proposed project. The O&M expenses are supported by information regarding service characteristics of the transit agency, such as projected vehicle revenue miles, vehicles in service, and directional route miles.

Two major types of models can be used to estimate future O&M costs. A *cost allocation model* assumes that each expense incurred by a transit system is "driven" by a key supply variable such as revenue hours, revenue miles, and peak vehicles. [FTA, undated] A unit cost rate is calculated for each expense line item and an estimated future O&M cost can be calculated by summing the future revenue hours, revenue miles, and peak vehicles multiplied by their respective unit costs. Twelve (12) months of actual transit expense data are preferred, with expenses defined as either fixed or variable.

A *resource build-up model* identifies every factor that contributes to the provision of transit service and the cost of each. As new services are added to the network, the transit agency can then estimate the change in the number of these input factors and the corresponding cost. An example of an operations cost estimation is shown in Table 5-12. As shown, the key variables are annual revenue miles and annual revenue hours.

VII. ENVIRONMENTAL JUSTICE ANALYSIS

The equitable distribution of funds has been a growing concern among transportation policy makers for many years. [Wachs, 2003; Committee on Equity Implications of Evolving Transportation Finance Mechanisms, 2011] As part of the transportation planning process, the development of the TIP is subject to the requirements that guide the

Table 5-12. Example Operations Cost Estimation, District of Columbia Streetcar

	Annual Revenue Miles	Unit Cost per Revenue Mile	Mileage Based Annual Cost	Annual Revenue Hours	Unit Cost per Revenue Hour	Hourly Based Annual Cost	Total Annual O&M Costs 2009 dollars	Total Annual O&M Costs 2012 dollars	Total Annual O&M Costs 2013 dollars
Alt. 1 Streetcar	263,852	$5.23	$1,379,946	30,821	$216.81	$6,683,013	$8,062,959	--	$9,074,860
Alt. 2 Streetcar	278,554	$5.23	$1,456,835	37,269	$216.81	$8,081,133	$9,537,968	--	$10,734,982
Alt. 3 Premium Bus	N/A	N/A	N/A	33,788	$95.00	$3,209,814	--	$3,209,814	$3,306,108

Source: District DOT, 2014

process and substance of the planning program. One of these requirements in the United States is that the capital investment program should not unduly burden low-income and minority populations. Those who develop the TIPs must self-certify that such is the case. In some instances, the MPO undertakes a fairly involved analysis of the equity implications of the TIP.

An example of this is the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area. As part of the 2013 TIP development, the MTC conducted an analysis that specifically addressed the equity implications of the proposed TIP investments. In 2015, the MTC conducted an update of this analysis to reflect the additional TIP investments that had occurred since 2013. The purpose of the analysis was to "understand if low-income and minority populations are sharing equitably in the TIP's financial investments." [MTC, 2014b] The analysis calculated the shares of 2015 TIP investments that affected the identified communities, and compared those shares with the proportional size of this group's population and trip-making relative to that of the general population. The methodology consisted of:

1) The 2015 TIP investments were separated into two modes: transit and road/highway.
2) Investments were allocated in each category to low-income and minority populations, and other populations according to each group's usage share of each mode at the county or transit-operator level.
3) The assignment of investment by usage was performed by multiplying the percent of use of the mode by the investment in that particular mode. This analysis was conducted at the county level for highways and roadways and at the transit-operator level for transit. A similar approach was followed for transit investment allocations.
4) The investments by mode (from county or transit-operator data) were summed for low-income and minority populations and for all other populations based on each group's usage share of each mode. The percent of usage of the system by the target and other populations was then calculated and the percent investment was compared to the percent use of the system by user group.

Tables 5-13 to 5-15 illustrate the information that resulted from this analysis. Based on these results, MTC concluded that there was not disparate impact in the distribution of federal and state funding for public transportation purposes between minority and nonminority populations.

Table 5-13. Population-based Comparison of TIP Investment by Income Distribution

	2015 TIP Investments	% of Investment	% of Trips
Trips by people living in low-income households (< $50,000/year)	$2,331, 948,851	25%	18%
Trips by people living in non-low-income households (> $50,000/year)	$7,176,862,582	75%	82%
Total	$9,508,811,413	100%	100%

Source: MTC, 2014b, Reproduced with permission of MTC.

Table 5-14. Comparison of Federal and State Transit 2015 TIP Investments by Minority Status

Race/Ethnicity	Total Federal/State Transit Funding ($millions)	% of Total Federal/State Transit Funding	% of Regional Transit Ridership	% of Total Regional Population
Minority	$1,355	61%	62%	58%
Nonminority	$869	39%	38%	42%
Total	$2,225	100%	100%	100%

Source: MTC, 2014b, Reproduced with permission of MTC.

Table 5-15. Disparate Impact Analysis of 2015 TIP Investment: Population Analysis				
Race/Ethnicity	**Total Federal/State Transit Funding ($millions)**	**Regional Population (2010)**	**Per Capita Benefit**	**Minority Per Capita Benefit as % of Nonminority Per Capita Benefit**
Minority	$1,355	4,117,836	$329	115%
Nonminority	$869	3,032,903	$287	
Total	$2,225	7,150,739		

Source: MTC, 2014b, Reproduced with permission of MTC.

VIII. FUTURE CHALLENGES

This chapter began with the statement that transportation funding and finance constitute perhaps the greatest challenge facing the transportation industry today. This challenge is likely to become even greater in the future. The PSRC identified some crosscutting issues in transportation finance that characterize the ongoing debate about transportation finance. [PSRC, 2014] They are presented here, somewhat modified, to reflect the finance and funding environment of tomorrow.

The Future of Fuel Taxes. In the face of inflationary pressures, vehicles with improved fuel mileage, and alternately fueled vehicles, the future of a fuel-tax-based approach to highway finance may be limited. Alternate approaches to collecting user fees have been contemplated for many years. Technical advances have revolutionized road user fee collection approaches and may someday offer a replacement alternative for fuel taxes. As the transportation sector strives to better understand the connection between personal and freight mobility and carbon emissions, taxes on motor fuels will become an even less viable means of funding future investments. One option away from gas taxes is a VMT fee, which would charge a driver per mile traveled. This type of fee would be more attuned to the economic principle of user fees, but several proposals in the United States have been rejected because of the consequences of such a fee structure on those who drive long distances (even though today's gas tax and vehicle fuel economy is doing much the same thing).

Bond Financing. Historically, transportation systems in the United States have been financed on a pay-as-you-go basis. However, the pay-as-you-go approach is no longer working well in providing the level of investment dollars needed to enhance the capacity of the transportation system. Many states have turned to debt financing as a way of providing the necessary upfront dollars to implement a capital program. The problem is that, depending on how much is borrowed, the principle and interest payments could well burden future generations with repayment costs that do not allow them to invest in their own transportation strategies.

Reliance on Non-Transportation-Related Tax Sources. Increased reliance on non-transportation-related revenue sources, such as the sales taxes and municipal general funds, exposes transportation systems to greater revenue uncertainty. For example, e-commerce has likely eroded the sales-tax base for many communities, given that, in most cases, sales taxes are not charged for Internet purchases. Transit agencies that rely on sales tax revenues will be affected by economic downturns; for example, many had to significantly cut services during the economic recession of 2008–2012 as their sales-tax revenues plummeted.

Geographic Equity for Statewide and Regional Sources. Politics lends itself to geographic divides, and these divisions have been a source of debate as to whether transportation dollars are distributed fairly. The issue of "Am I getting my fair share?" is one that will continue to be faced in the future, especially if funding levels decline.

Cost Burden across User Groups. The distributional effects of transportation investment—that is, "who wins? and who loses?"—relate to issues of fairness and political viability, but also have implications for efficient transportation system management. Some users of the transportation system impose greater costs than others. Heavy vehicles create more pavement and structural damage; commuters on busy roadways during the peak travel period impose delay on other users. The financial systems that support investments in transportation need to reflect these cost structures.

Connected and Autonomous Vehicles. Arguably, the U.S. transportation system is at the cusp of a technology revolution. Connected vehicles, connected vehicle infrastructure, and autonomous vehicles raise important questions on how such vehicle operations can fit into a transportation finance strategy that supports the infrastructure that is still needed for such operations.

IX. SUMMARY

Transportation finance and funding represent two of the greatest challenges facing the transportation industry. Today, a variety of strategies are used to provide the investment capital needed to expand and maintain the transportation system. New partnerships among public agencies, and between public and private organizations, are using innovative finance strategies to support project implementation. In many ways, the finance and funding analysis process is much more complicated than it was many years ago, when the largest single contributor to state and regional capital programs came from the gas tax. Today, a menu of options is available for transportation officials to choose from.

This chapter has described the current configuration of the transportation finance and funding structure. It seems likely that the way we financially support the transportation system will change a great deal in the future. We are already seeing new institutional arrangements and partnerships that support investment in the system. New technologies are allowing states to capture tolls and fees in a nonintrusive manner, and this capability is only likely to increase in the future.

Although, historically, transportation finance was not part of the transportation planning process, today it is. Very few plans are produced today that do not have a requirement to identify potential financial and funding strategies. Transportation planners thus need to understand the basics of financial analysis as well as the types of strategies that can be considered as part of a state or regional investment program.

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Travel Demand and Network Modeling[1]

I. INTRODUCTION

Travel demand in the (noncommodity) urban environment refers to the personal travel or passenger trips generated by economic and/or personal needs. Demand for travel is often organized into market segments that reflect a range of factors—including household income, gender, and age of the traveler; auto ownership; and household structure—that influence how many and what kinds of travel activities occur. Transportation supply is represented by the roads, transit facilities and services, information technology, and other infrastructure that enable trips to be made. Transportation supply and travel demand are interdependent—inadequate capacity, which results in congestion, affects travel decisions, and the cumulative effects of individual travelers' decisions affect the performance of the transportation system. Travel demand modeling focuses on this interaction between transportation demand and supply. Given the need for making deliberate, long-term infrastructure investment choices, transportation planners need to know how to model future travel demand and how to interpret the results.

This chapter begins with a brief historical perspective on the evolution of travel demand modeling. The next section discusses some of the key principles and concepts that serve as the foundation of demand modeling, which leads into the next section's description of the major modeling approaches in use today—the four-step model and activity-based modeling. The third section discusses the important relationship between travel demand modeling and air quality analysis, and the final section describes different travel demand software packages available to the transportation community. The reader should note that freight demand modeling is not discussed in this chapter, but is described in chapter 22 on freight transportation.

II. MODELING TRAVEL DEMAND

A. Brief Historical Perspective

Prior to the mid-1950s, many urban areas relied on simple uniform growth factors for estimating future travel demand. [Weiner, 1987] In other words, planners simply looked at the historical growth in travel and extrapolated to future years. As transportation became more important to the growing metropolitan areas of the 1950s and 1960s—and especially when a formal transportation planning process was required in federal transportation legislation (see chapter 1)—the need for more formalized forecasting methods became crucial. During the early years of travel demand modeling, demand forecasting was used largely to ensure that sufficient highway capacity was available to meet the growing demand for automobile trips. Very little effort was devoted to predicting the demand for other modes of transportation. Many of the analysis techniques developed during this period became the technical foundation for what is now known as the four-step modeling process.

The 1960s and 1970s saw many important changes in transportation planning. Environmental concerns started to play a small, but more significant role in transportation decision making. Oil embargoes in the 1970s led to a growing concern about the reliance of the U.S. transportation system on imported oil, and models were once again expected to provide information on the likely effects of different transportation strategies in response. Beginning in the mid-1980s, larger urban areas began to look more seriously at ways of providing mobility other than with single-occupant cars, and travel demand models were expected to provide some indication of the most effective types of transit and travel

[1]The original chapter in Volume 3 of this handbook was written by Debbie A. Niemeier, Ph.D., P.E., Professor, and Song Bai, Ph.D., Civil and Environmental Engineering, University of California-Davis. Changes made to this updated chapter are solely the responsibility of the editor.

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demand management (TDM) strategies under varying system conditions. During the past 20 years, the emphasis on expanding system capacity to *meet* demand has shifted to a philosophy of *managing* demand. Consider, for example, the application of intelligent transportation system (ITS) technologies to manage system performance and provide better information to travelers (see chapter 10 on transportation system management and operations). To know which investments make sense, travel demand models were called on to determine the effect of these technologies and other operations-oriented strategies on travel decisions. [TRB, 2007]

Today's land-use planning and transportation investment decisions are accompanied by a variety of other considerations unheard of in the 1950s—ranging from air-quality conformity, environmental impacts, and environmental justice issues to informing regulatory processes and addressing reporting requirements associated with government accountability. These context-related changes to planning have also been accompanied by fundamental changes in household factors that often drive demand, resulting in different travel markets today than those of 20 years ago. For example, declining household size and increasing vehicle ownership have had perhaps the greatest impact on travel activity (see chapter 2 on travel statistics). The average household size has dropped by roughly one person in the last 40 years. During the same period, vehicle ownership has continued to rise. As noted by the American Association of State Highway and Transportation Officials (AASHTO), the changes over the past 50 years in auto ownership have been dramatic:

> *"The number of households with one vehicle remained roughly constant for 30 years, but after 1990 it began to increase, perhaps attributable to the influx of immigrant populations and growth in single-adult households. Note that, for the most part, the great changes were in the two-and three-vehicle households. Households with two vehicles increased from about 10 million to more than 40 million in the period, and households with three or more vehicles increased an incredible amount, from 1.3 million to more than 22 million, almost 20 times the 1969 figure."*
>
> *—AASHTO, [2013]*

Household composition and the organization of household activities also continued to evolve. As household structure changed, so did travel patterns, which were also influenced by rapid suburbanization of U.S. metropolitan areas. As the number of single-parent and two-worker households increased, the ways in which individuals arranged their daily travel also became more complicated. Nonwork trips are now often linked to work commute trips, resulting in a linking—or trip chaining—of different types of activities. As early as the mid-1990s, Strathman et al. [1994] found that 31.5 percent of all trip chains were work-related and 68.5 percent were nonwork-related.

Partially in response to these changes, the last two decades of travel demand forecasting have seen significant improvement in tools and methods. The complexity of policy and infrastructure decisions has driven the development of many innovations, which have now made their way into mainstream practice.

B. Principles and Concepts

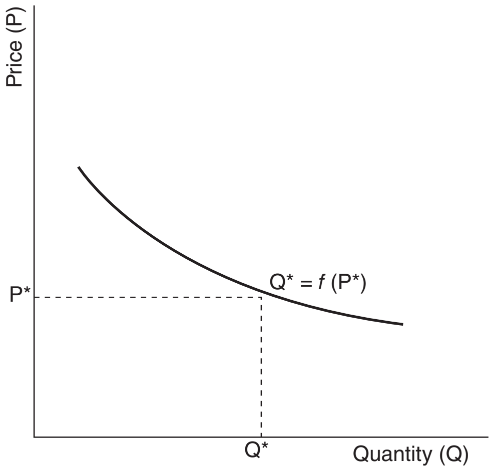
Travel demand models are based on several fundamental concepts and principles that have served as the foundation for demand modeling for decades. These concepts range from consumer theory to the idea of travel being considered a derived demand. It is beyond the scope of this chapter to discuss each of these topics in detail. However, transportation planners should understand some of the basic foundations of travel demand modeling in order to understand why models are formulated the way they are.

Travel as a Derived Demand. Viewing travel as a *derived demand* is perhaps one of the most important concepts in travel demand modeling and has been incorporated into traditional models as well as some of the newer modeling approaches. Put simply, derived demand says that travel occurs because of activities that occur at the destination … travel is simply a means to an end. Demand is derived from the need or satisfaction in arriving at a destination. This has resulted in model variables that describe the attractiveness of destination zones (for example, thousands of square feet of retail space) as well as characteristics of the origin zones (for example, household incomes).

Travelers as Consumers of Travel. Consumers of goods usually consider a range of factors when deciding to purchase one product over another. So too in transportation. Travelers are considered to be "purchasing" one mode of travel over another. In travel demand parlance, a mode is considered to have a utility attached to its use (or a disutility, if the characteristic does not lead to higher consumption, for example, cost of travel). The utility of a mode is associated with such things as travel cost, convenience, travel time, availability of the mode, and the like. Travelers are assumed to weigh the utility of one mode versus another and then choose the one with the greatest utility. Importantly, the choice of one mode versus another is observable, that is, one can develop models based on the observed behavior of individual travelers, aggregated over all travelers in a network.

Network Flows as Equilibrium Flows. Figure 6-1 shows a very common representation of the demand for a good and its relationship to price. As shown, the demand curve represents expected quantities consumed at a particular price. For transportation modeling, at an aggregate level, it is assumed that individual travelers cannot increase their utility by choosing another path or another means of arriving at a destination. Using travel cost as a simple representation of utility, this means that a traveler cannot find another least cost travel path different than the one chosen, all things being equal. Thus, the overall trip-making flows on a network for a given price is assumed to be an equilibrium flow. Travel demand modeling must therefore reflect not only the characteristics of travelers, but also the characteristics of network performance. It is the interaction between the demand and supply of transportation that is reflected in demand estimates. Note that the demand curve could shift depending on factors that are outside the control of a transportation planner (for example, the population gradually getting older) and that demand elasticities (change in demand in proportion to change in price) can vary by whether the effect is short term or long term.

Figure 6-1. Demand Curve



Stochastic Behavior. Although one would expect a "rational" person to always choose the mode of travel that maximizes utility, such is not the case. There are some travelers who will not drive during peak periods, while others will never use a bus. If one believes in the concept of derived demand, a "rational" person would always choose the shortest time path between origins and destinations; however, many choose routes that are longer for no other reason than to "see the sights." Thus, there is some uncertainty associated with trip-making decisions that must be considered as part of travel demand modeling. This is manifested in travel demand models by using the probabilities of certain trips being taken by different modes.

Trip Purpose and Time of Day. As noted in chapter 2, trips are made for some purpose (derived demand) and occur at specific times of the day. Thus, travel demand models incorporate trip purpose into the structure and functioning of the models themselves. In traditional models, demand analysis is actually done sequentially by trip purpose. Thus, one would forecast work trips, shopping trips, school trips, and so on individually. These would then be aggregated to obtain a total trip-making "picture." Similarly, time-of-day was handled by forecasting a 24-hour trip table and then reducing it to individual times of the day (for example, peak three hours, peak hour, or off peak hours) using historical percentages of the amount of travel occurring in these time periods. In many recent modeling efforts, trip purpose and time-of-day have been combined by looking at the typical trip-making activities of individuals during the day. For example, a traveler might start from home in the morning, drop off a child at a day care center, drive to work, walk to a nearby coffee shop, walk back to work, walk to a nearby restaurant for lunch, walk back to work, drive to pick up the child at daycare, and drive home in late afternoon. Many of today's demand models are able to represent this trip-making behavior by focusing on a traveler's activities during the day, and thus the term "activity-based models."

Spatial Distribution of Activities. Just as trip-making occurs over time, so too do trips occur over spatial areas. Thus, when predicting the demand for travel, transportation planners will want to know where trips are likely coming from and where they are going to. From a modeling perspective, this becomes important for assigning travel flows to transportation networks, such as a highway or transit network. Identifying the spatial nature of trip-making has become more challenging in recent years with employees who work at home, or who work from sites not considered normally as a work location, for example, a coffee shop. As society becomes ever more distributed via the Internet, understanding the spatial distribution of where many of our everyday activities occur could become even more important.

C. Travel Demand Model Applications

Travel demand estimation occurs in a variety of problem-solving and planning contexts. In each case, the inputs to a model or forecasting tool will vary according to the complexity of the desired outcomes and the scale of demand analysis. Thus, for example, a regional demand forecast will require a representation of the entire region (for example, traffic analysis zones) and of the entire transportation system (for example, transit, highway, and nonmotorized networks). The degree of sophistication and complexity in forecasting future demand for travel can range from the use

Table 6-1. Typical Output Measures by Road Demand Forecasting Application			
Travel Forecasting Application	**Typical Volume-based MOEs**	**Typical Time-Based MOEs**	**Accessibility MOEs**
Air quality conformity analysis	Area-wide vehicle miles traveled (VMT)	Speeds	
Asset management, including bridge and pavement needs	Link-specific volumes		
Capital improvement program, prioritization	Benefit/cost, level of service (LOS)		
Congestion management process	Corridor volumes	Speeds	
Corridor mobility studies	Intersection: LOS, Intersection turning movements, travel volumes		
Demand management plans	Number of peak-hour trips, LOS		
Environmental impact statements	VMT, emissions, crashes	Vehicle hours of travel (VHT)	
Energy consumption	Fuel consumed (related to miles per gallon)		
Evacuation plans	Hourly travel volumes, throughput	Travel times	
Facility design and operations	Design hour travel volumes		
Highway feasibility studies	Benefit/cost, screenline volumes, LOS	VHT	Access to labor market and jobs
Interchange justification requests	Travel volumes, LOS		
Roadway (general and freight) long-range planning	VMT, LOS	VHT	Access to labor market and jobs
Travel impact studies	Intersection turning movements, LOS, delay per vehicle		

Source: As modified from CDM Smith et al., 2014, Reproduced with permission of the Transportation Research Board.

of simple growth rates and trend-line analysis to large-scale travel demand and simulation models. Table 6-1 shows different applications for travel demand forecasting and the type of information produced by demand analysis. This information describes the condition and performance of the future transportation system such that investment or operations decisions can be made today in anticipation of future capacity and operational problems. Measures of effectiveness (MOEs) in this table refer to the types of outputs from the forecasting tool. Also note that the focus of the travel demand forecasting tools shown in Table 6-1 is primarily on road demand; forecasts for transit ridership and pedestrian/bicycle use rely on similar, but slightly different approaches.

NCHRP Report 765, *Analytical Travel Forecasting Approaches for Project-level Planning and Design*, [CDM Smith et al., 2014] provides useful insights on the strengths and weaknesses of volume-based, travel-based, and accessibility output measures. Table 6-2 shows this assessment.

NCHRP Report 765 also provides a useful checklist or "rules of thumb" for applying travel forecasting techniques in a transportation analysis, including:

- Every effort should be made to forecast travel on the basis of an analysis of the interaction of transportation demand and supply using well-validated travel demand models. Travel demand forecasts should be based on behavioral/socioeconomic factors, rather than trend-line extrapolations of travel growth whenever possible.
- Additional area detail (additional zones and links) may be created for project-level forecasts.
- Adjustments for over/under forecasting should be conducted at the level of the trip table first, before link-level adjustments are made.
- Link-level adjustments for over/under estimation against base year travel counts should not exceed 15 percent.
- Intersection turning movement forecasts beyond a five-year timeframe are highly susceptible to error and should be avoided.

Table 6-2. Strengths and Weaknesses of Travel Forecasting Model Outputs			
	Volume-based Measures	**Time-based Measures**	**Accessibility Measures**
Definition	Volume-based measures deal with the quantity of use of transportation facilities at a point on a transportation network along several points on a screenline, or between origins and destinations. Demand is associated with specific timeframes.	Travel time measures describe the trip duration of travel by a vehicle between two points or the total effort incurred in travel by a group of travelers between or within regions.	Accessibility measures can be used to assess how environmental justice populations are affected by transportation investments and development and to estimate the proximity of facilities such as ports, airports, warehouses, and distribution facilities to shippers and site retail and other commercial developments, using measures such as the population within a reasonable distance of a development site.
Strengths/Weaknesses	Travel volumes are the most basic, readily understood, readily accepted, and thus most important output of the travel forecasting process. However, travel volumes do not convey the traveler's experience of congestion or delay.	Travel time-based measures more closely describe a traveler's experience than do volume-based measures. However, most forecasting applications estimate travel time less accurately than travel demand volumes.	Higher levels of accessibility correspond to increased destination choices and modal choices and thus better economic and social outcomes. Basic measures of accessibility are readily understandable when the choices or opportunities available are simply counted. When used at large geographic scales, the measure can be relatively insensitive to small to moderate changes in transportation capacity. Aggregate measures of accessibility that produce unitless results (such as change in utility) can be difficult to explain and understand.
Application/Purpose	Travel volumes describe the number of vehicles at a point on a roadway. Travel forecasts are often developed for specific travel markets, such as passenger vehicles and trucks. Special-purpose studies may focus on additional vehicle classes, such as buses or combination and single unit trucks.	Travel time information is often compared to some norm or standard to describe performance. The standard or baseline against which travel time performance is being measured should be realistic and clear. When comparing travel times between two points, often the point of comparison is a no-build scenario. A related measure, travel time delay, is expressed as the increment of time incurred in travel, over and above some expected level. Often the expected level is defined as travel in uncongested conditions (free flow times). However, uncongested conditions may be an unrealistic standard in some urbanized areas and during peak periods of travel. This is less of an issue when delay is used as a relative measure, as a way to compare alternatives.	Typical applications include the relationship between a smaller area and a larger region: • Number of households (larger region) within 30/45/60 minutes of an employment or activity center (smaller area), as a measure of access to labor. • Number of jobs (larger region) within 30/45/60 minutes of a residential area (smaller area), as a measure of access to jobs. Researchers and planners have developed more generalized measures of accessibility, suitable for application at a regional level. Such measures rely on formulations similar to the gravity model; the denominator of a destination or mode choice model, the logsum, can also be used as a measure of accessibility across all modes represented.

Source: CDM Smith et al., 2014, Reproduced with permission of the Transportation Research Board.

- Projected decreases in travel (negative growth rates) volumes in a study area should be examined carefully and explained fully. Possible causes include economic factors; creation of new, parallel routes; shifts in through travel; and forecasting procedures based on unusual and/or unrepresentative travel conditions.
- Benefit/cost analysis should be applied to travel forecasting for investment decision making whenever possible.
- Travel forecasts should be documented in a brief report that includes sufficient information to inform a reader about the purpose of the analysis, the principal finding of the analysis, the rationale or supporting evidence

Table 6-3. Travel Forecast Precision	
Travel Forecast Prediction	
Forecast Volume	**Round to Nearest**
<100	10
100 to 999	50
1,000 to 9,999	100
10,000 to 99,999	500
>99,999	1,000

for the finding of the study area's existing conditions, and the approach/methodology used to conduct the analysis.

- Good travel forecasting depends on reliable and timely baseline data. At a minimum, hourly travel counts for automobiles and trucks should be collected at a project site for travel forecasting.
- The assumptions, analysis process, and results of a travel forecasting process should be thoroughly documented and made available for public review.
- Rounding should be done by AADT levels to avoid implied precision, see Table 6-3. [CDM Smith, 2014]

Some useful references for the travel demand modeling process include:

- Travel Model Improvement Program (TMIP), *Travel Model Validation and Reasonableness Checking Manual*, Second Edition, http://www.fhwa.dot.gov/planning/tmip/publications/other_reports/validation_and_reasonableness_2010/index.cfm.
- *TMIP Guide for Travel Model Transfer*, http://www.fhwa.dot.gov/planning/tmip/publications/other_reports/travel_model_transfer/index.cfm.

White papers:

- "Improving Existing Travel Models and Forecasting Processes" https://www.fhwa.dot.gov/planning/tmip/publications/other_reports/improving_existing_models/.
- "Managing Uncertainty and Risk in Travel Forecasting" http://www.fhwa.dot.gov/planning/tmip/publications/other_reports/uncertainty_and_risk/uncertaintyandrisk.pdf.

TMIP tools:

- Road Pricing Feasibility Screening Tool https://www.fhwa.dot.gov/planning/tmip/publications/other_reports/feasibility_screening/.
- TAZ Data Consistency Checking Tool (forthcoming).

Demand forecasting for transit and nonmotorized travel have some similarities to the road demand forecasting described above. With respect to transit riders, the same basic approach to forecasting is used to forecast future ridership, except that the expected transit riders are assigned to a transit network instead of a road network (of course, for bus planning, the road network is the basic structure of the bus transit network). The outputs for a transit forecasting model are number of riders by trip purpose, time of day, and usually household income.

Walking and bicycle riding are important in many cases not only as a primary mode of travel, but also as a mode for accessing other higher-capacity modes. This is illustrated in Table 6-4 where mode share was estimated in a study in Arlington, Virginia, with different values of pedestrian-conducive environments reflected in a walk score. As shown, as the walkability score increased, the amount of walking and transit ridership increased, while the use of the automobile declined.

For pedestrian and bicycle demand forecasting, greater detail is required on the characteristics of the travelers and of the origins and destinations. Thus, for example, a recent pedestrian forecasting model that is integrated with the

Table 6-4. Mode Split for HBW and HBO Trips in Relation to Walk Accessibility Scores, Arlington, Virginia

	HBW Origin			HBW Destination		
WALK Score[1]	Auto	Transit	Walk	Auto	Transit	Walk
<100	65%	30%	1%	85%	10%	3%
200	55	37	5	79	17	5
400	50	43	8	70	21	6
600	43	45	10	67	24	7
800	40	47	11	65	27	7
1000	38	48	13	62	29	8
>1200	35	50	14	60	30	9
	HBO Origin			**HBO Destination**		
WALK Score	**Auto**	**Transit**	**Walk**	**Auto**	**Transit**	**Walk**
<100	88%	2%	10%	88%	1%	12%
200	75	8	17	81	3	13
400	65	12	23	79	8	14
600	59	15	26	76	10	14
800	54	16	29	74	11	15
1000	51	18	31	72	12	15
>1200	48	18	32	70	13	15

[1] https://www.walkscore.com/methodology.shtml

Source: Kuzmyak et al., 2014, Reproduced with permission of the Transportation Research Board.

traditional travel demand modeling process uses pedestrian analysis zones (PAZs) that are different from the travel analysis zones utilized for travel demand forecasting. [Singleton et al., 2014] The PAZ's reflect the urban design and land-use characteristics that encourage travelers to walk (known as a pedestrian index of the environment), such as people density, transit access, development density, block size, sidewalk density, and comfortable facilities. The number of travelers walking would then be deducted from the trip-generation estimates (which are usually not mode-specific in the traditional modeling approach), and used to estimate the walking demand for the study area. Figure 6-2 shows the pedestrian index for the environment as estimated for Portland, Oregon. Not surprisingly, the more conducive and more likely areas for walking as a primary mode of travel are in the downtown area.

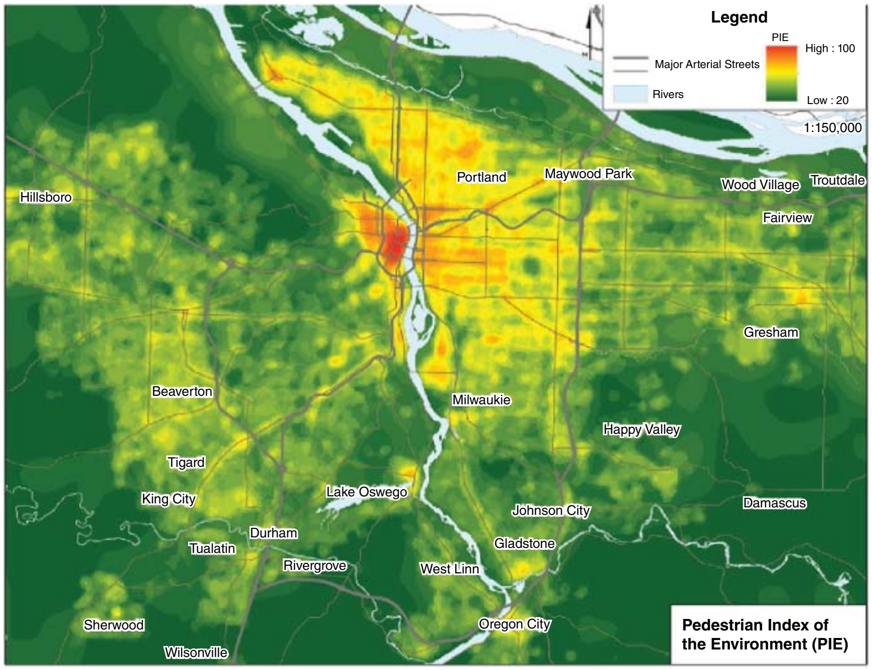
For additional material on demand forecasting for walking and bicycle riding, see chapter 13.

D. Model Zones and Networks

Travel demand models often depend on a zonal system reflecting the sociodemographic characteristics of the households in the study area (travel analysis zones) and on a coded network. Recent advances in travel demand modeling as reflected in activity-based modeling and microsimulation focus more on individual traveler use of a network, and thus do not rely on travel analysis zones. Chapter 2 and chapter 3 on data collection and land use, respectively, describe the types of data used to populate the zonal systems, and will thus not be repeated here. However, how a transportation network is created and depicted requires some attention.

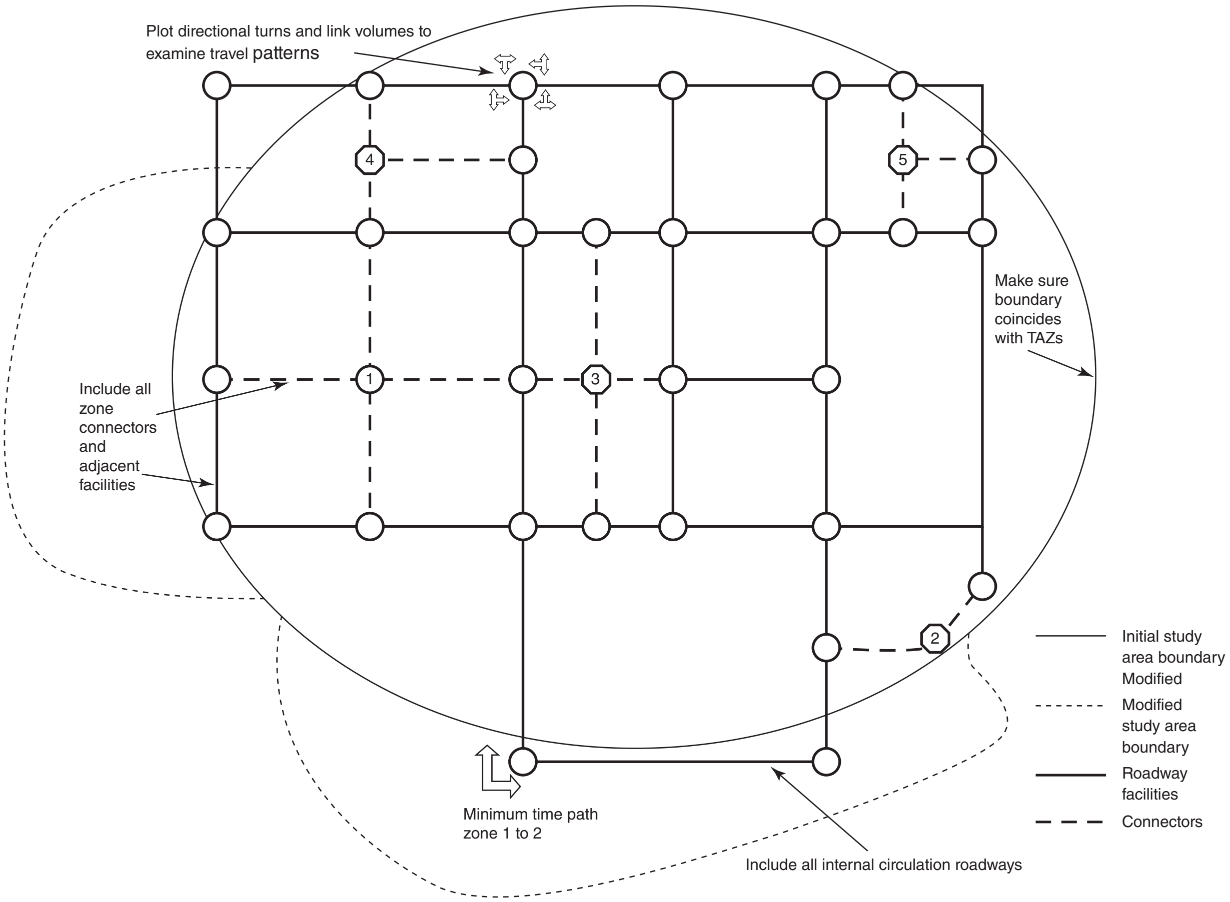
Figure 6-3 shows a typical representation of a network model. As shown, a network consists of two major elements—nodes and links. A node represents any point in the network where a user can enter the network (for example, an intersection or transit station) or where some change in direction occurs (for example, a ramp or access point to a major activity center). Links represent the connections between the nodes, for example, roads, transit lines, bike paths, and the like. Usually, for modeling purposes, each link has a link performance function that defines how that link performs as volume builds (discussed later in the network assignment section). In other words, as more and more volume is assigned to a particular link, the more congested that link becomes and thus the more time it takes to traverse the link. From the perspective of the model algorithms, this link might become so congested that the model

Figure 6-2. Pedestrian Index of the Environment Estimation for Portland, Oregon



Source: Singleton et al., 2014

Figure 6-3. Representation of a Transportation Network



Source: CDM Smith et al., 2014, Reproduced with permission of the Transportation Research Board.

will look for other paths for users to get to a particular destination. Because the model results depend so much on the valid specification of the network (for example, distance, speed, and location), the modeler needs to be very careful in developing and coding the network. Modern software and GIS packages provide modelers with the capability of building a network fairly easily; however, the modeler must still input the link attribute data.

The following link attributes are most often included in a road network database:

- Node identifiers, usually numeric, and their associated geocoordinates.
- Link identifiers, either numeric, defined by "A" and "B" nodes, or both.
- Locational information (for example, zone, cutline, or screenline location).
- Link length/distance.
- Functional classification/facility type, including the divided or undivided status of the link's cross section.
- Number of lanes.
- Uncongested (free-flow) speed.
- Capacity.
- Controlled or uncontrolled access indicator.
- One-way versus two-way status.
- Area type.
- Travel count volume (where available). [CDM Smith et al., 2014]

Transit link definition is a bit more complicated than that for road networks because riders can access transit services in many different ways, for example, walking, bicycling, auto drop-off, auto parking, other transit services, and so on. Table 6-5 shows some of the transit links that are often used for coding transit service networks.

In most cases, such as regional or community-level modeling, a zonal system and network model already exist, and planners must then ask themselves if the zone system and network are at a level of detail sufficient for the desired analysis. For example, most metropolitan planning organizations (MPOs) have traffic analysis zones (TAZs) based on the latest census information. For large MPOs in particular, these zones have been used in a land-use forecasting model. In addition, census block data are available at the sub-tract level. [Cambridge Systematics and AECOM Consult, 2007] As can be seen in Figure 6-4, the TAZ system for large metropolitan areas (in this case, for the Atlanta, Georgia, metropolitan area) can be extensive.

In many cases, the TAZ boundaries closely replicate census tracts simply to allow the transfer of census data to TAZ databases. Many of these zones, however, might be too large for the study purposes, especially if the study is examining travel flows at a much finer level of detail. For example, a corridor study in Atlanta used the TAZ structure developed by the Atlanta Regional Commission for the analysis of travel flows. The corridor itself was a large regional corridor serving trips throughout the region and thus 1,683 TAZs were included in the analysis. However, because the corridor study was interested in travel flows at key locations included within much larger zones (for example, major development sites near interchanges), 131 new zones were created by subdividing some of the original TAZs into smaller zones. By so doing, the study was able to examine travel flows into and out of key trip generators in the corridor.

E. Model Calibration and Validation

Two of the most important tasks in developing a credible model are calibrating the demand model with existing data and then validating its results. As will be seen later, many demand models use equations to predict either the demand itself or some aspect of system performance that influences a traveler's decision, such as the level of congestion on the network. These equations often consist of variables such as travel cost, travel time, number of transfers, and so forth, as well as coefficients that reflect the relative magnitude of each variable in the equation. The value of each variable is obtained from existing databases or is measured through data collection efforts. These values are then used

Table 6-5. Transit Link Characteristics	
Characteristic	**Description**
Drive access link	A link that connects TAZs to a transit network via auto access to a park-and-ride or kiss-and-ride location.
Effective headway	Time between successive transit vehicles on multiple routes with some or all stops in common.
Headway	Time between successive arrivals (or departures) of transit vehicles on a given route.
Local transit service	Transit service with frequent stops within a shared right-of-way with other motorized vehicles.
Mode number	Code to distinguish local bus routes from express bus, rail, and the like.
Park-and-ride-to-stop link	A walk link between a park-and-ride lot and a bus stop, which is used to capture out-of-vehicle time associated with auto access trips, and also for application of penalties associated with transfers.
Premium transit service	Transit service (for example, bus rapid transit, light rail transit, heavy rail, commuter rail) with long distances between infrequent stops that may use exclusive right-of-way and travel at speeds much higher than local service.
Route description	Route name and number/letter.
Run time	The time in minutes the transit vehicle takes to go from the start to the finish of its route and measure of the average speed of the vehicle on that route. Often estimated by the program based on segment length and speed.
Transfer link	A link used to represent the connection between stops on two transit lines that estimates the out-of-vehicle time associated with transfers, and also for application of time penalties associated with transfers.
Transfer penalty	Transit riders generally would rather have a longer total trip without transfers than a shorter trip that includes transferring from one vehicle to another; therefore, a penalty is often imposed on transfers to discourage excess transfers during the path-building process.
Walk access link	A link that connects TAZs to a transit network by walking from one zone to a bus, ferry or rail service; usually no longer than 1/3 mile for local service and 1/2 mile for premium service.
Walking link	A link used exclusively for walking from one location to another. These links are used in dense areas with small TAZs to allow trips to walk between locations rather than take short transit trips.

Note: Italics indicate those characteristics that should be in all transit networks

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to estimate coefficients or other parameters of the demand model. Typical approaches for this estimation include regression analysis or maximum likelihood analysis. The intent is to develop the most credible demand model by estimating the variable coefficients based on real-world data. This is called calibrating the model.

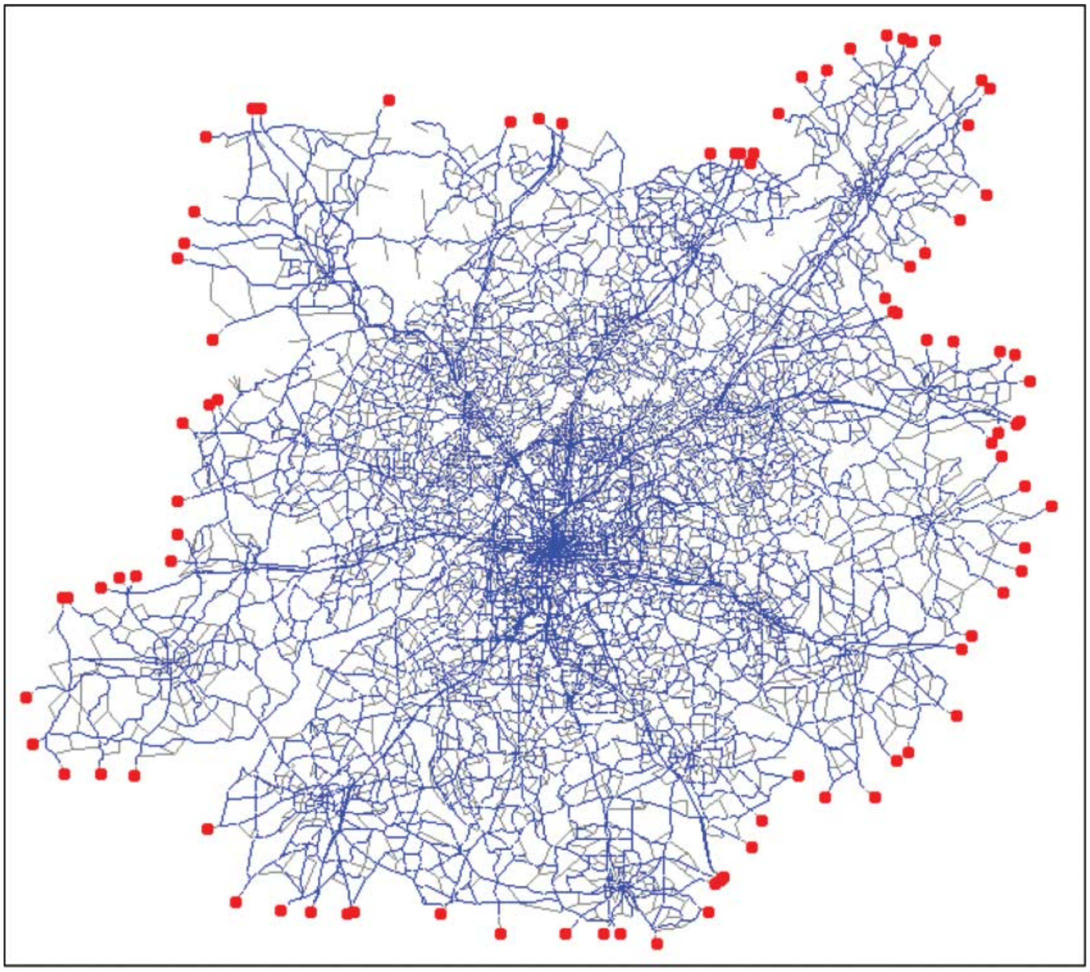
Model validation is the process of using the calibrated model and running it against some known values to check if the model is producing valid results. For example, a calibrated demand model could be used to estimate the ridership on existing transit routes and the model results compared to actual ridership for validation. For highways, a typical approach is to estimate travel volumes on specific links on the network, then compare modeled volumes with actual travel counts at those locations. Screenline counts are often used for this purpose. Table 6-6 shows different ways that model results can be validated.

Good practice in model development and use starts with close attention to model calibration and validation.

III. DEMAND MODELS AND TOOLS

Demand analysis uses many different tools and models, depending on the type of information desired. As mentioned earlier, these tools can be as simple as trend projections based on historical data, or as sophisticated as simulated travel behavior using the aggregate movements of simulated individual travel behavior. The following sections provide an overview of some of the most used analysis tools for demand forecasting. For those interested in participating in on-going discussions relating to travel demand modeling, see http://tfresource.org/Travel_Forecasting_Resource.

Figure 6-4. Traffic Analysis Zones in the Atlanta Regional Commission Travel Demand Model



Source: ARC, 2015, Reproduced with permission of the Atlanta Regional Commission.

A. Demand Elasticity Analysis

Demand elasticity is an important tool used by transportation planners for very special types of problems. The analysis approach is based on the economic concept that consumer behavior will respond to changes in the characteristics of the product or service being offered. Thus, the elasticity of demand with respect to price refers to the change in demand when price either goes up or down. In general, as price increases, demand should go down, and vice versa. Demand elasticity analysis is most useful when one is dealing with transportation services or products where a relationship between service characteristic and travel demand is clear, such as, what happens to transit ridership when fares are raised? Or what happens to transit ridership when more frequent service is provided? Or what happens to parking demand when parking fees are applied?

Some important terms for demand elasticity analysis include: [Meyer and Miller, 2014]

Direct Elasticity. Direct demand elasticities are those that involve variable relationships relating "directly" to the demand in question. In other words, there is assumed to be a direct causal relationship between the two. If the price of parking goes up, parking demand goes down … a direct linkage between cause and effect. The elasticity of transit demand with respect to transit fare, transit travel time, transit service headway, and so on, would all be direct elasticities. The demand elasticity is considered *elastic* if a 1 percent change in any variable produces more than a 1 percent change in demand. The demand elasticity is considered *inelastic* if a 1 percent change in any variable produces a less than 1 percent change in demand. A demand elasticity is considered *unit elastic* if a 1 percent change in any variable produces a 1 percent change in demand.

Table 6-6. Examples of Primary and Secondary Model Validation Tests

Component	Primary Tests	Secondary Tests	Potential Validation Data Sources
Networks/Zones	• Correct distance and speeds on links • Network topology, including balance between roadway network detail and zone detail • Appropriateness of zone size given spatial distribution of population and employment • Network attributes (managed lanes, area types, speeds, capacities) • Network connectivity • Transit run times	• Intrazonal travel distances (model design issue) • Zone structure compatibility with transit analysis needs (model design issue) • Final quality control checks based on review by end users • Transit paths by mode on selected interchanges	• GIS centerline files • Transit on-board or household survey data
Socio- economic Data/Models	• Locations of special generators • Qualitative logic test on growth • Population by geographic area • Types and locations of group quarters • Frequency distribution of households and jobs (or household and job densities) by TAZ	• Households by income or auto ownership • Jobs by employment sector by geographic location • Dwelling units by geographic location or jurisdiction • Households and population by land-use type and land-use density categories • Historical zonal data trends and projections to identify "large" changes (for example, in autos/household from 1995 to 2005)	• Census data • Quarterly Census of Employment and Wages • Private sources, such as Dun & Bradstreet
Trip Generation	• Reasonableness check of trip rates versus other areas • Logic check of trip rate relationships	• Checks on proportions or rates of nonmotorized trips • Reasonableness check of tour rates • Cordon lines by homogeneous land-use type	• NCHRP 716 • Travel counts (or intercept survey data) for cordon lines • Historic household survey data for region • National travel surveys
Trip Distribution	• Trip length frequency distributions (time and distance) by market segments • Worker flows by district • District-to-district flows/desire lines • Intrazonal trips • External station volumes by vehicle class	• Area biases (psychological barrier, for example, river) • Use of k-factors (design issue) • Comparison to roadside intercept origin destination surveys • Small market movements • Special groups/markets • Balancing methods	• National freight flow data • NCHRP 716 • Travel counts (or intercept survey data) for screenlines • Historic household survey data for region • National travel surveys

(*continued*)

Table 6-6. (*Continued*)

Component	Primary Tests	Secondary Tests	Potential Validation Data Sources
Time of Day of Travel	• Time of day versus volume peaking • Speeds by time of day	• Cordon counts • Market segments by time of day	• Permanent travel recorder data • National travel surveys • Historic household survey data for region • Transit boarding count data
Mode Choice	• Mode shares (geographic level/ market segments) • Check magnitude of constants and reasonableness of parameters • District-level flows • Sensitivity of parameters to LOS variables/elasticities	• Input variables • Mode split by screenlines • Frequency distributions of key variables • Reasonableness of structure • Market segments by transit service • Existence of "cliffs" (cutoffs on continuous variables) • Disaggregate validation comparing modeled choice to observed choice for individual observations	• Travel counts and transit (or intercept survey data) for screenlines • National Census data • NCHRP 716 • Transit on-board survey data • National travel surveys • Household survey data (separate from data used for model estimation)
Transit Assignment	• Major station boardings • Bus line, transit corridor, screenline volumes • Park-and-ride lot vehicle demand • Transfer rates • Transit run times	• Kiss-and-ride demand • Transfer volumes at specific points • Load factors (peak points)	• Transit boarding counts • Transit on-board survey data • Special surveys (such as parking lot counts) • Transit schedules and schedule adherence checks
Travel Assignment	• Assigned versus observed vehicles by screenline or cutline • Assigned versus observed vehicles speeds/times (or vehicle hours traveled) • Assigned versus observed vehicles (or vehicle miles traveled) by direction by time of day • Assigned versus observed vehicles (or vehicle miles traveled) by functional class • Assigned versus observed vehicles by vehicle class (for example, passenger cars, single-unit trucks, combination trucks)	• Sub-hour volumes • Cordon line volumes • Reasonable bounds on assignment parameters • Available assignment parameters versus required assignment parameters for policy analysis • Modeled versus observed route choice (based on data collected using GPS equipped vehicles)	• Permanent travel recorders • Travel count files • HPMS data • Special speed surveys (possibly collected using GPS-equipped vehicles)

Source: As reported in CDM Smith et al., 2014, Reproduced with permission of the Transportation Research Board.

Indirect or Cross Elasticity. Indirect or cross elasticity typically relates to the effect on the demand for other modes of travel when some characteristic of the target mode is changed. The elasticity of transit demand with respect to changes in automobile parking prices or road tolls would be an example of a cross elasticity. In other words, if parking prices go up, parking demand will go down (the direct relationship). However, some of the former parkers will now use transit (the secondary relationship).

Short-Term Elasticity. The change in demand over the short term (usually defined as two years) reflects the immediate response to changes in price and does not take into account longer-term decisions (such as auto ownership) that might be taken by a household in response to a price change.

Long-Term Elasticity. The change in demand over the long term (usually defined as 5 years or more) reflects the longer-term decisions that households might make in response to a price change (such as ownership or vehicle technology choice, house location and/or lifestyle changes). Long-term elasticity might be influenced by a threshold level, that is, price elasticity may not be the same for large as compared to small changes in underlying price.

Shrinkage Ratio. If one assumes a linear demand function, one can easily estimate the change in demand by applying the slope (or elasticity) of the demand curve. This is called a shrinkage ratio. For example, assuming an elasticity of -0.50 and a 10 percent increase in price, one would expect a ($-0.5 \times 0.1 = -0.05$) or 5 percent reduction in demand.

Arc Elasticity. In reality, most demand curves are not linear (see Figure 6-1), and a price elasticity represents the percent change in demand with respect to a 1 percent change in price. So using the preceding example, a 10 percent increase in price really represents ten 0.5 percent reductions. For those familiar with engineering economy, this can be denoted as an effective interest rate over 10 interest periods of $(1 + 0.005)^{10} = 1.0511$, or a reduction from an original amount of $1/(1.0511) = 0.9514$, or a 4.86 reduction, which is smaller than the 5 percent estimate obtained with the shrinkage ratio. Given the variation in the demand curve at the ends of the function, the change in quantity should be approximated by a midpoint formulation based on the average value of each independent variable.

Assuming an arc elasticity midpoint formulation, the following equations can be used to determine either quantity or price given a change in the other variable and an estimated arc elasticity $\bar{e}$.

$$\bar{e} = \frac{(Q_2 - Q_1)\,(P_1 + P_2)}{(P_2 - P_1)(Q_1 + Q_2)} \tag{6-1}$$

$$P_2 = P_1 \frac{Q_1(\bar{e} - 1) + Q_2(\bar{e} + 1)}{Q_2(\bar{e} - 1) + Q_1(\bar{e} + 1)} \tag{6-2}$$

$$Q_2 = Q_1 \frac{P_1(\bar{e} - 1) - P_2(\bar{e} + 1)}{P_2(\bar{e} - 1) - P_1(\bar{e} + 1)} \tag{6-3}$$

Litman [2013] notes several studies that have produced demand elasticities. Table 6-7, for example, shows a range of elasticities of vehicle travel with respect to fuel price. In addition, he makes the following general observations concerning travel demand elasticity:

- Higher-value travel, such as business and commute travel, tends to be less price sensitive than lower-value travel.
- Wealthy people tend to be less sensitive to pricing and more sensitive to service quality than lower-income people.
- Prices tend to affect consumption in proportion to their share of household budgets.
- When there are good or easy substitutes available for a good/service, the elasticity is likely to be greater (in absolute terms).
- Consumers tend to be more responsive to price changes they consider durable, such as fuel tax increases, compared with oil market fluctuations perceived as temporary.
- Pricing impacts tend to increase over time. Short-run (first year) effects are typically a third of long-run (more than five years) effects.
- Travel tends to be more price sensitive if travelers have better options, including different routes, modes, and destinations.

Table 6-7. Examples of the Range of Elasticities of Vehicle Travel with Respect to Fuel Price, Various Studies			
Johannson and Schipper	Summary of various previous studies	International	−0.2 long run
		1929 to 1991, mostly North America and Europe	−0.1 short run −0.3 long run
Schimek		1950 to 1994 time series and 1988 to 1992 pooled data, U.S.	−0.26
Small and Van Dender	Vehicle travel elasticity with respect to fuel price, comprehensive model	1966–2001, U.S.	−0.047 short run −0.22 long run *1997 to 2001* −0.026 short run −0.121 long run
Hymel, Small and Van Dender	State-level cross sectional time series gasoline price elasticities; comprehensive model	1966–2004, U.S.	−0.026 short run −0.131 long run
Li, Linn and Muehlegger	Vehicle travel with respect to fuel price; comprehensive model	1968–2008, U.S.	−0.24 to −0.34
Brand	Gasoline price elasticities	2007–2008, U.S.	−0.12 to −0,17 short run −0.21 to −0,30 long run
Gillingham	Odometer and fuel consumption data; comprehensive model	2005–2008 California	−0.15 to −0.20 medium run, varies by vehicle type and location

Source: Litman, 2013, Reproduced with permission of Todd Litman.

Table 6-8. Typical Midpoint Arc Elasticities, Changes in Transit Service			
Item	**Travel Time**	**Bus Miles**	**Bus Frequencies**
Application	**New routes, replace or complement existing routes**	**Service expansion**	**Greater frequency of existing routes**
Range	−0.3 to −0.5	0.6 to 1.0	0.3 to 0.5
Typical	−0.4	0.7 to 0.8	0.4

Source: Kittelson, 2007, Reproduced with permission of the Transportation Research Board.

- Travelers tend to be particularly sensitive to visible and frequent prices, such as road tolls, parking fees, and public transit fares.
- How fees are promoted, structured, and collected can affect their impacts.

Table 6-8 shows some typical elasticity values for changes in transit service characteristics.

See Litman [2013] and FHWA, https://www.fhwa.dot.gov/asset/hersst/pubs/tech/tech11.cfm, for a good overview of elasticity analysis.

B. Travel Demand Models

Travel demand models can generally be divided into two categories. The first includes models using a four-step analysis process, which is perhaps the most commonly used approach. The second category includes techniques used to model individual trip makers' activities during a given travel time period; these are referred to as activity-based models. Over the years, the techniques associated with four-step models have dramatically improved, yet there remains a fundamental limitation—the decision-making process associated with individual travel behavior is not well-represented in the structured approach to trip-making found in four-step models. The need to better reflect the range of individual travel decisions and intrahousehold interactions has motivated the development of activity-based modeling. Activity-based models estimate travel demand based on a basic premise—the demand to accomplish personal activities during the day (for example, work, school, personal business, on so forth) produces a demand for travel that is often connected (for example, trip chaining).

The transition from conventional four-step models to activity-based models is occurring in many of the larger metropolitan areas in the United States, although the transition has faced some challenges. The data requirements for both model types are very different. New models usually require the collection of new data to develop and validate the model against existing travel volumes. Data collection is always a large budget item and thus many agencies hesitate to embark upon a new modeling regime. This is an important issue for activity-based modeling. In contrast to the four-step data collection methods, such as household travel surveys and use of census data, activity-based models require detailed information on the daily activities of representative travelers. This type of information is often collected with trip diaries, which is a much more involved method of data collection than traditionally required in the four-step process (see chapter 2 on data collection).

The following sections describe the four-step modeling approach, followed by tour-based models (a transition model form to activity-based models), and activity-based models. Space does not allow a detailed discussion of the theory and mathematical foundations of travel demand modeling. For more information on these concepts, refer to [Goulias, 2003; Ortuzar and Willumsen, 2011; and Meyer and Miller, 2014]. In addition, most MPOs have placed on their agency websites background and explanatory information on the demand models used to forecast travel in their study area. Readers are encouraged to examine such information for more detailed information regarding demand modeling applications.

1. Four-Step Models

Traditional travel demand modeling consists of four sequential steps: trip generation, trip distribution, mode choice, and trip assignment. These four-step models answer the questions: How many people travel? What are the travel patterns for the study area? What travel modes are used? What trip paths will be followed through the transportation network? Figure 6-5 shows the general framework for a four-step modeling system. Although the four steps have remained the major structural form for modeling since the 1950s, the methods and approaches used to perform each of the steps have matured through the years. However, model sophistication varies by region size, budget constraints, and the knowledge and depth of technical staff.

Figure 6-5. The Four Steps in Traditional Travel Demand Modeling

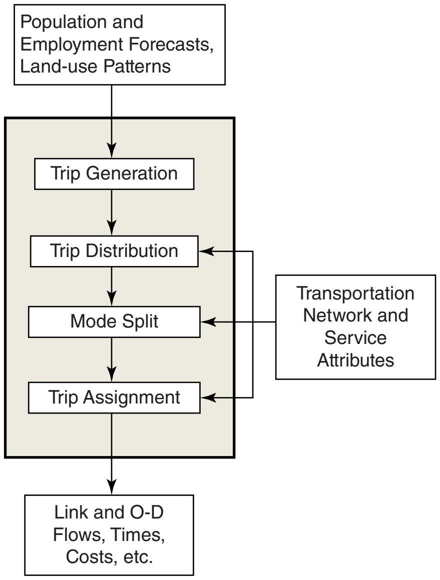


Figure 6-5 begins with population, employment, and land-use forecasts, which are often provided by other agencies or staff within a planning agency. Chapter 3 describes typical approaches for providing this input into the transportation planning process. The box "Transportation Network and Service Attributes" relates to the discussion earlier on network representation.

Trip Generation. The generation of trips, either from a point of origin or attracted to a destination, is one of the most important components of travel demand modeling (see chapter 3 on land use and urban design and chapter 19 on site planning and traffic impact analysis). The number of trips generated by each unit of land or type of activity varies according to social, economic, geographic, and land-use factors. Comprehensive studies include estimating both trip productions and trip attractions. Trip productions relate to the home end of the trip, while trip attractions relate to employment or other non-home ends of the trip. Normally, trip productions serve as the control total to which aggregate trip attractions are adjusted.

State, regional, and local transportation agencies often compile their own trip generation rates used in their study areas. Some of these rates are based on local surveys of different types of land use. Many of these analyses have focused on vehicle-related person trips (vehicle driver, vehicle passenger, transit passenger). However, more recent analyses have also included pedestrian and bicycle trips. Thus, a clear definition of the specific trips included in the trip generation analysis is essential.

Trip generation relationships to land-use characteristics are established either by regression techniques or through cross-classification (or category) analysis. Household trip generation is usually a function of median income per family, household size as well as automobile ownership and availability. Other factors may include net residential density and distance from the city center. Rates (or relationships) are normally derived for total trips and for key trip purposes such as home-to-work. They are computed for a 24-hour period or for peak hours. A typical trip generation rate analysis such as that shown in Table 6-9 gives daily person-trips per household as a function of auto ownership and family

Table 6-9. Illustrative Trip Generation Rate Analysis				
	Trip Generation Rates			
	Person Trips per Household per Day			
	Autos per Dwelling Unit			
Persons per Dwelling Unit	**0**	**1**	**2**	**3+**
1	2.8	3.1	3.6	-
2	5.1	6.1	7.9	-
3	6.8	9.2	10.2	14.5
4	8.0	10.2	13.6	18.5

Table 6-10. Typical Zonal Trip Attraction Rates							
				Employment			
	Number of MPO Models Summarized	Households[a]	School Enrollment[b]	Basic[c]	Retail[d]	Service[e]	Total
All Person Trips							
			Home-based Work				
Model 1	16						1.2
			Home-based Nonwork				
Model 1	2	1.2	1.4	0.2	8.1	1.5	
Model 2	8	2.4	1.1		7.7	0.7	
Model 3	2	0.7		0.7	8.4	3.5	
			Nonhome-based				
Model 1	5	0.6		0.5	4.7	1.4	
Model 2	8	1.4			6.9	0.9	
Motorized Person Trips							
			Home-based Work				
Model 1	8						1.2
			Home-based Nonwork				
Model 1	1	0.4	1.1	0.6	4.4	2.5	
Model 3	4	1.0		0.3	5.9	2.3	
			Nonhome-based				
Model 1	6	0.6		0.7	2.6	1.0	

[a]Number of households in a zone

[b]Number of elementary, middle school, high school, and college/university students in a zone

[c]Employment in two-digit North American Industry Classification System (NAICS) codes 1-42 and 48-51 (Standard Industrial Classification (SIC) codes 52-59

[d]Employment primarily in NAICS codes 44-45 (SIC codes 52-59)

[e]Employment primarily in NAICS codes 52-92 (SIC codes 60-97)

Source: Cambridge Systematics, Inc. et al., 2012, Reproduced with permission of the Transportation Research Board.

size (income could be used as an alternate to car ownership). As shown in Table 6-9, two-person households with two cars would generate on average 7.9 person trips per day.

Typical trip attraction rates are shown in Table 6-10, summarized from a study of travel forecasting techniques in National Cooperative Highway Research Program (NCHRP) Report 716*: Travel Demand Forecasting: Parameters and Techniques.* [Cambridge Systematics, Inc. et al., 2012] Trip attractions are keyed to factors such as floor space, hospital beds, employees, and stadium seats. In comprehensive studies, various types of employment are commonly used to obtain trip attraction rates. From Table 6-10, the number of nonhome-based person trips attracted to a zone using model 1 would be 0.6 × number of households in the zone + 0.5 × basic employment + 4.7 × retail employment + 1.4 x service employment.

Most trip generation models use cross-classification or linear regression to estimate the number of productions (trips produced by a zone) and attractions (trips attracted to a zone). Trip productions are typically expressed in units of trips per household or zone, while attractions usually relate to variables associated with employment or commercial activities (for example, the number of employees or retail square footage). Whether trip attraction model parameters are estimated from local data or are transferred from another study area, they are usually derived from household survey data. Commonly, linear regression equations are used to estimate the parameters, such as the coefficients in linear regression equations at an aggregate level such as districts (groups of zones).

Both productions and attractions are estimated for different trip types. The most common trip types are home-based work (home to work or work to home), nonhome-based (for example, work to/from shopping) and home-based other (for example, home to/from shopping). This latter category is often defined for special trip generators. In Atlanta and Dallas-Ft. Worth, for example, the travel demand model has a special trip generation module for trips to the airport.

Defining a larger number of trip purposes and types for trip generation is one of the major changes in trip generation modeling over the past several years, which also reflects a more complex travel behavior of today's travelers compared to those of 30 years ago. With greater definition or segmentation of trip types, presumably better trip generation rates can be estimated. In Chicago, for example, the planning agency has developed an expansive list of trip purposes with trip generation rates produced for 11 different purposes, and separate trip generation rates estimated for adult workers and nonworkers for home-based shop and home-based other trips. Thus, for each trip purpose, trip rates for key market segments are usually estimated separately. Market segments for productions are usually defined by variables such as the number of autos per household, household income, and/or household size.

Person and vehicular trip rates for specific activities can be obtained by drawing a cordon around the activity under consideration and then counting the number of people entering and leaving by time of day and by mode of travel. In urban settings, people counts are essential in transportation studies, especially in the city center. For free-standing suburban developments, vehicle trip rates will usually be sufficient (see chapter 2 on data collection).

Other chapters in this handbook provide more detail on how trip generation data are used in different types of transportation studies. In addition, the Institute of Transportation Engineers sponsors a trip generation website with up-to-date information (see http://www.ite.org/tripgeneration/otherresources.asp).

Trip Distribution. Trip distribution translates the zonal productions and attractions derived during the trip generation step into origins and destinations, and identifies the impedance (for example, travel time or travel cost) for each origin-destination pair for all zones in the study area. The output of the trip distribution step is an origin-destination (O-D) trip table for all trips by trip purpose.

The gravity model or variants of it are still the most widely used technique for trip distribution. It assumes that the number of trips from zone *i* to zone *j* is directly proportional to the product of trip productions in zone *i* and trip attractions in zone *j,* and inversely proportional to a friction factor (a function of impedance) between the two zones (which is the basic concept of the Law of Gravity, hence the name). Impedance captures elements of the spatial separation for two zones and can be represented as travel time, cost, distance, or some composite (referred to as a generalized cost function). It is also common to estimate a gravity model for each travel purpose because trip distribution characteristics can vary by purpose of travel. Socioeconomic adjustment factors (or K-factors) are sometimes specified as adjustments to impedances. In general, it is difficult to justify the use of K-factors, yet MPOs have continued to rely on them as a way of improving model fit.

Equation 6-4 shows the mathematical formulation of the gravity model.

$$T_{ij}^{P} = P_i^{P} \frac{A_j^{P} x\, f(t_{ij}) x\, K_{ij}}{\sum_{j'} A_{j'}^{P}\, x\, f(t_{ij'}) x\, K_{ij'}} \tag{6-4}$$

Where:

T_{ij}^{P} = Trips produced in zone *i* and attracted to zone *j*

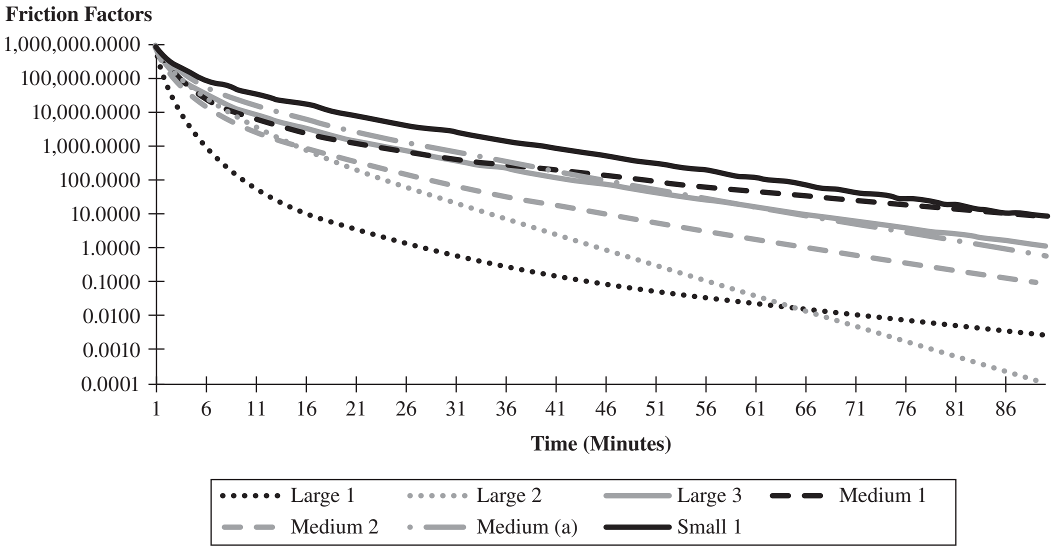
P_i^{P} = Production of trip ends for purpose *p* in zone *i*

A_j^{P} = Attraction of trip ends for purpose *p* in zone *j*

$f_{t_{ij}}$ = Friction factor, a function of the travel impedance between zone *i* and zone *j*

K_{ij} = Optional adjustment factor used to account for factors other than travel impedance

Figure 6-6. Home-based, Nonwork Trip Distribution Gamma Functions, by Metropolitan Area Size



Source: Cambridge Systematics, Inc. et al., 2012, Reproduced with permission of the Transportation Research Board.

In some recent models, trip distribution uses a multinomial logit choice model of the attraction location (for a description of logit models, see the following section on mode choice). In this case, the alternatives among which a traveler chooses are the attraction zones themselves, and the utility functions that define the level of attractiveness for each zone include travel impedance and the number of attractions in the zone.

Formulating the friction factors, or the travel impedance between every zone, is an important step in the use of the gravity model. Three major approaches are used in practice. The first simply assumes that the friction factor is a measure of travel time between the zones usually with an exponent. The second adopts an exponential formulation where the friction factor is $1/\exp^{(m \times t_{ij})}$. A third formulation assumes a Gamma distribution with scaling factors used to provide the best fit for the distribution (see Cambridge Systematics, Inc. et al., 2012). Such friction factors are usually formulated by trip purpose as shown in Figure 6-6. Readers are referred to [Cambridge Systematics, Inc. et al., 2012] for more detail on the trip distribution model step.

Mode Choice. Mode choice models are used to predict the number of trips that will use each of the available modes for origin-destination pairs. Modes can include, for example, auto, premium transit, local transit, ridesharing, and walking. Discrete choice models, such as multinomial logit and nested logit models, are the predominant modeling approach used in practice. The most widely used discrete-outcome modeling approach is the multinomial logit model, which is based on the concept of utility. This approach assumes that individual travelers assign a utility to each of the available modes, where utility is defined as: $U = V + e$, where V is the systematic utility (that is, an equation consisting of known variables and their values) and e is an error term. The error term represents those variables that are not in the data set or that are perhaps unknown to the planner, but that affect an individual's choice among alternatives. For example, some drivers avoid a short path to their destination simply because they do not want to drive on freeways, which are perceived as being unsafe. This type of behavioral factor is not likely found in any database, but could affect the probability that some travelers will not follow the least-time path.

The systematic utility, that is, the value of V, is most often represented as a linear equation. Some examples include:

$$V = -0.030 \times (\text{In-vehicle time}) - 0.075 \times (\text{Out-of-vehicle time}) - 0.0043 \times (\text{Travel cost})$$

$$V = -0.019 \times (\text{In-vehicle time}) - 0.058 \times (\text{Walk time}) - 0.081 \times (\text{First wait time}) - 0.040 \times (\text{Transfer time}) - 0.0072 \times (\text{Travel cost})$$

Each mode alternative would have its own systematic utility function that has been estimated based on the trip characteristics faced by travelers that have actually made trips. If actual trip data are unavailable, the utility model coefficients can be estimated from surveys. Depending on the number of mode alternatives available to trip makers, there would be a utility function for auto, shared ride auto, different types of transit and pedestrian/bicycle trips, and any other mode that is considered an option for an individual traveler.

The systematic or measurable utility, V, does not take into account the randomness often associated with individual travel decisions (the "e" value in the systematic utility equation). If "e" is treated as a random variable, one can then develop an equation assuming an underlying distribution for this random variable that predicts the mode an individual will choose among a set of modes that are available for the trip. Research has shown that a Type II Gumbel distribution for this variable provides the most usable form of an equation (called a logit equation) that predicts mode choice, as formulated in Eq. 6-5.

$$P_n = \frac{e^{V_n}}{\sum_{for\ all\ alternatives} e^{V_{n'}}} \tag{6-5}$$

Where:

P_n = Probability of choosing mode n
V_n = Measurable utility of mode n
n' = number of alternatives available for the trip
e = base logarithmic e

As an example, suppose the systematic utility function has the following form, with the definition of each variable and the respective values for both auto and bus shown in the table:

$$V_{\text{mode}} = a_{\text{mode}} - a_1X_1 - a_2X_2 - a_3X_3 - a_4X_4$$

	X_1 = Access time	X_2 = Transfer time	X_3 = Travel time	X_4 = Cost (cents)
Auto	5	0	20	250
Bus	15	10	35	75

The utility function values for both auto and bus, where the coefficients have been provided, are as follows:

$$V_{\text{auto}} = -0.02 - 0.025(5) - 0.05(0) - 0.15(20) - 0.016(250) = -7.145$$
$$V_{\text{bus}} = -0.90 - 0.025(15) - 0.05(10) - 0.15(35) - 0.016(75) = -8.225$$

Assume as well that there are 15,000 trips between zone i and zone j. Using Eq. 6-5, the probabilities of an individual choosing auto or bus, and the estimated number of auto and bus trips, are:

$$\text{Probability Auto} = \frac{e^{-7.145}}{e^{-7.145} + e^{-8.225}}$$

Probability Auto = 0.75
# of Auto Trips = 0.75 × 15,000
Auto Trips = 11,250 Trips

$$\text{Probability Bus} = \frac{e^{-8.225}}{e^{-7.145} + e^{-8.225}}$$

Probability Bus = 0.25
# of Bus Trips = 0.25 × 15,000
Bus Trips = 3,750 Trips

In practice, the use of discrete choice models has revolutionized the way user choices can be modeled. Perhaps the most significant development has been the expansion of the mode types now included in the choice set of most MPO models, and the variables used as measurable characteristics of a household's and individual's satisfaction with the available mode choice set.

A typical mode choice model is estimated for different trip purposes, at a minimum home-based work, home-based nonwork and nonhome-based, with available modes defined by trip purpose. For example, the Denver Regional Council of Governments assumes five modes are available for home-based work: drive alone, shared ride 2, shared ride 3+, transit walk access, and transit drive access. For home-based, nonwork trip purposes, the available modes are auto, transit walk access, and transit drive access. Usually, home-based work models are estimated separately for different market segments as well, such as low-, middle- and high-income groups. Sometimes, models provide geographic segmentation with alternative-specific constants for different geographic markets.

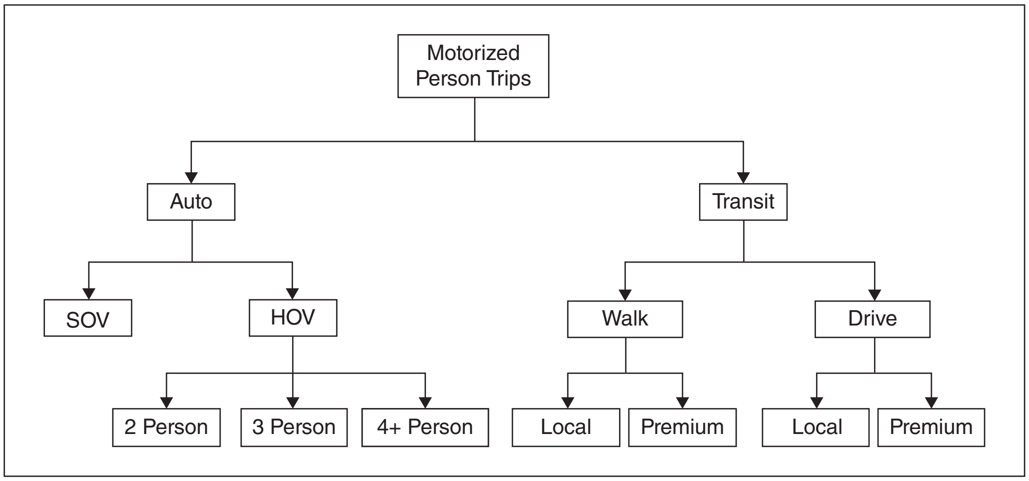
The multinomial logit model described earlier assumes that each of the alternatives available to a traveler can be defined with alternative-specific characteristics. Research has shown, however, that many of these alternatives are perceived by the travelers as having similar characteristics and that instead of being viewed as independent alternatives they are bundled into different categories of alternatives. The logic is that a traveler's first decision is between high-level characteristics, for example, travel time or perceived comfort, and that subsequent mode choice decisions then lead to a more specific choice on how to travel. This research has led to nested logit models. Figure 6-7 illustrates the concept of nested logit models. As shown, the model assumes that a traveler choosing to use a motorized mode of transportation will first decide to use either auto or transit. Once that choice is made, the traveler can then decide which form of auto or transit mode will be selected. For the auto choice, the traveler can choose single-occupant vehicle (SOV) or high-occupancy vehicle (HOV). If the HOV mode is chosen, the traveler then has the choice of 2 persons, 3 persons, or 4+ persons in a rideshare vehicle. For transit, the traveler has a choice of accessing transit by walking or driving, and the walk or drive access mode is also differentiated by whether the transit service being accessed is a local or premium service. Each of these "modal" decisions has associated with it utility functions describing the alternatives available to the traveler.

Another major reason for using nested choice models is to help overcome the irrelevance of independent alternatives (IIA) concept found in logit mode choice models, which can potentially cause erroneous results when new modes are introduced into the choice set (say, a new transit mode). In essence, this result says that this new transit mode would be treated as another new mode (and thus attract trips from the existing modes) even though it might have similar characteristics to modes already available, which in reality would not make it as attractive as a stand-alone mode. By putting the new mode in the first tier of a nested model, this effect is reduced.

A nested logit model is often used to better represent substitution patterns. For example, an improvement in the level of service of one alternative will proportionally draw more share from alternatives in that nest than from alternatives not in the nest. As shown in Figure 6-7, an improvement in the drive access time for premium transit is expected to proportionally draw more riders from those driving to use local transit (as these alternatives are in the same lower-level nest). In addition, greater substitution will be observed among the other transit modes (walking to local and premium transit) than auto modes.

Finally, it is worth noting that there are a few MPOs that have a combined mode-destination choice model, which combines mode choice and trip distribution decisions into one discrete choice model.

Figure 6-7. Illustrative Nested Mode Choice Model



Trip Assignment (Route Choice). Trip assignment results in an estimated demand on each of the network links. Link attributes (for example, road or transit line capacity, link length, speed limits, turning restrictions, and travel signals) are represented in the network database and are used to calculate the "cost" of using the link. In its simplest form, this can be measured using the average travel time to traverse the link, or in more sophisticated network models, a generalized cost function is used. In both cases the network assignment models assign trips through the network to minimize the time or cost of travel.

Generally, the process is done separately for highway and transit network assignment. The two networks are related in that congested highway travel times should be used to estimate bus performance, assuming that buses are not provided with preferential treatment on the road network. Highway network assignment focuses on auto vehicle trips and can model trip makers' network paths using approaches such as all-or-nothing, incremental, capacity-restrained, user equilibrium, and system optimum assignment. In current practice, almost all large MPOs use the user equilibrium method in highway network assignment. This method is based on the behavioral assumption that users will choose routes that minimize their own generalized travel cost. Equilibrium occurs when no users can reduce their travel costs by switching routes. Transit assignment uses variables specific to transit link performance such as transit fare, stop or station transfers, waiting times, and trip times.

Most contemporary trip assignment models use similar approaches: (1) a static user-equilibrium assignment algorithm; (2) a multiple-time-period assignment for multiple classes (for example, drive-alone, rideshare, and bike/walk); (3) an iterative feedback loop mechanism between, at a minimum, the network assignment step and the trip distribution step; (4) separate specification of facilities like HOV and high-occupancy toll (HOT) lanes; and (5) independent transit assignment using congested highway travel times to estimate a bus ridership assignment.

One of the most important elements of the assignment process is the construction of link performance functions. This is often where models begin to distinguish themselves. A link performance function (often a volume-delay function for roads) defines the relationship between speed and travel flow on a roadway segment and is used to estimate travel time or cost in the trip assignment procedure. The function can be linear, polynomial, exponential, hyperbolic, or a conical specification. For many years, the most commonly used function was the Bureau of Public Roads (BPR) equation—or a simple modification of it—that represented generalized travel costs. This equation estimated travel time on a link as being the free-flow travel time (no congestion) plus a factor that represented an increase in travel time as the link became more congested, usually represented by the link volume/capacity ratio raised to some exponent. However, as more experience with network operations and traffic flows occurred, planners found out that much of the delay in urban road networks occurred at intersections with conflicting and opposing traffic flows causing much of the delay. Volume-delay functions did not easily capture this phenomenon, and thus many of today's trip-assignment models incorporate delay relationships that have been developed from research and practical experience, with the basic concepts coming from the *Highway Capacity Manual.*

Time-of-Day Factors. As a final note in this section, the traditional four-step modeling process divides the day into modeling periods to better reflect capacity constraints likely to occur during peak travel periods, such as a.m. peak or p.m. peak periods. The factor defined for each modeling period is usually referred to as a time-of-day factor and is used to determine the proportion of total daily trips occurring in a specified hour or modeling period. Such factors are usually estimated separately by trip purpose.

Time-of-day factors should be independently derived and a variety of sources can be used, depending on where in the four-step process the time-of-day factors are applied. If the time-of-day factors are applied after network assignment, travel data (for example, volume counts) can be used to develop the hourly or period proportions. Alternately, if the time-of-day factors are applied prior to network assignment, household surveys can be used to derive the appropriate proportions. There are also a number of emerging techniques, such as departure choice models, that provide a more sophisticated approach toward time-of-day modeling (for a good discussion of time-of-day factor methods, see [Cambridge Systematics, 1997]).

2. Activity-Based Models

Four-step models have a number of limitations, most notably the lack of a strong behavioral framework that consistently represents human decision making throughout the modeling process, and a reliance on zonal averages for many key variables. Activity-based models overcome many of the theoretical deficiencies associated with the conventional four-step models. By directly considering the linkages among different trip purposes that a traveler might accomplish during a typical trip-making time period, an activity-based model can provide a greater sensitivity to transportation policies relating to travel behavior. Activity-based models provide good approaches for estimating the effect on travel behavior of policies relating to land use, congestion pricing, parking costs, travel subsidies, and travel demand management strategies. [TMIP, 2012] Davidson et al. [2007] identified three key components of any activity-based approach, including: (1) an activity-based foundation with household activities as the starting platform, (2) a tour-based structure that retains associations between individual household activities, and (3) the use of micro-simulation tools to preserve a disaggregate modeling approach. As they note, a model can have one or all of these features at any given time in its evolution, that is, the components are relatively independent of one another.

The Strategic Highway Research Program (SHRP), Phase 2 primer on activity-based models is an excellent source of information on this type of modeling. [Castiglione et al., 2015] This material will not be repeated here. However, there are several observations in the primer that warrant some attention. Table 6-11, for example, shows the major differences between four-step and activity-based models in the form of questions that the planner must ask as part of the analysis. Table 6-12 indicates the differences in detail and the level of policy sensitivity of model results. As seen, activity-based model results provide a much higher level of detail spatially and temporally, as well as at the person and household levels.

Activity-based models are usually part of a much larger integrated modeling system that includes the following components:

- Population synthesis models create detailed, synthetic representations of populations of individuals within households (agents) whose choices are simulated in activity-based models.
- Activity-based travel demand models predict the long-term choices (such as work location and automobile ownership) and the daily activity patterns of a given synthetic population, including activity purposes, locations, timing, and modes of access.
- Auxiliary models provide information about truck and commercial travel, as well as special purpose travel such as trips to and from airports or travel made by visitors.
- Network supply models are tightly linked with activity-based demand models. The flows of travel by time of day and mode predicted by activity-based travel demand models and auxiliary models are assigned to roadway, transit, and other networks to generate estimates of volumes and travel times. Measures of impedance output from network supply models are usually used as input to activity-based models and other integrated model components. [Castiglione et al., 2015]

In some of the early applications of activity-based models it was found that the data requirements are much greater for such models than the traditional trip-based models. Figure 6-8 shows the basic structure of the model components. Table 6-13 shows the types of data input for activity-based models, the use of that data, and typical sources. As seen,

Table 6-11. Travel Questions and How They Are Handled in Demand Models

Key Travel Questions	Trip-Based Model Components	Activity-Based Model Components
What activities do people want to participate in?	Trip generation	Activity generation and scheduling
Where are these activities?	Trip distribution	Tour and trip destination choice
When are these activities?	None	Tour and trip time of day
What travel mode is used?	Trip mode choice	Tour and trip mode choice
What route is used?	Network assignment	Network assignment

Source: Castiglione et al., 2015, Reproduced with permission of the Transportation Research Board.

Table 6-12. Characteristics of Different Model Types

Model Type	Spatial/Temporal Detail	Person/Household Detail	Policy Sensitivity	Run Time	Cost
Sketch Planning	Low	Low	Low	Low	Low
Strategic Planning	Low–Moderate	Low–High	Moderate–High	Low	Low
Trip-Based	Low–Moderate	Moderate	Moderate	Moderate	Moderate
Activity-Based	Moderate–High	High	Moderate–High	Moderate	Moderate

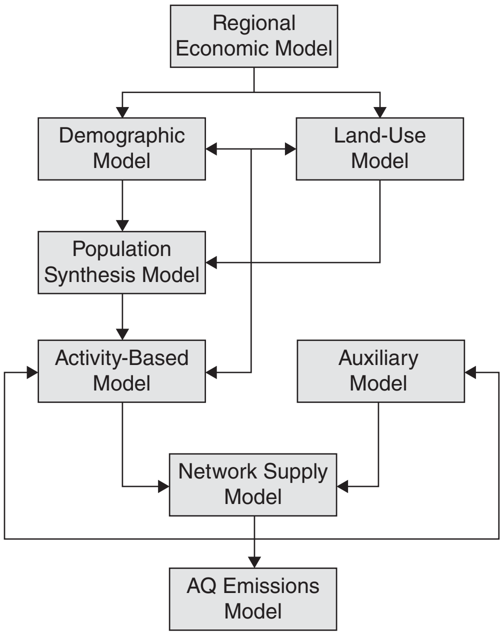
Source: Castiglione et al., 2015, Reproduced with permission of the Transportation Research Board.

Table 6-13. Data Used in Activity-Based Models by Purpose and Source		
Item	**Use**	**Source**
Household survey	Model estimation Calibration targets	Local data collection of the National Household Travel Survey
Land use	Synthetic population generation Activity generation Location choice	U.S. Census Business databases Tax assessors data Regional land use data School departments
Demographic	Synthetic population All component models	U.S. Census Regional demographic forecasts
Network	Transportation network geometries	GIS databases Transit agencies Public works agencies
Calibration and validation	Model calibration and validation	Count databases Highway performance monitoring Transit agency reporting

Source: Castiglione et al., 2015, Reproduced with permission of the Transportation Research Board.

many of the data uses described earlier in this chapter for four-step models are found in activity-based models as well. A number of activity-based models have been developed since the 1990s that address a range of specific travel-related issues, but it is really in the last decade that implementation of activity-based models for travel forecasting has accelerated markedly. Among the U.S. regions using some form of activity-based travel demand modeling are Atlanta; Columbus, Ohio; New York; Portland, Oregon; and San Francisco.

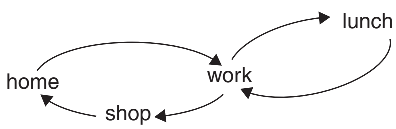
Figure 6-8. Integrated Model Structure with Activity-Based Modeling Component



Source: Castiglione et al., 2015, Reproduced with permission of the Transportation Research Board.

Unlike a four-step model that estimates individual trips, an activity-based model uses "tours" as a way of estimating trip-making. Castiglione et al. [2015] define a tour as a "series of trips beginning and ending at home or work anchor location. By modeling decisions on a tour basis, there is an enforced consistency between the outbound and return portions of the tour, so that a mode chosen to go to work conditions the mode available for the return home." The types of activities that constitute a tour can vary widely, and most activity-based models examine one or more of the following activities: at home, work at home, work (at workplace), school (K–12), university/college, personal business/medical, shopping, eat meal, social/recreational, and escort passenger. An example of two tours (the work to lunch to work tour is considered a subtour) is shown in Figure 6-9. Note that in a four-step model, the trips shown in this figure would have been modeled as one home-based-work trip, two nonhome-based other trips, one nonhome-based shopping trip, and one home-based shopping trip.

Figure 6-9. Illustration of Trip Tours as Used in Activity-based Models



Source: Castiglione et al., 2015, Reproduced with permission of the Transportation Research Board.

The output of most activity-based models is an origin-destination matrix, which is then provided as input to a trip assignment model.

Atlanta Regional Commission (ARC) Activity-Based Model Example. The ARC decided to develop an activity-based model in order to provide an analysis capability that better reflected travel behavior in the region. [ARC, 2014] Key characteristics of the ARC approach include:

1) The model's zonal system consisted of 2,027 zones, which were subdivided into three categories of transit access: 7 minutes or less walking to transit, 13 minutes or less walking to transit, and no walking to transit. This resulted in 6,081 subzones.

2) Trip decision makers in the model system included both persons and households. These decision makers are created (synthesized) for each simulation year based on tables of households and persons from 2,000 pieces of census data and forecasted TAZ-level distributions of households and persons by key socioeconomic categories.

3) Eight person-types were used, with each person-type mutually exclusive with respect to age, work status, and school status. The person-types were based on the results of a household survey.

4) Households were segmented by four income ranges—<$20,000, $20,000 to $50,000, $50,000 to $100,000, and >$100,000.

5) Ten activity types, also defined as being mandatory, maintenance, or discretionary, were identified. The classification of each activity type reflected the relative importance or natural hierarchy of the activity; for example, work and school activities are most inflexible in terms of generation, scheduling, and location. Typical activity types included:

Mandatory

a. Work—Working at regular workplace or work-related activities outside the home.

b. University—College +

c. High School—Grades 9–12

d. Grade School—Grades K–8

Maintenance

e. Escorting—Pick up/drop off passengers (auto trips only).

f. Shopping—Shopping away from home.

g. Other Maintenance—Personal business/services and medical appointments.

Discretionary

h. Social/Recreational—Recreation, visiting friends/family.

i. Eat Out—Eating outside of home.

j. Other Discretionary—Volunteer work, religious activities.

6) One hour increments, beginning at 3 a.m. and ending with 3 a.m., were used for the activity-based tours.

7) Thirteen modes were available for modeled trips.

Figure 6-10 shows the different submodels that were part of this new modeling approach. The approach reflected a sequence of "choices" made by the model leading to predicted travel volumes on the transportation system. The results of each submodel become input into the submodel that follows it. This sequence included:

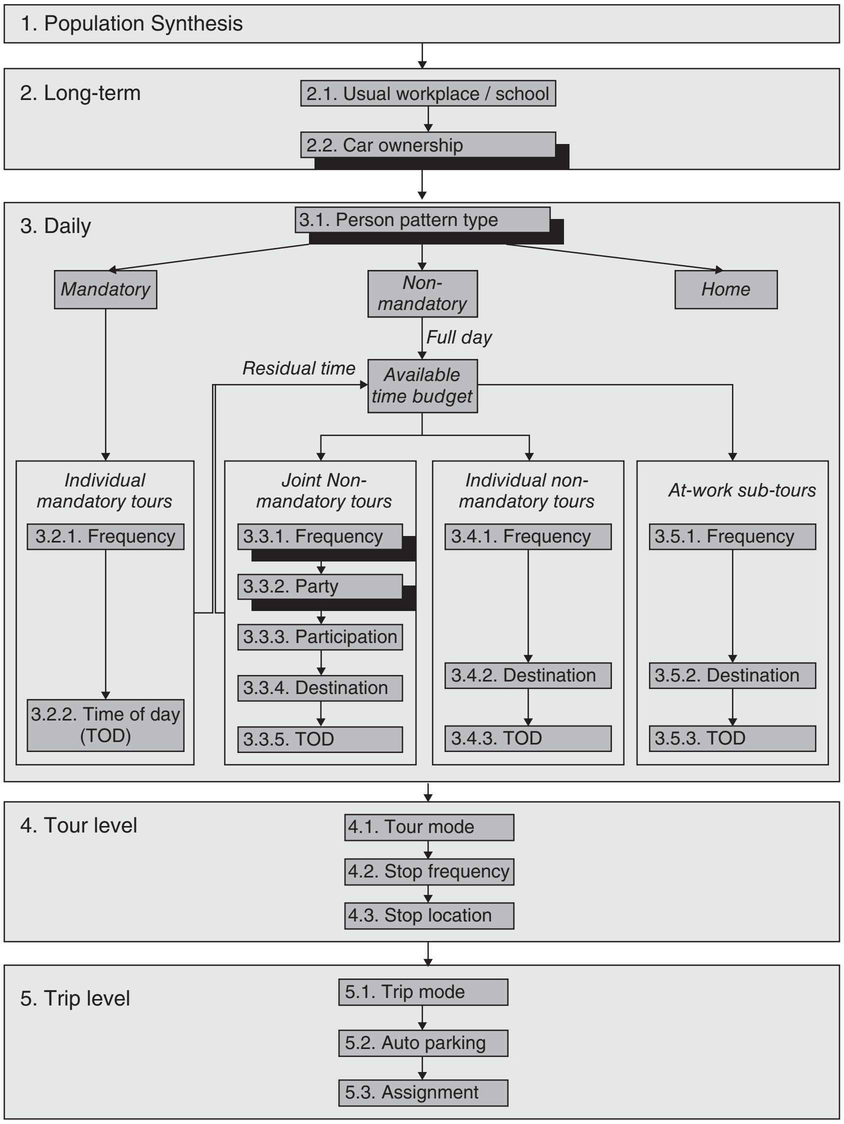
Synthetic population

- Zonal distributions of population by controlled variables.
- Household residential location choice (allocation to zones).

Long-term level

- Usual location for each mandatory activity for each relevant household member (workplace/university/school).
- Household car ownership.

Figure 6-10. Illustration of Trip Tours as Used in Activity-Based Models, Atlanta Regional Commission



Source: ARC, 2014, Reproduced with permission of the Atlanta Regional Commission.

Daily pattern/schedule level

- Daily pattern type for each household member (main activity combination, at home versus on tour) with a linkage of choices across various person categories.
- Individual mandatory activities/tours for each household member (note that locations of mandatory tours have already been determined in long-term choice model).
    - Frequency of mandatory tours.
    - Mandatory tour time of day (departure/arrival time combination).
- Joint travel tours (conditional upon the available time window left for each person after the scheduling of mandatory activities).
    - Joint tour frequency.
    - Travel party composition (adults, children, mixed).
    - Person participation in each joint tour.

    - Primary destination for each joint tour.
    - Joint tour time of day (departure/arrival time combination).
- Individual nonmandatory activities/tours (conditional upon the available time window left for each person after the scheduling of mandatory and joint nonmandatory activities).
    - Person frequency of maintenance/discretionary tours.
    - Primary destination for each individual maintenance/discretionary tour.
    - Individual maintenance/discretionary tour departure/arrival time.
    - Individual at-work subtours (conditional upon the available time window within the work tour duration).
    - Person frequency of at-work subtours.
    - Primary destination for each at-work subtour.
    - At-work subtour departure/arrival time.

Tour level

- Tour mode.
- Frequency of secondary stops.
- Location of secondary stops.

Trip level

- Trip depart time model.
- Trip mode choice conditional upon the tour mode.
- Auto trip parking location choice.
- Trip assignment.

As can be seen in this list of submodel choices, the activity-based model reflects many of the travel choices facing trip makers on a daily basis. Each submodel must be based on a credible and defensible logic and, as with all models, has to be calibrated and validated against real trip data (or with survey results).

In summary, activity-based modeling uses a variety of approaches ranging from decision trees, Monte Carlo simulation, and neural networks to utility maximizing and discrete choice models (logit or nested logit models). Like the four-step models, these approaches can require a fairly large database of detailed surveys of activities. In contrast to the traditional four-step software packages, however, there are few commercially available software packages that include activity-based models. See the following references for more detailed description of activity-based model applications: [Donnelly et al., 2010; Vanasse, Hangen, and Brustlin, 2011; Ferdous et al., 2011; Resource Systems Group, 2012]

C. Linkage to Air Quality Modeling

For metropolitan areas that are in nonattainment or maintenance of air quality standards, estimated future mobile source emissions must not exceed the emission limits (called budgets) established in the state implementation plans (SIPs). With the exception of California, states estimate their mobile source emissions by combining travel model outputs, volumes, and travel times/speeds with emissions factors derived using the Environmental Protection Agency's (EPA) MOtor Vehicle Emissions Simulator (MOVES) emissions model. [FHWA, 2014] However, transportation modeling and air quality modeling have not been integrated consistently. The travel activity data—particularly link speed data from travel demand models—are rarely resolved as finely as needed to estimate mobile source emissions. Consequently, additional post-processing of travel model output is often required. The post-processing procedures employed will differ by region, but in general can have a significant effect on subsequent emissions estimates.

The EPA specifies six criteria that travel models must meet to be acceptable for air quality conformity analysis: (1) models must be validated against observed travel, and future travel estimates must be reasonable given past trends; (2) land use, population, and employment estimates and projections must be based on the latest planning assumptions; (3) projected trends in land development should be consistent with future transportation system alternatives; (4) a capacity-sensitive assignment method must be used, and peak- and off-peak link volumes must be estimated; (5) a feedback mechanism must be used; and (6) the model should be reasonably sensitive to changes in travel times and costs.

Using sensitivity analyses, the EPA has identified two input parameters to which MOVES emissions factors are particularly sensitive: speed and time-of-day distributions of travel activity. There are two major difficulties with how speeds are estimated. First, speed estimates used in the travel models are rarely validated on a wide-scale basis because of high data collection costs and very limited available data. Second, a variety of link performance functions can be used in trip assignment models, producing substantial variations in post-processed speed estimates. The effect of using different performance function forms for assigning travel volume is not usually a major concern for travel demand modelers since results can be validated against travel counts. However, the impact on post-processed speeds and on subsequent emissions modeling may not be trivial. Research suggests that using different speed-flow functions or post-processing methods may result in significantly different emissions estimates. Little research has been done to identify how an MPO should select a speed-flow function both for the assignment step and for any post-processing that is performed. Attention to the selection and effect of post-processing techniques will be required as legislative mandates and/or policy initiatives related to air quality become more stringent.

With respect to time-of-day distributions, roadway (or link) travel volumes are estimated per modeling period (for example, a.m. or p.m. peak), where periods typically embrace two to four hours. Conversely, photochemical air quality models, such as EPA's urban air shed model (UAM), require hourly volumes. A variety of post-processing strategies can and have been used to address this particular problem including, among others, categorizing roadway segments by peaking characteristics and applying specific hourly proportions based on observed travel for selected roadway facilities or by applying various probabilistic strategies. Although the need for increasing the time resolution of travel models is more often linked to improving our understanding of operational effects (for example, peak spreading), it is also a critical ingredient in assessing air quality.

For a good overview of air quality modeling and its relationship to transportation demand modeling, see [PB Americas et al., 2013].

D. Software

The four-step modeling structure has evolved slowly over a lengthy period of time. Various planning agencies have used a similar structure throughout the modeling process—a sequential model application with feedback loops and aggregate-level calibrations/validations. Most MPOs use advanced commercial travel demand modeling software packages, such as TransCAD®, EMME/2, and CUBE. These packages are professionally designed and are generally well maintained. This has substantially reduced the computational burden with modeling applications and made many advanced techniques more routine. The recent development of many four-step models suggests significant improvements related to algorithmic or technical details, including increased spatial precision (for example, adding new zones/links), better temporal resolution (increased time of day slices) and the use of additional modeling steps (for example, the addition of vehicle ownership models and greater segregation of trip types).

Menu-driven software (for example, TransCAD®, EMME/2) generally incorporates a wide variety of modeling approaches in the form of menu options. These packages are somewhat easier to use and allow less experienced modelers to access more advanced techniques, and the embedded GIS tools are slightly easier to learn in the integrated environment for scenario runs. Many of the menu-driven software packages also allow for scripts. Regardless of the software chosen, each individual region must develop its own model specific for that region. Many of the menu approaches allow a user to accept default national or regional averages for some variables.

Current software development trends suggest that most developers are moving toward the integration of different modeling processes into a suite or a family of packages to improve modeling efficiency. One example is the CUBE System developed by Citilabs, which is built on an interface with ArcGIS and incorporates four different modules as a family of software products: (1) Cube Voyager, which performs travel forecasting based on the four-step approach and provides some advanced techniques; (2) Cube Dynasim, which performs dynamic multimodal microsimulations for intersection design and analysis; (3) Cube Cargo, which performs freight forecasting and facility analysis; and (4) Cube Me, which performs statistically optimized trip matrix estimation. Another example is the PTV Vision Suite developed by PTV America, Inc., which integrates a travel demand-forecasting model, VISUM; a travel/transit simulation model, VISSIM; a transit planning and optimization model, VISUM PuT; a real-time travel management model, VISUM On-Line; and a travel conditions displaying model, TML. The trend seems to be oriented toward developing computer-based packages that include both travel demand-forecasting models and travel simulation models that require greater technical expertise.

IV. SUMMARY

One of transportation planning's most important roles is to provide information to decision makers on the potential consequences of investments in the transportation system—and the consequences of not investing in the system. Modeling travel demand and assessing the performance of the transportation system are fundamental to this role. Travel demand modeling has been an important element of transportation planning for many decades and to this day remains the foundational approach for producing estimates of future travel demand. Every metropolitan planning organization uses some degree of travel demand modeling, often with substantial portions of the budget allocated to data collection, model calibration, and forecasting activities.

Travel demand models have been used for nearly 50 years, but in the last 20 years, significant policy demands have pushed the limits of what can be reasonably achieved with the standard four-step models. Although numerous federal agencies provide a wealth of guidance on travel modeling for various policy issues, accepted practices vary widely throughout the U.S. In fact, model performance standards are often determined and evaluated unique to the policy application. In spite of this, the development of travel models has continued at a rapid rate. As our understanding of travel behavior has improved, researchers and practitioners have continued to extend and refine the functional performance of the models. In many cases, practitioners have been innovative and have accommodated a variety of different contemporary policy issues using the standard four-step model.

The four-step models that continue to be used, at least in the short-term, will place greater focus on implementing best practices, such as those identified by Davidson et al. [2007]: (1) using disaggregated modeling; (2) considering within-household relationships and their impact on travel decisions; (3) evaluating individual characteristics in addition to household variables; (4) considering household aging and how it affects future travel decisions; (5) defining feasible choice sets; (6) using accessibility measures; and (7) developing realistic estimates of performance characteristics, such as travel time.

However, the next decade of modeling will likely see continued shifts from the four-step models to activity-based and simulation models and continued increases in data collection and computational costs. Many MPOs are considering the development of tour-based models, with a number already in practice. As modeling practices continue to become more complex and software evolves to accommodate this complexity, transportation analysts will need greater technical expertise, whether in-house or through the use of consultants. Balancing resources between the maintenance of current models and the migration to new models will be difficult, but it is important that larger MPOs begin the migration to models that will allow them successfully to meet new and expanding regulatory and policy needs.

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Evaluation and Prioritization Methods[1]

I. INTRODUCTION

Prudent management of public investment in the transportation system requires transportation planners and engineers to identify cost-effective investment strategies and actions. Evaluation is the process of synthesizing the results of an analysis of alternatives and comparing the alternatives to identify the relative value of one alternative over another. Evaluation is one of the most important components of transportation planning because it provides the information needed to make decisions. Evaluation can also influence the definition of alternatives as well as the credibility of the planning process itself.

Although evaluation provides a structured set of information for decisions, transportation planning lies at a unique intersection of technical analysis and political prerogative. The goal of the evaluation process is to provide information to help decision makers reach informed decisions that provide the greatest public good. Certainly, the technical information on the system performance of different alternatives is a critical underpinning of such decision making. However, depending on the size, nature, and complexity of a problem, it is also important to have participation throughout the process by citizens, other stakeholders, and elected officials who finally adopt a plan.

Figure 7-1 presents an overall framework for evaluation. The shaded area indicates the scope of this chapter. The following section considers the basic concepts that are part of every evaluation process. These include relating the alternatives to goals, objectives, and performance measures and basic economic analysis concepts such as inflation, defining costs and benefits, and identifying equity impacts. Next, various evaluation techniques are examined, including the selection of the appropriate evaluation methods. The following section describes how uncertainty and risk should be incorporated into the evaluation process. The chapter continues with an examination of some of the mistakes that commonly occur in evaluation, and a description of different approaches to project prioritization and programming. The remainder of the chapter presents examples of evaluation efforts that have been undertaken by public agencies.

The chapter identifies important references for those interested in the evaluation process. A number of websites are also available on benefit/cost analysis, including some free spreadsheet models, such as: http://bca.transportationeconomics.org/home and http://www.dot.ca.gov/hq/tpp/offices/eab/benefit_files/Cal-BCv4-1.xls.

II. CHARACTERISTICS OF THE EVALUATION PROCESS

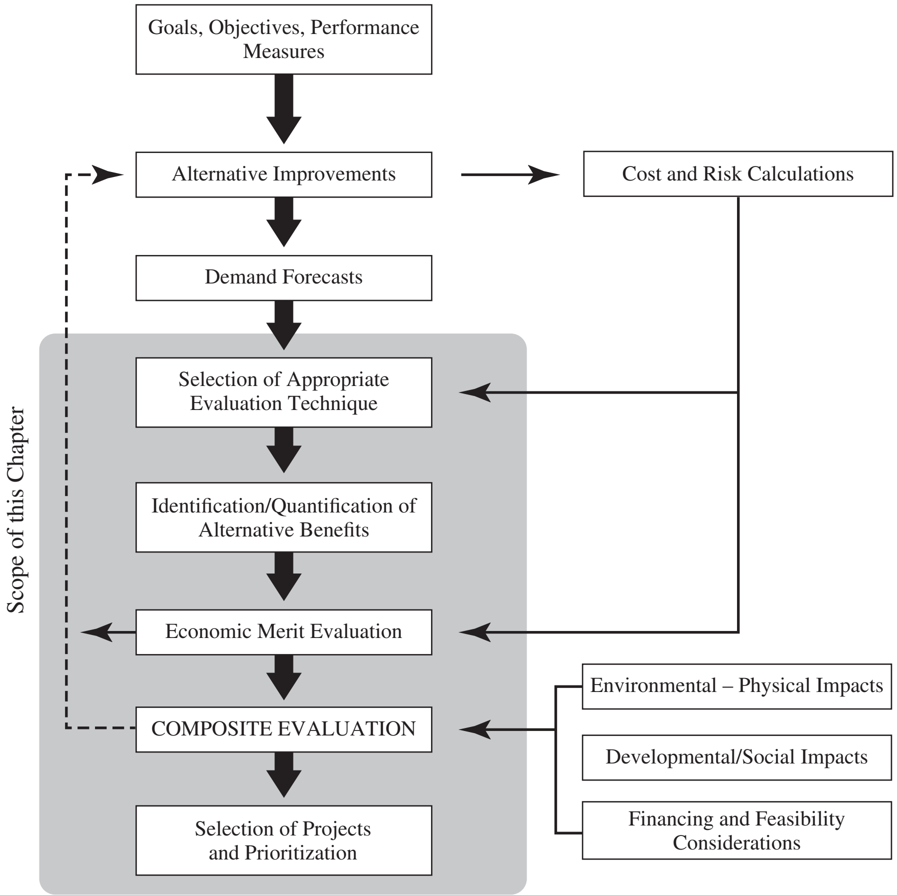
The following characteristics of the evaluation process are important for planners to know:

- Most transportation studies examine several alternative courses of action. At the plan level, these alternatives might be a small number of different investment strategies, such as focusing on a different modal emphasis or on different investment levels. At the corridor or site level, these alternatives are usually more numerous and are described in more detail. In environmental analyses, one of these alternatives is the *do-nothing* alternative.
- Ideally, but not always in practice, evaluating all relevant factors (called the composite evaluation) may lead to improved definitions of alternatives (shown as the dashed feedback line in Figure 7-1). If a preliminary evaluation shows the need to modify the scope and/or scale of an alternative, this can be used to define a modified alternative, which then proceeds to a more detailed assessment.

[1]The original chapter in Volume 3 of this handbook was written by Steven B. Colman, Principal, Dowling Associates Inc. Changes made to this updated chapter are solely the responsibility of the editor.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

Figure 7-1. Overall Evaluation Framework



- Most alternatives include projects having different life spans, with benefits and costs occurring at different points in time. Thus, evaluation must provide a way to meaningfully compare projects with different costs and benefits over the study timeframe.
- Transportation projects and programs typically involve an initial expenditure of funds (called capital costs), followed by a period of ongoing costs, such as operations, maintenance, and eventual rehabilitation and reconstruction costs. These costs may vary from year to year. The discounted costs over the life of a project are called its *life-cycle costs*.
- Many project costs and benefits can be measured in monetary terms because there are market costs associated with them (for example, the cost per ton of concrete or per transit bus). Frequently, however, there are costs and benefits for which no market values are readily available (for example, the community disruption caused by construction activities or the aesthetic value of a project design, among others). In such cases, the evaluation process needs to incorporate this information into the assessment in creative ways.
- Because the primary purpose of evaluation is to provide decision makers with information on the relative merits of one alternative versus others, evaluation criteria should relate directly to the information needed and desired by decision makers. Specifically, the criteria should reflect closely the goals and objectives defined earlier in the planning process. Criteria used that result in the selection of the "correct" alternative (from the viewpoint of the decision makers), but that do not reflect the goals and objectives of the process, could indicate a breakdown in the overall evaluation process.

Generally, this chapter considers only the direct (or primary) effects of transportation projects. Examples include changes in travel time, operating costs, and safety outcomes. Indirect (or secondary) effects or nonquantifiable costs—such as economic development impacts that occur after a project has been constructed or an alternative implemented—are outside the scope of this chapter. Of course, transportation planners and engineers should be aware that the potential for such impacts exists (see [Berger & Assocs., 1998; Economic Development Research Group et al., 2012; FTA, 2013; Forkenbrock and Weisbrod, 2001; Lakshmanan and Chatterjee, 2005; Weisbrod et al., 2001]; and the website *Transportation Project Impact Case Studies*, http://tpics.us/, for a review of social and economic development impacts of transportation improvements). Those interested in land-use and development impacts of transportation investment are referred to chapter 3 on land use and urban design.

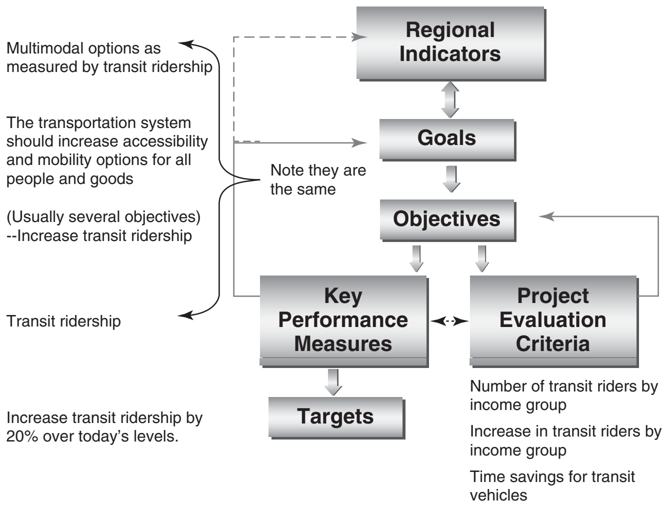
A. Basic Concepts

1. Goals, Objectives, Evaluation Criteria, and Performance Measures

The relationship between goals and objectives and the evaluation process is an important, but often overlooked characteristic of effective planning. A clear and comprehensive statement of the goals and objectives of a project or plan is critical to developing and evaluating plan alternatives. All studies can benefit from using available goals and objectives from other planning documents (for example, a regional or long-range transportation plan). Smaller and simple projects may require only very brief statements of the goals and objectives, or a purpose and needs statement.

Goals are statements of broadly expressed desired end states. Objectives provide more specifics on how the goals can be accomplished. One of the most common mistakes in developing goals and objectives is confusing *means* and *ends*. For example, "adding capacity to a presently congested highway" is not a valid goal statement in that it is a strategy for accomplishing a related goal. In this instance, a possible goal might be to improve mobility. The following are definitions (illustrated in Figure 7-2) of terms often found in planning practice:

Figure 7-2. Performance Measurement Hierarchy



Source: Meyer, M. 2006. "Performance Measures for Regional Transportation Planning," Memorandum prepared for the Atlanta Regional Commission. Atlanta, GA: Atlanta Regional Commission.

- *Regional Indicator*. This high-level indicator reflects a characteristic of a region or its transportation system and presents an indication of what is happening to the region over time. In Figure 7-2, the indicator is the level of multimodal options available in the region, with the surrogate being overall transit ridership. Often, but not always, a regional indicator might not be under the control or direct influence of transportation agencies. For example, air quality is a regional indicator in many areas, for which transportation is only one contributor.
- *Goals*. Goals are generalized statements that indicate a desired end state or characteristic of a system. Thus, in Figure 7-2, the goal is to have a transportation system that increases mobility and accessibility for people and goods, but it does not say how this should be done.
- *Objectives*. Objectives are more specific statements of how a plan will achieve the goal. In Figure 7-2, one way of improving mobility and accessibility is to increase transit ridership. Usually, there are several objectives associated with a goal. A key difference between goals and objectives is that objectives are typically measurable (quantifiable), but goals are not.
- *Key Performance Measures*. These are a small set of measures that indicate how the transportation system is performing. This core group of perhaps 10 to 12 performance measures reflects critical success factors and measures progress toward organizational goals. Thus, they are critically important to decision makers

and for public dissemination. In Figure 7-2, the system performance measure is "aggregate transit ridership." This measure allows decision makers to determine the effectiveness of a system plan in the context of this objective.

- *Project Evaluation Criteria/Measures of Effectiveness*. Evaluation criteria relate directly to the evaluation of alternatives and scenarios and to a variety of issues that might be relevant to a particular alternative. Thus, in Figure 7-2, several criteria are shown that are not exactly the same as the system performance measures, but that feed directly into understanding the effects of alternatives and/or scenarios. They are called criteria because they help guide the decision as to which alternative under consideration is best.

- *Targets*. In some instances, it is desirable to establish a standard or desired outcome to focus attention on what is considered to be success. In Figure 7-2, the target is "increase ridership by 20 percent over current levels by the year 2020." Not only does this provide a more specific focus on achieving the goal, but it also allows planners and decision makers to monitor system performance over time to determine if it is at least heading in the right direction. [Meyer and Miller, 2014]

Clearly, the criteria used in evaluating a scenario or alternative should relate directly to important system performance measures. Thus, for every key performance measure, one or more similar project evaluation criteria are used to allow a direct connection to system performance, as indicated with a two-headed arrow in Figure 7-2.

The set of evaluation criteria should be comprehensive, but not duplicative, nor too lengthy. The criteria should be transparent (that is, readily understood by decision makers and the public), and the costs of data collection when using these criteria should be commensurate with the size of the project or plan and its complexity (see [Cambridge Systematics, 1996; Meyer and Miller, 2014; and Rothblatt and Colman,1996] for a more detailed discussion on goals, objectives, evaluation criteria, and performance measures). Table 7-1 presents a list of typical evaluation criteria for different performance measure categories.

2. Importance of Project or Alternative Definition

Most transportation plans recommend a set of cost-effective projects for implementation. For metropolitan plans, the number can reach thousands over the lifetime of the plan itself. For an individual project, improvements could take place over time as a series of one or more related construction phases. Depending on the scale of the planning effort, project definition can be an important input into the evaluation process. Project definition reflects the level of funding that will be necessary through cost estimation, likely environmental impacts, and the place of the project in the overall transportation system.

A transportation project is usually defined by its:

- Project identity and location (at the plan level, this is often described in very general terms).
- Project type.
- Length.
- Capacity (for example, number of lanes, degree of grade separation, or additional transit vehicles).
- Access points (stations, interchanges).
- Degree of grade separation and vertical alignment.
- Average and maximum operating speed.
- Horizontal and vertical alignment (including tunnels, cuts).

Transportation plans usually deal with broader categories to test the effects of different long-range policies, such as the number and type of community groups affected, proximity to important land uses, and the role transportation investment plays in the broader transportation network (for example, part of an evacuation route). Table 7-2 shows some of the factors that might be considered as part of a transportation plan.

Another method of incorporating the different dimensions shown in Table 7-2 into the planning and evaluation process is through scenario planning. In essence, scenarios examine different land use and transportation investment

Table 7-1. Sample Criteria for Evaluating Major Urban Transportation Alternatives	
Performance Categories	**Evaluation Criteria**
System Performance Criteria	
Mobility	• Sum of travel times (peak/off-peak) to selected points • Travel time index (ratio of congested travel times to free flow travel times) • Average speed weighted by travel flows • Congestion cost per person • Commercial vehicle delay per mile
Accessibility	• Number of areas or major activity centers served by a project • Availability of service to transportation-disadvantaged groups • Accessibility index from a gravity model • Percent of all jobs within 30-minute commute time • Percent of dwellings within 1/4 mile walking distance of transit
Traffic Relief	• Number of intersections and miles of street where level of service is below standard • Average speed by facility type (or classification) • Vehicle-miles or hours of travel by level of service
Safety	• Number or cost of collisions, injuries, and fatalities
Modal Balance	• Percent trips by transit, carpool, etc. • Mode share to regionally significant activity centers
System Efficiency	• Gallons of fuel consumed • User cost (vehicle operating cost plus time cost)
Impact Criteria	
Regional Development	• Consistency with adopted land-development goals/policies
Neighborhood Disruption	• Number of dwelling units, and businesses displaced or impacted • Number of defined neighborhoods or homes encroached upon • Acres of existing developed land affected • Net dwelling units within unacceptable noise contours
Air Quality	• Tons of emissions, by type • Exceedance days of national or state standards • Conformity to National Ambient Air Quality Standards
Special Land Use Impacts	• Acres of parks, recreational lands, or schools affected • Acres of prime farmland affected • Acres of wetlands affected • Number and significance of historical sites, archaeological districts, etc.

(*continued*)

Table 7-1. (*Continued*)	
Performance Categories	**Evaluation Criteria**
	Implementation Criteria
Cost	• Capital, maintenance, and operating costs • Probability of funding availability • Percentage of funding from nonlocal sources
Attitudes and Equity	• Degree of acceptance by elected officials and citizens • Amount of tax base shift from one jurisdiction to another • Impact on low-income neighborhoods and groups

Source: Adapted and expanded from Maricopa Association of Governments, Transportation and Planning Office, 2010, Phoenix, Arizona

Table 7-2. Possible Scenario Factors for Long-Range Transportation Planning	
Modal Emphasis	• Transit versus auto emphasis (could also affect land use) • Freeway versus surface street improvements
Funding Levels Available	• Low • Medium • High
Geographic Emphasis	• Change/growth areas versus maintenance/slow growth areas
Type of Growth	• Compact/infill versus sprawl • Transit-oriented development/pedestrian development versus existing trends for the past 20 years • Industry-type emphasis (e.g., emphasis on encouraging service industry growth, telecom, manufacturing, tourism, and so on) • Balanced versus imbalanced jobs/housing growth (e.g., jobs grow faster than the number of employed residents) • High versus low countywide/regional growth rate
Pricing	• Stable gas prices versus increasing real gas prices • Free parking (existing) versus paid parking • Reduced real transit fares versus higher real transit fares

packages to determine which scenario provides the best outcome from a transportation system performance perspective. For example, a study in Atlanta, Georgia, that focused on approximately 1,000 square miles of the area's fastest rates of development growth examined the following scenarios as part of the analysis and evaluation process:

- *Current Atlanta Regional Commission (ARC) Forecast*—What happens if development is spread throughout the study area with the greatest concentrations in the southern half of the study area?
- *Existing Communities*—What happens if development is largely concentrated in and around existing communities and activity centers in the study area?
- *Transit-Oriented Development*—What happens if a grid network of radial and east-west transit is developed and future land use concentrates along these lines?
- *Equity (East-West Corridor)*—What happens if development is further concentrated along east-west corridors and transit is enhanced?

- *Managed Growth*—What happens if much of the new growth is distributed in "hamlets" of balanced residential and commercial development in the north?
- *Local Plans*—What happens if development occurs as anticipated in the plans of the local jurisdictions, and total development is higher than projected by ARC?
- *Less Growth*—What happens if roughly half of the development projected by ARC occurs, and there is little new highway capacity added? [GRTA, 2004]

By examining the implications of these different scenarios, transportation planners were able to identify the key factors driving transportation demands in the study area; identify the likely consequences of different land use and transportation strategies; and, perhaps most importantly, inform local officials regarding the strong linkage between land-use decisions and resulting transportation system performance.

3. Defining Costs and Benefits

The choice of which costs and benefits to include in an evaluation can strongly influence the ultimate outcome of the evaluation process. [AASHTO, 2010; Cambridge Systematics, 1996; ECONorthwest et al., 2002; European Conference of Ministers of Transport, 2001; and VTPI, 2009] Defining costs and benefits in public sector evaluations is often more complicated than for those in the private sector, simply because public choice needs to include the societal costs of resource consumption that do not normally have a market price. The rest of this section will take the viewpoint of public sector decisions, with the understanding that a subset of the tools presented also could be used to evaluate a private investment decision.

Costs and benefits can affect three major groups: (1) suppliers or owners of transportation facilities or services, usually public agencies, (2) users of the transportation facility or service, and (3) everyone else (nonusers, society at large). Noise, air and water pollution, aesthetics, and neighborhood/social cohesion impacts, among others, are considered nonuser costs or costs to society, although in many instances such costs are faced by users as well. These are felt by groups other than suppliers and users, although clearly overlaps are possible (for example, drivers may also be subject to unhealthy air quality and traffic noise).

Costs and benefits are sometimes mirror images of each other. For example, an environmental mitigation (a noise barrier) may be a cost to the owner agency, but a benefit to the surrounding neighborhood. The choice of whether to consider an impact a cost or benefit can affect the results of an evaluation, such as in a benefit/cost analysis. As an example, consider a project where, without taking into account the value of the noise effects of the project, the costs and benefits are both equal to $1,000. The project will result in a reduction in noise exposure, which is valued at $150. If reduced noise is treated as a negative cost, the benefit/cost (B/C) ratio is ($1,000/($1,000 − 150)) = 1.18. On the other hand, if the reduced noise is considered a project benefit, the B/C ratio will be (($1,000 + 150)/($1000)) = 1.15. Most engineering economy texts recommend the *modified benefit/ cost analysis method*, which treats the reduction of costs as a positive benefit, in this case resulting in a B/C ratio of 1.15.

Classifying an item as a cost or benefit becomes particularly difficult when secondary or indirect impacts of a project are considered. For example, a large transit project might reduce the number of second (or third) cars owned by households, which would be considered a benefit in most evaluations. However, to auto dealers, mechanics, and banks making auto loans, this would actually be a cost—or at least a reduction in revenue. Similarly, projects intended to stimulate new job creation may in fact merely attract jobs away from other locations. For this reason, as well as the possibility of double-counting benefits, it is usually best to focus the evaluation on the primary—or direct—impacts of a plan or project, and consider the secondary effects separately.

4. Costs Included in Evaluation

Costs are usually divided into two categories: *capital* and *operating and maintenance* (O&M) costs, although, as will be seen, the division is not always simple. *Capital costs* are defined as those costs needed to implement an alternative or start a project. Thus, they include the costs of construction and initial vehicle procurement (for transit projects), associated allowances for contingencies, and administration. They also include the costs of planning, environmental studies, project design, and engineering, and any other *one-time* costs. Excluded from this definition is the out-year reconstruction or replacement of facilities and components, including the replacement of vehicles acquired as part of the implementation of an alternative. Costs of reconstruction and replacement are treated as part of the life-cycle cost analysis and are not included specifically in the capital costs, so as to avoid double-counting. Capital costs thus typically include items such as: (1) right-of-way acquisition and relocation costs, (2) construction costs, (3) vehicle acquisition costs (for transit), and (4) engineering and design costs.

From an accounting perspective, capital costs relate to assets that have a useful life of at least 1 year. O&M costs are recurring costs, or costs that last less than a year and may include: maintenance, operation, and administration costs; insurance and collision/mishaps; user travel costs; and taxes (typically for private sector only).

Because prices of goods and services tend to rise over time, it is important to distinguish between *real* dollars (also called *constant*, *inflation-adjusted*, or *base-year dollars*) and *nominal*, *current*, or *data-year* dollars, which are not adjusted for inflation.

Because planning studies often derive unit costs from historic data, it is necessary to convert historic costs to current values. This conversion is generally done with a factor called a construction cost index (CCI) number. The Federal Highway Administration (FHWA), trade publications (such as *Engineering News-Record*), and some state departments of transportation (DOTs) provide such information. An example of the national highway CCI as disseminated by the Federal Highway Administration is shown in Table 7-3. An index number of 100 represents the average prices in a given month, quarter, or year; thus, for example, if transportation agencies use March 2003, shown in Table 7-3, as the *base year*, the index number is equal to 100 for that quarter. CCIs for individual contract items can also be easily found; these standard items and their units are typically expressed in dollars per some unit quantity.

5. Cost Estimation for Transit Projects

Although the names and definitions are somewhat arbitrary, the procedural phases in the development of a major transit project can be divided into system planning, project development (including environmental review of alternatives), engineering, and final design/construction. These steps are structured around the major choices that must be made as a project emerges from broad regional planning efforts and proceeds toward implementation, such as: Which corridor(s) has/have the greatest needs? What kind of improvement is appropriate? Which design standards should be used? For transit projects, the first substantial engineering efforts usually occur in the project development process and alternatives analysis, with progressively more detailed engineering work as a project development process is completed and enters into the engineering phase.

Table 7-3. National Highway Construction Cost Index (NHCCI)

Year	Quarter	NHCCI Index
2003	March	1.0000
	June	1.0156
	September	1.0038
	December	0.9929
2004	March	1.0260
	June	1.0638
	September	1.0849
	December	1.0910
↓	↓	↓
2013	March	1.1002
	June	1.1092
	September	1.1195
	December	-
2014	March	1.0947
	June	1.1007
	September	1.1354
	December	1.1158
2015	March	1.1334

Source: http://www.fhwa.dot.gov/policy information/nhcci/pt1.cfm

System planning typically includes general concepts and options for technology, alignments, engineering feasibility, priorities, and costs. Cost in this phase of work is preliminary and is often expressed in ranges. In the alternatives analysis phases, conceptual engineering is performed, prototype design standards are developed, preferred modes are selected, and a financial plan is developed. In this stage, cost ranges are significantly narrowed.

As part of the project development process, design standards are developed along with proposed alignments and financial commitments. Approximately 30 percent of the total engineering effort is performed during project development, in most cases to satisfy environmental analysis needs. In final engineering, construction drawings are prepared, including specifications and other construction documents.

A clear understanding of the context of each project phase is crucial because it provides a guide for identifying the appropriate level of effort and detail for the engineering and cost-estimating work. Although the varying contexts make it impossible to specify a particular level of effort that is correct for every project planning effort, it is important to remember that project planning is used to select the best alternative, not to accomplish all the steps necessary to its implementation.

During project planning, two levels of engineering effort are often applied: one for typical facilities and the other, much more detailed, for special situations. For segments of alternatives that can be analyzed at a fairly aggregate level, a typical cross section for the segment is defined. Detailed unit costs are used with quantities (such as square yards, pounds, person-hours) taken from the typical sections to derive costs per linear foot (LF) for each section. A similar approach is used to derive per-facility composite costs for various facility types: interchanges, transit stations, park-and-ride lots, and the like. Plan and profile drawings are prepared for each alternative, and quantities—lengths, number of grade separations, special features—are taken from these estimates. Segment costs are computed to represent the capital costs of each identified segment, exclusive of systemwide elements and add-on items.

Segments that cannot be handled with the typical section approach are those where special conditions exist—typically a major structure or an uncertain alignment in areas with major existing structures or difficult terrain. These segments are costed in detail, with drawings, detailed quantities, and detailed unit costs. Additional specialized investigations may be carried out in these areas, for example, of soil conditions, archaeological constraints, hazardous materials, and the like.

For a major transit investment, systemwide elements include (as applicable) vehicles, electrification, signal/central control systems, and similar items, because these items are not related to individual segments. As such, they are estimated with unit costs applied to systemwide quantities. Add-on items of contingency allowances, costs of engineering and construction management services, and design are then added. These items are usually estimated through multipliers that express the add-on costs as percentages of the estimated baseline capital costs.

6. Measuring Societal Costs and Externalities

Externalities, also known as spillover or third-party effects, are impacts that are not captured by the free exchange of money (that is, by markets). A project can impose externalities on others (in which case they are known as negative externalities), or can confer benefits (positive externalities). Motor vehicle air pollutants are an example of externalities. It might cost $30 to fill the gas tank of an automobile, for which there is an active market price. However, those who breathe the pollutants emitted by burning the gasoline are not voluntary parties to this transaction and are not compensated for it. Economists estimate this cost to society by examining the health-related costs associated with air pollutant–related illnesses.

Societal costs are similar and have been defined as the disutility that accrues to society as a result of a particular act, such as the production or consumption of a commodity. [Greene, Jones, and Delucchi, 1997] Societal benefits involve the added utility resulting from the production or consumption of a good or service. Economists have long known that private markets do not always capture all of the costs or benefits of certain actions. Excluding externalities in the evaluation process can lead to the wrong choices being made. This points out an important distinction between private and public decision making—private firm decisions will generally include only actual internal costs.

The difficulty with including externalities in an analysis is that it is often difficult to give them a monetary value because, by definition, there are few active economic markets for trading them (the only two major ones are in California and Europe, where greenhouse gas emission markets have been established). This has led to a number of attempts to provide values for external costs based on indirect methods (see [Freeman, 1993; and Greene, Jones, and Delucchi, 1997]).

One practical approach is cost of avoidance. Cost of avoidance places a value on the attempt to avoid or prevent the impact. For example, road alignment A subjects 250 more homes to noise exposure above the state's 70-dB standard than does alignment B. Clearly, this makes alignment A less desirable than B, all else being equal. How do we evaluate the additional noise externality associated with alignment A? The avoidance approach asks: How much would it cost to avert the impact—say, through double-glazing windows, insulation, air conditioning, construction of noise barriers—on the 250 homes to bring their noise exposure to within the 70-dB standard? This cost is then added to the other costs of alignment A.

An obvious problem with this approach is that it may not always be possible to avoid all of the related impacts of alignment A. The interior noise levels may be comparable, but exterior levels will be higher for the 250 homes affected. Placing a value on the additional irritation of higher noise levels in outdoor activities is more difficult, as there is no effective way to avert that impact, although it could be mitigated by a noise barrier or alignment change. Nevertheless, various measures related to environmental mitigations often take this approach; for example, the addition of pollution-control equipment to cars or the reformulation of gasoline to reduce air pollution, among others.

7. Benefits Included in Evaluation

Economic benefits associated with capital investments in transportation facilities are usually measured in terms of user benefits. User benefits for each alternative are determined by calculating the values of anticipated reductions in negative effects compared to the no-build alternative. The type of benefits will relate closely to the purpose and need for the project. For most large projects, travel time savings will be the largest source of benefits, followed by savings from reductions in collisions and from reductions in user or vehicle costs. Direct and quantifiable economic benefits to transportation facility users from a major capital investment usually relate to the following:

Savings to users of the project, in terms of:

- Travel time savings (or increases) to private vehicles, both those using the facility and those using other facilities that are substitutes.
- Travel time savings (or increases) to public transit passengers and vehicles.
- Travel time savings to commercial vehicles.
- Out-of-pocket vehicle operating costs (for example, fuel, wear-and-tear).
- Collision costs (improved safety).
- Savings to users diverted from one facility (or route)/mode to another.
- Constant auto and transit user travel time savings (congestion relief on existing parallel routes and such). "Constant" refers to (1) those users not changing their route or mode, (2) constant transit users (those who continue to use transit), and (3) constant auto users (those who continue to drive).

Travel Time Savings. Travel time savings is the largest single benefit category in most major road projects, often accounting for 60 percent or more of the total benefits. Major transit projects often will have time savings for existing transit users, and will also shift some trips from highway to transit. The shifted auto user will, on average, spend *more* time per trip using transit than driving, for most types of trips. However, positive travel time benefits will accrue to all remaining auto users (constant auto users), including both those diverted to a new road and those continuing to use existing facilities (as a result of congestion relief). Some transit users (constant transit users) also will benefit from the provision of improved transit services, even though they do not change mode.

The overall amount of travel time savings can be estimated from network models. However, in order to attach a monetary value to this amount, one must know the economic value of an hour of travel time. The approach used in most studies is to estimate the value of time as one-third to one-half the pre-tax wage rate of the users. The U.S. Office of Management and Budget (OMB) recommends using 50 percent of the average *work* wage rate, before taxes. The U.S. DOT recommends using 50 percent of the average wage rate in the region. [AASHTO, 2010] The approach used for estimating the value of travel time for a particular study will depend on the accepted practice in that study area.

A few caveats should be noted when applying a single value of time to travel time savings. First, small blocks of travel time (say, 2 minutes) may be valued at less (per minute) than large blocks (say, 15 minutes), because the small blocks do not present usable or perhaps even noticeable changes for the user. AASHTO suggests that individual travel time savings of less than 5 or 10 minutes per trip are of relatively little value, although AASHTO eliminated this distinction in 2003. [AASHTO, 2010] The travel time value reflects the fact that time saved does *not* usually result in increased earnings for the user, but does have some real value as reflected in observed traveler behavior. In fact, studies have generally shown that people do not place value on travel time savings of 2 minutes or less.

It should be acknowledged that there is some controversy on the nonlinear valuation of time value. Small [1999], for example, offers arguments contrary to the AASHTO approach.

Second, value of time will depend on trip purpose. A driver who is late to work might be willing to spend quite a bit to save a few minutes, but the weekend driver out for sightseeing might not. Indeed, current interest in pricing managed lanes on urban freeways focuses on congested periods during the day, usually during peak commute times when the work trip is most prevalent. In such a case, the value of time, and thus commuter willingness to pay, is much higher than at other times of the day or of the week.

Third, many regions derive values of travel time from the *mode choice* module of the regional travel demand model. Although this model is theoretically acceptable, in practice, transportation planners must be careful that misspecification of the mode choice model does not lead to an undervaluation of travel time.

Many commercial vehicle operators also will realize economic benefits from time savings due to reduced congestion. Such savings result in greater productivity and/or reduced labor costs. Where such benefits do occur, they reflect the drivers' wage rate and fringe benefits, plus certain other values related to the ownership and operation of the vehicle. Appropriate values of freight value of time for economic analysis range between $50 and $80 per vehicle-hour and sometimes higher. The estimated value often depends on the size of the truck, the goods being moved, and the distance over which the goods are being transported. Intercity trips tend to have higher time values than shorter trips.

Out-of-Pocket Auto-Operating Cost Savings. Variable (avoidable) motor vehicle–operating costs for auto users diverted to transit, carpools, or another facility represent an important source of potential project benefits. Fuel-, oil-, and mileage-related vehicle maintenance costs typically average 13 to 20 cents per mile. Assuming a vehicle left at home is not used by others during the day, the reduction in O&M costs are a net benefit to the driver.

For auto users diverted to transit modes, a factor must be applied to account for the fact that an auto typically can carry more than one person in the peak and off-peak periods. To get a reduction in the vehicle miles of travel, the number of auto person trips is typically divided by 1.15 to 1.2 for peak-period trips, and 1.25 to 1.4 for off-peak trips. Benefits in this category also include reductions in operating costs due to reductions in stop-and-go operation on free-flow facilities and a reduced number of stops on interrupted-flow facilities.

Operating cost savings to the owner of the facility would be considered benefits in the calculation.

Savings Due to Reduced Injuries and Fatalities. One of the major benefits associated with transportation investment is the reduction in the number and severity of crashes. These include crashes with other motor vehicles as well as crashes between motor vehicles and pedestrians or bicyclists. Estimating the safety benefits of a specific alternative requires one to identify the reduction in safety-related societal costs. One widely used source from the U.S. DOT suggests that the appropriate costs (in 2012 dollars) for crash categories for a single person injured is:

- Fatality: $9,100,000
- Critical injury: $5,396,300
- Severe injury: $2,420,600
- Serious: $955,500
- Moderate injury: $427,700
- Minor injury: $27,300 [USDOT, 2013]

The U.S. DOT also strongly encourages any safety analysis to use both a 3 percent and 7 percent discount rate in the analysis to assess the sensitivity of the analysis results to the choice of discount rate.

If these costs are to be used, they should be inflated to the study year. They represent comprehensive costs, including a measure of the value of lost life, obtained through empirical studies of what people would actually pay to reduce their safety and health risks. Even this raises some controversy because the actual economic costs—such as lost income, medical expenses, and the like—are generally much lower (for example, $1.1 million per fatality). Further confusion over the value of human life occurs given that several U.S. government agencies use different values for a single life.

Estimating Costs and Benefits by Measuring Individual Preferences. Two major approaches have been used to value benefits through the actual prices that consumers are willing to pay for them, or through some estimate of what they would be willing to pay. [Meyer and Miller, 2014] For example, on the presumption that consumers prefer houses on quiet streets to those on noisy ones, and are therefore willing to pay higher prices for them, transportation planners might compare the sales price paid for houses on streets with differing noise levels. In economic terms, consumers should be willing to bid up the prices of houses on quiet streets relative to noisy streets. This approach to valuing such benefits or costs is called revealed preferences (RP).

The disadvantage of this approach is that there are many factors that determine house prices in a neighborhood, not just noise levels. Of course, the size, quality, and sale date of the house must be considered and standardized by statistical techniques. But many other factors can come into play. Houses on noisy streets may be considered to be less safe (for example, higher traffic volumes may make it less safe for children); they may be closer to other noise generators (schools, commercial buildings); they may be considered dirtier (because of more vehicular and pedestrian traffic); and so on. In practice, it takes a very large amount of sales data to assess the impact accurately. See Diaz [undated] for additional literature and discussion. Nevertheless, through statistical techniques, this method has gained some currency, particularly for valuing environmental impacts, such as noise and air pollution.

RP data have also been used to estimate values of travel time when there is a tolled and untolled facility in proximity to one another, and data exists on which facility drivers use. Drivers who willingly pay a $2 toll to save 15 minutes of travel time must be valuing their time for that trip at a rate of *at least* $8 per hour (although we do not know how much more). This is one of the inherent limitations of RP methods. They tell us only about people's behavior given an observable choice set. If there is little variation across the attribute (for example, all houses in a city are exposed to an equal amount of traffic noise), there will be no way to determine the actual value placed on the attribute. Also, co-linearity between variables (variables where two or more attributes tend to be associated with each other) often exists, which makes the disentanglement of values placed on a single attribute extremely difficult.

Because of the problems inherent in RP methods, stated preference (SP) methods have been developed in an attempt to derive estimated values from hypothetical comparisons. Many of the same problems occur with RP and SP surveys, such as sample and response bias. SP methods have unique problems, including the wording and presentation of trade-offs (which is key to obtaining accurate values), and also the way the project impacts are presented to respondents for comparison (asking respondents how much they would be willing to pay for noise reductions in decibels will not elicit good responses). Questions presented without trade-offs ("Would you use … ?" or "How much would it be worth to you … ?") are likely to elicit invalid information. However, SP surveys do have the potential to examine a much wider range of conditions than exist at the time of the survey. SP surveys have been used successfully in studies to assess the value of travel time and in aesthetic/visual preference issues.

Good SP questions need to be counter-posed with the trade-offs involved. Asking people if they would use transit if it were available in their neighborhood is not likely to elicit as accurate a response as asking them if they would use transit if they had to walk two blocks and wait an average of 10 minutes for the bus to arrive, and if the overall trip would take 50 percent more time than by automobile.

Distributional Impacts and Equity. Equity addresses the question of who pays and who benefits from the expenditures of resources. An equity analysis is not required in every evaluation; in fact, it is probably appropriate only for very large projects, where potential costs (and benefits) are large, and the distributional impacts are uneven.

Even when projects have large net benefits, the distribution of costs and benefits can be uneven geographically among different income groups and between neighborhoods. For example, the construction of interstate highways in U.S. metropolitan areas unquestionably increased mobility; however, because of the nature of the highways, the relative gain in mobility was much greater for suburbs and outlying cities than it was for those in inner cities and near downtowns. In some cases, the interstates divided existing neighborhoods and, because of the closure of local streets, actually made some trips more circuitous. These impacts were generally ignored at the time much of the interstate was planned (the late 1950s and 1960s). In fact, some of the environmental legislation in the late 1960s in the United States relating to road planning and construction originated because of egregious decisions on the part of transportation agencies (for example, aligning new freeways in parks, cemeteries, and low income neighborhoods because the land was cheap).

Equity is essentially a normative issue—that is, it concerns what ought to be. There is no completely objective way to assess what is an equitable impact and what is not. Facts can inform that decision. In the end, disagreements over normative statements cannot be settled solely by an appeal to facts. It is the public will, as expressed through elected officials in a democratic society, that determines what is equitable and what is not.

Assessment of equity impacts should generally begin at the stage of developing goals and objectives. For example, Table 7-1 indicated consideration of two potential equity impacts: (1) amount of tax base shifted from one jurisdiction to another and (2) impact on low-income neighborhoods and groups. These evaluation criteria illustrate common ways of looking at equity—spatially and modally—among income groups and for identifiable groups of people.

Spatial Impacts. Travel forecasting models and geographic information system (GIS) techniques have made it much easier to assess the spatial impacts of projects. For example, choropleth maps can be created fairly easily at the census geography or travel zone level, illustrating things such as auto availability, travel time accessibility by different modes, pollution impacts, and so on. Imagine a range of transit improvements in a city. The changes in travel times (positive or negative) could be examined at the traffic analysis zone (TAZ) level, with shades representing less than a 5-minute change in travel time due to an alternative, warm colors representing various levels of increases in travel time, and cool colors representing travel time decreases. The overall spatial impact on different areas and neighborhoods can become readily apparent from such a map. It is important to note that any project can have both positive and negative impacts; for example, a rail alternative might assume that parallel bus services are eliminated or redirected as feeders to rail stations. This may actually cause in-vehicle or overall travel times to increase for certain users.

Modal Impacts. These occur as the generalized cost of one (or more) mode(s) improves relative to that of other modes. High-occupancy vehicle (HOV) lanes might improve travel times for carpools and transit users but not for single-occupant vehicle users, which is a distributional impact. General capacity increases may reduce the use of transit in a corridor. These impacts are readily determined from the outputs of a multimodal travel model, although the state-of-the-art in predicting nonmotorized trips is such that, in most areas, only qualitative effects can be assessed for pedestrian and bicycle travel.

Income Impacts. Transportation impacts sometimes distribute costs and benefits unevenly because of the manner in which transportation projects are paid for. Transportation projects in the United States are most commonly funded through consumption taxes, such as taxes on gasoline or general retail sales. Such taxes have a tendency to be regressive; that is, they tend to take a higher share of income from poorer households than from richer ones. In 2011, the bottom 20 percent of U.S. household incomes spent an average 5.6 percent of their income on gasoline and oil, whereas the top 20 percent of household incomes spent just 4.3 percent. However, when one excludes gasoline from the expenditures, the bottom 20 percent spent 9.2 percent of their income on transportation, whereas the top 20 percent of household incomes spent 11.8 percent, likely reflecting the cost of vehicles. [AASHTO, 2013] Thus, even an apparently fair method of raising revenue, such as a tax on gasoline, disproportionately affects lower-income groups. If proportionality is a goal (that is, treating all income groups equally), the use of consumption-based taxes is not the best strategy.

Information on personal income can be obtained from the U.S. Bureau of the Census and the U.S. Department of Labor. There are other proxies that can be used for income that may be more current, if currency is important: (1) unemployment rates in an areas, and (2) areas experiencing job losses (or gains) in prior years.

Impacts on Identifiable Groups. Impacts also may occur disproportionately to ethnic minority populations, the elderly, or those with transportation disabilities, who are often geographically concentrated. For example, in many U.S. cities, ethnic minorities and immigrant populations are concentrated in parts of the region (most often in the center city or in dense, radial corridors) that do not benefit directly from investments in suburban transportation systems. In some cases, the courts have had to decide whether the investment using federal funds did or did not cause disproportionate hardship to such populations. These issues are addressed partly through the Executive Order on Environmental Justice (see chapter 1).

Least-Cost Planning. Another approach toward planning that has important implications for evaluation is least-cost planning, also known as integrated resource planning. Least-cost planning had, as its genesis, the energy planning efforts of the 1970s. It was found that under certain conditions, it might be less costly to promote energy conservation programs (for example, more energy-efficient appliances) than to build new energy-generating capacity. Utility planners had traditionally only looked at the expansion of supply, rather than both the supply and demand for electricity. In some areas, least-cost planning led to laws requiring more energy efficiency in new appliances, additional insulation in buildings, and rebates to consumers for the purchase of energy-efficient appliances. This concept has been expanded to water conservation and other areas.

From an evaluation perspective, least-cost planning places great weight on the definition and valuation of all possible effects of a project and the determination of the least-cost approach, where costs include all societal costs. In addition, acknowledging and estimating uncertainty in the results of evaluation become an inherent part of the planning process.

B. Evaluation Techniques

Many useful and valid methods can be used in transportation planning to evaluate the relative effectiveness of different alternatives. If a travel forecasting model is available, it can often provide many of the inputs necessary for a good evaluation (see chapter 6 on travel demand modeling). In fact, the problem may be that too much information is available, and the analyst's major challenge becomes choosing data that are key to the evaluation. There is also a danger that when much time and effort has been expended in developing a complex travel forecasting model, there will be a temptation to put too much faith in its results. Particularly with respect to long-range forecasts, the analyst should always be aware that many of the assumptions implicit in any forecast of conditions several decades from now may be subject to considerable uncertainty.

1. Selecting the Appropriate Analysis Method

Two basic requirements of an appropriate evaluation procedure are that: (1) it should produce understandable results to those who make the final decisions, and (2) it should be appropriate for the range of alternatives under consideration and the complexity of decisions being made. Descriptions of four basic evaluation techniques are found in Meyer and Miller [2014].

Effectiveness Matrix. An effectiveness matrix is the simplest of all the evaluation techniques. A measure for each criterion and alternative is inserted into the cells of a matrix, where the columns represent the different alternatives under consideration, and the rows represent the different evaluation criteria. The value entered in the matrix may be an actual measured value, a ranking, or a normalized value (that is, adjusted to make the total of all the scores add up to one, or some other arbitrary number, such as 10 or 100). This matrix enables stakeholders and decision makers to see the effectiveness of each alternative compared to all the other alternatives. This technique is useful if the number of alternatives and evaluation criteria is reasonably small, and the costs and benefits are difficult to measure. Cell entries may be, for example, best or worst, may rank the alternatives from one through *N* alternatives, or may consist of judgments as good, poor, or average. Effectiveness matrices are often used in environmental analyses.

Aggregate Ranking. If an effectiveness matrix becomes too large and unwieldy to assist in making a decision, bottom-line scores may be derived through some form of aggregation. Use of normalized values provides a good method of aggregating measures with different units or dimensions. A second method of aggregation involves summing the scores associated with the criteria for each alternative. The aggregation may be made for each category of criteria (performance, impact, and implementation) and/or for all criteria together. Evaluation scores must be made at the ordinal level of data measurement, such as best (first) to worst (last). Alternatively, ratio-level scores may be developed for each alternative (for example, Plan A has 92 percent of the ridership of Plan B).

Careful attention should be given to selecting the appropriate evaluation criteria (this is true of most evaluation techniques, but particularly for aggregation approaches). Unless criteria are weighted, the selection of less important criteria can bias the selection toward a less desirable alternative. Alternatively, bias can be introduced with weights if they do not reflect local values as expressed by the goals and objectives defined outside of the evaluation process. Weights may sometimes be developed as part of the development of the goals and objectives in the public participation process, with a technical advisory committee, or both.

Final selection of an alternative often requires the weighting of criteria to reflect the varying importance of the objectives being measured. Input from citizens and elected officials is essential in determining proper weighting so that the complete range of differing viewpoints and interests will be represented in the final analysis. A case study applying aggregate ranking to conversion of one-way streets to two-way operation is provided later in this chapter.

Cost-Effectiveness. This evaluation method can be used as an independent technique or in combination with the two above. This procedure involves the direct comparison of two related criteria or groups of criteria. Usually, the monetary cost of each alternative is compared to some performance measure of the plan or project. Alternative improvements may then be compared based on their efficiency in meeting common objectives. For example, cost-effectiveness methods have been used to assess noise reduction strategies (dollars per decibel reduction), water-quality improvements (dollars per salt concentration reduction) and transit investments (annualized dollars per new rider). The method is particularly useful when plans are being measured against benefits for which it is difficult to assign a dollar value.

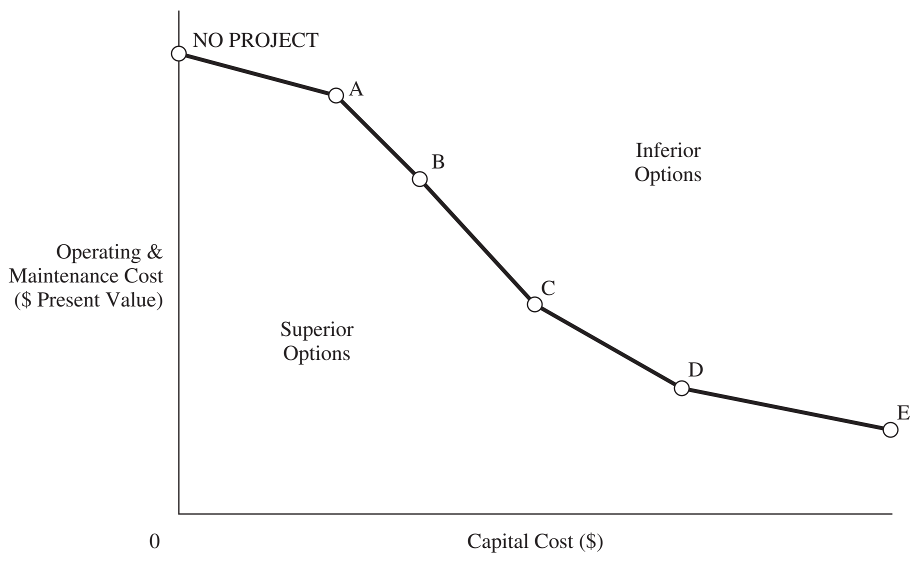
A common example in transportation safety is the proper value to place on a fatality. Rather than attempting to make such a valuation, which inevitably will be subjective and controversial, the planner can merely keep the original units in the comparison. For example, during a 20-year period, Plan A might eliminate 40 injuries (compared to some baseline) at a total cost of $50,000, while Plan B saves 55 injuries at a cost of $65,000. Thus, comparing plans, B costs $15,000 more than A, but results in 15 fewer injuries. The relevant question to ask is, "Is each injury reduction worth at least $1,000?" If it is, then Plan B dominates; if not, then Plan A is preferred. This gives decision makers the opportunity to subjectively evaluate the costs and benefits (or output measures) of the plans. The planner is not required to determine the exact value of a prevented injury. The key in cost-effectiveness analysis is to look at differences between the results of alternatives, divided by the difference in cost. This is illustrated in Figure 7-3.

One approach, perhaps not entirely satisfactory, is to evaluate the project with ranges of costs associated with the difficult-to-quantify factors. If there is a positive net benefit even with high values placed upon the nonmonetary costs, it is likely that the project is desirable. On the other hand, if even low values placed on nonmonetary costs result in low, or negative, net benefits, transportation planners may conclude that the alternative is not desirable. In most cases, however, many project alternatives are likely to fall between these two extremes.

Benefit/Cost Analysis and Net Present Value (or Net Benefit). These related measures (sometimes also called cost/benefit analysis) involve measuring as many criteria as possible in terms of monetary units (dollars). The performance criteria represent the benefits, while the impact and implementation criteria represent the costs. Costs are usually easier to estimate than benefits simply because they are already expressed in dollar terms. Because many costs usually occur in the early stages of a project, and benefits are spread out over a number of years (see Figure 7-4), discounting is used to bring all monetary streams (both costs and benefits) back to a current year (usually the year in which the analysis is being done). That way, the costs and benefits can be put in equivalent year values. Discounting is discussed in greater detail later in this chapter.

The alternative with the largest net benefit (present value of discounted benefits minus present value of discounted costs) is the best alternative. Net benefit must exceed zero to justify the plan/alternative, and typically it must do so by a considerable margin.

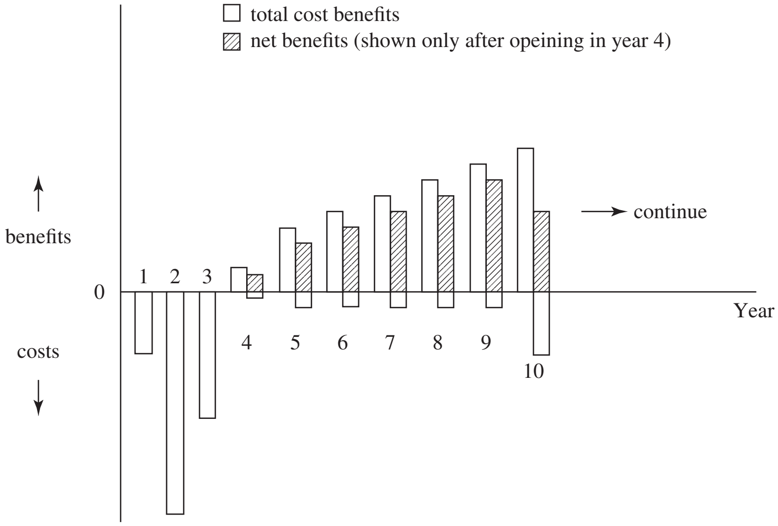
Figure 7-3. Illustration of Cost-Effectiveness Evaluation



Benefit/cost (B/C) ratios should be used with great care because of the misleading results they can produce. Small projects often have very high B/C ratios, but are not necessarily the only project that should be undertaken. Large projects may include components with poor B/C ratios, and the ineffectiveness of these components may be masked by averaging them with other components with high B/C ratios. Both B/C and net benefit evaluations suffer from the limitation that they require dollar values for all benefits.

Another important point to recognize with B/C analysis is that when multiple projects are being compared, the incremental B/C of one project over another is the key to best project selection, not just the overall B/C ratio. The incremental B/C ratio of project *j* compared to project *k* would then be:

Figure 7-4. Illustration of Costs and Benefits for a Major Transportation Investment



$$\text{Incremental B/C of project } j \text{ over } k = (B_j - B_k)/(C_j - C_k)$$

Remember, this incremental approach was also true for cost-effectiveness analysis.

A simple example illustrates the concept of incremental B/C ratios, as well as the mistake of simply accepting the first B/C ratios as the criterion for selecting the best project. Assume that a planner has estimated the present value of costs and benefits as shown in Table 7-4 for five projects. As can be seen from this table, project A has the largest B/C ratio, and thus one might be tempted to choose this project. However, one must first conduct an incremental B/C analysis to make such a determination.

First note that the B/C ratio for project C is less than 1.0, so this means that project C is no longer in consideration. Comparing the lowest cost alternative with the next highest alternative, we look at the value of A compared to B.

$$\text{Incremental B/C Comparing B to A} = \frac{PVB_B - PVB_A}{PVC_B - PVC_A} = \$\frac{460{,}000 - \$375{,}000}{\$200{,}000 - \$150{,}000} = 1.7$$

Given that the incremental B/C ratio is greater than 1.0, the higher cost alternative (B) dominates the lower cost alternative (A). In plain English, what the 1.7 means is that for every \$1 of additional cost to construct project A, one would get \$1.70 in additional benefit. In the absence of any extenuating circumstances, this would be a logical action to take.

We now conduct the next incremental B/C analysis by comparing project D to project B, remembering that project C is no longer in the mix.

$$\text{Incremental B/C Comparing D to B} = \frac{PVB_D - PVB_B}{PVC_D - PVC_B} = \frac{\$500{,}000 - \$460{,}000}{\$250{,}000 - \$200{,}000} = 0.8$$

Table 7-4. Example Benefit/Cost Analysis

Discounted Benefits and Costs				
	A	**B**	**C**	**D**
PVB	$375,000	$460,000	$500,000	$500,000
PVC	$150,000	$200,000	$550,000	$250,000
B/C	2.5	2.3	< 1.0	2.0

Given that the incremental B/C ratio is less than 1.0, the lower cost alternative (B) dominates the higher cost alternative (D). Or in plain English, spending an extra $1 to construct project D will earn you $0.80, not a good return on your investment. Thus, alternative B is the recommended project.

Note in this case that the initial B/C ratios of each project gave project A the highest initial value, and yet project B was the recommended choice. This is one of the mistakes often made by engineers—choosing the highest B/C ratio after the initial comparison. In other words, we want to find the project alternative with the highest marginal benefit per additional unit cost which may not necessarily be the project with the highest overall benefit/cost ratio. Also note that by simply finding the net annual worth, we would have chosen project B immediately because it has the highest NPV ($460,000 – $200,000 = $260,000).

B/C analysis and net present value work best when there are active markets for goods and services that can be used to provide prices for the additional expenditure or savings. An alternative that reduces fuel consumption by 30,000 gallons per year can be said to save $90,000 a year if fuel is valued at $3 per gallon. However, not all items have active markets. Most environmental costs do not, nor do health effects. A shortcoming of B/C analysis is that it cannot assess the large number of social, environmental, and political effects that often must be considered in evaluating large projects. Various attempts have been made to place monetary values on factors such as noise, air pollution, aesthetics, displacement, safety, and so on, that are intrinsically difficult to value. Generally, there has been a tendency to ignore these nonmonetary costs in B/C analysis because they are difficult to value, and this can result in a biased selection of alternatives.

For an overview of benefit/cost techniques for evaluating highway investments, see FHWA's *Economic Analysis Primer* at http://www.fhwa.dot.gov/infrastructure/asstmgmt/primer05.cfm.

Return on Investment. Return on investment (ROI, or rate of return) is another technique applicable to analyses in which cost and benefits can be measured in dollar terms. The rate of return is the interest rate that makes the costs equivalent to the income stream. For example, a $300,000 investment will result in new operating revenue of $50,000 per year, and annual operating costs of $20,000 per year. It is estimated that the salvage (resale) price of the investment will be $150,000 in 10 years. The rate of return on this investment would be approximately 6.2 percent per year.

An obvious limitation of the ROI method is that although it tells us the rate of return on the investment, it says nothing about the overall benefit achieved. A very small project might have a very high rate of return, whereas a large project might have a lower but still substantial rate of return. This does not mean that the very small project should be chosen over the large project. Rate of return has mostly found favor in the private sector, where it is sometimes used to guide management investments and evaluation of performance. The popularity of ROI has caused some confusion, however, in public-sector evaluation. The interest rate charged (effectively a discount rate for the project) in the private sector will almost always include the risk associated with borrowing the capital funds to build the project; firms teetering on bankruptcy can only sell bonds at interest rates much higher than those of a stable, profitable company. This is known as a risk premium.

In public-sector economics, it is better to consider risk through an explicit evaluation of different outcomes, rather than through a higher discount rate. Private-sector risk often includes the possibility of default—that is, the bonds (or other financial instruments) have zero value. In the public sector, the risk is generally that costs will be greater, or benefits lower, than forecast (or both). This is discussed in the section on risk and uncertainty.

Project Evaluation Period, Useful Life, and Salvage Values. Costs and benefits are usually accumulated over a project period that represents some reasonable planning horizon. The planning horizon will depend on the nature of the project and the technology employed. Ten to 30 years is most common, although occasionally analyses are done for 40- or 50-year periods. Long evaluation periods are problematic because the accuracy of the projections of demand and usefulness of the improvement becomes increasingly less certain as the project time horizon is extended into the future. Technology—along with public attitudes and values—may change in unpredictable ways. A reasonable rule of thumb for defining a planning horizon is to use the service life of the alternative with the longest service life under consideration. This is usually not more than 40 years.

Different components of a transportation system have differing service or useful lives. Some commonly used values are shown in Table 7-5. Those with an asterisk are ones specifically recommended by the Federal Transit Administration (FTA).

Table 7-5. Typical Service Lives of Transportation Assets	
Diesel bus (urban standard)	12 years*
Mid-size bus (medium duty)	10 years
Van (9–15 passengers)	4 years
Rail vehicles	25 years*
Fixed guideway trolleys	25+ years*
Parking lot	20 years*
Parking structure	25 to 50* years
Fixed facilities (stations, structures)	50+ years*
Land (including clearance and relocation)	100* years to Infinite
Pavement (asphalt)	20 years
Train control systems	30 years*

Source: FTA, 2008

These estimated service lives assume a relatively high level of maintenance (both corrective and preventive); thus, the service life is a function of technological obsolescence, rather than of the physical deterioration of the subsystem itself. Technical obsolescence can be due to a number of factors, including better ways of doing something, maintenance costs growing relative to the replacement costs, and better uses for the asset. As an example, high fuel prices can make a serviceable transit fleet obsolete because of the availability of newer, more fuel-efficient vehicles.

The useful lives noted above assume that there will be periodic major maintenance and overhaul activities, which must be included in the cost analysis. These occur at various intervals throughout the study period. For example, a study period of 25 years may require that a bus fleet be replaced twice—once at year 12 and again at year 24. A capital recovery factor (annualized cost) can be used to avoid the problem of the leftover or residual values of the vehicles in the 25th year. Because land is technically not "worn out," it typically has an infinite life. (The difference between the assumption of 100 years and infinite is virtually nil in the discount tables.)

Longer useful lives, all other things being equal, will tend to reduce the annualized cost of an asset. Because of discounting, the analysis will not be very sensitive to errors made in the far "out" years; for example, there is a relatively small difference between the annualized cost of an asset lasting 30 years and one lasting 35 years. However, the error can be substantial with mis-estimation in the early years. For example, the difference in annual cost for an asset lasting 5 years is very different from one lasting 10 years.

Salvage values represent the value of a project or project component at the end of the study period. Just like an old car being turned in for a new model, most of the components noted have some remaining value at the end of their service life. However, because many of the subsystems have long service lives, the salvage value is typically not realized until some distant out-year. Thus, it is often more convenient to ignore them as part of the economic analysis. In addition, the values are often insignificant because they are so small at the end of a long project evaluation period, and their present worth often turns out to be less than 1 percent of the cumulative project cost. With increased emphasis on recycling building materials, however, this could change for certain physical assets.

2. Definition and Use of Discount Rates

Because projected costs and benefits occur at different times, a present-value analysis needs to be employed to account for the *time value of money*. A discount must be applied to future values because a dollar received today is not the same as a dollar received in the future—even after making allowance for inflation and the risk of not being paid. The present value (or present worth) of net project costs is the basic cost measure used in comparing costs and the cost-effectiveness of alternatives. A discount factor is used to convert future costs and benefits to a present-year value. Thus, the annual estimates of future benefits and costs are discounted to present values using a discount factor that acknowledges the potential rate of return from an alternative investment of the same amount of money.

Given a discount rate of r, an interest rate of i and costs (or benefits) occurring t years from now, the equation that relates future values to current values is given as:

$$F = P(1 + i)^t \text{ or } P = F/(1 + r)^t$$

where:

P = Present value of an amount
F = Equivalent future value of the amount (nominal dollars)
i = interest rate per annum
r = discount rate per annum

In this equation, estimating the future value of a present sum uses an *interest rate* similar to the interest rate provided by lending institutions. However, if you want to estimate the present value, P, of a future sum, F, then you discount the future sum to the present time with a *discount rate*. The discount or interest rate is expressed as a decimal value. For example, a 7 percent discount rate would be 0.07. If a cost (or benefit) accrues 5 years from now, with an interest rate of 5 percent, the interest rate factor applied to it should be $(1 + .05)^5 \approx 1.28$. In other words, $1.00 in current costs (or benefits) is equivalent to $1.28 five years from now assuming an interest rate of 5 percent. Or alternatively, a future value of $1.28 is equivalent to $1.00 in current costs (or benefits) discounted over 5 years at a 5 percent discount rate.

As can be seen above, strictly speaking, a discount rate is not identical to an interest rate. In public sector economics, a discount rate actually represents society's preference between the value of consumption today and consumption in the future—in other words, a social time preference rate. Most practicing planners and engineers will not have to deal with this distinction, but should be aware it exists. There are many readings on engineering economy for those interested in pursuing this topic in greater depth (see, for example, [Berechman, 2009; Sinha and Labi, 2007; and Markow, 2012]).

Choice of the appropriate discount rate can often be a controversial decision. Discount rates in the range of 5 to 10 percent are most commonly used. For a U.S. federally funded project, at least one analysis must be done with a 7 percent discount rate, as mandated by the U.S. Office of Management and Budget (OMB) in Circular A-94. As noted by OMB, "The 7 percent rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy. It is a broad measure that reflects the returns to real estate and small business capital as well as corporate capital" (see [OMB, 1992] for further discussion). Interestingly, the FTA recommends a discount rate of 2 percent for major transit investment analysis.

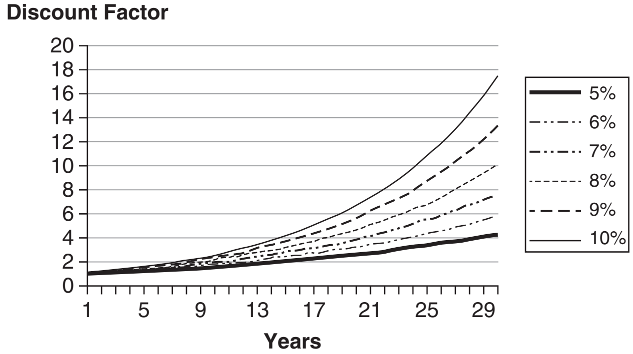
Many agencies prefer to use as their discount rate the interest rate at which they can normally borrow funds. For example, at the time of this writing, most U.S. state and local public agencies can issue long-term bonds at an interest rate of 2.5 to 5 percent per annum that are exempt from state and federal taxation.

One approach to defining a discount rate is based on the concept that the no-build alternative, which by definition assumes little or no investment, leaves money available in the lending market for private sector investment. Thus, the discount rate could be estimated as the assumed rate of return on an alternative private investment with the amount of money needed for a build project, before taxes and excluding inflation.

The higher the discount rate, the greater the comparative effect on the economic efficiency of costs incurred during the early years of the project period, and the lower the comparative effect of costs incurred in later years. Thus, low discount rates will favor large, capital-intensive projects with long lives, whereas high interest rates will favor projects with lower capital, greater operating and maintenance costs, and shorter useful lives. This is why capital-intensive projects in countries with very high interest rates (for example, much of the developing world) do not make as much sense to investors as in countries with relatively low costs of capital, all things being equal.

Figure 7-5 graphically shows the effect on present worth of discount rates between 5 and 10 percent over a period of 30 years. Note that after 30 years (the far right of the graph), $4 at a 5 percent discount rate and $17 at a 10 percent discount rate are both equivalent to $1 in current dollars. The analyst can either program the formula noted earlier for discount factors, use several widely available software packages, or use tables available in most textbooks dealing with engineering economy or economic evaluation.

Figure 7-5. Effect of Discount Rate on Present Worth



Capital Recovery Factor. Once a useful life and discount rate have been selected, it is possible to define an annual capital recovery factor (CRF) for an asset. The CRF is merely a combination of the cost of funds tied up in an investment, plus an annual amount to recover the asset's depreciation and replacement costs. More formally, it is the future series of end-of-period payments that will just cover a present sum (P) over t periods, with compound interest r. The CRF is estimated as:

$$CRF = \frac{r(1+r)^t}{(1+r)^t - 1}$$

Tables are widely available in engineering economy textbooks for different interest or discount rates, and number of time periods (usually in years). Notice that over a long period (t is very large), the CRF will approach r as a limit. Here is an example:

What is the CRF and annualized cost of a $300,000 bus, assuming no salvage value and a 7 percent discount rate? The useful life of a bus, as previously noted, is 12 years. Thus, the CRF will be:

$$CRF = \frac{0.07(1+0.07)^{12}}{(1+0.07)^{12} - 1} = \frac{0.15765}{1.2522} = 0.1259$$

Of this amount, one-twelfth (or 0.08333) will be for depreciation of the asset (assuming the bus depreciates uniformly over 12 years), and the remainder (0.04257) for the average payment on the remaining balance. The annualized cost will be:

$$\$300{,}000 \times 0.1259 = \$37{,}770 \text{ per year}$$

The example includes some rounding. In most cases, it is not necessary to carry out the results to more than four or five decimal places unless a very large sum is involved. CRFs can also be extremely useful in thinking about renting an asset at a given rate of return (the discount rate). They can also be used to determine the equivalent annual cost of assets with varying service lives.

Effects of Inflation. Annual costs and benefits are usually measured in constant (for example, 2016) dollars, thereby excluding the effects of inflation. Adjustments are sometimes made to base unit costs to account for net or real changes in the economic values for costs expected to change at rates higher or lower than the average inflation rate in the economy. Although some cost items at one time rose faster than inflation, historically, future extrapolations of such differences have not been very accurate. Some forecasts have been spectacularly wrong, especially because sharp price spikes sometimes turn out to be relatively short-lived.

The important thing to understand is that inflation will have no effect on determining present values for the economic efficiency analysis. Inflation will, however, be a major consideration in the financial feasibility analysis for which projections of future capital and operating needs will have to be expressed in inflated dollars. Basic financial comparisons are usually performed using an assumed inflation rate, or better yet, a range representing the most reasonable optimistic (lower) and pessimistic (higher) rate range. A "real" discount rate is the discount rate net of inflation and is used to estimate constant dollar amounts. A "nominal' discount rate includes the rate of inflation and is used to estimate current or end-of-year dollar amounts.

An oft-heard complaint is: "If we don't build this now, the cost will keep going up due to inflation!" The economic cost of the project is determined by real resources that must be invested in the project: hours of labor, pounds of steel, cubic yards of earth moved, and so forth. If correctly estimated, these quantities should change little over time. On the other hand, financial costs—wage rates, unit prices for materials—mostly increase over time due to inflation. Thus, from a financial perspective, that is, the amount of money that will be necessary to build the project in the future, the complaint is correct.

Take an example of a project estimated to cost $30 million if built today. Waiting until next year, with inflation at 5 percent per year, the project will cost $31.5 million. If project funds were placed in an investment earning 5 percent per year, there would be $31.5 million next year to build it. Of course, the problem with this illustration is that most government budgeting works with a fixed dollar amount without regard to inflation. If the funding agency has set aside a fixed amount (such as $30 million) for the project, then someone will have to come up with the additional $1.5 million at the actual time of construction next year, to cover inflation. However, this problem is due to governmental budgeting practices, not due to inflation. The more important issue is that whatever benefits the project would have produced in the year's delay are lost. The lost travel time, cost of crashes, and so forth, cannot be regained.

3. Treatment of Risk and Uncertainty in Project Evaluation

Inadequate treatment of uncertainty (risk) and potential error in cost estimates has been a recurring problem for major transportation projects (both highway and transit). Generally, the tendency at the planning stage has been to underestimate costs and overestimate benefits (see, for example, [Button, 2009; Danata et al., 2006; and Flyvbjerg et al., 2002]). Defining error as the difference between the planning estimates and the actual cost to build the project, it is possible to identify four potential sources of error:

1) Changes in the scope of the project
2) Changes in the design standards used to build the project
3) Incorrect unit cost assumptions in the planning estimates
4) Unforeseen problems in implementing the project (including delays)

Each of these is briefly covered below:

Changes in Scope—In the project planning phase, planners often face a wide variety of options: alignments, degree or type of grade separation, length and location of the facility, design speed, quality of service, and so forth. The design speed and quality of service overlap with changes in design standards. Citizen participation in the project development process may result in scope changes at a later phase of development, which is one reason for incorporating stakeholder participation early in the planning process. For example, citizen protests regarding an elevated freeway might require it to be placed below grade in a cut. Another example is costing a bus tunnel and then later deciding to add tracks to accommodate a future light-rail system. Unforeseen environmental mitigations are also incorporated, including remediation of toxic substances.

Changes in Design Standards—These are similar to the broader uncertainties about scope, but are more specific in nature. Design standards cover the entire range of the physical characteristics of the project, including vertical and horizontal clearances, seismic standards, materials, upgrading amenities, environmental mitigations, and so forth. Examples include: (1) requirements for higher vertical clearances for all new interchanges after the cost estimates had been prepared, (2) changes in accessibility requirements for the disabled/handicapped, (3) revisions to flood maps requiring higher elevations, and (4) discovery of endangered species, requiring additional study (time delays) and project mitigation.

Errors in Unit Cost Assumptions—A variety of potential errors exist in the unit cost assumptions used in project planning. Unit costs are generally derived from actual (submitted) bids from other similar projects. These costs are averaged from several projects. Their transfer to the current situation is often uncertain in terms of the commonality of definitions used for both the historic data and the unit costs defined for the project planning effort. The use of cost averages from comparable projects can also introduce errors because of cost differences due to time of construction, region of construction (costs can vary widely even county to county), incomplete understanding of all elements of "comparable" projects, and the like. Additional uncertainty in unit costs includes the availability of appropriate construction firms and skilled labor, the bid climate during the construction period, the actual quantities supplied, and fluctuations in basic materials prices.

Difficulties in Implementation—Perhaps the largest source of uncertainty in costs during the planning stage is the inability to anticipate difficulties that will be uncovered in later stages of project development. These uncertainties often come with right-of-way acquisition, utility relocations, soil conditions, lawsuits, and discovery of historically significant artifacts during excavation. Delays in implementation generally raise costs because of inflation and because of the costs of stopping and then remobilizing labor. Contractors may be owed special payments for such stopping and restarting, and scope changes during construction (*extra work orders*) can prove costly because there is relatively little bargaining power with the contractor who is already contracted to do the work. Encountering the unexpected during construction is not unusual; archaeological finds, toxic wastes, flammable or poisonous gases, water intrusion, and unforeseen damage to nearby buildings have all been factors raising the cost of major transportation projects in recent years. Wilson discusses the role of value engineering (VE) and risk management in controlling such costs. [Wilson, 2005]

The problem of cost mis-estimation is international in scope, with many high-profile megaprojects going over budget by significant amounts. Flyvbyerg et al. [2003] found numerous examples of cost overruns on large projects, including the Boston, Massachusetts, Central Artery (actual cost was three times the estimate); the Humber Bridge in England (actual cost was 2.75 times the estimate); the Washington, DC Metro (actual cost was 1.85 times the estimate), and the Channel Tunnel rail project (actual cost was 1.8 times the estimate). Their other significant conclusions about large infrastructure projects included:

- Ninety percent of very large infrastructure projects had underestimated costs.
- Rail projects had the worst cost accuracy, costing on average 45 percent more than the estimates.
- Tunnels and bridges cost 34 percent more on average than estimated.
- Roads were 20 percent more costly on average than estimated.
- Over all, transportation projects were 28 percent more costly than estimated.
- Cost underestimation has not decreased over time; no learning seems to be taking place.

One way of dealing with uncertainty, especially for cost estimates, is to assign contingency factors to cost estimates during the planning stage. The net effect of this approach is to increase project cost estimates (especially for cost estimation during project planning stages) to take uncertainties or risks into account. For example, Table 7-6 shows contingency percentages (of the estimated project costs) associated with different components of a planned streetcar line in Washington, DC. Allocated contingency is used for projects where the engineering design level is determined to be less than preliminary engineering completed. Because project information is incomplete for individual components of the project, and the risk associated with this lack of information is potentially large, a contingency allowance is added to the planning cost estimate. Unallocated contingency is primarily an allowance for unknowns and risk related to the level of engineering design completed. As a project or alternative goes through more detailed engineering, the uncertainties should decrease, and thus the contingency percentages as well.

Another way of treating uncertainty is to assign probabilities to specific outcomes. For example, consider Table 7-7, showing the net present value of benefits for three projects. The rankings of the three projects will depend on the ultimate outcome. Under the most optimistic or most likely outcome, Project A is superior to the others, but under worst-case conditions, it is far worse. Let's say that there is a 10 percent probability that either the best or worst case will occur, and an 80 percent probability that the most likely outcome will occur. Expected values can be associated with each project:

$$E(\mathrm{A}) = (0.1)500 + (0.8)(100) + (0.1)(-500) = +80$$

$$E(\mathrm{B}) = (0.1)(400) + (0.8)(50) + (0.1)(0) = +80$$

$$E(\mathrm{C}) = (0.1)(80) + (0.8)(80) + (0.1)(80) = +80$$

In this example, all three projects have an equal expected value. If there is no good reason to alter either the probabilities or the net benefit estimates, risk aversion may be a tie-breaker. Project C, although it has the poorest payoff under either the best or most likely case, is a "sure thing." Project A offers the highest potential payoff under the most optimistic set of assumptions, but also has a very large downside risk. It may wind up having substantial negative net benefits. Other factors that might be considered include: (1) equity impacts of the various projects and (2) support among the public or decision makers for specific projects (including level of controversy).

An obvious limitation on the expected value technique is that it may be difficult to assign reliable numbers to the probabilities of outcomes. Some ways of doing so might be through Delphi planning techniques, with simulation techniques for inputs and assumptions, or by looking at the outcomes of other projects of a similar size and nature. [Small, 1999] For example, if a third of similar projects ran 50 percent over budget, a worst-case analysis might include a scenario in which costs actually turn out 50 percent greater than assumed for the analysis.

Risk Assessment in Climate Change Adaptation Planning. The transportation planning profession has begun to consider the potential effects of a changing climate on the performance of the transportation system. Such a consideration takes uncertainty to a new level in transportation planning—what will a change in climate 50 years from now mean to transportation systems, and what should we be doing now in terms of facility design or land-use plans to reduce such impacts?

Table 7-6. Contingency Percentages for Planning Estimates, Anacostia Streetcar Project, Washington, DC

FTA Category No.	Description	Allocated Contingency Percentage
Allocated Contingency		
10	Guideway and Track Elements	
	• Guideway elements (except underground)	25%
	• Guideway elements (underground)	35%
	• Track elements	20%
20	Stations, Stops, Terminals, and Intermodal	20%
30	Support Facilities: Yard, Shops, and Admin Buildings	20%
40	Sitework and Special Conditions	
	• Demolition, clearing earthwork	25%
	• Site utilities, utility relocation	30%
	• Hazardous materials, contaminated soil removal/mitigation, ground water treatment	30%
	• Environmental mitigation, e.g., wetlands, historic/archaeological, parks	30%
	• Site structures including retaining walls, sound walls	25%
	• Pedestrian/bike access and accommodation, landscaping	25%
	• Auto, bus, van access including roads, parking lots	25%
50	Systems	20%
60	Right-of-way, Land, Existing Improvements	50%
70	Vehicles	10%
Unallocated Contingency		
Estimate Type	**Description**	**Unallocated Contingency Percentage**
Planning	System planning Alternative analysis	15% 10%
Design	Preliminary engineering Final design Construction	20% 15% 10%

Source: DC DOT, 2013

Table 7-7. Comparison of Values of Three Mutually Exclusive Scenarios with Three Potential Outcomes

	Outcome (Net Benefits)		
	Best Case	**Most Likely**	**Worst Case**
Project A	500	100	−500
Project B	400	50	0
Project C	80	80	80

According to FHWA, "A risk assessment integrates the severity or consequence of an impact with the probability or likelihood that an asset will experience a particular impact. To determine consequence, transportation agencies may wish to consider the level of use of an asset, the degree of redundancy in the system, or the value of an asset (in terms of cost of replacement, economic loss, environmental impacts, cultural value, or loss of life)." [Federal Highway Administration, 2012] Table 7-8 shows some of the evaluation techniques that could be used to assess the risks associated with climate change adaptation projects.

Table 7-8. General Adaptation Option Evaluation Methods			
Tool/Technique	**Qualitative Methods**	**Alternative Methods**	**Quantitative and/or Economics-based Methods**
Consultation Exercises	X		
Focus Groups	X		
Ranking/Dominance Analysis	X		
Screening		X	
Scenario Analysis	X	X	X
Cross-Impact Analysis	X		
Pairwise Comparison	X		
Sieve Mapping	X		
Maximax, Maxi-min, Minimax, Regret			X
Expected Value			X
Cost-Effectiveness Analysis			X
Cost-Benefit Analysis			X
Decision Analysis			X
Bayesian Methods			X
Decision Conferencing			X
Discounting			X
Environmental Impact Assessment/Strategic Environmental Assessment		X	
Multi-Criteria Analysis (Scoring and Weighting)		X	
Risk-Risk Analysis		X	
Contingent Valuation			
• Revealed performance			X
• Stated performance		X	X
Fixed Rule-based Fuzzy Logic	X	X	X
Financial Analysis			X
Partial Cost-benefit Analysis	X		X
Preference Scales	X		
Free-form Gaming	X		
Policy Exercise	X		

Source: Wall and Meyer, 2013 adapted from Willows and Connell, 2003

One of the approaches suggested by those who have examined this issue is a risk-based planning approach (see [Meyer et al., 2014; Wall and Meyer, 2013] for an overview of risk in climate adaptation planning).

4. Typical Problems, Issues, and Errors in Project Evaluation

This section reviews some common errors and misunderstandings that occur in evaluating transportation projects. It is intended to illustrate frequently found errors, rather than an exhaustive review of all possible problems.

External Funds (Grants) Are Subtracted from the Capital or Operating Costs of the Project. External grants (for example, from a state or federal agency) represent real resources and as such must be counted in the cost calculation for the project. Although external grants may provide local economic benefits, their application to a specific project means that resources have been diverted from other uses or other entities paying taxes. Therefore, external grant sources should never be subtracted from costs.

This problem can also lead to selection of capital-intensive projects because external funding programs will often pay for capital but not operating or maintenance expenses. Although this problem can be noted in the analysis, a fair analysis should still consider all real resources used. External grants (or any other matching funding, for that matter) may be legitimately considered at the prioritization stage of project development.

All Costs of the Project Are Not Included (Construction Period Delays, Energy Use). This problem frequently occurs in highway construction projects, where the cost of traffic delays during construction is omitted. Including such costs gives a truer picture of the benefits of an improvement and may also lead to better traffic-control plans during construction to minimize construction delay. Another example is in the analysis of the net energy payback from transit projects. In some cases, the considerable energy used in constructing a subway has been ignored, and only the operating and maintenance energy consumption of the subway versus autos is used. Ignoring the energy used during a construction project will bias the result toward a lower operational energy cost.

Some Benefits Are Double-Counted. This occurs very often in analyses that consider both user and supplier impacts. For example, in one study of the social costs of automotive use, the authors calculated the total cost of crashes, then added in auto insurance premiums to get a total cost of crashes. In reality, of course, insurance offsets some of the cost of crashes; only the amount not compensated by insurance should appropriately be considered in such a calculation. Another example includes travel time savings from a new rail system and increases in property values near stations. In fact, this is a double-counting because the increase in property value is merely a way that property owners reap a benefit from reductions in user travel time; one is a function of the other, and adding the benefits together results in double-counting.

Average Rather Than Marginal Costs/Benefits Are Used in the Analysis. In economic decision theory, it is the *differences* between alternative choices that count, not the average value. As economists say, all decisions are at the margin. What counts is how much additional benefit can be achieved for how much additional cost. The average cost is not the relevant consideration. Average costs (or benefits) are often used to mask politically motivated decisions.

Differences between Market and Societal Costs (Prices) Are Ignored. Ignoring societal costs of inputs or byproducts of a project can again lead to less than optimal decisions and overconsumption of a good. One such case is that of a city considering electric trolley buses to replace diesel services. One of the major operating costs of the system was electrical power. The city also owned a hydroelectric-power system, which would sell excess power to other departments at a cost based on the historical investment cost of the system, which was about 2.5 cents/kilowatt-hour, a price well below the market rate. This energy price was used in the economic assessment of the replacement service.

The economic evaluation should have used the going market rate. The opportunity cost of the power was the price at which it could be sold to willing buyers (for example, a local private utility). That cost was easily determined because such a market existed; the lower price reflected a bias among the evaluators to promote electric trolley bus services.

An Inappropriate Discount Rate Is Chosen. Excessively low discount rates will artificially favor projects that are capital-intensive and have a very long life. Many water projects in the United States have been historically based on 3 percent discount rates and 100-year service lives—assumptions that tended to strongly favor major capital investments. Any analysis using a discount rate less than the agency's cost of capital—currently at least 4.5 percent—should be suspect. At least one analysis should be done using a 7 percent rate. In less developed countries, higher discount rates may be appropriate to reflect the scarcity of capital available for investments.

Network and Other Important Effects Are Ignored. Examining a significant improvement in isolation from the rest of the transportation network is likely to give misleading results, especially when it is part of a congested network. For example, if only the travel time benefits to a single route are examined, the benefit to parallel facilities (in terms of reduced delay, collisions, and the like) will be improperly ignored. These effects can only be estimated when a network travel model is available. The author's experience has been that in certain instances, the travel time savings to other nonimproved facilities is as great, or greater, than the benefit to the improved facility when the network is highly congested.

Similarly, the analyst should be careful that when estimating travel time savings due to new capacity, the impact of travel time shifting is accounted for. This effect has been shown in a number of empirical studies: When new capacity is available, drivers may shift their travel time closer to the peak hour, negating some of the benefits of the capacity increase. Naturally, there is some benefit to drivers who can time their trips closer to the time they would prefer to make them, but the point is that the benefit analysis, which is based on travel time savings, may overestimate the improved travel speeds. Similarly, if the project will save a considerable amount of driver time, it may draw some passengers from parallel transit routes or, if high-occupancy vehicle (HOV) lanes are to be implemented, some transit riders may switch to carpools.

C. Prioritization and Programming of Projects

Once a set of desirable projects has been developed, it is necessary to identify which projects are better than others, and also to establish the timing for project implementation. This timing will need to consider budget constraints (not all projects can be done at once) and also the precedence and interdependencies between projects (Project B may require that Project A be completed first in order to be effective).

Project prioritization is inherently normative, with the usual objective being "given a budget constraint of *x* dollars over *y* years, what combination of projects will maximize the benefits achieved?" For example, a metropolitan planning organization (MPO) might have discretion over $20 billion in capital investments over 20 years (not all available equally each year). The budget constraint is assumed to be exogenously determined (that is, taken as a given), although information on project benefits might be used to persuade decision makers to increase the budget, if justified.

A peer review of state department of transportation (DOT) and metropolitan planning organization (MPO) efforts at multimodal project prioritization made the following recommendations in developing prioritization criteria.

- Criteria should be simple and articulated at a high level to keep decision making transparent.
- Prioritization criteria should calculate the benefits of proposed projects, and not simply assess the existing conditions.
- The content of long-range transportation plans and other multimodal plans should support an agency's choice of prioritization criteria.
- Agencies should choose a manageable number of criteria (i.e., five or six) to focus on meaningful and comprehensible outcomes.
- Criteria should focus on impacts to the traveling public rather than on impacts to infrastructure itself (e.g., amount of traffic crossing deficient bridges rather than the number of deficient bridges).
- Criteria should consider the context of each project (e.g., a rural project should not necessarily lose points for not including sidewalks).
- Where possible, criteria should rate projects based on mode-neutral characteristics, such as "asset condition" rather than "pavement condition."
- Criteria should focus on outcomes rather than outputs. [Middleton, 2014]

A recommended best practice not identified in this list, but mentioned in earlier sections, is that prioritization criteria need to reflect the goals and objectives of the planning study. For example, Table 7-9 from the Delaware DOT shows how the criteria used in the project prioritization process relate to the mission, vision, and goals established for the state's transportation program.

The prioritization process is easier where both costs and benefits are quantifiable. AASHTO recommends ranking projects in descending order of B/C ratios (where available), independent of their net present values (NPVs), and then selecting projects for construction until the budget is exhausted. [AASHTO, 2010] The process is easiest when projects are mutually exclusive—one, and only one, project will be picked. Where projects are interdependent, it may be best to try to group together projects that require a second project to be fully usable. If possible, the NPV of the first-phase project or project segment should be estimated. In most cases, the first-phase project should have some independent utility, even if it must precede another project to obtain its full benefit.

A further complication in government finance is that some projects will be eligible for matching or restricted funds from an external funding source (typically the federal or state government). In that case, some agencies' program projects maximize the capture of external funds, until the maximum available in any fiscal year is reached. This is often done at state DOTs to maximize the use of federal highway funds. Projects that exceed external funding eligibility are then moved to a second tier of competition with projects not eligible for external aid. Another consideration may be that states or counties are statutorily entitled to minimum budget allocations (a normative form of geographic equity). Regardless of these special provisions, it is critical that all projects should have positive NPVs.

Programming is a different process than prioritization. Programming is simply matching the projects that have been selected to the cash flow and investment timeframes that characterize a particular study time horizon. Programming

Table 7-9. Delaware DOT's Prioritization Criteria in Relation to Agency's Mission, Vision, and Goals			
Mission	**Vision**	**Goals**	**Prioritization Criteria**
Every Trip	We strive to make every trip taken in Delaware safe, reliable, and convenient for people and commerce.	Minimize the number of fatalities and injuries on our system. Build and maintain a nationally recognized system benefiting travelers and commerce.	Safety System Operating Effectiveness System Preservation
Every Mode	We provide safe choices for travelers in Delaware to access roads, rails, buses, airways, waterways, bike trails, and walking paths.	Provide every traveler with access and choices to our transportation system.	Multimodal Mobility/Flexibility/Access
Every Dollar	We seek the best value for every dollar spent for the benefit of all.	Minimize the environmental impact of the state's transportation system. Achieve financial sustainability through accuracy, transparency, and accountability.	Environmental Impact/Stewardship Revenue Generation and Economic Development
Everyone	We engage and communicate with our customers and employees openly and respectfully as we deliver our services.	Develop and maintain a place where talented and motivated employees love to work and can be national leaders in transportation.	Impact on the Public/Social Disruption/Environmental Justice

Source: Middleton, 2014

can also take into account other difficult-to-quantify factors, such as equity, level of project controversy, environmental impacts, statutory requirements, and project readiness. These factors may be overlapping. For example, a controversial project may also have undesirable equity or environmental impacts.

The evaluation techniques discussed earlier—effectiveness matrix, aggregate ranking, and cost-effectiveness— can also be used to establish priorities and timing of projects. Typically, prioritizing projects will involve a wider range of issues, including project financing. For example, a large, expensive project may require an agency to borrow funds for its construction; the resulting debt service payments on the borrowed funds will reduce the amount available for other projects later on.

An example of a prioritization scheme from Vancouver, Washington, is summarized in Table 7-10. Notice that this prioritization scheme is based on assigning points to individual projects, summing the total points by "Needs" categories, and then multiplying by defined weights. Projects with the highest scores have greater priority over those with smaller scores.

The peer review of cross-modal project prioritization mentioned earlier provided some useful observations of the feasibility and ease of use of many of the more common prioritization criteria.

- *Congestion*. Measuring congestion provides transportation agencies with a good sense of system operating effectiveness and a general assessment of the health of a transportation system. Several of the peers indicated that congestion relief was one of the most easily quantifiable prioritization criteria.
- *Economic Development/Competitiveness*. Economic development and economic competitiveness are key considerations for any transportation project; however, defining, estimating, and quantifying the economic impacts of any given project can be a challenging and multifaceted task. Observations included: (1) estimates of economic impacts might account for a wide range of factors, including: access to jobs, job creation, job retention, port connectivity, freight mobility, attractiveness to new/existing businesses, access to shopping, and even impacts to regional food systems, (2) job creation estimates often favor the selection of highway construction projects, which tend to require higher labor costs over projects from other modes, and (3) access to key job centers may be a more useful criterion for cross-modal project prioritization.

Table 7-10. Example Selection Criteria, Transportation Improvement Program, Vancouver, Washington

Summary of Needs Criteria

Evaluation Criteria	Maximum Weight
Mobility	20
Multimodal/Operations	15
Safety	20
Economic Development	20
Financial/Implementation	15
Sustainability/Air Quality	10
Total Weight	100

Example Assignment of Points

<u>Mobility, 20 Maximum Points</u>

Existing Peak Hour Condition, 0–8 points

• V/C Ratio 0.9 or greater/Less than 60% of Posted Speed	8 points
• V/C Ratio 0.8 to 0.89/60–64% of Posted Speed	6
• V/C Ratio 0.7 to 0.79/65–69% of Posted Speed	4
• V/C Ratio 0.5 to 0.69/70–74% of Posted Speed	2
• Transit (Unless corridor can be identified)	5

Network Development, 0-4 points

• Extends Improvements	1–2 points
• Completes Gap	2–3
• Completes Corridor	3–4
• New Network Connection	0–4
• Improves Parallel Corridor	0–2

<u>Multimodal/Operations, 15 Maximum Points</u>

Multimodal, 0–10 points

• Transit Expansion	0–8 points
• Peak Hour Transit Buses (1 point per 2 Buses)	0–5
• Transit Replacement	0–3
• Exclusive Transit Lanes (Transit Only, BAT Lanes, etc.)	2–8
• Transit Amenities (Shelter, Bus-Pullout)	0–2
• Park and Ride Construction	5–8
• Carpool/Vanpool	1–3
• Improve Non-Motorized Access to Park and Ride/Transit	1–2
• Extends or Completes Gap in Bicycle Route	1–3
• Construct 10-foot separated path or two 5-foot striped bicycle lanes	2
• Sidewalks (Both Sides)	1–2
• Sidewalks wider than 5′ and/or Planter Strip (3′ minimum)	1–3
• Improves Transit Speed/Reliability	1–3
• Transportation Demand Management	1–3
• Contact C-TRAN’s Capital Project Manager (10+ days)	1
• Adopted Complete Street Policy	1

<u>Safety, 20 Maximum Points</u>

Existing Conditions, 0-6 points

• Pavement Widths (Deviation from standards)	0–2 points
• Shoulder Widths (1 pt. per 2 feet less than 6′)	0–3
• No Center Turn lane/Pocket (Project must correct)	1

Table 7-10. (*Continued*)	
Provides Access Management, 0–6 points	
• Add Non-Traversable Median greater than 50% of Project Length	3
• Add C-Curb at Intersections or less than 50% of Project Length	2
• Close Minor Intersections	1
• Reduce Access Points	2
• Eliminate Existing At-Grade Crossing	5
Economic Development, 20 Maximum Points	
Employment Growth 0-12 points	
• Retail Employment Growth (Regional Model-Select Link)	0–5 points
• Other Employment Growth (Regional Model-Select Link)	0–7
Financial/Implementation, 15 Maximum Points	
Previously Completed Work (Prior to application deadline), 0–6 points	
• Environmental Permits Submitted/Approved	1–2 points
• Plans, Specs, and Estimate Completed	2
• Right of Way Acquisition Complete	2
• No Sensitive Areas or Issues Pending	2
Sustainability/Air Quality, 10 Maximum Points	
Sustainability Measures, 0–10 points	
• Enhanced Treatment Stormwater Control	2 points
• Hardscaping or Native Planting (no permanent irrigation)	1
• Correction of Fish Barrier	0–3
• Enhances Stream Bank Conditions	1
• Corrects Existing Sensitive Area Impacts	2
• Appropriate Reduction in Existing Pavement Width	0–3
• Replace or Install Low-Energy Street Lighting	3
• Reuse/Recycling of Materials	2
• In-Place Pavement Reconstruction or Structural Retrofit	2

Source: Southwest Washington Regional Transportation Commission (RTC). 2015. *Selection Criteria Transportation Improvement Program*. Vancouver, WA: RTC. Accessed August 7, 2015, from http://www.rtc.wa.gov/programs/tip/docs/tipcrit15.pdf

- *Public Health*. Transportation agencies are increasingly considering the impact of transportation projects on public health in their planning and project development processes. Some agencies are developing metrics for the impacts of transportation projects on physical activity, particularly with regard to bicycle and pedestrian facilities.
- *Revenue Generation*. Apart from economic impacts, some transportation agencies score projects based on a revenue-generation criterion. This criterion refers to both project funding from partner agencies and the potential for continual revenue generation through tolling or other means.
- *Safety*. Meeting participants observed that comparing the safety impacts of projects across modes is a major challenge. In developing a truly cross-modal project prioritization process, the peers noted that agencies must develop a strategy for valuing lives equally across all modes of travel. [Middleton, 2014]

The following case studies illustrate many of the characteristics of evaluation and prioritization that have been discussed in this chapter.

III. CASE STUDIES

A. MPO Regional Transportation Plan (RTP)

The Metropolitan Transportation Commission (MTC) is the federally designated MPO for the nine-county San Francisco Bay Area. Its jurisdiction encompasses approximately 7 million people, and it is one of the larger MPOs in the United States. MTC is responsible under both federal and state law for programming billions of dollars of transportation funds (capital and operating) each year.

Like all MPOs, MTC is responsible for maintaining the Regional Transportation Plan (RTP). The 2013 transportation plan was one of the first in the United States to use a performance measure structure to assess the effectiveness of proposed strategies and projects. In addition, the transportation plan was integrated with a proposed land-use/development plan that promoted strong interaction between transportation investment and community development. As noted in the plan:

> *"The Plan Bay Area will address new requirements flowing from California's 2008 Senate Bill 375, which calls on each of the state's 18 metropolitan areas to reduce greenhouse gas (GHG) emissions from cars and light trucks.... The mechanism for achieving these reductions will be a Sustainable Communities Strategy that promotes compact, mixed-use commercial and residential development that is walkable and bikeable and close to mass transit, jobs, schools, shopping, parks, recreation and other amenities. If successful, Plan Bay Area will give people more transportation choices, create more livable communities and reduce the pollution that causes climate change." [MTC, 2013]*

Table 7-11 shows the relative impacts of the proposed plan on the performance measures identified as part of the transportation planning process. Note in the figure the use of an arrow to indicate the extent to which a particular performance target is met. Table 7-12 shows the equity assessment for the transportation plan. MTC also performed a project performance assessment to identify the highest-performing investments. Each major project was evaluated based on two criteria: benefit/cost ratio and a "target" score (which measures the contribution the project makes toward achieving Plan Bay Area's 10 adopted performance targets). Figure 7-6 shows the results of the project level assessment. By using such a formulation, MTC was able to show decision makers what types of projects were most cost-effective.

B. Corridor Plan

The Texas DOT conducted a corridor study of a major interstate highway in the Dallas-Ft. Worth metropolitan area. Proposed improvements at different locations along the corridor included highway expansion with frontage roads; managed lanes that utilize strategies for managing hours of operation, auto occupancy, and value/toll pricing; travel demand management and transportation systems management (TDM/TSM) actions; and bicycle and pedestrian measures designed to decrease and manage demand on the transportation system. These elements include employer trip generation programs, telecommuting options, traveler information, special event options, and signal and intersection improvements.

The following goals and objectives were identified to guide the study. [Texas DOT, 2015]

Goal 1: Transportation Mobility and Efficiency: Provide transportation facilities and services in the corridor that improve mobility, circulation, connectivity, and efficiency, reduce congestion, and effectively carry increased local, regional and interstate traffic.

- Objective 1.1: Reduce traffic congestion and travel time on the facility for the safe, efficient, and effective movement of people and goods.
- Objective 1.2: Plan transportation improvements in the corridor that provide sufficient accessibility to facilities, including the appropriate design of highway main lanes, high-occupancy vehicle lanes, interchanges, frontage roads, and bus transit facilities, and park-and-ride facilities, as needed.
- Objective 1.3: Verify that proposed corridor improvements are consistent with existing transportation plans and coordinated with local and regional planning organizations.

Table 7-11. Performance Assessment of Regional Transportation Plan, MTC, San Francisco Bay Area

Plan Meets or Exceeds Target			
Climate Protection	**Target #1:** Reduce per-capita CO_2 emissions from cars and light-duty trucks by 15 percent.	Plan meets and exceeds target; reduces per-capita emissions of CO_2 by 18 percent (by 2040).	
Adequate Housing	**Target #2:** House 100 percent of the region's projected growth by income level (very-low, low, moderate, above-moderate) without displacing current low-income residents.	Plan meets target; houses 100 percent of population growth.	
Healthy and Safe Communities Reduce Particulate Matter	**Target #3a:** Reduce premature deaths from exposure to fine particulates ($PM_{2.5}$) by 10 percent.	Plan meets and exceeds target; reduces premature deaths from exposure to fine particulates by 71 percent.	
Open Space and Agricultural Land	**Target #6:** Direct all non-agricultural development within the year 2010 urban footprint (existing urban development and urban growth boundaries).	Plan meets target; directs all non-agricultural development within the existing urban footprint.	
Economic Vitality	**Target #8:** Increase gross regional product (GRP) by 110 percent—an average annual growth rate of approximately 2 percent (in current dollars).	Plan meets and exceeds the economic growth target; 119 percent increase in GRP is forecasted over the life of the plan.	
Plan Makes Progress Toward Target			
Healthy and Safe Communities Reduce Particulate Matter	**Target #3b:** Reduce coarse particulate emissions (PM_{10}) by 30 percent.	Plan reduces coarse particulate emissions by 17 percent, but falls short of target.	
Active Transport	**Target #5:** Increase the average daily time walking or biking per person for transportation by 70 percent (for an average of 15 minutes per person per day).	Plan boosts per-person active transportation by 17 percent, but falls short of target.	
Transportation System Effectiveness			
Increase Non-Auto Mode Share	**Target #9a:** Increase non-auto mode share by 10 percentage points (to 26 percent of trips).	Plan boosts non-auto mode share to 20 percent of trips, but falls short of target.	
Reduce VMT per Capita	**Target #9b:** Decrease automobile vehicle miles traveled (VMT) per capita by 10 percent.	Plan reduces VMT per capita by 9 percent, but falls short of target.	
Local Road Maintenance	**Target #10a:** Increase local road pavement condition index (PCI) to 75 or better.	Plan improves pavement condition of local roads to a PCI of 68, but falls short of target.	
Plan Moves in Opposite Direction From Target			
Reduce Injuries and Fatalities from Collisions	**Target #4:** Reduce by 50 percent the number of injuries and fatalities from all collisions (including bike and pedestrian).	Plan moves in opposite direction from target; injury and fatality collisions are projected to increase during plan period by 18 percent.	
Equitable Access	**Target #7:** Decrease by 10 percentage points (to 56 percent from 66 percent) the share of low-income and lower-middle income residents' household income consumed by transportation and housing.	Plan moves in wrong direction; the share of household income needed to cover transportation and housing costs is projected to rise to 69 percent for low-income and lower-middle income residents during the Plan Bay Area period.	

(*continued*)

Table 7-11. (*Continued*)			
Transportation System Effectiveness			
Highway Maintenance	**Target #10b:** Decrease distressed lane-miles of state highways to less than 10 percent of total lane-miles.	Plan moves in opposite direction from target; the percentage of distressed state highway lane-miles in the region will rise to 44 percent of the regional highway system by year 2040.	
Transit Maintenance	**Target #10c:** Reduce the share of transit assets past their useful life to 0 percent.	Plan moves in opposite direction from target; the share of transit assets past their useful life is projected to increase to 24 percent of all assets during the Plan Bay Area period.	

Source: MTC, 2013, Reproduced with permission of the Metropolitan Transportation Commission.

Table 7-12. Results of Plan Bay Area Equity Analysis, 2010–2040, San Francisco Bay Area

Performance Measure	Target Population	2010	2040 (Baseline Forecast)	2040 (Plan Bay Area)
Housing and Transportation Affordability	Low-Income Households	72%	80%	74%
Percentage of income spent on housing and transportation by low-income households	All Other Households	41%	44%	43%
Potential for Displacement	Communities of Concern	n/a	21%	36%
Percentage of rent-burdened households in high-growth areas	Remainder of Region	n/a	5%	8%
Healthy Communities	Communities of Concern	9,737	11,447	11,693
Average daily vehicle miles traveled per populated square mile within 1,000 feet of heavily used roadways	Remainder of Region	9,861	11,717	11,895
Access to Jobs	Communities of Concern	25	26	26
Average travel time in minutes for commute trips	Remainder of Region	27	29	27
Equitable Mobility	Communities of Concern	12	13	13
Average travel time in minutes for nonwork-based trips	Remainder of Region	13	13	13

Source: MTC, 2013, Reproduced with permission of the Metropolitan Transportation Commission.

- Objective 1.4: Use cost-effective, innovative strategies that may include (but are not limited to) travel demand management (TDM), transportation systems management (TSM), and intelligent transportation systems (ITS).
- Objective 1.5: Schedule planned corridor improvements to maintain traffic flow during construction.

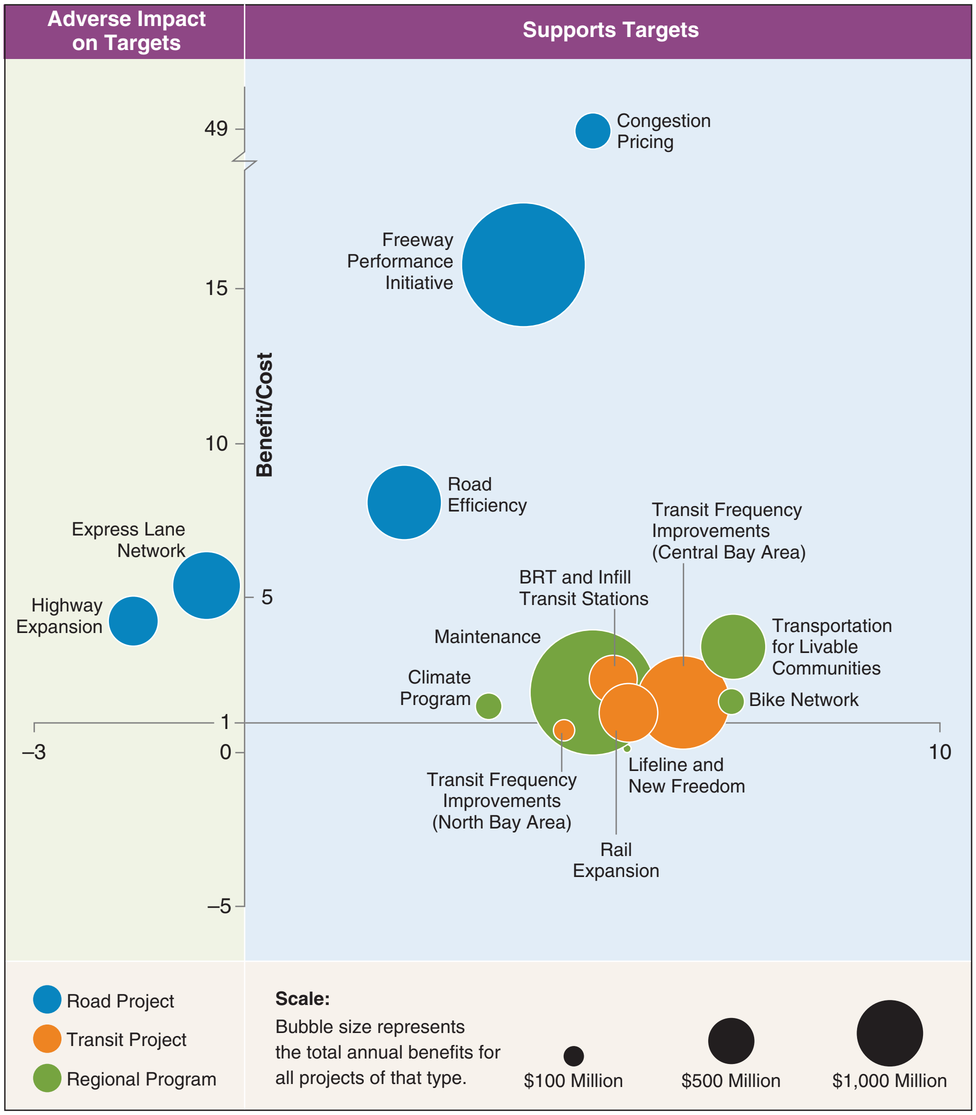
Goal 2: Safety: Enhance safety on transportation facilities for all travel modes in the corridor.

- Objective 2.1: Reduce the rate of accidents on transportation facilities in the corridor.

Goal 3: Multiple Travel Modes: Provide a balanced corridor transportation system with multiple travel modes that provides adequate capacity for and convenient access to high-occupancy vehicle (HOV) facilities, bus and rail transit, and bicycle/pedestrian travel modes within the study area.

- Objective 3.1: Provide transportation improvements in the corridor that combine multiple motorized travel modes, including bus transit services (e.g., express lanes), high-occupancy vehicle (HOV) facilities, and rail transit facilities, as needed.

Figure 7-6. Project-Level Assessment for Project Types by Benefit/Cost and Project Scores, Metropolitan Transportation Commission



Source: MTC, 2013, Reproduced with permission of the Metropolitan Transportation Commission.

- Objective 3.2: Provide transportation improvements that promote bus and rail transit services in the corridor, facilitating connections to neighborhoods and downtown areas of Fort Worth and Arlington, and other local and regional activity centers.
- Objective 3.3: Improve and extend bicycle and pedestrian facilities in the corridor in coordination with improvements to motorized transportation.

Goal 4: Environmental Quality: Provide a corridor transportation system that protects and enhances air quality; has minimal negative impact on the natural and social environment; protects ecological, cultural, and historic resources; and adheres to environmental justice.

- Objective 4.1: Provide transportation improvements in the corridor that improve regional air quality, minimize noise impacts, and conserve energy.
- Objective 4.2: Provide transportation improvements in the corridor compatible with conservation of natural resources, preservation of open space, parklands, and ecologically significant areas, and mitigate where necessary.

- Objective 4.3: Provide transportation improvements in the corridor compatible with the preservation and protection of historic, archeological, and cultural resources.
- Objective 4.4: Minimize neighborhood and community disruption and dislocation of residences and businesses resulting from corridor transportation improvements, as well as disproportionate adverse impacts on minority and low-income populations.

Goal 5: Quality of Life: Provide transportation improvements in the corridor that will enhance and not detract from neighborhood, community, and regional quality of life.

- Objective 5.1: Improve access to existing and emerging residential and employment centers in the corridor to encourage economic development and employment opportunities.
- Objective 5.2: Provide transportation improvements that encourage mixed land use development, transit- and pedestrian-friendly urban design, and compatibility with existing adjacent land uses and community land use plans.
- Objective 5.3: Provide equity in access to all travel modes to the traditionally underserved.
- Objective 5.4: Reduce adverse impacts of corridor transportation improvements on aesthetics and visual quality.

Goal 6: Financial Feasibility: Provide transportation facilities and services in the corridor that are fiscally responsible and economically feasible.

- Objective 6.1: Provide cost-effective and financially feasible transportation facilities in the corridor that are affordable to users, transportation providers, the region's communities, and participating agencies, and where the costs and benefits of the system are fairly distributed.

In order to narrow the number of alternatives considered by the study, a set of criteria was defined that met four requirements:

- *Effectiveness and Comprehensiveness in Measuring Goal Attainment*—The screening and evaluation measures were selected to reflect and measure the extent to which the alternative strategies contribute to the achievement of accepted transportation-related goals and objectives. Similarly, they were proposed to conform to federal guidelines governing the evaluation of major transportation investments.
- *Ability to Reflect the Specific Nature of the Alternatives*—The recommended screening and evaluation measures are relevant to the need to evaluate alternative transportation strategies in isolation, as well as in combination. These measures are capable of reflecting interactions between transportation and other factors, such as land use and the environment, and among travel modes.
- *Realistic in Terms of Technical and Resource Requirements*—The computation of measures should allow for efficient use of available data and provide comparable levels of detail, both among different screening and evaluation categories and across alternative strategies.
- *Relevance for Policy Evaluation*—The total number of screening and evaluation measures is reasonable and allows for thorough coverage of key goals and issues. Where possible, quantitative as opposed to qualitative methods are employed to depict potential effects in an objective manner.

The criteria have been grouped into five categories to facilitate analysis. These include:

- **Mobility Effects:** travel demand, roadway capacity, level of service, travel time, circulation, access, truck movement, safety, and access to multiple travel modes.
- **Social and Economic Effects:** socioeconomic and cultural environment (historic, cultural, and archaeological resources; residential and business displacement/dislocation; socioeconomics and equity; neighborhood integrity and cohesion).
- **Environmental Effects:** natural environment (air quality, noise, energy consumption, water quality and quantity, vegetation, wildlife, soils, open space, parklands, ecologically significant areas, drainage/flooding,

aesthetics, and visual quality); land use (residential patterns, compatible uses, development suitability according to community values).

- **Cost-effectiveness and Affordability:** capital costs, operations and maintenance costs, achievement of benefits commensurate with resource commitment, sources and sufficiency of revenues.
- **Other Factors:** compatibility with local and regional plans and policies, constructability, and construction effects.

Finally, Table 7-13 shows the evaluation criteria used to assess the alternatives that resulted in a preferred alternative for the corridor.

C. Small Bus Life-Cycle Cost Analysis

Life-cycle analysis of a small bus is an excellent example of economic evaluation in action. [KFH Group et al., 2000] Life-cycle costing (LCC) is a technique for estimating the total cost of owning and operating an asset over the economic life of that asset. The predicted LCC provides a basis for planning decisions, for comparing different equipment or different design features, and for the awarding of bids for the provision of equipment and/or services. The U.S. Office of Management and Budget (OMB) defines LCC as:

> *"The sum total of the direct, indirect, recurring, non-recurring and other related costs incurred, or estimated to be incurred, in the design, development, production, operation, maintenance and support of a major system over its anticipated useful life."*

The lowest bid procurement process has been commonly used in public sector acquisitions of capital goods and is sometimes required by statute. This procedure has been used for many years for purchasing conventional urban transit buses (typically 35–40 ft long and seating 40–55 passengers). These buses are produced by a limited number of manufacturers and are designed for an urban environment. Changes in vehicle design have occurred at a gradual pace, and most operators are experienced in maintaining and operating such equipment. Most transit properties are prepared to write specifications and to evaluate proposals.

A different situation exists for small transit buses. These buses vary from vehicles resembling vans to coaches less than 35 feet long. Small buses are classified as light-, medium-, or heavy-duty, depending upon their size, cost, and anticipated service life, and the type of service for which they are appropriate. Although many of these vehicles are owned by urban transit properties, they are also used in private businesses and by cities, suburban and rural communities, and social service agencies.

Service requirements range from fixed-route, fixed-schedule center-city operations to demand-responsive operations involving long distances in rural areas. The vehicle market is served by many manufacturers offering vehicle components, stock vehicles, and a wide spectrum of modifications. In many cases, the bus is not specifically designed for the type of service it will enter. The result is that, in purchasing small buses, the operator is offered a multitude of possible choices. These vehicles vary greatly in initial cost.

LCC offers certain advantages over low-bid procedures. LCC permits the operator to rely on a broad performance specification, and to make a selection based on the predicted total cost of owning and operating the vehicle or equipment. Unlike low-bid procurement, LCC does not limit the bidder to the specific vehicle design features. LCC ensures, ideally, that all aspects of maintenance and operation are considered in making the final selection.

One of the dangers of LCC is that it entails estimates of future repair frequency, future usage rates, useful life, and rates for future inflation. Some of these factors, such as usage rates and inflation rates, are applied similarly to all vehicles being compared. But others, such as useful life, repair frequency, or fuel consumption rates, are estimated for each vehicle using similar operating experience data as a basis for the estimate, unless actual on-property test rates are available. The accuracy of the estimates depends on how nearly the assumed future conditions (for example, price inflation, fuel costs, vehicle usage rates) approach the conditions that will actually prevail. Another factor is how representative the operating experience is of the future performance of new vehicles. The estimates of useful life, condition and mileage at retirement, price of fuel, and similar factors are critical.

Table 7-13. Criteria for Detailed Evaluation of Corridor Alternatives
Criteria
A. Mobility Effects
1. Travel demand and facility capacity:
Average peak period speed Person trips per peak hour Person trips per day Percent of demand being accommodated Level of service Person hours traveled Person miles traveled per day Congestion delay
2. Incorporation of multiple travel modes:
Level of multimodal elements Bicycle accommodation Pedestrian accommodation
3. Access, circulation and connectivity:
Improvements to facilities providing access to intercity and interstate corridors Total number of interchanges & intersections improved Frontage roads/length of improvement
B. Social and Economic Effects
Effects on known historic, archaeological, and cultural resources Total number of residential and commercial displacements Effects on major utilities Effects on aesthetics and visual quality Effects on neighborhood and business access, circulation, and emergency services
C. Environmental Effects
1. Effects on natural environment:
Effects on air quality Effects on noise Energy consumption Disturbances to floodplains, hydrology, water quality, and water resources Disturbances to wetlands/jurisdictional waters Effects on/from potential hazardous materials sites Effects on threatened & endangered species/wildlife habitat Effects on parklands
2. Effects on land use:
Effects on land use patterns/land use compatibility Effects on potential land development
D. Cost-Effectiveness and Affordability
1. Capital costs (in current year dollars):
Cost of residential and commercial displacements Cost of right-of-way requirements Cost of construction Total capital cost
2. Annual costs (in current year dollars):
Annual operations and maintenance costs Total annualized cost (capital + O&M) Annual user delay savings

Table 7-13. (*Continued*)
3. Cost-effectiveness:
Costs per passenger trip per hour
E. Other Factors
1. Consistent with plans:
Consistent with regional and local transportation plans Consistent with regional and local land use plans
2. Construction:
Temporary construction effects Constructability

Source: Texas DOT, 2015

Table 7-14. Comparison of LCC for Three Small Transit Vehicles

Cost Category	Units	Vehicle 1	Vehicle 2	Vehicle 3
Maintenance				
—Labor	$/mile	0.0831	0.0336	0.1638
—Parts	$/mile	0.0459	0.0753	0.0963
Commodities				
—Fuel	$/mile	0.3000	0.3429	0.2400
—Oil	$/mile	0.0018	0.0015	0.0024
Total Maintenance Cost	$/mile $ present value	0.4308 258,480/year	0.4533 271,980/year	0.5025 301,500/year
Present Value of Total Maintenance Cost for 6 Years @ 7%	Total fleet	$1,318,299	$1,387,152	$1,537,710
Salvage Value (after 6 years, in discounted dollars)	Per bus Total fleet	$36,500 $438,000	$23,000 $276,000	$43,000 $516,000
Net cost after salvage	Total fleet	$880,299	$1,111,152	$1,021,710

The basic LCC analysis consists of four major steps: (1) compilation of vehicle operating cost data and projection of future costs, (2) estimation of salvage (resale) value, (3) adjustment for time-value of money (discount rate), and (4) determination of total life-cycle cost. As an example, consider three different vehicles that will be operated an average of 50,000 miles per year during a 6-year period. Twelve vehicles will be required, with 10 vehicles in service and two spare. The fleet will operate 600,000 miles per year, or 3.6 million miles during the fleet's 6-year life.

The data shown in Table 7-14 are derived from tests and operating experience and related to the number of miles operated. In this case, Vehicle 1 proves to be the least costly to operate. However, Vehicle 3 is ranked second, despite its operating cost being higher than Vehicle 2's (primarily because its salvage value is higher). If the unit price of Vehicle 1 were $12,000 more than Vehicle 3's, then Vehicle 3 could actually be more economical. For 12 buses, the $12,000 price difference would be $144,000, which is more than the LCC difference between Vehicles 3 and 1 (See KFH Group, Inc. et al., TCRP Report 61, for further detail on this analysis approach).

D. One-Way Street Conversion in a Central Business District

The purpose of this evaluation was to consider the potential for converting certain existing one-way streets to two-way operation in the central business district of Oakland, California, a city of approximately 400,000. Although one-way streets have many advantages, the identified benefits of conversion to two-way operation were:

- A decrease in travel speeds to benefit pedestrians and reduce noise.
- Reduction in vehicle miles of travel (VMT) because fewer "around the block" movements would be required.

- Decrease in turning movements at intersections.
- Consolidation of transit stops to a single street, which had been split in two due to the use of couplets in the central business district (CBD), resulting in less confusion to transit passengers.
- Less confusion to visitors unfamiliar with the street system, especially where there is a lack of uniformity in the street grid.
- Promoting CBD retailing (businesses generally dislike one-way streets, on the assumption that it reduces visibility and makes it less convenient to shop).
- Ability to include raised-median pedestrian refuge islands on some two-way streets.

A ring of three freeways was completed around Oakland's CBD between the mid-1950s and 1982. During this period, virtually every street in the CBD was made one-way (the primary exception being the major shopping and transit artery, Broadway, which remained two-way).

While the noted benefits seemed reasonably certain, the costs seemed less certain or quantifiable; therefore, an aggregate ranking was selected for the evaluation. Scoring criteria were developed, shown in the following paragraphs. This resulted in candidate locations for further investigation. These were field-checked then readjusted as needed, and the recommendations made.

Because the impact of two-way operation could be both good and bad, the scoring system used a range of –5 to 5. A score of 0 was used to indicate no benefit or impact. For example, the effect on transit operations for a street with no transit would be given a 0. The extreme scores (−5 or 5) were assigned if the conversion would have a highly adverse impact (−5) or a highly favorable impact (5). The scores were then summed for a total value assigned to each street.

The eight criteria used for evaluation were:

- *Peak Traffic Volume*. Streets with high existing traffic volumes were given scores close to −5, whereas very low volume streets were given scores closer to 5. This evaluation was somewhat qualitative, because traffic volumes were not available on every street segment.
- *Primary Connection to a Freeway*. Certain streets operate as major freeway connectors and, thus, would require a major reconfiguration or reconstruction of freeway ramps if converted to two-way, so they were given low scores. The latest freeway incorporates several ramps, which would be particularly difficult to make compatible with two-way operation on intersecting streets. The actual costs were not developed for this first-cut evaluation. Only some streets have bridges or freeway underpasses; changing them could involve costly new construction.
- *Land-Use Compatibility*. Streets with residential or retail frontage (especially small shops) were given higher scores than streets with offices, off-street parking, or other uses.
- *Availability of Parallel Routes*. A high score (4 or 5) was given to a street that had a nearby street with sufficient capacity to accommodate traffic diverted from the converted street.
- *Transit Benefits*. Transit benefits were assigned if there was bus service on the street. In addition, points were given if ridership was likely to increase if two-way service were instituted.
- *Suitable Street Width*. If reconfigured to two-way operation, can a suitable number of lanes (including turning lanes) be provided with parking? Generally, streets with a greater curb-to-curb width were given higher scores, whereas narrower streets were given lower scores.
- *Network Connectivity*. Will two-way traffic confer network connectivity benefits by allowing for improved circulation and fewer turning movements? Is the street a discontinuous, isolated segment, or part of a larger grid? Short, disconnected segments can probably be changed to two-way without adverse impacts, and so were given higher scores.

- *Signal Coordination*. Signals are far easier to coordinate (synchronize) on one-way than two-way streets. Unless there is optimal signal spacing, effective vehicle progression cannot be provided in *both* directions. This usually requires favoring one direction of traffic over another (this in fact is done on Broadway today). Depending on the controller, the favored movement can be adjusted by time of day to serve the greatest traffic flow (for example, inbound in the morning peak, outbound in the evening, and balanced during the rest of the day).

Low scores were given if signals were well-coordinated on the street; high scores were given if there was no coordination. Higher scores were also given if there was (approximate) uniformity of block length, which can be used to provide two-way traffic signal coordination.

The final ranking of 29 streets led to scores ranging from −18 to 26. A phased implementation program was recommended, with streets scoring more than 13 included in the first phase.

E. Rail Transit Projects

Facing a need to prioritize funding for as many as 69 competing rail projects, the California State Senate passed a concurrent resolution requesting that the California Transportation Commission (CTC) submit a listing of high-priority rail projects that could be implemented within 5 years. The criteria for determining which projects qualified for the high-priority designation were:

- *Project Readiness*—A measure of the status of the project planning that helps determine if a project can be implemented in 5 years.
- *Local Support*—The degree of local support for a project, as reflected in local funding commitments, actual levels of transit ridership in the area, and formal actions by local authorities.
- *Local Priority*—The priority ranking a project has been given by local agencies among its competitors within a particularly urban region or system.
- *Project Worth*—Measures of the worthiness of the project in terms of relationships between costs and potential ridership and/or other anticipated project benefits. Environmental consequences: each project's major impacts representing consideration in priority determination.
- *Need for State Funding*—The amount of state funding required, the project's ability to capture federal funds for the state, potential private-sector involvement, and other indications of the need for and desirability of state funding assistance.
- *Other Considerations*—Any unique circumstances or conditions that affected the appropriate timing or justification of a particular project.

IV. SUMMARY

The development of transportation alternatives and the fair presentation of competing choices are among the key activities transportation planners engage in. Because transportation problems and deficiencies will almost always exceed the resources available to solve them, it is important that transportation planners be able to recommend the best choices available, or, in the case of decisions that involve changes to current public policy, make the fairest presentation to those entrusted with decision-making authority. This chapter discussed how alternative solutions to transportation problems can be evaluated and compared so that the best course of action can be taken. Evaluating and prioritizing transportation projects are usually the last steps in the transportation planning process, but they are some of the most important. All of the other information developed—planning goals, objectives, measures, information alternatives—is brought together in this step to select the best actions for the agency.

Transportation alternatives are a natural outgrowth of the goals and objectives developed as part of the transportation planning process. Good goal definition can help generate a wider range of potential problem solutions than narrowly focused goals. If a goal automatically suggests a single appropriate solution, it is probably too narrowly conceived.

The next step is to enumerate and, to the extent possible, quantify all of the potential costs and benefits of a project or plan. This is a valuable exercise even when all of the costs and benefits may not be known or quantifiable. The analyst should be careful that benefits are not double-counted. It is during this phase that it begins to become clear where project risks—in terms of both costs and benefits—may lie.

After costs and benefits are quantified, the appropriate evaluation technique may be selected. This selection usually will be based on the size and complexity of the project, the stage of project planning, the degree to which project costs and benefits can be quantified, and the amount of time available to perform the evaluation. This chapter suggests a number of techniques ranging from the very simple to more complex net present-value computations.

Comparative estimates of system (alternative) costs and benefits should be developed in terms of constant dollars, usually dollars in the year in which the analysis is performed, excluding the effects of inflation. The costs should include capital outlay, operations, and maintenance cost elements. The cost analysis should consist of the following steps:

- Determine the present value of the cumulative costs of the base plan over the project period (could be the "do-nothing" or "null" alternative).
- Determine the present value of each alternative system, using the same basic assumptions as applied to the base alternative.
- Calculate the incremental cumulative cost of each alternative, compared to the base alternative, subtracting residual land values.

Cumulative costs are determined by annualizing total estimated capital costs and then summing for the number of years under consideration. These annual costs are then discounted at a selected discount rate to a present value. Unit-cost assumptions to be made in developing these cost estimates are usually documented in a report. Historical cost data can be adjusted to current values with a construction cost index (CCI).

Economic benefits are usually calculated for each alternative at weekday usage levels based on available projections of the out-year (horizon year) usage (demand), which may be in terms of vehicles or passenger trips per day. Annual demand levels and project benefits for each year between the base year and the horizon (out) year are typically approximated by straight-line interpolation. Most travel models will only provide forecasts for base year and one or two out-year conditions, although occasionally more data points are available. These estimates of future benefits are then discounted to determine their present worth, using the discount rate.

The discount rate in most evaluations will be specified by an external source, such as the analyst or an external funding agency. Discount rates can significantly affect the results of the analysis, so they should be chosen carefully to be consistent with the nature of other types of projects undertaken by the agency. A sensitivity analysis may be desirable to show the potential difference in outcomes if different discount rates are assumed. This can be easily done in a spreadsheet and in most commercially available benefit/cost programs. Risk factors should be considered explicitly, not by using varying discount rates for different alternatives.

Travel-time savings probably should be given the greatest amount of attention by the analyst because, for large projects, they will frequently be more than half of the total project's benefit. Some standards have been presented for determining the value of travel time for different classes of users. Once again, a sensitivity analysis using different values of time may be desirable. Consistency between project evaluations is also important, as differences in the value of travel time could lead to misleading conclusions. Cost-effectiveness analysis can also be used to rank projects according to the least cost per travel minute saved.

The analyst should be aware that transportation decisions can have important equity and distributional impacts with respect to both costs and benefits. There are traditionally several dimensions used to measure distributional impacts, including spatial, modal, income, and demographic groups. Census data and a travel-demand forecasting model can provide much of the information needed for this assessment.

Prioritization and evaluation share a number of key characteristics. They both seek to select the best projects from a field of contenders based on several factors. The major difference is that evaluation seeks to determine whether, and by how much, a plan or project is worthy of investment of public (or public/private) funds, given other, alternative ways of using the money. Once this is accomplished, prioritization seeks to determine the best order in which to sequence or program funds, which may include nontechnical considerations. Those factors might include project readiness, degree of consensus, equity considerations, availability of external funds, and other similar factors.

Risk and uncertainty are inherent in any public (or private) investment, especially as there has been a bias toward underestimating costs and overstating benefits. Recent megaprojects have had a history of going significantly over budget. In general, the larger the project and the more novel the technology and conditions, the greater the risk. Several techniques for attempting to control risk and uncertainty were noted in this chapter, including value engineering (VE), scenario planning with expected values, and peer review by outside experts (often part of the VE process). In the end, the analyst needs to be frank about appraising some of the project risks in the evaluation analysis.

Frequently made errors in project evaluation include the following:

- External funds (such as grants) are used to reduce costs.
- Some project costs are overlooked.
- Benefits are double-counted.
- Average (rather than marginal) costs or benefits are used.
- Differences between market and social costs are ignored.
- An inappropriate discount rate is used (usually, one that is too low).
- Network or other important effects are ignored.

In summary, a good evaluation should: (1) account for the cumulative cost of all alternatives over the total project period, recognizing that some alternatives may have a shorter useful life than others, (2) use demand projections for an appropriate horizon year (usually from 10 to 30 years from the year in which the analysis is done), (3) recognize the effects of differing service lives of alternative capital (or major maintenance) investments, (4) eliminate the effects of inflation because inflated benefits or costs do not represent increases in *real* economic values, (5) account for the time value of money, by employing a present-value economic analysis, using a discount factor that accounts for the potential rate of return of alternative investments, and (6) apply appropriate unit values for benefits.

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Asset Management[1]

I. INTRODUCTION

Transportation infrastructure in the United States is valued in the trillions of dollars. Much of this infrastructure, such as many portions of the interstate highway system, was constructed in the late 1950s and early 1960s and is in need of renewal. Similarly, transit infrastructure such as rail track and maintenance facilities are in need of repair or reconstruction (known in the transit industry as maintaining a state of good repair). Just as much as this infrastructure reaches the end of its useful life, additional network capacity is needed to handle growing travel demands and to provide improved levels of service, particularly in those areas experiencing high congestion levels. It is not surprising, therefore, that federal, state, and local governments face a challenging task in allocating finite resources to address various community needs for infrastructure capital expansion, renewal, and preservation. Asset management is one of the tools that can be used in support of such decisions.

There are several reasons why asset management as a topic is being presented in a handbook on transportation planning. The first reflects the types of projects and investments that many states/provinces, metropolitan areas, and cities/towns are facing. As indicated in the previous paragraph, much of the transportation investment focuses on renewal, rehabilitation, and reconstruction of the infrastructure. The priorities for this type of investment most often comes from asset management systems. Second, the tools and techniques for asset management inherently deal in uncertainty and risk, two concepts that are rapidly being integrated into the transportation planning process. Finally, the new focus on system performance and condition necessarily leads to a discussion of how asset management systems can provide input into the performance measurement program implemented by a state transportation agency or a metropolitan planning organization (MPO).

The benefits of an asset management system are many. For example, the Organization for Economic Cooperation and Development (OECD) notes benefits of better internal and external communications; improved asset inventory, condition, and level of use; enhanced network performance; increased use of asset management tools; better information for the budget process; and professional development of staff members. [OECD, 2001]

With respect to transit, the Federal Transit Administration (FTA) has defined the benefits of asset management as:

- Improved customer service—improves on-time performance and service operations, vehicle, and facility cleanliness; reduces missed trips, slow orders, and station shutdowns; and focuses investments around customer centered goals and metrics.
- Improved productivity and reduced costs—maintains assets more effectively, using condition-based approaches and using predictive and preventive maintenance strategies (where these can be employed) to reduce costs while improving service delivery.
- Optimized resource allocation—better aligns spending with an agency's goals and objectives to obtain the greatest return from limited funds and incorporates lifecycle cost, risk, and performance trade-offs into capital programming and operations & maintenance budgeting.
- Improved stakeholder communications—provides stakeholders with more accurate and timely customer-centered performance indicators, and provides tools to communicate forecasted performance metrics (including level of service) based on different levels of funding. [FTA, 2012]

[1] The original chapter in Volume 3 of this handbook was written by Professor Adjo Amekudzi-Kennedy, Georgia Institute of Technology. Changes made to this updated chapter are solely the responsibility of the editor.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

As identified by the American Association of State Highway and Transportation Officials (AASHTO), asset management can lead to continuous improvement in the following areas:

- Lower long-term costs for infrastructure preservation.
- Improved performance and service to customers.
- Improved cost-effectiveness and use of available resources.
- Focus on performance and outcomes.
- Improved credibility and accountability for decisions and expenditures.
- Improved stewardship capacity.
- Development of stronger stakeholder relationships, transparency, and accountability.
- Planning for growth. [AASHTO, 2002, 2011]

These characteristics of asset management are relevant to transportation planners by their focus on improving transportation system performance in the most cost-effective manner possible. In other words, transportation asset management (TAM) represents good planning and decision-making practice. The last characteristic mentioned, planning for growth, is an important consideration in the adoption of many TAM programs around the world—and this accountability often begins in the transportation planning process.

The next section defines transportation asset management, followed by a description of how to adopt an asset management approach in an organizational context. The next section provides a brief history of the evolution of transportation asset management in the United States. The following section describes the role of transportation asset management and transportation planning, including its relationship to goals and objectives, performance measures, data collection, analysis tools, and evaluation. The final section discusses the challenges in adopting an asset management approach.

II. WHAT IS TRANSPORTATION ASSET MANAGEMENT?

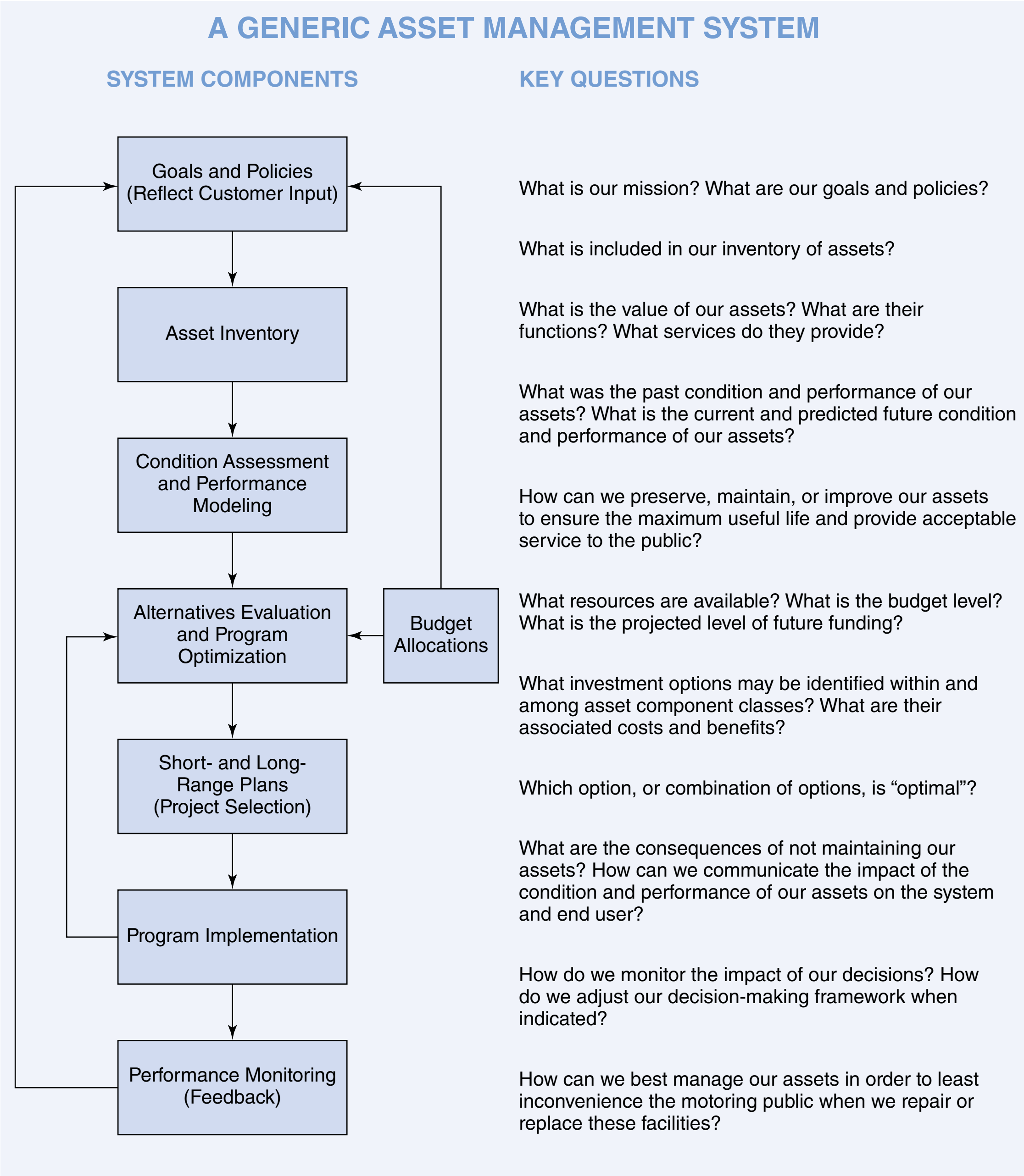
Transportation asset management is a "strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their lifecycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well-defined objectives." [AASHTO, 2014] A similar definition is found in the U.S. federal transportation legislation, Moving Ahead for Progress in the 21st Century (MAP-21), which defines asset management as a "strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost." [23 U.S.C. 101(a)(2), MAP-21 § 1103] With respect to transit assets, a guide from the Federal Transit Administration (FTA) defined asset management as "a strategic and systematic process through which an organization procures, operates, maintains, rehabilitates, and replaces transit assets to manage their performance, risks, and costs over their lifecycle to provide safe, cost effective, reliable service to current and future customers." [FTA, 2012]

Asset management is a value- and performance-oriented approach to system visioning, goal setting, alternatives development, identifying the preferred alternatives, programming and implementing projects, monitoring performance, and defining community and agency vision. It includes the planning, design, construction, operations, maintenance, and rehabilitation and renewal of facilities, in other words, the entire life cycle of a project. Although some of the original applications of asset management focused simply on the condition of the asset, more recent approaches have taken many different factors into consideration in a more comprehensive way, such as traveler data, customer opinions, and risk analysis. More and more, asset management is being embraced as a business process for delivering agency strategic goals [AASHTO, 2011a]—meaning it becomes a comprehensive approach to delivering system and organizational performance.

In essence, five core questions constitute the key aspects of an asset management program: (1) What is the current state of my assets? (2) What are the required levels of service and performance delivery? (3) Which assets are critical to sustained performance delivery? (4) What are the best investment strategies for operations, maintenance, replacements, and improvement? and (5) What is the best long-term funding strategy? [FHWA, 2009]

A generic TAM framework introduced by the Federal Highway Administration (FHWA) highlights the integral role of performance monitoring in asset management (see Figure 8-1). [FHWA, 2007a] Such monitoring provides a feedback loop between how the transportation system is actually performing and the early steps in transportation planning—visioning and setting goals and objectives. TAM expands on infrastructure monitoring to apply it to the decision-making process. The framework shown in Figure 8-1 depicts TAM as a systematic, fact-based, and reproducible decision-making approach that can be used to analyze trade-offs to determine the most desirable alternatives when allocating resources for system expansion, preservation, and renewal. Figure 8-2 shows a similar framework developed for transit asset management systems. In particular, this framework shows the relationship between asset management actions and the decisions that need to be made by transit agency decision makers.

Figure 8-1. A Generic Asset Management System



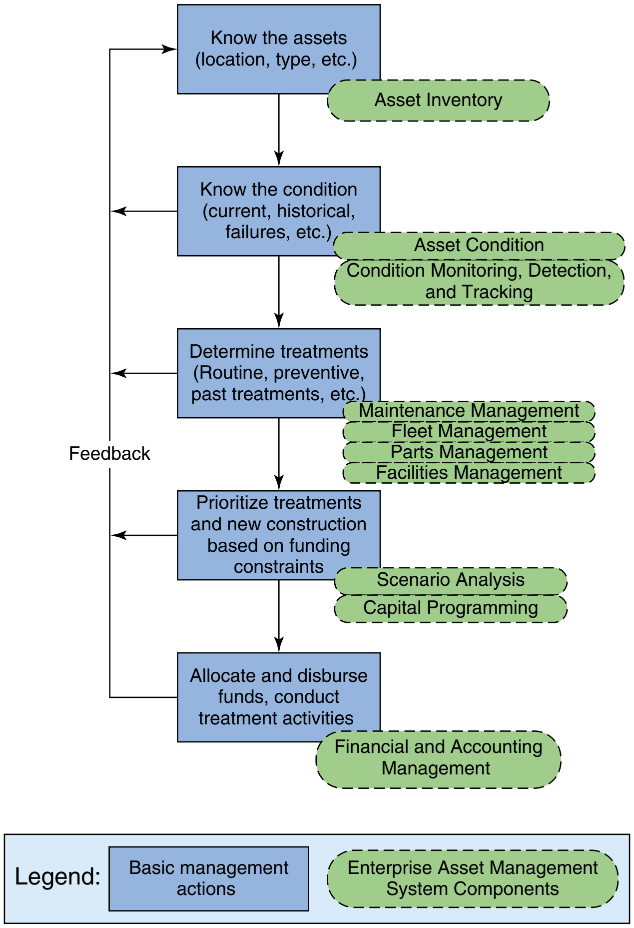
Source: FHWA, 2007a

A long-term commitment to asset management may involve incremental changes to an agency's policies, business processes, and information technology (IT) capabilities. Some agencies have taken a comprehensive look at their investment decision-making processes and developed an asset management plan to address gaps in their policies, planning procedures, and IT systems. Application of asset management in an agency setting can help to build a common vision for all management and staff both horizontally and vertically in the agency by helping all involved to speak the same language regarding near-term or longer-term expectations.

A self-assessment tool in the AASHTO *Transportation Asset Management Guide* offers a means for taking stock of the overall investment decision-making apparatus as it relates to asset management. [AASHTO, 2011a] Tailored to help agencies identify areas for improvement, the guide prompts agencies to answer the following questions:

- How can your agency improve the way it currently manages assets?
- Are current and planned initiatives sufficient, or do they require modification, addition, or redirection?
- What approaches may work well in your agency or have worked well in other agencies similar to yours?

Figure 8-2. Transit Asset Management Framework



Source: FTA, 2012

The self-assessment tool is organized around four key areas of asset management: (1) policy goals and objectives, (2) planning and programming, (3) program delivery, and (4) information analysis. Table 8-1 shows the policy goals and objectives module, and Table 8-2 shows the information systems and analysis module of the tool. The tool asks targeted questions to help agency officials determine their strengths and gaps in the four areas and assigns an overall score at the end of the survey. Because the tool is tailored for a wide range of employees, it can help agency officials to reach consensus on what areas need work, and thus position the overall agency strategically to develop an effective asset management plan that places priorities on addressing existing deficiencies and opportunities.

Many state DOTs have conducted self-assessments and developed blueprints to move toward an asset management-oriented approach to transportation planning.

III. RECENT U.S. HISTORY OF TRANSPORTATION ASSET MANAGEMENT

Asset management is not a new concept; it has been used in the private sector for many years. [AASHTO, 1997] For several decades, many transportation agencies in the public sector used some aspect of asset management to support transportation investment decision making. In a well-recognized effort during the late 1950s and early 1960s, the American Association of State Highway Officials (AASHO), as it was then called, collected data on surface roadway condition and ride quality. Empirical models were developed to link pavement condition with serviceability, thus enabling officials to estimate pavement ride quality from pavement distress data. The AASHO road tests are considered seminal work in the development of performance prediction models for transportation facilities and have served as an important foundation for pavement management systems. [Carey and Irick, 1960] Many advances were made since these original tests, particularly in the development of new performance prediction models that link the causes and effects of facility deterioration.

A recent Transportation Research Board (TRB) synthesis on asset management in state DOTs showed over 70 percent of the responding agencies (43 state DOTs) noted that using asset management principles made their decisions more

Table 8-1. Self-Assessment for Policy Guidance Role of Asset Management				
Do Policies Support Improved Asset Management Practice?				
	Fully Disagree	**Disagree**	**Agree**	**Fully Agree**
	1	**2**	**3**	**4**
Policy guidance enables good asset management practice				
A1. Policy guidance supports preservation of existing assets.				
A2. Policy guidance encourages decisions based on cost-effectiveness or benefit/cost analysis.				
A3. Policies support a long-term, life-cycle view.				
A4. Policy guidance considers customer perceptions and expectations.				
A5. Our customers contribute to the formulation of policy goals and objectives.				
Strong framework for performance-based resource allocation				
A6. Well-defined policy goals and objectives guide our resource allocation process.				
A7. Our policies enable us to pursue performance-based resource allocation.				
A8. Goals and objectives are linked to specific performance measures and project evaluation criteria.				
Proactive role in policy formulation				
A9. Polices are developed with an understanding of the budget required to achieve them.				
A10. We work with political leaders to understand funding options and their expected consequences on system performance.				

Source: Michigan Transportation Asset Management Council. 2006

data-driven, defensible, and performance-based. [Hawkins and Smadi, 2013] Sixty percent of the agencies claimed to be balancing preservation and capital improvement needs with their asset management program, and 50 percent of the agencies had developed a process to share asset management information with elected and appointed officials, which is helpful for communicating investment needs, trade-offs, and adding transparency to the decision-making process. More than 90 percent of the agencies used asset management information to select bridge and pavement projects; however, for other asset decisions (e.g., maintenance, operations, and safety) this number dropped to below 40 percent, indicating a need for looking at how ancillary assets could be incorporated into transportation asset management plans. A number of agencies are making significant efforts to management ancillary assets with a range of asset management policies, system/program integration approaches, data collection methods and costs, benefit qualification, and asset category prioritization approaches. [Akofio-Sowah et al., 2014]

Asset management techniques in transportation investment decisions began with bridges. In 1967, the Silver Bridge in West Virginia collapsed, killing 46 people. This disaster shocked the nation and raised public awareness of the importance of systematic monitoring of the condition of built facilities in general. As a result, a National Bridge Program was authorized by Congress in the Federal Aid Highway Act of 1970. This program initiated a nationwide system for monitoring and tracking the condition of bridges. As part of the program, periodic collection of data on both the inventory and the condition of bridges was required. The goal of the bridge monitoring system was to provide decision-support information for evaluating the relative needs for bridge maintenance, repair, and rehabilitation (MR&R), and for prioritizing projects. Bridge condition assessment in the United States has been formally required on a regular basis ever since. Attention on this requirement was renewed by the 2007 collapse of a highway bridge in Minneapolis, Minnesota, that killed 13 people.

By the 1980s, several state and local agencies had developed capabilities for periodic inventory and condition assessment as well as for performance prediction for pavements and bridges. By the 1990s, several agencies had also developed economic analysis tools for evaluating and prioritizing project alternatives. [McNeil et al., 2000] However, in the United States, one of the most important motivations for asset management among state transportation agencies has been federal transportation legislation, described in the next section.

Table 8-2. Self-Assessment for Information and Analysis Role of Asset Management				
Do Information Resources Support Improved Asset Management Practice?				
	Fully Disagree	**Disagree**	**Agree**	**Fully Agree**
	1	**2**	**3**	**4**
Effective and efficient data collection				
D1. We have a complete and up-to-date inventory of our major assets.				
D2. We collect timely, accurate, and useful infrastructure condition data (e.g., for pavements, bridges, rest areas, etc.).				
D3. We collect timely, accurate, and useful system *performance data* (e.g., for mobility, congestion, safety, etc.).				
D4. We regularly collect customer perceptions of asset condition and performance.				
D5. We continually seek to improve the efficiency of data collection.				
Data integration and access				
D6. Decision makers can quickly obtain all of the information they need.				
D7. Agency-wide geographic referencing standards have been developed.				
D8. Maps showing needs/deficiencies for different asset classes and planned and programmed projects are readily available.				
D9. We have standards that promote the consistent treatment of data and guide the development of future applications.				
Management system models based on actual data				
D10. Actual cost data are used periodically to update our management systems' *cost estimation models*.				
D11. Actual data regarding changes in asset condition over time are used periodically to update our systems' *deterioration models*.				
Use of decision-support tools . . . Decision-support tools are used to:				
D12 Calculate and report actual system performance.				
D13 Identify system deficiencies or needs.				
D14 Rank candidate projects for the capital program.				
D15 Forecast future system performance for a proposed program of projects.				
D16 Forecast future system performance for various investment levels.				
System monitoring and feedback				
D17. Actual system condition is compared to projected targets for our *preservation program*.				
D18. Actual system performance is compared to projected targets for our *capital improvement program*.				
D19. Actual system condition and performance are compared to projected targets for our *maintenance and operations programs*.				
D20. Performance measures relevant to customer/stakeholder satisfaction are periodically reported.				

Source: Michigan Transportation Asset Management Council, 2006

A. Early Asset Management-Related Legislation

In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) required state departments of transportation (DOTs) and MPOs to develop six infrastructure management/monitoring systems as part of the planning requirements of the act. These management systems focused on pavements, bridges, highway safety, traffic congestion, public transportation facilities, equipment, and intermodal transportation facilities and systems. These requirements were motivated by a desire to foster a more systematic and systemic consideration of the functional capability and conditions of transportation assets on the nation's transportation system. Whereas pavement and bridge management systems were fairly common to transportation engineering practice and highway safety management systems had been developed in many states, the congestion management systems, intermodal management systems, and public transportation facilities and equipment management systems were relatively new to most agencies.

In 1995, partly in response to state DOT pressure to remove unfunded mandates, Congress removed the requirement for these systems (except for congestion management systems in air quality nonattainment areas). The brief consideration of these management systems, however, left a legacy in many transportation agencies, and many continued developing and using them for infrastructure management.

Many state DOTs, MPOs, and local agencies incorporated some level of asset management into their transportation planning, programming, and project development processes because of state law. For example, the Virginia legislature passed the nation's first public/private partnership law in 1995, allowing Virginia DOT to contract out roadway maintenance to the private sector while retaining management functions for quality control/quality assurance. The Vermont (2001) and Michigan (2002) legislatures both passed asset management laws for transportation that required the consideration of asset management principles in investment decision making. In Michigan, for example, the state's Asset Management Law (Public Act 499 of 2002) established an 11-member Transportation Asset Management Council to provide input for the development of a statewide asset management strategy. Because of this law, there are several examples of Michigan counties at various stages in the adoption and use of asset management in their business processes. The council adopted the following program activities as a primary means of accomplishing its goal:

- Survey and report on the condition of roads and bridges by functional classification categories for the state and regional planning areas.
- Assess completed and planned investments in roads and bridges by the various transportation agencies of the state.
- Support the development of appropriate asset management tools and procedures.
- Provide education and training on the benefits of developing road improvement programs through the use of asset management principles and procedures. [Michigan Asset Management Council, 2011a]

In an initiative to promote asset management in local agencies, the council developed agency guidebooks (see [Michigan Transportation Asset Management Council, 2011a, b]). Experiences in Michigan demonstrate that funded mandates can be used as an effective means to implement asset management widely.

B. Governmental Accounting Standards Board (GASB) 34

The Governmental Accounting Standards Board (GASB) in 1999 issued recommendations for state and local government agencies to report financial information on their assets, including civil infrastructure facilities, based on accounting standards contained in GASB Statement 34. [GASB, 1999] GASB recommends agencies report on their civil infrastructure assets using the book value method (historical costs less depreciation over their life cycles); otherwise, they must demonstrate that their assets are being maintained above a certain minimum condition level using an asset management system (AMS).

GASB 34 resulted in a surge of interest in asset valuation both in practice and academia and led to a distinction between depreciation-based and condition-based methods for infrastructure reporting. Depreciation-based methods simply depreciate the value of an asset using a depreciation schedule (usually a straight-line depreciation). A condition-based method takes into account, based on asset management systems, the current condition of the asset given the demands that have been placed on it and determines the value associated with its replacement.

C. International Asset Management Scanning Tour

In April 2005, the U.S. DOT, AASHTO and NCHRP sponsored an international scanning study to investigate best practices in asset management in the world. The team, made up of local, state, federal transportation officials, and professors, visited national, provincial/state, and regional-level transportation agencies in Australia, Canada, England,

and New Zealand. The study identified the following important characteristics for agencies that were successful in adopting asset management:

- Top-level management commitment (at the very highest levels) was apparent.
- A dramatic change had occurred in viewing asset management as a key business area of the agency.
- A position or office had been created with responsibility for asset management.
- Asset management was fully integrated into several agency planning and policy documents.
- Life-cycle costing and risk assessment were used when establishing investment priorities.
- Facility valuation was used in infrastructure reporting.
- Asset management was used for developing a program of investment and capital renewal.
- The concept of a *gap analysis* was used to identify asset management needs.
- Asset management training for all levels of officials was important for fostering a change in the organizational culture. [FHWA, 2005]

The team also found asset management practices and processes were used successfully to obtain funding for transportation infrastructure, even when governmental budgets were being cut. Importantly, asset management practices were also found to be essential when entering into public-private partnerships for the provision of transportation infrastructure.

D. Domestic Asset Management Scanning Tour

One of the recommendations of the international scanning tour was to conduct a similar fact-finding exercise among U.S. transportation agencies. Such a tour occurred in 2006. The scan team met with a range of organizations representing state transportation agencies (Florida, Michigan, Minnesota, Ohio, Oregon, and Utah), a city transportation department (Portland, Oregon), metropolitan planning organizations (SEMCOG in Detroit, Michigan, and Grand Valley Metropolitan Council in Grand Rapids, Michigan), two county transportation departments (Hillsborough County, Florida, and Kent County, Michigan), a tollway authority (Florida Turnpike Enterprise), and a statewide asset management association in Michigan. The major observations from this scan included the following:

- The agencies visited had all adopted a *preservation-first* strategy for their investment priorities. However, in many cases, this strategy ran up against concerns for reducing congestion on existing roads as well as dealing with the need for new road capacity to handle population and employment growth.
- In each case, the success of the asset management process was directly linked to the actions of an asset management champion or champions within the organization. Until asset management became institutionalized within the agency's standard operating procedures, the role of the champion was especially critical.
- In several cases, the existence of an asset management process, and more importantly, of the information that justifies a transportation investment in a road system, was instrumental in securing additional dollars from the legislature. The use of an asset management approach was critical for providing officials with the needs and consequences of investing (or not investing) in highway infrastructure.
- The most successful asset management processes moved away from a *worst-first* investment strategy. Instead they adopted investment principles based on life-cycle costing and result in the most cost-effective preservation and maintenance strategies.
- The most successful asset management processes had performance measures that guided investment decisions throughout the organization. These performance measures became important indicators for system monitoring and were used in one case for annual personnel evaluations. A performance-based asset management approach became the normal way of doing business in many of the sites visited.

- Scenario analysis showing the consequences on performance measures was one of the most effective methods of convincing decision makers of the need for investment in the transportation system. This capability was instrumental in supporting political discussions on the needs for infrastructure investment.
- There was no one organizational model for successful asset management. Many different successful organizational models of asset management were found during the scan. Perhaps the most important organizational characteristic found was the use of a team approach in defining and implementing an asset management process.
- The growing pains of an asset management process in almost all cases fostered enhanced communications among many different organizational units. Many of the participants agreed the need to promote cross-organizational coordination in an asset management process led to more effective planning and decision making in the agency.
- One of the most important starting points for implementing an asset management process was to conduct an organizational self-assessment.
- There was little evidence of the application of risk analysis techniques in the asset management processes observed. The concept of risk assessment allows transportation officials to determine the economic costs associated with infrastructure failure and to incorporate these costs into the analysis process.
- In several cases, agencies viewed data as an asset and the data collection process as an important decision-support function. Effective communication tools were needed to leverage the information and value derived from data collection efforts and the strategy of "*collect once, use often*."
- Customer input had been adopted as part of the asset management process in several cases. Surveys were used to determine those aspects of the infrastructure maintenance and condition that were most important to the users of the road system. Some performance measures were selected (for example, ride quality) because of their impact on public perceptions of the agency's performance.
- New technologies have the potential to make data collection for asset management activities more cost effective and efficient. For example, laptop computers or tablets combined with global positioning systems (GPS) powerful tools can be used to collect condition data on the road network. [Cambridge Systematics and Meyer, 2007]

E. TAM Asset Management Guide

A *Transportation Asset Management Guide* was published in 2002. [AASHTO, 2002] The guide offered a useful framework for agencies to assess how well their current business processes and operations were tailored to deliver the best value with existing resources and to identify opportunities to improve existing procedures and capabilities. An agency exerts varying influence on the factors controlling facility expenditures over the facility life cycle. Hence, the nature and timing of decisions are critical and have a measurable impact on the cost-effectiveness of infrastructure service delivery (this is discussed later).

In 2011, AASHTO produced volume 2 of the *Asset Management Guide*, titled *Asset Management Guide: A Focus on Implementation* [AASHTO, 2011a]. Volume 2 focused on the characteristics of successfully implementing asset management within transportation agencies. It explicitly recognized that the exact nature and substance of the material included in a transportation asset management plan (TAMP) would vary by the level of maturity of the agency's TAM process and its impact on decision making. For example, the content of an initial TAMP might simply be a diagnostic document intended to understand the strengths and weaknesses of TAM practices, and may include asset management objectives and measures, performance gap identification, life-cycle cost and risk management analysis, and a financial plan, all to establish the directions and steps necessary to reach a higher level of TAM maturity. It would "record current policies, standards, lifecycle tactics, levels of service, information systems, critical assets, knowledge of assets, and work programs." [AASHTO, 2011a]

Meeting the requirements of an initial and core TAMP for pavements and bridges would rely on the existence of information and data that could be input into each section of the TAMP above. For example, with respect to performance measures (found in the levels of service section), action would relate to the existence of performance measures relating to condition preservation for both pavements and bridges; this could be expanded to include the degree to which stakeholders are involved in the definition of performance measures, including the linkage to federally defined performance measures. One could also focus on the co-benefits of asset investments on goals relating to such things as safety, mobility, environmental quality, and financial sustainability.

F. MAP-21 and Asset Management Regulations

The 2012 U.S. surface transportation legislation, MAP-21, has been the most specific legislation with respect to transportation asset management requirements. The law required every state to develop and implement a "risk-based State Asset Management Plan" for the National Highway System (NHS), including data collection, maintenance and integration, software costs, and equipment costs [FHWA, 2012a]. Subsequent to the law, FHWA issued a Notice of Proposed Rulemaking relating to the required asset management systems. The proposed rule establishes the basic structure of a risk-based transportation asset management plan. The minimum topics to be included in a TAMP and the process for developing the plan are identified, as are the timeframes for plan development. The following highlights some of the key requirements:

- State DOTs are required to develop and implement asset management plans for the National Highway System (NHS) to improve or preserve the condition of the assets and the performance of the NHS relating to physical assets (although state DOTs are encouraged to include all highway infrastructure assets within the right-of-way).
- State asset management plans must include strategies leading to a program of projects that would: (1) make progress toward achievement of the state targets for asset condition and performance of the NHS, and (2) support progress toward the achievement of the national goals.
- With respect to required processes, each state DOT must establish a process for:
  - Conducting a performance-gap analysis and identifying strategies to close gaps.
  - Conducting life-cycle cost analysis for an asset class or asset subgroups at the network level.
  - Undertaking a risk-management analysis for assets in the plan. As part of this process, state DOTs would identify and assess risks (e.g., extreme weather) that can affect asset condition or the effectiveness of the NHS as it relates to physical assets.
  - Addressing the risks to assets and to the highway system associated with current and future environmental conditions, including extreme weather events, climate change, and seismic activity, in order to provide information for decisions about how to minimize their impacts and increase asset and system resiliency. A mitigation plan for addressing the top priority risks must also be described.
  - Evaluating roads, highways, and bridges that have repeatedly required repair or reconstruction due to emergency events. For assets in the asset management plan, state DOTs are required to develop an approach to address and monitor high-priority risks to assets and the performance of the system.
  - Developing a financial plan covering a 10-year period.
  - Developing investment strategies to improve or preserve the condition of the assets and the performance of the NHS.
  - Using pavement and bridge management systems to analyze the condition of interstate highway pavements, non-interstate NHS pavements, and NHS bridges, and to determine optimal management and investment strategies.
- A TAMP should include, at a minimum, (1) asset management objectives, which should align with the agency's mission; (2) measures and targets designed to achieve and sustain a desired state of good repair over the life cycle of the assets at minimum practicable cost; (3) summary listing of the pavement and bridge assets on the NHS, including at a minimum a description of the condition of those assets for: interstate pavement, non-interstate NHS pavement, and NHS bridge assets; (4) performance gap identification; (5) life-cycle cost analysis; and (6) risk management analysis for assets and the highway network included in the plan, and including for those assets a summary of the statewide periodic evaluations, financial plan, and investment strategies.
- The TAMP must discuss a set of investment strategies leading to an immediate program of projects.

One of the key characteristics of the MAP-21-required asset management approach is the emphasis on risk and risk management. As noted by FHWA, "risk is the positive or negative effects of uncertainty or variability upon agency objectives. Risk management generally consists of the cultures, processes, and structures that are directed toward the effective management of potential opportunities and threats." FHWA sponsored pilot studies in three states in 2012 (Louisiana, Minnesota, and New York) to outline what a risk-based asset management approach and a risk-based transportation asset management plan looks like.

The most recent federal transportation legislation, Fixing America's Surface Transportation (FAST) Act, reaffirms the MAP-21 requirements for asset management plans and the reporting of performance and condition metrics. The act states that if a state DOT does not achieve or make significant progress toward achieving targets in any performance measurement area after one reporting cycle, the state must submit a report describing the actions they will undertake to achieve the targets in the future. The penalty for falling below the minimum condition levels for pavements on the Interstate system is also imposed after the first reporting cycle.

Those interested in asset management should stay abreast of FHWA-sponsored studies and pilot programs on asset management at https://www.fhwa.dot.gov/asset.

IV. ASSET MANAGEMENT AND TRANSPORTATION PLANNING

As noted by the FHWA, "several key planning functions and activities where asset management principles are likely to have the most impact and where the current state of practice could be strengthened significantly" include:

Long-Range Plan Development and Updates—The development and updating of long-range plans offer an opportunity to develop clear policy goals for executive management and key stakeholders; establish system performance measures; broaden the range of investments and actions included in the planning effort, including freight, safety, preventive maintenance, operations, and intermodal and multimodal options as appropriate; and broaden the range and level of integration of the data and analysis tools used to support the planning and programming process.

Performance Measurement—Whether established as part of a long-range plan update or as a stand-alone initiative, defining a set of system performance measures is a prerequisite to good asset management. Because they focus on system performance, these measures can help encourage the culture change required for asset management, which is a "systems view" not a project view. Such measures should be tied to the policy goals and objectives of the planning process.

Strategic Resource Allocation and Trade-Offs—The planning process examines strategic resource allocation issues and trade-offs. Most agencies do not have the full set of tools, data, or organizational structure and roles to really examine expenditures in all key areas in a consistent manner and consider options and trade-offs. Broadening the role and focus of planning can incrementally broaden the type of trade-offs considered and that move an agency toward a more integrated decision-making model.

Linkage to Programming and Budgeting—The extent to which plans and planning activities influence program and budget decisions varies widely. Unless this linkage is clear and strong the value of planning can be questioned—the ability to directly impact programming and budgeting decisions is often viewed as the single most important criterion for judging the effectiveness of transportation planning. Thus, planning can utilize data produced by the asset management system to establish priorities for infrastructure renewal that are part of the transportation plan.

Data and Analytic Tool Development and Support—In many agencies, the planning function is the "owner" of some of the data and tools required to support a variety of planning activities. However, as the range of issues and investment trade-offs considered in planning increases, many key databases and tools will be maintained by other functional units (for example, system physical conditions, real-time operations data, crash statistics, pavement and bridge management systems). Shared access to, and common definition of, data and joint use and understanding of analysis tools is important. As noted by FHWA, "The planning function provides a platform for a more integrated agency-wide data collection and management strategy and the development of new, or enhanced, analytic tools to support a broader and more integrated set of tradeoff analyses."

The rest of this section describes how asset management can provide important information to the transportation planning process. (See chapter 1 for more detailed discussion on the different components of the transportation planning process).

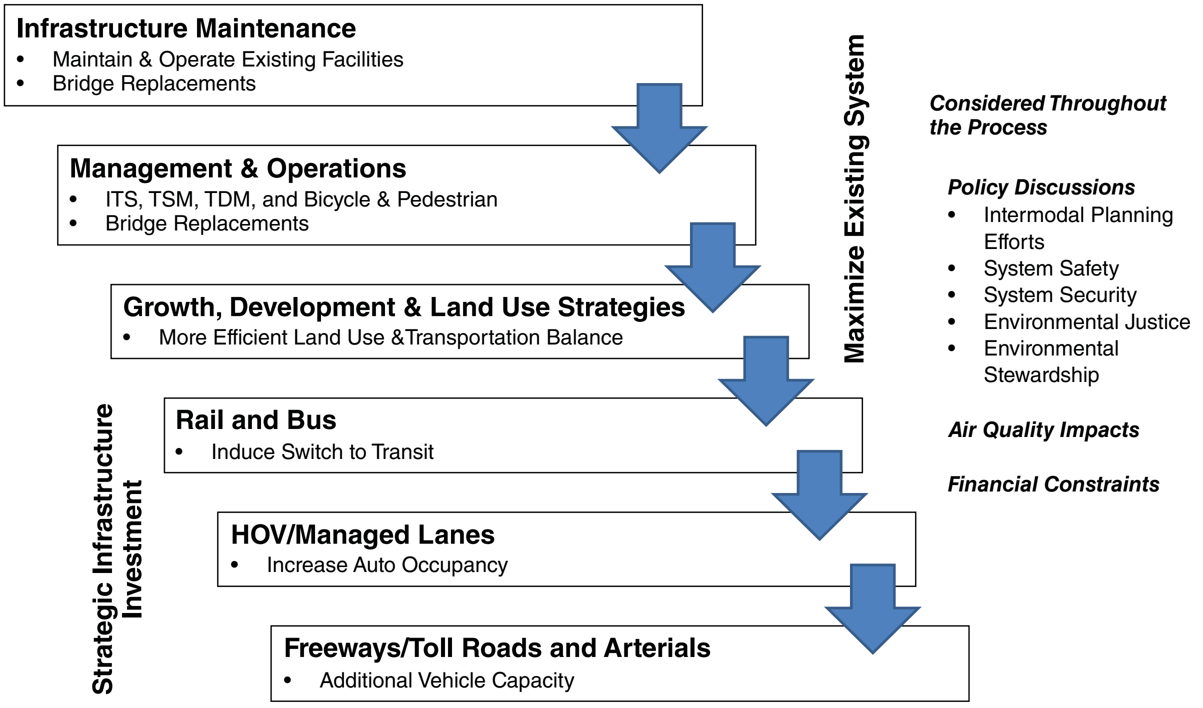
A. Vision, Goals and Objectives

An effective asset management approach will align an agency's vision, goals, and objectives with a set of performance measures and targets at various levels of decision making (for example, network-level [strategic], operations, and project development). Experience suggests that successfully achieving this alignment makes the decision-making process more effective in achieving desired outcomes. For example, if one goal of a state DOT is to provide the state's citizens with a road network that meets the needs of both personal and freight travel, then one objective might be to maintain the road network in good condition. A possible performance measure connected to this objective might be *the number of lane-miles of road maintained at a specified condition level*. This measure provides direct feedback to decision makers on the extent to which the identified goal is being achieved.

Most asset management programs have a set of defined goals and/or objectives to guide rehabilitation and maintenance decisions. The linkage between asset management activities and transportation planning with respect to more general vision, goals, and objectives statements is most often found in the types of goal statements that guide statewide and metropolitan transportation planning studies. Figure 8-3, for example, shows the logic underlying the development of the metropolitan transportation plan in Dallas–Fort Worth, Texas. As shown, the first priority for the region's transportation investment is infrastructure maintenance, followed by other initiatives that are important to the region.

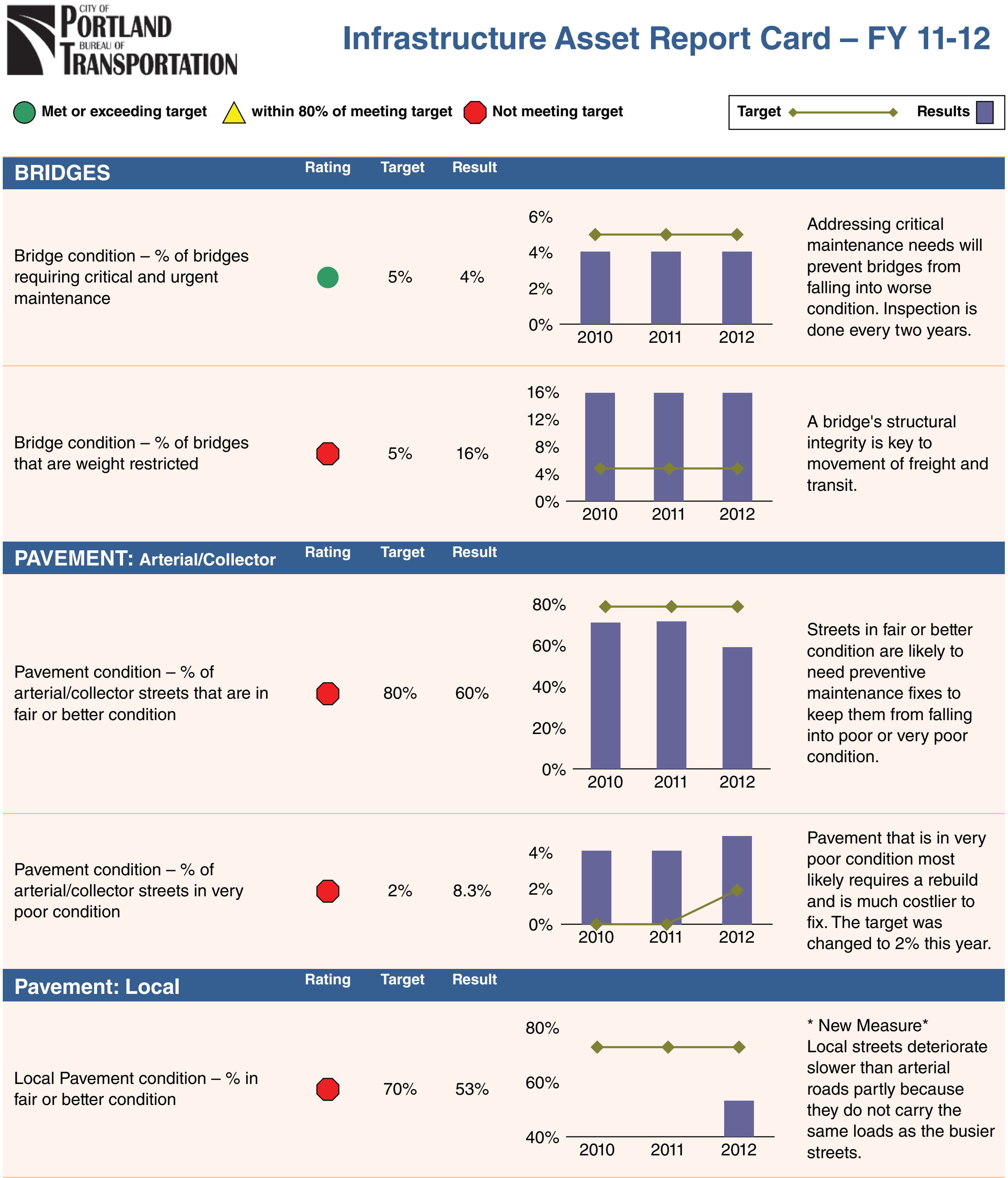
A local asset management example comes from Portland, Oregon, where the vision statement of the city transportation department states the transportation system will be "maintained and preserved" to support the many different uses streets serve in an urban environment. According to the city, the asset management program "provides a targeted level of service and performance for various assets within the transportation network, in a cost-effective manner, by making the right amount of investment for the right asset in the right location at the right time." [City of Portland, 2014] Figure 8-4 shows a typical reporting of the condition of the city's assets.

Figure 8-3. Priority Consideration of Investment Factors, Dallas–Ft. Worth, Texas



Source: North Central Texas Council of Governments. 2009

Figure 8-4. Example of Infrastructure Report Card, Portland, Oregon



Source: City of Portland, 2012

The Ohio Department of Transportation (ODOT) is another example of an integrated approach to asset management. Asset management is considered a core value and function of the organization. ODOT's asset management plan goals that relate to planning include:

1) Adopt a Transportation Asset Management policy as the Department's business process for managing critical assets and making capital investment decisions.

2) Establish an Asset Management oversight group to direct the respective Central Office Divisions to establish and lead Asset Task Committees to determine statewide standards, procedures, and formats for a centralized asset inventory database.

3) Develop a centralized Asset Management platform for integration of all asset inventory databases to reside in a geo-Spatial environment tied to the Base Transportation Referencing System.

4) Mandate the collection of asset data directly related to supporting a "Safety First" philosophy in all aspects of transportation system development and operation. Leverage existing resources and new innovative technologies to enhance asset inventory collection with improved safety, efficiency, and data quality.

5) Implement management systems around critical assets, with a focus on developing an integrated asset management process.

6) Require as-built plans for all future projects and establish a work order based asset inventory updating process to ensure that the centralized asset database remains updated.

7) Utilize the Department's Research and Development Program to support Transportation Asset Management activities.

ODOT decisions are guided by a set of principles and strategic goals that link to performance measures found at all levels of organizational decision making. ODOT has adopted goals in five major strategic decision-making areas: transportation safety, economic development and quality of life, efficient and reliable traffic flow, system preservation, and resource management. The system preservation goal is defined as "achieving a steady-state condition for pavement and bridges, that is, a state of relatively low and stable level of deficiencies, small enough that a predictable rate of preventative maintenance and regular repairs can sustain that level of acceptable conditions." Condition and performance measures are integrated within all departmental functions and are not really identified as asset management measures as such. Annual pavement and bridge inspections are conducted. Overall condition targets have been established for the different road systems. The DOT uses a "mix of fixes" to provide as close to a steady state in condition as possible.

It is important to note that, although this section has focused on asset management applications in planning, the asset management concept can be applied throughout the entire life cycle of facilities and systems. Operations asset management, for example, focuses on analytical procedures for managing the assets used to support facility operations. Similar to the approach used for planning, asset management includes consideration of the following:

- Associated goals and objectives (for the operation of the system).
- Linkages between goals, objectives, and performance.
- Trade-offs between alternative improvements.
- Engineering and economic evaluation results.
- Impacts of varying asset life-cycle and investment-cycle time horizons. [FHWA, 2004]

More detailed treatments of asset management for system operations may be found elsewhere (see, for example, [TRB, 2005]). While the applications are different, the overarching asset management concepts remain the same. As asset management implementation advances in the different stages of the life cycle of facilities and systems, it is expected that these asset management procedures and activities will be progressively integrated.

B. Performance Measures

Although visions, goals, and objectives are important points of departure for a planning process, they often do not provide enough detail on how progress or relative performance of different plan alternatives will be measured. Performance measures provide this greater level of detail. MAP-21 established a national policy in support of performance measurement: "Performance management will transform the Federal-aid highway program and provide a means to the most efficient investment of Federal transportation funds by refocusing on national transportation goals, increasing the accountability and transparency of the Federal-aid highway program, and improving project decision making."[§1203; 23 USC 150(a)] National performance goals were identified in seven areas:

safety, infrastructure condition, congestion reduction, system reliability, freight movement and economic vitality, environmental sustainability, and reduced project delivery delays.

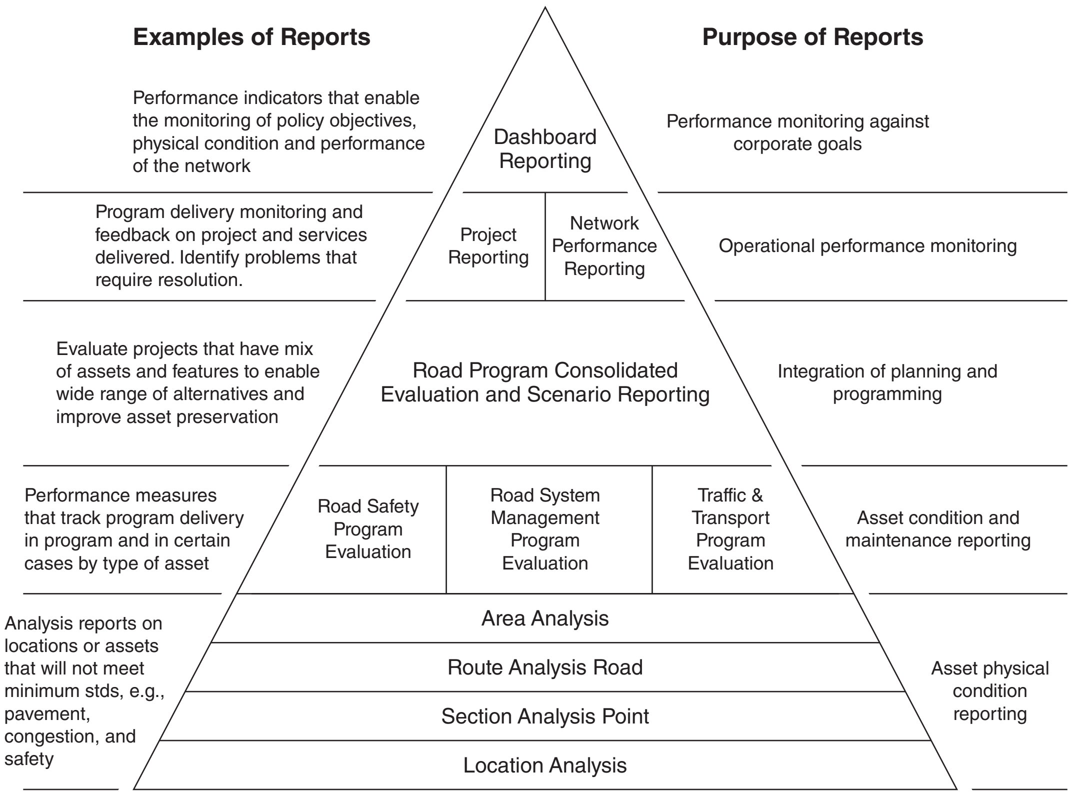
Effective performance measurement is an integral part of an asset management approach in transportation planning, programming, and project development. Well-defined policies that achieve the overall agency vision and goals must be related to clear measures of performance (measurable quantities that indicate level of achievement of objectives) with targets (target outcomes with time deadlines). Continuous performance monitoring is then required to close the loop between the planning objectives and actual system outcomes.

The report *Performance Measures and Targets for Transportation Asset Management* [AASHTO, 2011a] outlines critical considerations for developing performance measures for TAM. It emphasizes the following as important attributes for performance measures to support effective asset management: They must be policy-driven, embrace a strategic perspective, consider options and trade-offs, be supported by credible information, provide effective feedback relative to system goals and objectives, and be useful across various organizational units and levels.

The international scanning tour described earlier found a common framework for performance measurement in all the best practice case studies. Each country's effort was related to a broad set of goals and objectives defined either by a legislative body or through a public visioning process. These goals and objectives led to the identification of system-specific performance measures, often tied to target values to be achieved in a future year. Performance measurement was applied at several different levels of planning and decision making; for example, measures were targeted at longer-term strategic investment decisions and shorter-term network operations functions.

Figure 8-5 shows the performance reporting hierarchy used by VicRoads (the state's transportation agency) in Victoria, Australia. In some cases, these performance categories could provide the basis for cross-asset evaluation and investment prioritization. NCHRP Report 446, *A Guidebook for Performance-Based Transportation Planning,* provides a useful library of performance measures for all types of transportation goals and objectives. [Cambridge Systematics, 2000] For the system preservation goal, Table 8-3 presents some of the measures that are used more often than others.

Figure 8-5. Information Reporting Hierarchy at VicRoads, Victoria, Australia



Source: FHWA, 2005

Table 8-3. Typical Performance Measures for System Preservation	
System Preservation Category	**Common Measures**
System condition—Roadway, General	Percentage of roadway/bridge system below standard condition Age distribution
System condition—Roadway, Pavement	Percentage of highway mainline pavement or bridges rated good or better
System condition—Roadway, Bridge	Percentage of highway mainline bridges rated good or better
System condition—Roadway, Freight facilities	Pavement condition on links to intermodal facilities
System condition—Bicycle facilities	Miles of highway rated good or fair for bicycle travel
System condition—Rail	Miles of track in operation
System condition—Transit vehicle	Miles between road calls for transit vehicles Age distribution
System condition—Other modes	Miles to be dredged Runway surfacing frequency
System condition—Multimodal	Hours or days out of service (roads, bridges, transit equipment or airports)
Program delivery—Time-related	Number of lane-miles let to contract for resurfacing Number of bridges let to contract for repair or replacement
Program delivery—Cost-related	Percentage of budget allocated to system preservation Average maintenance costs

Source: Based on Cambridge Systematics, 2000, Reproduced with permission of the Transportation Research Board.

C. Data Needs

Data needs for asset management relate directly to an agency's responsibilities and its goals concerning infrastructure condition and performance. Guidance for data collection for various infrastructure and asset management systems is available in standard references such as [AASHTO, 1996; 2011a; 2011b; AASHTO et al., 1996; Pierce et al., 2013; and FHWA, 2012c, 2013a,b] Several of the early asset management applications typically categorized data into inventory and attribute data. This categorization still characterizes many of the infrastructure management systems used today for all aspects of asset management.

Inventory data are critical. They provide a current description of an agency's assets (what the agency owns, where it is located and such). Attribute data, on the other hand, refer to characteristics of facilities/systems that are subject to change, such as facility demand, the condition of the facility, and so forth. Table 8-4 shows the type of data typically collected for pavement management for decisions at the network and project levels. [Pierce et al., 2013]

Classification of data needs at different levels of detail (for planning, programming, and project development) is important because data collection can be very expensive and time-consuming. An adequate level of data detail must be available for project selection and programming as well as planning at the network level. In addition, some of the needed data may be used in more than one unit within an agency. Agency-wide data management is thus necessary to ensure the data themselves are being treated as an asset and managed most cost-effectively to provide up-to-date information.

Several agencies (for example, Colorado DOT, Arizona DOT, Virginia DOT, and Pennsylvania DOT) continue to modernize their legacy databases and applications, some of which were developed for very specific functional responsibilities within the organization (for example, one database format for pavements, another for bridges). The goal is to integrate their databases into a comprehensive system that can be accessed and used effectively by multiple business units. In many cases, geographic information systems (GIS) are used as the common platform for data integration. Quality assurance and quality control for data collection are critical elements in these efforts for modernization. Additionally, ensuring that data are up to date is particularly important for generating useful information for decision making and earning or increasing credibility with the legislature and public.

A good example of a strategic approach toward asset data management comes from the Pennsylvania DOT (PennDOT). Responsible for the fifth-largest highway system in the United States, PennDOT has an annual budget

Table 8-4. Network- and Project-Level Data Collection		
Aspect	**Network-level**	**Project-level**
Uses	Planning Programming Budgeting Pavement management system treatment triggers, identification of candidate projects, life-cycle cost analysis Network-level condition reporting *Mechanistic-Empirical Pavement Design Guide* (MEPDG) calibration	Project scope Refine pavement management system treatment recommendations MEPDG calibration
Data Items Typically Collected	International Roughness Index Rut depth Faulting Cracking Punchouts Patching Joint condition Raveling Bleeding Surface texture	Detailed crack mapping and other distresses Structural capacity (e.g., falling weight deflectometer) Joint load transfer Base/soils characterization (e.g., ground penetrating radar, cores, trenches)
Other Items Collected Concurrently	Video GPS coordinates Geometrics (e.g., curve, grade, elevation, cross slope) Other assets (e.g., bridges, signals) Events (e.g., construction zones, railroad crossings)	Drainage conditions Appurtenances (e.g., sign and guardrail location and condition) Geometrics (e.g., curve, grade, elevation and cross slope)
Speed	Typically highway speeds	Walking or slower speeds

Source: Flintsch and McGhee, 2009, as reported in Pierce et al., 2013

of more than $4 billion. During the past 20 years, PennDOT made significant investments in the following suite of management systems designed to support its business operations:

- Roadway Management System (RMS).
- Bridge Management System (BMS).
- Maintenance Operations Reporting Information System (MORIS).
- Engineering Construction Management System (ECMS).
- Multimodal Project Management System (MPMS).
- Automated Permit Routing/Analysis System (APRAS).
- Electronic Document Management System (EDMS).
- Financial Management Information System (FMIS).

Developed in-house, these mainframe applications evolved over time in reaction to the changing needs of the agency and provided a wealth of standard inventory and condition data for the last 15 to 20 years. In the 1990s, PennDOT undertook an extensive evaluation of its business operations to integrate its information systems and strategic business planning. The process was designed to ensure that the management systems were compatible with one another from a business process point of view. Simultaneously, it worked on technically integrating individual data systems so that they could combine data and analysis results from the updated management systems and provide integrated information to decision makers across the agency.

D. Analysis Methods and Tools

This section discusses several asset management methods and tools that are being used to determine the most cost-effective approach toward enhancing infrastructure performance. Some of these methods are more appropriately used within an agency's asset management program, while others could possibly be applied within a transportation planning context. It should be noted that several asset management software programs have been developed for both highway and transit assets. The intent of these programs is to automate the analysis of asset condition, ultimately resulting in investment priorities. Readers are encouraged to search the Internet to identify available asset management programs.

1. Infrastructure Condition Assessment Methods

An objective and repeatable rating system must be used to evaluate facility condition. Various types of condition indices have been developed, including the Army Corps of Engineers' (ACOE) pavement condition index (PCI), FHWA's bridge sufficiency index, and Caltrans' bridge health index. Other indices exist for pavements, bridges, signs, and other appurtenances (see [Patidar et al., 2007; Pierce et al., 2013]).

The American Society for Testing and Materials' (ASTM) standard for the condition evaluation of airport and roadway pavements and parking lots is the ACOE's Pavement Condition Survey and Rating Procedure, which results in the PCI. The condition assessment procedure is based on visual assessment of the type, quantity, and severity levels of pavement distresses and provides a methodology for converting the data to a single value on a scale of 0 (failed pavement) to 100 (excellent pavement). [Shahin, 1994] The bridge health index relates the physical condition of bridges to the overall asset value of the bridge, capturing losses in bridge condition as reductions in the replacement value of the facility. [Shephard and Johnson, 2001]

State DOTs have adopted their own set of pavement condition measures that are provided to agency leadership as well as disseminated in annual reports. The Minnesota DOT (MnDOT), for example, reports on four measures: the Ride Quality Index (RQI), the Surface Rating (SR), the Pavement Quality Index (PQI), and Remaining Service Life (RSL). As noted in the annual report, "each index captures a different aspect of the pavement's health and can be used to rank pavement sections and predict the need for future maintenance and rehabilitation." [MnDOT, 2015] The definition of these measures are:

RQI: Ride Quality Index—The RQI is MnDOT's ride, or smoothness, index. It uses a zero to five rating scale, rounded to the nearest tenth. The higher the RQI, the smoother the road is. The RQI is intended to represent the rating that a typical road user would give to the pavement's smoothness as felt while driving his/her vehicle.

SR: Surface Rating—Pavement distresses are those defects visible on the pavement surface, symptoms indicating some problem or phenomenon of pavement deterioration such as cracks, patches, and ruts. MnDOT uses the SR to quantify pavement distress. The distress identification is done by viewing digital images of the pavement captured by a van that rides along the state highway collecting different types of pavement data. The percentage of each distress in the 500-foot sample is determined and multiplied by a weighting factor to get a weighted distress value.

PQI: Pavement Quality Index—The PQI is a composite index, equal to the square root of the product of RQI and SR. It gives an overall indication of the condition of the pavement, taking into account both the pavement smoothness and cracking. The PQI is the index used to determine if the state highway system is meeting performance thresholds established for the Government Accounting Standards Board, Standard 34 (GASB 34).

RSL: Remaining Service Life—The RSL is an estimate, in years, until the RQI will reach a value of 2.5, which is generally considered the end of a pavement's design life. The RSL is determined from pavement deterioration curves. A regression curve is fit through the historical RQI data for each pavement section and the year the RQI will reach 2.5 is estimated.

Table 8-5 shows how the measures relate to standard condition values, in this case for the RQI measure. Table 8-6 shows how MnDOT has defined ride quality index.

2. Deterioration Modeling for Performance Prediction

Infrastructure deterioration models describe infrastructure condition or performance in terms of factors that cause deterioration in facilities, such as usage, loads, climatic factors, construction quality, and maintenance activities. These

Table 8-5. Ride Quality Index (RQI) Performance Categories, Minnesota DOT		
Descriptive Category	**RQI Range**	**Performance Measure Category**
Very Good	5.0–4.1	Good
Good	4.0–3.1	
Fair	3.0–2.1	Fair
Poor	2.0–1.1	Poor
Very Poor	1.0–0.0	

Source: Minnesota DOT, 2015

Table 8-6. Ride Quality Index (RQI) Targets by System, Minnesota DOT		
	Ride Quality Index	
System	**"Good" RQI Target**	**"Poor" RQI Target**
Interstate	70% or more	2% or less
Other-NHS	65% or more	4% or less
Non-NHS	60% or more	10% or less

Source: Minnesota DOT, 2015

types of models can help agencies allocate their budgets more effectively when planning for preservation, maintenance, and renewal of the highway network and bridge inventory.

Several types of models have been developed for pavement and bridge management systems. Such models may be classified based on their mechanical properties (mechanistic) or statistical data relationships (empirical) and whether they capture uncertainty (probabilistic or stochastic) or not (deterministic). They may be developed for network-level decision making (with aggregate properties) or project-level decision making (using more detailed data). Empirical models include statistical regression models, fuzzy sets, artificial neural networks, fuzzy neural networks, and genetic algorithms. They are more common than mechanistic models, which predict future changes based on expected physical response (such as material strain, stress, or deflection) as a function of known factors that cause changes in these responses (such as load on the facility). Empirical models must be validated periodically for accuracy.

Figure 8-6 shows the difference between probabilistic and deterministic models. In the probabilistic formulation, the probability of going from one pavement condition state to another is found through analysis of historical data and the application of statistical analysis techniques. Thus, in the example, the probability of going from an initial state of "very good" to "good" using the life frequency data was 0.09, or 9 percent. The deterministic model uses historical data to plot the condition of different pavements with different service lives over time.

Markov models, semi-Markov models, and survivor curves are examples of probabilistic models commonly used in the development of performance prediction models. Markov models use transition matrices to describe the probability that a facility in a known condition state at a known time will change to some other condition state in the next time period.

Regression models are another model form often used to predict future pavement condition. Regression models are simple to use. However, developing and validating them usually requires a database with many years of data from which to discern cause-and-effect relationships. Hence, they must be recalibrated periodically for quality assurance. They are also not readily transferable from one site to another. An example of the use of regression models to predict pavement condition is found in [Chou, Pulugurta, and Datta, 2008]. The following is a sample regression model for of a strategy for pavement overlay with repairs for one district.

$$PCR_P = 98.401 - 6.142 \times [(Age + 1)^{0.728} - 1]$$

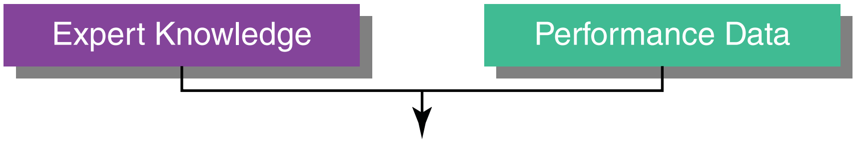
$$n = 1523, \; R^2 = 0.74$$

where

PCR_P is the pavement condition measure for pavement strategy.

Age is the age of the pavement since treatment.

Figure 8-6. Example of Probabilistic and Deterministic Pavement Condition Models

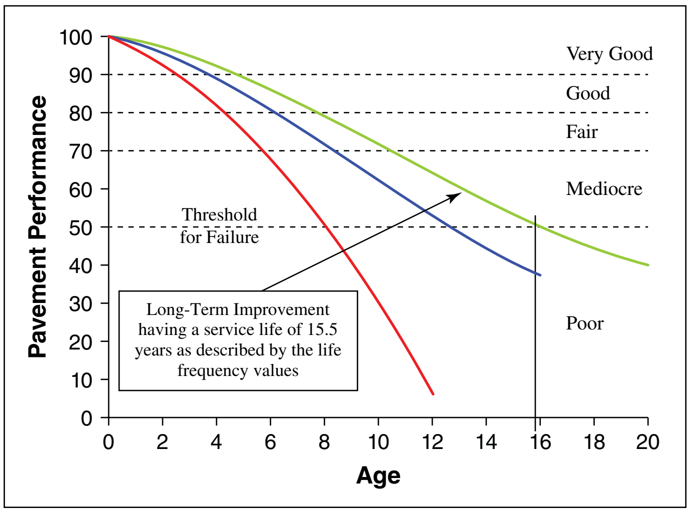


CONDITION STATE	LIFE FREQUENCY
Very Good	4.5 years
Good	3.5 years
Fair	3.0 years
Mediocre	4.5 years
Total Life	**15.5 years**

Probabilistic Model

		Future Condition States				
		Very Good	Good	Fair	Mediocre	Poor
Initial Condition States	Very Good	0.85	0.09	0.03	0.02	0.01
	Good	0.00	0.73	0.22	0.04	0.01
	Fair	0.00	0.00	0.71	0.24	0.05
	Mediocre	0.00	0.00	0.00	0.75	0.25
	Poor	0.00	0.00	0.00	0.00	0.00

Deterministic Model



Source: Hedfi and Stephanos, 2001

Interestingly, the authors compared two types of regression models and a Markov model and determined that the Markov model was a better model form for prediction purposes in this case.

The RQI deterioration in the Minnesota DOT example used regression curves that were based on section-specific historical data or statewide data. If adequate historical data exists since the last rehabilitation on a section, a regression curve is fit through the data and used to predict the RQI. If there is inadequate historical data for the section, or if the regression through the historical data results in an unrealistic curve, a default curve is used to predict the future RQI. Table 8-7 shows a comparison between the RQI as predicted with the deterioration curves and actual measurements.

As shown in the table, the difference between the predicted 2014 condition and the actual 2014 condition was not that great. MnDOT attributed differences to one, or more, of the following: (1) timing of the construction work was different than expected (versus our van schedule), (2) districts were tested in a different order than originally expected, (3) construction projects were advanced, reducing "Poor" and increasing "Good," (4) construction projects

Table 8-7. Comparison of Predicted 2014 RQI versus Actual 2014 RQI, Minnesota DOT

Interstate System RQI Category	Actual 2013 Data	Predicted 2014 Data	Actual 2014 Data	Difference Actual vs. Predicted
Good RQI (RQI > 3.0)	75.2%	77.3%	75.9%	(1.4%)
Poor RQI (RQI <= 2.0)	2.4%	1.5%	1.9%	0.4%
Other NHS System RQI Category	**Actual 2013 Data**	**Predicted 2014 Data**	**Actual 2014 Data**	**Difference Actual vs. Predicted**
Good RQI (RQI > 3.0)	71.0%	68.9%	70.9%	2.0%
Poor RQI (RQI <= 2.0)	2.9%	3.3%	3.0%	(0.3%)
Non-NHS System RQI Category	**Actual 2013 Data**	**Predicted 2014 Data**	**Actual 2014 Data**	**Difference Actual vs. Predicted**
Good RQI (RQI > 3.0)	62.5%	63.1%	67.2%	4.1%
Poor RQI (RQI <= 2.0)	6.8%	6.2%	4.4%	(1.8%)

Source: [Minnesota DOT, 2015]

were incomplete, keeping “Poor” from becoming “Good,” (5) maintenance work kept roads from falling into “Poor” or out of “Good,” (6) a change in a road’s rate of deterioration (either faster or slower), and (7) unforeseen funding or projects improving the road. [MnDOT, 2015]

3. Valuation

Many asset management approaches used throughout the world rely on asset valuation. To evaluate or place a value on something is to determine its significance, worth, or condition. Several methods exist for valuing physical assets (see Table 8-8). GASB 34 allows governments to report either a depreciation expense or to apply an alternative modified/preservation approach. Government agencies may use the modified approach in lieu of depreciating their assets if they have a systematic approach to managing their assets that, at a minimum, meets the following four requirements: (1) have a current inventory of eligible assets, (2) document the condition of those assets via a reproducible assessment procedure, (3) demonstrate that assets are being preserved at a level predetermined by the government, and (4) estimate the actual cost to maintain and preserve the assets. [MnDOT, 2015]

The GASB 34 Statement, which requires state and local agencies to report on their infrastructure value, has renewed broad interest in valuation methods, both in practice and in academia. As noted earlier, one of the key distinctions in valuation methods is between traditional accounting-based methods (for example, book value) and condition-based methods (for example, replacement cost value).

Table 8-8. Description of Valuation Approaches

Valuation Approach	Description
Book Value	Present worth of capital and subsequent costs of asset depreciated to the present
Equivalent Present Worth in Place	Represents worth “as is.” Based on historic costs adjusted for inflation, depreciation, depletion, and wear
Productivity Realized Value	Represents value of asset in use. Present worth of future benefits for the remaining service life of the facility
Written-Down Replacement Costs	Uses current market prices to determine costs to rebuild or replace facility in its current condition
Market Value	Price that the buyer is willing to pay
Net Liquidation Value	Present worth of amount obtainable from selling off the components of an asset over a reasonable period of time
Salvage Value	Present worth of the amount obtainable disposing or recycling a facility
Option Value	Value of asset in specific circumstances

Source: Adapted from Haas, R. and C. Raymond. “Asset Management for Roads and other Infrastructure” Presented at the 8th Annual Fall Asphalt Seminar, Ontario Hot Mix Producers Association, Toronto, Ontario, Canada, December 1, 1999; Valentine, G. S. “Appraising a Transportation Corridor.” *Right of Way* (November/December 1998); and Damodaran, A. *Investment Valuation: Tools and Techniques for Determining the Value of Any Asset*. Hoboken, NJ, USA: John Wiley and Sons Inc., 1996.

4. Economic Analyses

Many transportation agencies use economic analysis methods to determine the best economic decision with respect to return on investment. In most cases, the economic test that is applied to different asset management strategies is benefit-cost analysis. A good example of this approach is found in the New York State DOT (NYSDOT). [FHWA, 2012d]

Basic network-level transportation management systems were established at NYSDOT as early as the 1960s. Over time, these systems were continuously improved by the use of more sophisticated database management technology and the addition of economic analysis methods for project-level evaluation of investment candidates for different classes of assets. NYSDOT's pavement management system, bridge management system, safety management system, and congestion needs assessment model employ life-cycle cost analysis (LCCA), least-cost analysis, benefit-cost analysis, and user cost analysis, respectively, for alternatives analysis. The agency developed a prototype of a TAM trade-off model that draws available economic and performance data from almost 2,000 investment candidates identified by the separate management systems. The TAM trade-off model ranks these projects both within and among program areas based on benefit/cost ratios.

One of the strengths of the TAM trade-off model is its ability to assess the cost-effectiveness of grouping assets together, such as facilities in a corridor. The model is designed to provide a network-level or program-level assessment of investment priorities, cutting across asset-specific system results. The TAM trade-off model is used as a first cut in program development.

5. Risk Analysis and Management

Conducting risk analysis and management is an important element of asset management programs. Risks arise because of uncertainty; they represent the probability of loss. Although relatively little analysis has been incorporated into the planning process to address risks, a range of planning and project development risks are associated with a typical transportation plan's recommendations, including possible inadequate funding, long-term political risk associated with changing societal values and their impacts on transportation, local opposition to a plan or project, technological obsolescence, and the risks of a changing market. [Meyer and Miller, 2014; Mehndiratta, Brand, and Parody, 2000]

Approaches to address risk identify the sources of uncertainty and take measures to avoid, reduce, mitigate, or otherwise manage them. Several risk management approaches have been developed to address these uncertainties, for example, incremental planning, coalition building and staged implementations, sensitivity analysis for forecasting risks, legislation to limit or clarify liability, transparency in the bidding process, and turnkey contracts. [Brand, Mehndiratta and Parody, 2000; Mehndiratta, Brand, and Parody, 2000] Risks may be addressed at any stage of the planning and project development process. However, success in managing risks is related to the stage of the infrastructure life cycle where risks are addressed. For example, some environmental risks are managed more effectively at the earlier planning stages than at the project development stage. [Lytton, 1987] Thus, risk treatments can occur at the visioning stages when planning alternatives are being considered all the way through the project development stage. The following examples depict the types of risk treatments used at various agencies. Risk analysis can be a highly effective asset management tool. Identifying and planning for risks at the outset of planning and project development, when done appropriately, will promote decisions with more robust outcomes.

Probabilistic models address risk by considering uncertainty or variability in the analysis. Markov models, discussed earlier, used for deterioration modeling of pavements, bridges, and other facilities, capture the uncertainties associated with varying demand for different facilities in the network and other sources of variation such as the characteristics of the vehicle fleets, using the facilities, maintenance histories of facilities, and the like.

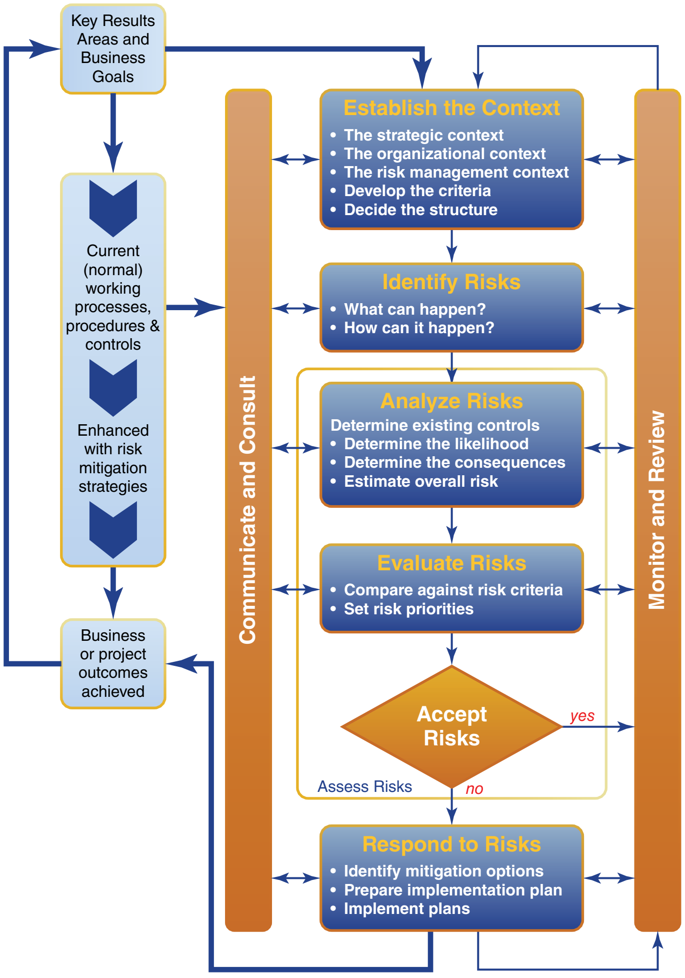
Models such as the Surface Transportation Efficiency Analysis Model (STEAM) developed by the FHWA take into account uncertainty by modeling demand probabilistically and applying Monte Carlo simulation to generate several probable levels of travel demand. Thus, the model outputs are generated as a range of values with associated probabilities rather than a single value with 100 percent certainty. This provides decision support information that reflects the underlying uncertainty for those inputs with a strong potential to affect the outputs of the model most significantly, for example, facility demand. [FHWA, 2007b]

Real options models are a relatively new approach toward considering risk in transportation decision making (see, for example, [Gavin and Cheah, 2004; Brand et al., 2000]). The real options approach differs from the traditional investment paradigm in a number of ways:

- While transportation investment opportunities have potential benefits, there is a risk of unintended negative outcomes, which are difficult to reverse once the investment decision is made.
- It recognizes that there may be value in deferring an investment decision and wait for new information because such information could lower risks. Thus, the value of the decision to wait for new information is an opportunity cost whose lost value should be included as a cost in the net present value formulation.
- Because the optimal timing of transportation investments could be to defer investments, alternatives should include flexible options that can be staged over time and have the potential to capitalize on more favorable future conditions.

MnDOT has one of the most advanced risk-based asset management plans in the United States. To a large extent the development of the asset management plan benefitted from the adoption years before of an Enterprise Risk Management Framework for agency decision making (see Figure 8-7). This framework, "establishes the standards, processes and accountability structure used to identify, assess, prioritize and manage key risk exposures across the agency." [MnDOT, 2014] A risk-based approach was used to develop the Statewide Highway Systems Operation Plan (HSOP), as well as the Statewide Long-range Transportation Plan. Developing a risk-based asset management plan thus was part of the culture in the agency. Because many of the risks associated with the general threats to agency operations and budgets had been dealt with in other plans and programs, the asset management plan strategy was to focus on assessing and developing mitigation strategies for "underman-aged" risks, where opportunities existed for improving the asset management process.

Figure 8-7. Enterprise Risk Management Approach in Minnesota DOT



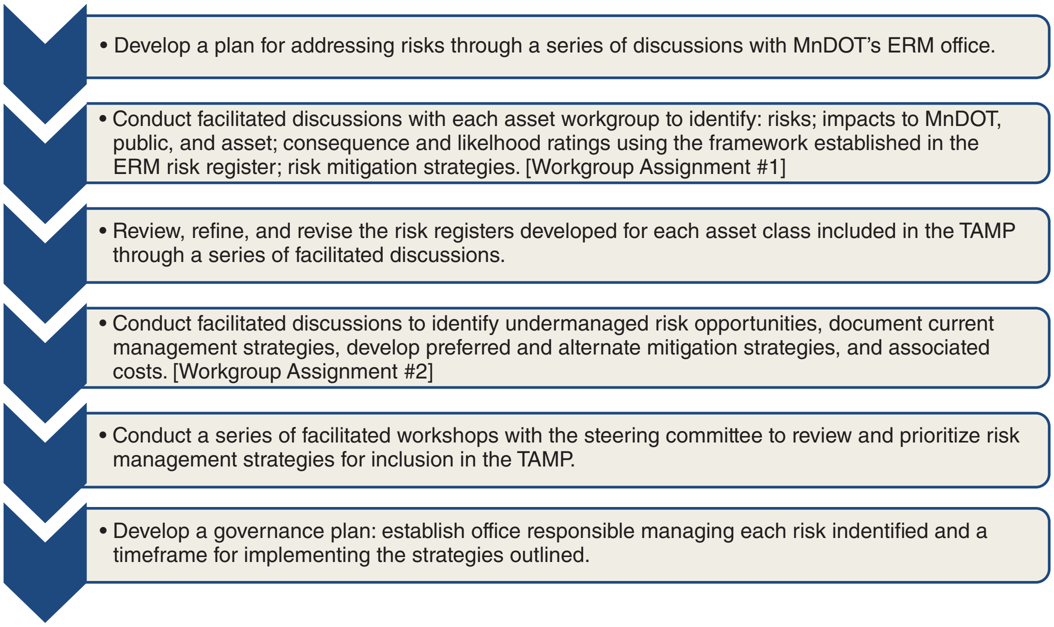
Source: Minnesota DOT, 2014

The following were identified as the major transportation-related risks:

- Natural events (for example, floods, storms, earth movement).
- Operational hazards (for example, vehicle and vessel collisions, failure or inadequacy of safety features, and construction incidents).
- Asset aging effects (for example, steel fatigue or corrosion, advanced deterioration due to insufficient preservation or maintenance).
- Adverse conditions in the economy (for example, shortage of labor or materials, recession).
- Staff errors or omissions in facility design, operations, or provision of services.
- Defective materials or equipment.
- Lack of up-to-date information about defects or deterioration.
- Insufficient understanding of deterioration processes and cost drivers.

The process followed in identifying risks and risk mitigation strategies is shown in Figure 8-8. MnDOT began by looking at the "global" risks such as natural events, operational hazards, and so on, and the potential impacts on the asset, the public, and the agency. Work groups of technical experts were formed to describe and rate the major risks related to each asset category that used a rating scale shown in Figure 8-9. Each work group developed a series of

Figure 8-8. Risk Identification Process, Minnesota DOT



Source: Minnesota DOT, 2014

Figure 8-9. Risk Rating Matrix, Minnesota DOT

CONSEQUENCE RATINGS	LIKELIHOOD RATINGS AND RISK LEVELS				
	RATE	UNLIKELY	POSSIBLE	LIKELY	ALMOST CERTAIN
CATASTROPHIC	Medium	Medium	High	Extreme	Extreme
MAJOR	Low	Medium	Medium	High	High
MODERATE	Low	Medium	Medium	Medium	High
MINOR	Low	Low	Low	Medium	Medium
INSIGNIFICANT	Low	Low	Low	Low	Medium

Source: Minnesota DOT, 2014

risk statements and risk ratings, identified risk mitigation strategies, and estimated mitigation costs. This process was iterative, extending over three workshops. The work groups ended up identifying the risks by asset type shown in Figure 8-10. The risks in italics were considered to be those that were undermanaged by MnDOT and became the focus of the TAMP risk management strategy.

Risk management strategies were identified in a seven-step process.

- *Step 1*: Define preferred mitigation strategy for addressing the risk identified.
- *Step 2*: Identify data, resources, tools, and/or training required to enact the strategy.
- *Step 3*: Describe whether the strategy will reduce the likelihood of another identified risk.
- *Step 4*: Estimate the approximate cost of implementing the preferred mitigation strategy.
- *Step 5*: Identify whether an alternate strategy might be available that does not fully mitigate the risk but lowers the overall likelihood or consequence associated with the risk.

Figure 8-10. Identified Asset Risks, Minnesota DOT

PAVEMENTS	BRIDGES
• *Not meeting public expectations for pavement quality/condition at the state/district/local levels* • *Inappropriately managing or not managing pavements such as frontage roads, ramps, and auxiliary lanes* • Inability to meet federal requirements (such as MAP-21, GASB, etc.) • Inability to appropriately manage to lowest life-cycle cost • Premature deterioration of pavements • Significant reduction in funding • Occurrence of an unanticipated event such as a natural disaster	• *Lack of or deferred funding* • *Inability to manage to lowest life-cycle cost* • Occurrence of an unanticipated natural event • Catastrophic failure of the asset • Significant damage to the asset through manmade events • *Premature deterioration of the asset* • Shortage of workforce
HIGHWAY CULVERTS AND DEEP STORM-WATER TUNNELS	**OVERHEAD SIGN STRUCTURES AND HIGH-MAST LIGHT TOWER STRUCTURES**
• *Failure/collapse of tunnel/culvert* • *Flooding and deterioration due lack of tunnel capacity* • *Lack of culvert capacity* • *Inability to appropriately manage culverts* • Inability to appropriately manage tunnels • Inappropriately distributing funds or inconsistency in culvert investments • Significant damage to culverts through manmade events	• Lack of having a mandated process for inspection • *Poor contract execution* • *Inability to manage to lowest life-cycle cost* • Significant damage to asset through manmade events • Premature deterioration of the asset • Unforeseen changes in regulatory requirements, travel demands, or technology • *Shortage of workforce*

Source: Minnesota DOT, 2014

- *Step 6*: Estimate the cost associated with the alternate strategy.
- *Step 7*: For both strategies developed, identify the impact on likelihood and consequence of the original risk should either of the strategies be adopted.

The process resulted in the following priority investments highlighted in the TAMP.

Priority Level 1: High Priority, Address Immediately

- *Pavements*—Annually track, monitor, and identify road segments that have been in poor condition for more than 5 years, and consistently consider them when programming.
- *Deep Stormwater Tunnels*—Address the repairs needed on the existing South I-35W tunnel system.
- *Deep Stormwater Tunnels*—Investigate the likelihood and impact of deep stormwater tunnel system failure.
- *Highway Culverts*—Develop a thorough methodology for monitoring highway culvert performance.
- *Overhead Sign Structures and High-Mast Light Tower Structures*—Develop and adequately communicate construction specifications for overhead sign structures and high-mast light tower structures.
- *Overhead Sign Structures and High-Mast Light Tower Structures*—Track overhead sign structures and high-mast light tower structures in a Transportation Asset Management System (TAMS).

Priority Level 2: Address Based on Established Priorities

- *Pavements*—Collect and evaluate performance data on ramps, auxiliary lanes, and frontage road pavements for the highway system in the Twin Cities Metro Area.
- *Bridges*—Augment investment in bridge maintenance modules and develop related measures and tools for reporting and analysis.

- *Highway Culverts*—Include highway culverts in MnDOT's TAMS.
- *Deep Stormwater Tunnels*—Place pressure transducers in deep stormwater tunnels with capacity issues.
- *Deep Stormwater Tunnels*—Incorporate the deep stormwater tunnel system into the bridge inventory.
- *Overhead Sign Structures*—Develop a policy requiring a 5-year inspection frequency for overhead sign structures, as well as related inspection training programs and forms.

Priority Level 3: Revisit When Additional Funding Becomes Available

- *Highway Culverts*—Repair or replace highway culverts in accordance with recommendations from the TAMS.

The Minnesota DOT case study presents a good model for considering asset risks in the development of a TAMP. The use of such an approach was most likely easier in MnDOT than it might be in another state DOT's simply because MnDOT had already progressed along the learning curve on how risks can be incorporated into agency planning and decision making. Nonetheless, the use of internal asset experts and facilitated meetings, along with a data-driven analysis process, were shown to be successful in developing a TAMP that is a national model.

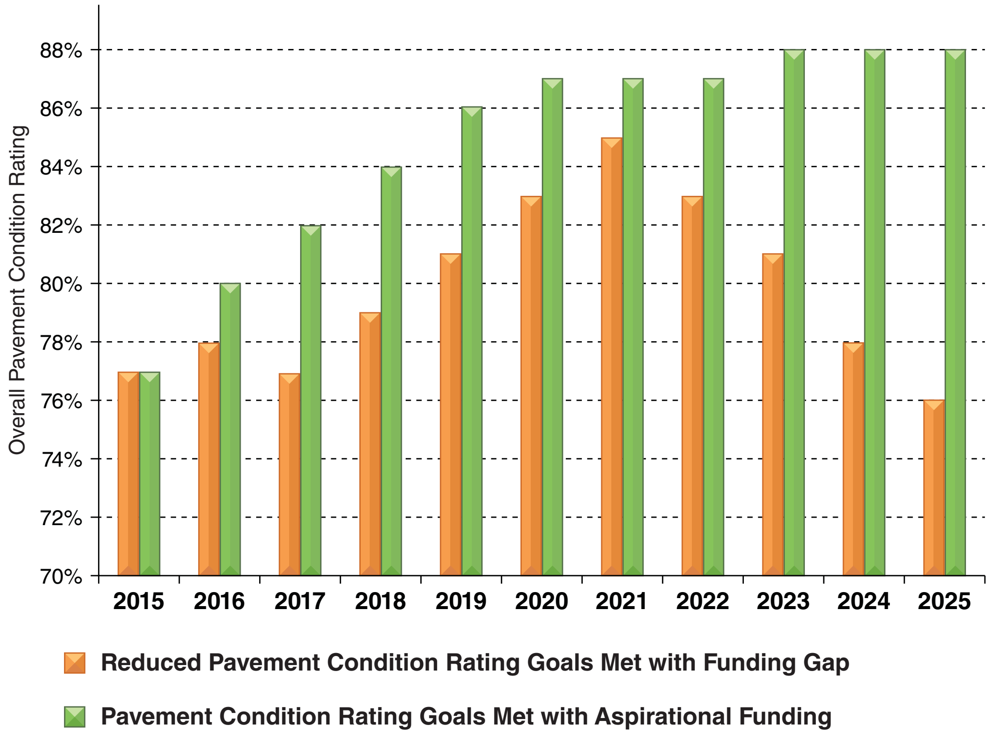
6. Scenario Planning Methods

Scenario planning is used in asset management in two major ways. Primarily, different budget scenarios are assumed for estimating the impact of limited resources on pavement condition. Typical scenarios in this case might be: "Maintain historical levels of pavement restoration/rehabilitation budget levels," "Reduce restoration/rehabilitation budget levels by *x* percent each year," or "Increase restoration/rehabilitation budget levels by *y* percent each year." Figures 8-11 and 8-12 show what the results of a scenario analysis might look like. In Figure 8-12, the following two financial scenarios were assumed. [FHWA, 2015]

Scenario 1—Bridge the Gap with Increased Funding

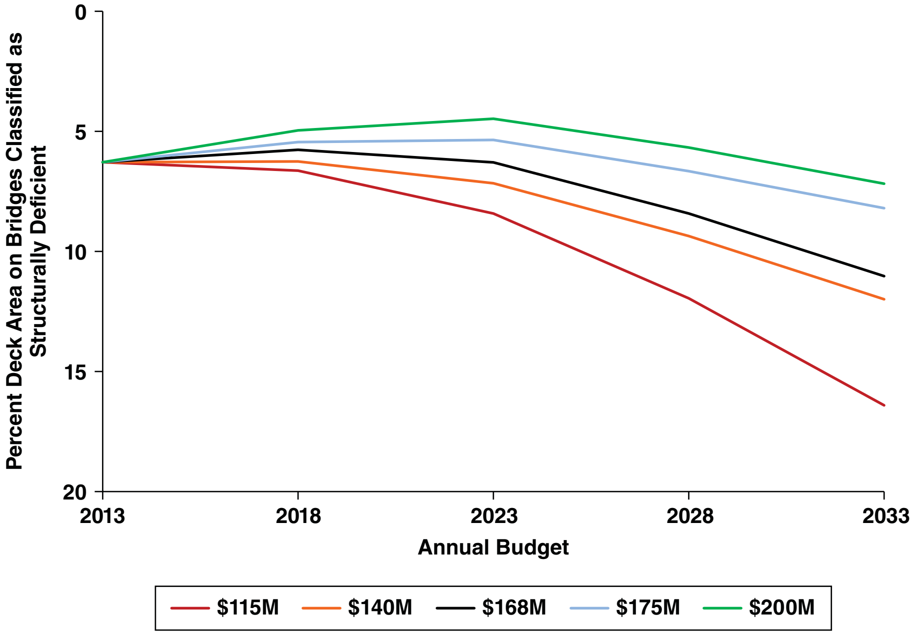
Scenario 2—Targets Reduced to Align Uses with Projected Funding

Figure 8-11. Illustrative Example of Percent Pavement Condition Rating with Two Assumed Levels of Investment



Source: FHWA, 2015

Figure 8-12. Impact on Bridge Condition with Varying Budget Levels, Colorado DOT



Source: Colorado DOT, 2013

Examples of risk treatment in asset management can also be seen in the use of scenario methodologies to address uncertainties in the visioning stage of planning (for example, Cape Cod and Portland). [Zegras et al., 2004] Systematic consideration of several plausible scenarios in planning allows the agency to address possible variation in the dominant factors influencing planning outcomes (such as actual versus forecasted growth, or the impacts of different policies on congestion, air quality and economic development, among others).

Scenario planning is particularly useful when planning for capital investments, especially when examining the impact of plan alternatives in an uncertain future. Rather than forecasting conditions given certain assumptions about the future, plausible future scenarios are considered, and the robustness of decisions under these scenarios is evaluated. The scenario approach enables planning agencies to assess the added value that could be derived from various types of planned investments and to use these as inputs in selecting the final recommended plan. Clearly, the extent of new infrastructure added to an area's transportation network will affect the necessary budget to support the transportation system. Thus, the use of scenarios can very clearly be linked to the asset management strategy that should be in place to handle the demands of the existing network as well as those of network additions. [Amekudzi and Meyer, 2006]

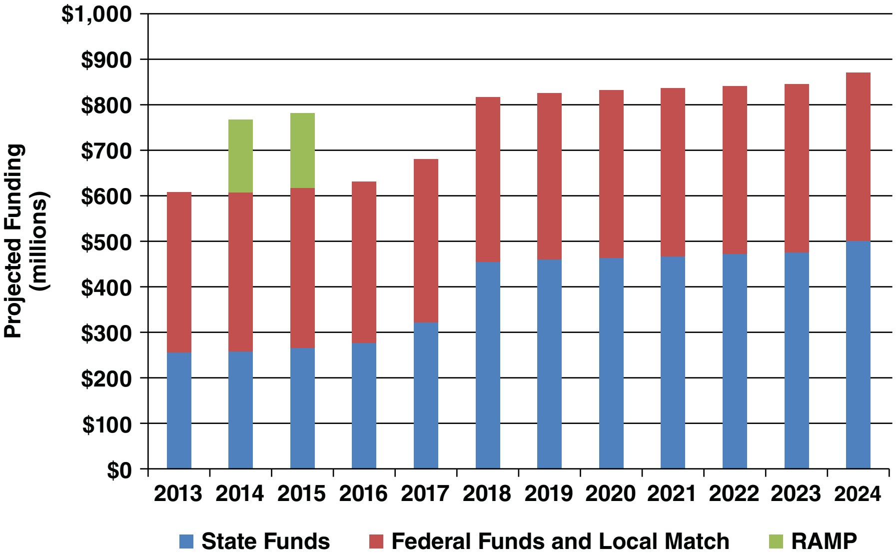
E. Evaluation and Prioritization

The overall level of funding expected by year, and the corresponding level of condition that can be achieved with such funding, are two important products of an asset management program. Figure 8-13 illustrates a typical outcome of an asset management planning process, in this case from the Colorado DOT. These results can provide some indication of the overall program investment that will occur over the next 10 to 15 years. Transportation agencies, however, must still identify specific projects within a given budget, and this means that some form of evaluation and prioritization will be necessary.

Priority programming and optimization methods are used by agencies to evaluate and prioritize improvement alternatives. They may be used at the network or project levels, that is, for planning, priority programming, or project selection. The primary intent of this step in the planning process is to determine which combination of strategies and projects provides the most cost effective approach to investment.

Priority programming methods for maintenance, repair and rehabilitation are fairly well developed and widely used in transportation operating agencies. Such decisions rest with implementing and operating agencies, although funding

Figure 8-13. Projected Funding Potentially Available for Asset Management, Colorado DOT



Note: Responsible Acceleration of Maintenance and Partnerships (RAMP) funding in 2014 and 2015 is a one-time infusion of capital funds resulting from restructuring cash flow in the agency.

Source: Colorado DOT, 2013

requests for certain types of infrastructure preservation strategies are often represented in the transportation plan. Prioritizing for maintenance activities should answer the following questions:

1) What projects or sections of a facility should be maintained, repaired, or rehabilitated (selection of candidates)?

2) How should they be built or maintained (selection of project-specific alternatives or maintenance-treatment alternatives)?

3) When should they be built or maintained (selection of timing)?

Modeling these questions simultaneously, that is, considering and evaluating all possible combinations and trade-offs, is not simple. Consequently, several agencies have models that deal with either of the first two questions. For an investment to be truly optimal, however, all three questions must be evaluated.

Several methods may be used to determine priorities ranging from simple subjective ranking to mathematical optimization techniques. Table 8-9 shows different classes of priority programming methods with their advantages and

Table 8-9. Different Classes of Priority Programming Methods

Class Method	**Advantages and Disadvantages**
Simple subjective ranking of projects based on judgment.	Quick, simple; subject to bias and inconsistency; could be far from optimal.
Ranking based on parameters, such as serviceability, deflection, etc.	Simple and easy to use; could be far from optimal.
Ranking based on parameters with economic analysis.	Reasonably simple; should be closer to optimal.
Optimization by mathematical programming model for year-by-year basis.	Less simple; may be close to optimal; effects of timing not considered.
Near optimization using heuristics and marginal cost-effectiveness.	Reasonably simple; can be used in a microcomputer environment; close to optimal.
Comprehensive optimization by mathematical programming model taking into account the effects.	Most complex; can give optimal program (max. of benefits).

Source: Adapted from Haas, R. and C. Raymond. "Asset Management for Roads and other Infrastructure." Presented at the 8th Annual Fall Asphalt Seminar, Ontario Hot Mix Producers Association, Toronto, Ontario, Canada, December 1, 1999.

disadvantages. [Haas and Raymond, 1999] Priority programming and optimization methods are essentially means of conducting trade-off analysis. Trade-off analysis seeks to move beyond the analysis of alternative treatments and timing of treatments for a single type of infrastructure to a more comprehensive evaluation of the multiple assets for which an agency is responsible. Effective trade-off analysis will help agencies determine the marginal benefits of expending the next additional dollar for a range of assets in order to accomplish various outcomes (for example, capital improvement, preservation, safety improvement, reliability risk reduction and such).

Some efforts have been made to develop more comprehensive asset management systems based on trade-off analysis. Developed through the NCHRP, the Asset Manager Network Tool (AssetManager NT) is designed to assist transportation executives and program managers in understanding how different patterns of investment will affect the overall performance of the transportation network over the long term and the trade-offs that result from different levels of investments in different categories. AssetManager NT enables users to explore systemwide performance implications of different budget levels for selected investment categories that can be defined based on asset types (for example, pavement versus bridge), geographic areas (for example, districts or regions), or system subnetworks (for example, National Highway System, trunk line system, priority truck networks and primary corridors). Assessing trade-offs for competing investments, if incorporated in decision making, will represent a departure from traditional methods of allocating resources for competing needs, particularly across different physical facilities (roadways versus bridges) and functions (for example, capital investment versus preservation).

Not surprisingly, given what was said in the previous section about risk, many of the evaluation and prioritization methods used in asset management incorporate risk assessment in their overall approach. For example, the international scan on asset management found that all of the agencies visited used some form of risk analysis in assigning priorities for investment. Experiences in England, Australia and Canada are described below.

England: Risk Analysis for Project Prioritization. The Department for Transport, England's transportation agency, uses a risk matrix in which project values are assigned a score that relates to the probability of failure associated with a specific component. The higher the likelihood of failure, the greater the attention received in the investment program. Table 8-10 shows the agency's values for calculating the likelihood of risk events.

The likelihood of a risk event is calculated as follows:

$$L(\text{Risk Event}) = L(\text{Cause}) * L(\text{Defect}) * L(\text{Exposure}) * L(\text{Effect})$$

where L stands for likelihood

As an example, suppose that for a particular project, it has been determined that the likelihood of the cause is high (0.85); there is a medium likelihood of the defect occurring (0.50), a low likelihood of exposure (0.15), and a high likelihood of the effect occurring (0.85).

The risk associated with the project is estimated as follows:

$$L(\text{Risk Event}) = 0.85 * 0.50 * 0.15 * 0.85 = 0.054$$

Similar assessments can be made of all projects being considered and ranked according to the level of risk associated with each. This type of analysis can be conducted to identify the projects that pose the highest risk of failure and allocate funds to solve the most serious problems.

Table 8-10. Values for Calculating Likelihood of Risk Events (England)

Likelihood Rating	Description	Range of Likelihood Values	Expected Value
Certain	Certainty	1.0	–
High	Highly Likely	0.7–0.99	0.85
Medium	Likely	0.3–0.69	0.50
Low	Possible, but not likely	0.0–0.29	0.15

Source: FHWA, 2005

Queensland: Risk Analysis for Bridge Prioritization. Queensland, a state in Australia, has developed a program called *Whichbridge*, which assigns a numerical score to each bridge based on the risks attached to the condition of the bridge. Factors considered in this assessment include the condition of bridge components, effect of multiple defective components, significance of members to load-carrying capacity, global and local environmental impacts, component materials, currency of inspection data, obsolete design standards, and traffic volumes. System reports rank structures based on risk exposure and safety considerations using a relative rather than absolute ranking. The risk is determined as a product of the probability of failure and the consequence of failure. Consequence is used as a surrogate for the costs of failure, which relate to things such as human factors, environmental factors, traffic access, economic significance, and industry access consequences. [FHWA, 2005]

Edmonton: Risk Analysis for Asset Prioritization. Edmonton, Alberta, Canada, uses a formal risk assessment process to evaluate the impact of failure for a given component of infrastructure. The first step in the risk analysis is to segment infrastructure assets into logical groupings based on common characteristics. For each segment (for example, one kilometer of road), data are collected describing the inventory, state and condition and the 10-year rehabilitation financial estimates for that asset. The condition of the asset is then categorized using Edmonton's standardized rating system and conditions assessed by reviewing the assets within a given department through a combination of workshops and independent analysis. To examine the state and condition of the city's assets, each asset is rated on the five-point ranking system (very good, good, fair, poor, and very poor) according to its physical condition, demand/capacity, and functionality. Failure is assumed to occur in two ways, either suddenly and unexpectedly, or gradually and expectedly. The approach uses 155 different deterioration curves and probabilities to determine expected failure.

Level of risk is measured using numerous indicators, for example:

- *Portion of an Asset Deemed to Be Critical (Expected to Fail)*—Represented by those assets that have deteriorated past the expected service life and are considered unacceptable.
- *Impact of Failure of an Asset*—Impacts of assessed failure are measured according to the social (health and safety of citizens), environmental (impact on the environment), and economic (cost of failure) indicators, factoring the city's objectives into the decision-making process.
- *Overall Condition*—Categorized by A (very good), B (good), C (fair), D (poor), or E (very poor), using the standardized rating system.
- *Severity*—Reflects the overall likelihood of asset failure, the expected amount of failure and the impact of the failure on the city. An analytical combination of expected assets in critical condition and the impacts of failure of those assets help to analyze infrastructure deterioration levels at a large-scale level. [City of Edmonton, 2015]

Another common approach to risk management is to assign project contingency funds to the cost estimates that are used in transportation plans and programs. These contingencies represent costs for unexpected occurrences during the construction period. A recent development in financial management is the use of shared-risk contingency funds. In the $715-million, 11.9-mile (19.2-km) Hiawatha light rail transit project in Minneapolis/St. Paul, MN, for example, a $5.5-million shared-risk contingency fund was established based on 19 risk items. The contractor was to keep 91 percent of whatever was left in the fund after project completion, thus creating incentives for the contractor to manage risks wisely and ensure that adverse events were minimized.

The use of contingencies in cost estimates can have a substantial effect on the estimation of fiscally constrained budgets that, by federal law, must be part of transportation plans and transportation improvement programs (TIPs). If the contingencies turn out to be insufficient to cover cost overruns, the TIP budget estimate must be adjusted to reallocate funds to the project from other project(s) or delay the project until enough funding is available (see chapter 5 on transportation finance and funding for further discussion on contingencies).

F. Monitoring System Condition and Performance

The final component of a transportation planning process—monitoring system condition and performance—is very much in line with asset management practices. A formal performance monitoring system is an integral component of an effective asset management system because it closes the loop between planning goals and objectives and actual system outcomes, and enables agency officials to regularly adjust or readjust their strategies to achieve desired outcomes.

It also provides a means for identifying unexpected performance gaps and addressing risks proactively rather than reactively. The previous sections have examined the different means of monitoring system performance and condition (for example, infrastructure management systems), and thus this information will not be repeated here.

V. ASSET MANAGEMENT CHALLENGES AND OPPORTUNITIES

As the nation's infrastructure continues to age and new infrastructure is added each year, asset management will likely become even more important in the future than it is today. The following asset management-related topics are likely to be included among what the transportation profession will be focusing on in coming years.

A. Expanding Information Management Capabilities

Most states have some legacy management systems from the ISTEA era that could serve as a foundation for the development of integrated asset management systems. Some state agencies have begun to integrate their data across various business units (for example, Pennsylvania, Michigan, Colorado, Arizona, and Virginia) to develop common platforms that support more comprehensive investment analysis (see, for example, [ADOT, 2006]). Other state agencies (for example, New York and Oregon) have invested in developing improved economic analysis capabilities for alternatives analysis. Both PENNDOT's data integration activities and NYSDOT's economic analysis tools initiatives highlight the potential for modernizing legacy systems to form the basis of an integrated asset management system.

It seems likely that more effective and efficient utilization of data to produce the information needed for decision making will continue to be a major focus of asset management development activities. Monitoring system performance is key for successful asset management efforts.

B. Public-Private Partnerships

Public-private partnerships in infrastructure provision are an increasingly common strategy both internationally and in the United States. These partnerships usually entail private consortia building, operating and maintaining transportation facilities under an agreement with a government agency. The government is still the owner of the facility and will in fact assume responsibility for the facility once the terms of the partnership agreement have been met (anywhere from 40 to 100 years). A comprehensive asset management effort needs to be part of any agreement to deliver good service to users during the life of the contract as well as to ensure that the asset is returned to the owner in good condition.

C. Outsourcing Contracts

Many transportation agencies contract out some portion of their operations and/or maintenance activities for limited time periods. Outsourcing per se is not necessarily asset management, but it uses asset management techniques to the extent that both the owner and the contractor adopt and use such methods. In fact, experience with alternative delivery systems both internationally and in the United States has shown that an asset management system is essential for overseeing the outsourcing of infrastructure services. As more government agencies consider outsourcing some of their operational functions, we will see a corresponding increase in the use of asset management within these agencies.

D. Funding Constraints and Pressures for New Infrastructure Capacity

Despite an overall growth of infrastructure expenditures in several sectors during the past several decades, funding constraints in various agencies are a major driver in the search for improved ways to obtain better levels of service with fewer funds. These constraints are the result of several factors, key among them are rapid urbanization and the resulting growth in demands for infrastructure services, and the need to renew significant portions of infrastructure networks and facilities as they near the end of their useful lives. Rapid urbanization is expected to continue over the next half-century simultaneous with an increasingly older population as life expectancies rise. These factors will further accentuate pressures to provide infrastructure services with fewer resources (given the dwindling tax base) and heighten the need for infrastructure finance reforms. They will also highlight the need for adopting better methods to maximize the effect of limited budgets, namely the adoption of asset management as a fundamental way of doing business.

E. Multimodal Trade-Offs

The transportation profession has been interested in multimodal trade-offs for many years, but there are very few examples where such an assessment actually occurred. However, identifying the most cost-effective alternatives that cut across multiple modes is increasingly important to ensure that the best solutions are found. We can thus expect to see further development of analytical capabilities in this area that evaluate trade-offs and co-benefits among such alternatives fairly confidently. The benefits to be gained are potentially tremendous particularly with respect to Development of Regional Impacts (DRIs) and megaprojects, which are becoming increasingly common—especially in cities with large-scale facilities that are at or nearing the end of their useful lives (for example, the Boston Central Artery Tunnel or New York's subway). We would also expect to see increased flexibility in the mechanisms used to fund such projects, allowing agencies to fund solutions involving multiple modes.

F. Infrastructure Renewal

Significant investments in transportation infrastructure were made over several decades, and a growing number of these assets are coming to the end of their useful lives either because of natural obsolescence or because of growing demands from rapid urbanization outpacing their ability to function effectively. The twenty-first century will thus be marked with the challenge of renewing existing infrastructure, including addressing obsolescence, which is usually under continuing heavy demand. Because of the demands placed on these systems, they cannot be conveniently shut down while they are being rehabilitated, reconstructed or renewed. The asset management approaches discussed in this chapter represent important opportunities to manage the risks associated with the renewal of substantial portions of the overall asset base. In particular, asset management offers a practical platform and business process to consider infrastructure renewal proactively to step up the resiliency of transportation systems to extreme weather events and other hazards.

VI. SUMMARY

The United States has made significant investments in transportation infrastructure during the past 60 years, estimated at more than $1.75 trillion. Large portions of this infrastructure are reaching the end of their useful lives and require renewal. While at the same time, there is a need to expand the capacity of existing transportation systems to accommodate rapidly growing urban populations, and these pressures will continue. Thus, trade-offs between investments for renewal and preservation versus capital expansion will likely be important decisions for the foreseeable future.

Asset management offers organizational resources, planning methodologies, and information technology capabilities to: (1) increase the value obtained from infrastructure expenditures, (2) demonstrate accountability more clearly, and (3) earn increased credibility with elected officials and their constituencies, while (4) achieving a progressively higher quality of infrastructure services for communities. This chapter explained how an asset management paradigm and tool kit can be used to enhance the transportation planning, programming and project development processes. The underlying concept is the efficient use of resources for the systematic delivery of best-value infrastructure for transportation system users, while demonstrating these values to political decision makers and the general public.

Readers are encouraged to check the FHWA website on transportation asset management for the latest information and regulations concerning asset management (https://www.fhwa.dot.gov/asset)

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Road and Highway Planning[1]

I. INTRODUCTION

Systems of interconnected, well-designed, and well-maintained streets and highways are critical to the economic well-being and quality of life of nations and their citizens. Such systems also represent a massive public investment in infrastructure. In 2013, there were 8,656,000 lane-miles of roadway in the United States, with just over 6 million in rural areas and 2.6 million in urban areas (a lane-mile is a one-mile length of one road lane). Although the post–World War II era of massive highway capacity expansion has ended, system growth (largely by rebuilding and expanding existing highways) indeed continues, albeit at a more modest pace. From 2012 to 2013, approximately 4,000 lane-miles of urban interstate highways and approximately 13,000 lane-miles of major urban arterial highways were added to the U.S. highway network. [BTS, 2015]

Most importantly, it is what the highway network enables that is critical to a nation, state, or community. In a study of the economic impact of the highway network in the United States, Shatz et al. [2011] observed that the highway network:

> *Enables producers to reach markets more cheaply, to increase the size of their market area, and to have a broader choice of input suppliers. It can increase the speed with which producers can reach markets or inputs, allowing them to hold lower inventories and carry out just-in-time production. Highway infrastructure can enable workers to choose among a wider array of employment opportunities and to live farther from their workplaces. It can enable consumers to have a more varied choice of goods, services, and prices.*

From a transportation planning perspective, the road network becomes not only a major means of providing mobility and accessibility, in so doing it supports other transportation modes in their use of the roadway right-of-way, such as sidewalks, bicycle lanes, and bus operations, as well as in providing access to transportation terminals and stations. Anecdotally, it seems likely that the vast majority of transportation planning in the United States focuses attention on roads, albeit in a multimodal context. Road and highway planning are an integral part of transportation planning in most countries and thus become an important part of the transportation planner's skills and knowledge base.

Every chapter in this handbook presents some topic that is tied to road and highway planning. Gaining a complete understanding of road and highway planning is difficult without an appreciation for how demographics, land use, travel demand, alternative modes, environmental considerations, stakeholders' concerns, and funding are all essential to the planning process. For example, chapter 10 on network and facility operations, examines how the road network can be better managed, and how new technologies can be applied to provide more productive network operations and more efficient trip-making by travelers. The Highway Trust Fund, discussed in chapter 5 on transportation finance and funding, depends on the motor fuel tax, and with more efficient vehicles and the likely transition to hybrid or electronic vehicles in the future, a major policy question becomes how will improvements to the road network be funded? Chapter 4 on environment and the community discusses many of the negative impacts associated with the construction of the road network and the vehicle operations on it. This chapter cannot possibly cover all of these aspects of road and highway planning. Where appropriate, the text indicates other chapters in the handbook for relevant information.

The next section presents urban roadway principles that should guide roadway and highway planning. It discusses some of the performance and capacity relationships used for determining "need" in highway planning, and this is followed by a discussion of infrastructure condition measures. This is followed by a discussion of context-sensitive solutions (CSS), traffic calming, Green Roads, and Complete Streets, four concepts that many transportation planners are involved in today. Finally, the last two sections present examples of highway system planning leading to a highway investment program.

[1]This chapter was written by Michael D. Meyer, WSP/Parsons Brinckerhoff, Inc.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

II. BEST PRACTICE FOR URBAN ROADWAY SYSTEMS

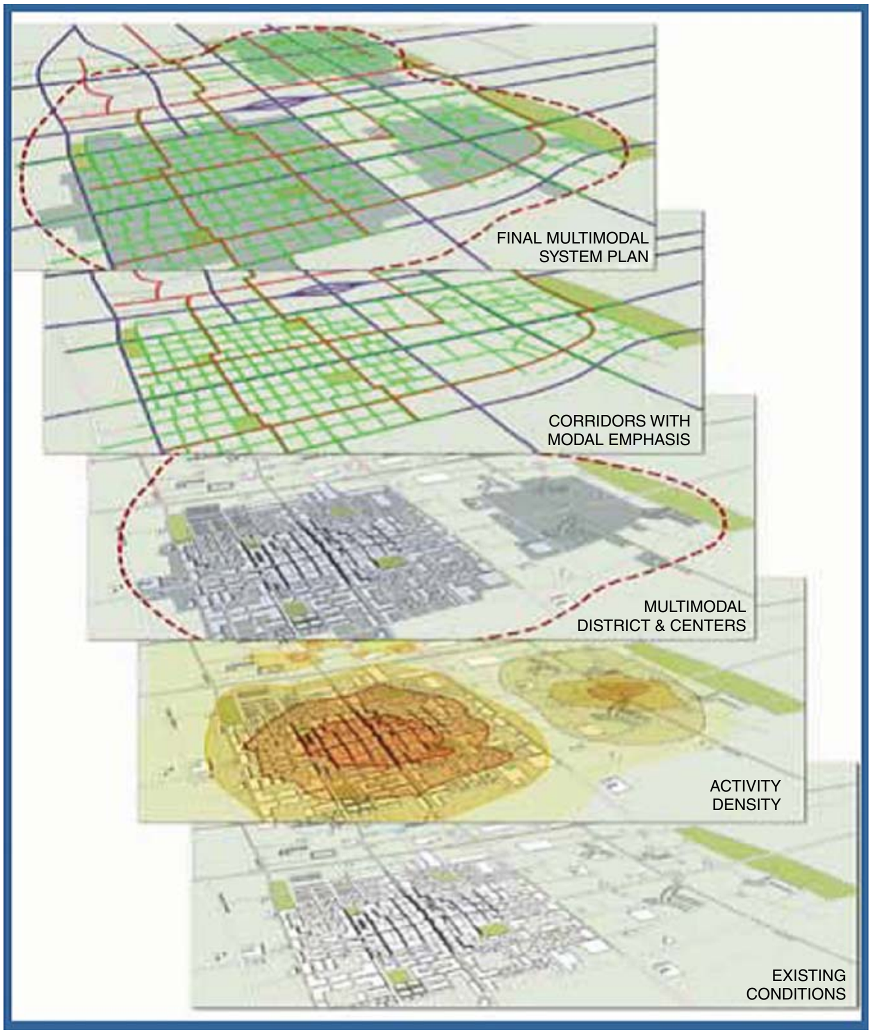
Planning best practice views transportation systems from a multimodal perspective, that is, transportation is a connected system providing modal options to travelers. Figure 9-1 represents this concept well. As shown, the system consists of different networks and activities that together constitute a transportation system. One of these layers is the road network, or in the figure's terms, "corridors with modal emphasis."

The Institute of Transportation Engineers (ITE)'s *Recommended Practice on Planning Urban Roadway Systems* identifies some of the key characteristics of planning an urban roadway network. [ITE, 2011] It is important to note that except for systems in newly developing areas or where new highway systems are being superimposed on existing development, much of the activity in planning urban roadway systems involves modifying existing facilities, or on occasions adding a major new facility. The best practices include:

Urban roadway systems should consist of a multimodal network of streets and highways that serves automobiles, trucks, transit, bicyclists, and pedestrians.

- Define the roadway network to handle traffic volumes safely and efficiently—providing convenient routes around the area for through traffic and routes within the area for traffic moving between major land uses.
- Define vehicular mobility appropriately in dense urban areas where multiple modes of transportation are served, to ensure that the plan will not result in speeds that threaten the safety of pedestrians or have negative environmental and aesthetic impacts from noise. For example, appropriate speeds on streets and highways in

Figure 9-1. Multimodal Transportation Systems



Source: VDOT, 2013

an urban setting should be driven by the functionality, the degree of access control, and the context of the street or highway. A freeway loop around a downtown might work well at 55 miles per hour, but if that same traffic must navigate surface streets, speed limits of 25 miles per hour or less may be more appropriate. The key is to design the physical form of the road (geometry, lane width, etc.) within the context of the road's surroundings.

- Develop the roadway system in such a manner that there are sufficient interconnections and a degree of redundancy, meaning that no single roadway has an overwhelming volume of traffic and most roadways can maintain a smaller scale and therefore provide a multimodal environment for pedestrians, bicyclists, and transit users. For example, transportation planners and urban planners agree that a functional grid, a network with a high degree of interconnectivity, is superior to urban/suburban networks where residential streets are discontinuous.
- Provide reasonably direct access for emergency and service vehicles.
- Arrange parking facilities, vehicular and pedestrian circulation routes, bicycle routes, and buildings to minimize conflicts between nonmotorized and vehicular movements.
- Provide direct routes for truck movements between freight generators and major roadway facilities.
- Provide a system of bicycle facilities and routes. Consider the most likely bicycle users, which may include commuters, students, or recreational bicyclists.
- Integrate transit service efficiently within the roadway network; ensure easy access for pedestrians, cyclists, and motorists accessing bus stops, terminals, or train stations.
- Consider direct connections to activity centers by transit and high-occupancy vehicles (HOV) during the planning stage of freeways to ensure good access by these modes.
- Develop a hierarchy of transit services that includes primary transit access on exclusive bus lanes or HOV lanes, secondary transit access on other major roadways in mixed traffic, and a feeder transit network on collector and local streets.
- Encourage coordination of the full hierarchy of transit services including the integration of public rapid transit with intercity passenger transportation, with suburban commuter railroads and feeder buses, and with park-and-ride facilities. City feeder bus routes should focus on either the central area or on high accessibility corridors.
- Consider traffic management techniques (including HOV and managed lanes, reversible lanes, and congestion pricing strategies) that can be employed to achieve more efficient use of roadway networks during peak hours.

Urban roadway systems should be planned such that individual roads and streets serve different functions within the network (functional classification), serving all modes of passenger and freight/goods movement.

- Balance the roadway system plan to meet the need for all modes of transportation, including private vehicles, commercial vehicles, transit, bicycles, and pedestrians. While each facility will not need to serve every mode, the system as a whole should provide a good level of service for each mode. Some individual roadways may have priority for specific modes.
- Consider the land-use context and urban form in determining the relative importance of each mode on various streets in the network. Areas that are intended to be walkable and transit-oriented should have street networks that will support these modes.

Urban roadway systems should have a high degree of connectivity to help provide multiple routing options for all user groups.

- Move toward a roadway system that includes redundancy in the roadway network to offer more than one direct route between points in the area.
- Identify layered and of necessity, overlapping, networks for pedestrians, bicyclists, transit, autos, and trucks so that each network has an appropriate level of connectivity and redundancy.

- Move toward networks with more frequently spaced roadways, as opposed to sparse networks of wide arterials.
- Consider emergency vehicle access as part of the network planning. Emergency vehicles will often operate more effectively within a dense network, where alternative routes are available in the case of severe accidents or emergency roadway closures.
- Provide direct access to the regional transportation system for industrial sites.
- Avoid having a concentration of vehicular traffic at bottleneck intersections and rely on connectivity improvements to reduce congestion.
- Provide high levels of roadway connectivity to afford more options for local trips and less dependence on arterials for short trips.
- Provide multiple roadway connections throughout neighborhoods to provide alternative routing, improve emergency response times, reduce travel costs for school buses and snowplows/street sweepers, and reduce the demand on the arterial system. Where vehicle connections are hindered by a natural feature or other obstacle, consider at least a pedestrian/bicycle link.

Urban roadway systems should have a network density appropriate to the land-use patterns and urban form that are served.

- Size the roadway network to complement the design and character of the surrounding community.
- Integrate the planned roadway system with the area's land-use plan so that it serves as a total and integrated multimodal system rather than as a series of loosely related roadway improvements.
- Provide high-density, walkable, mixed-use development along major transit corridors to maximize the opportunity for transit.
- Provide a roadway network conducive to pedestrians by planning small block sizes, high roadway connectivity (especially for local streets), and complete sidewalk systems. Pedestrian crossings are safer in a denser network of two- to four-lane roadways as opposed to a sparser network of six-lane roadways.

Urban roadway systems should recognize the role of roadways as public spaces and in shaping urban environments.

- Recognize the multiple roles of major urban roadways in access, place making, and economic development.
- Include an assessment of the context zones within the planning area. Plan the roadway system to be compatible with the appropriate context zones such a modal balance, connectivity, and scale of roadways.
- Plan the transportation facilities to be aesthetically attractive and, to the extent possible, to blend in with or highlight the surroundings and topographic features through which they pass.

Urban roadway systems should be planned with consideration of environmental, social, economic, and financial issues.

- Plan the roadway system to be sufficiently flexible so that it can be adapted over time to meet future challenges in travel patterns not foreseen at the time of the plan's formulation. Examples include preservation of corridor rights of way to facilitate network expansion as growth occurs or designation of flexible roadway cross sections to accommodate dedicated transit lanes or wider sidewalks.
- Plan for a roadway network that minimizes the length of vehicle trips to reduce vehicle miles traveled (VMT).
- Plan the roadway system to encourage development that reduces average trip lengths and is conducive to travel by transit, bicycle, or foot.
- Bring origins and destinations closer together through higher densities and appropriately mixed land use.
- Develop a financing plan over the long term to ensure implementation of the urban roadway system.

- Plan the roadway system to consider the safety of all users and seek to minimize conflicts.
- Plan the roadway system to be within the reasonable financial capabilities of the community.
- Consider incompatibilities in providing major goods movement mobility with other uses. For example, major truck routes should not cross major pedestrian corridors.

The application of these principles in transportation planning is described throughout this handbook such as in chapters that deal with land use; statewide, regional, and local planning; transit; pedestrian and bicycle planning; freight movement; and parking management.

One of the key themes running through these principles is the concept of "context." The relationship between road systems and land use has been a foundation of transportation planning since the very first studies were conducted in the 1950s. This relationship, however, was primarily focused on how many trips would be generated from, and attracted to, land parcels. The trip generation-land-use linkage was simply one of relating land-use characteristics to aggregate trip-making. Road design was based on widely accepted design standards reflecting the design volumes that were forecasted from the planning models. The role the road played in the network was directly related to the expected volumes it was to carry, not the land-use context.

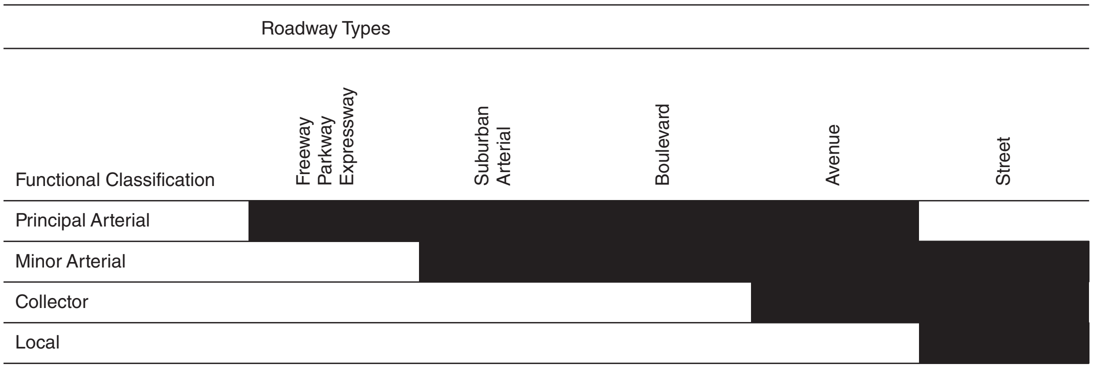
This relationship was the basis for the concept of a functional classification system where roads were classified (and design standards stipulated) for the function and role they played in the network. The most common classification scheme identified arterials, collectors, and local roads as the primary components of a functional classification for network planning (see chapter 2 on travel characteristics and data and [AASHTO, 2011]). However, many communities today have adopted a different approach, one that looks at roads for the role they play in the road network, and how they relate to land use and the urban context. Depending on the community, this typology can include many different road types (as will be seen below, New York City has defined 13). Table 9-1 shows some of the elements of this road typology, and Figure 9-2 shows the relationship to the more traditional functional classification system.

Table 9-1. Roadway Classification Descriptions

Typology	Description
Freeway/Parkway/Expressway	Freeways are high-speed (55+ mph), controlled-access roadways with grade-separated interchanges and no pedestrian access. They include tollways. Expressways and parkways are high- to medium-speed (45 mph) limited-access roadways with some at-grade intersections.
Suburban Arterial	High-speed (40 to 45 mph) divided arterial in suburban environments designed to carry primarily higher-speed, longer-distance traffic and serve large tracts of separated single land uses (e.g., residential subdivisions, shopping centers).
Boulevard	Walkable, low-speed (35 mph or less) divided arterial in urban environments designed to carry both through and local traffic, pedestrians, and bicyclists. Boulevards may be long corridors and be high transit ridership routes. Boulevards are primary goods movement and emergency response routes and use vehicular and pedestrian access management techniques. A multiway boulevard is a variation of a boulevard characterized by a central roadway for through traffic and parallel access lanes accessing abutting property, parking, and pedestrian and bicycle facilities.
Avenue	Walkable, low-speed (35 mph or less) urban arterial or collector roadways, generally shorter in length than boulevards, serving access to abutting land. Avenues serve as primary pedestrian and bicycle routes and may serve local transit routes. Goods movement is typically limited to local routes and deliveries. Avenues may serve commercial or mixed-use sectors and usually provide curb parking.
Street	Walkable, low-speed (25 mph) roadway in urban area, primarily serving abutting property and local traffic. A street is designed to (1) connect residential neighborhoods with each other, (2) connect neighborhoods with commercial and other districts, or (3) connect local streets to major roadways.

Source: ITE, 2011

Figure 9-2. Relationship of Functional Classification to Roadway Types



Source: ITE, 2010

While it is desirable from a pure mobility perspective to have high volumes of through-traffic circumvent an area on a controlled-access arterial, it is not always possible or even feasible. In fact, by far most arterials are surface streets, and therefore the presence and needs of transit, pedestrians, and cyclists must be considered in shaping the physical form even of arterials. Functional classification is one of the factors to drive physical form—the other being context. While streets have many nonvehicular functions, carrying vehicular through-traffic and providing access to adjacent land for vehicular traffic will remain the primary functions of roads and highways.

Figure 3-16 showed one of the more well-known context zone concepts from Andres Duany, one of the leading urbanists in the United States. The "transect" illustrates the idea that road function and design will most likely change as the urban environment changes. These context zones are not only useful for determining the physical form of appropriate transportation solutions, but they help the public understand how urban design and transportation strategies need to be considered together.

This contextual relationship has also been articulated in so-called "smart growth" policies and plans. According to an ITE *Recommended Practice on Smart Growth*, the transportation-related goals for smart growth include:

- Pursuing compact, efficient land-use patterns to maximize transportation efficiency and improve neighborhood environment.
- Providing multimodal mobility within developed areas.
- Providing accessibility within existing built-up areas.
- Making the most efficient use of transportation infrastructure.
- Supporting smart growth through pricing and sustainable funding. [ITE, 2011b]

In addition, the *Recommended Practice* noted that the principles of smart growth include "transportation system efficiency, preservation of transportation resources, maximum effectiveness of transportation investment, reduced urban sprawl, and reduced vehicle pollutant emissions."

Table 9-2 from the *Recommended Practice* shows the relationship between desired smart growth land-use characteristics (and policy decisions) and transportation. As noted, "urban form influences how people choose to travel . . . . pedestrian-friendly, mixed-use communities that emphasize and create environments for walking, bicycling, and transit use can help achieve the balance of modes that many areas seek." [ITE, 2011b]

Public and professional interest in roads that are more sensitive to their surroundings has led to the emergence of new ways of thinking about road planning of which the four most prominent are: context-sensitive solutions (CSS), traffic calming, Green Roads, and Complete Streets.

Table 9-2. Relationship of Land Use and Urban Form to Transportation			
Land-Use Elements Affecting Transportation	**Urban Form Factors Affecting Travel**	**Transportation-Oriented Results**	**Growth Objectives**
Accessibility	Street layout	Reduced VMT	*Financial* Lowers infrastructure costs Maximizes existing investment
Land-use mix	Mixed-use development	Elimination of trips	*Environmental* Improves air quality Reduces sprawl Conserves energy
Compact development	Neighborhood design	Facilitates HOV modes and travel choices	
Job-housing balance	Transit-oriented development	Reduced trip distance	Improves quality of life Contributes to family and community time Improves physical health
Development density	Development density	Reduced travel time	
Population intensity	Population density	Facilitates walking and bicycling	

Source: ITE, 2011b

III. CONTEXT-SENSITIVE SOLUTIONS (CSS)

The FHWA defines context-sensitive solutions (CSS) as "a collaborative, interdisciplinary approach that involves all stakeholders in providing a transportation facility that fits its setting. It is an approach that leads to preserving and enhancing scenic, aesthetic, historic, community, and environmental resources, while improving or maintaining safety, mobility, and infrastructure conditions." [FHWA, 2015a] CSS emphasizes "one size does not fit all" and is dependent upon the context of a community, its supporting infrastructure, as well as the vision of its leaders and stakeholders, community values, historical relationships, culture, financial constraints, environmental justice issues, and even political realities.

Whereas conventional road planning and design relies on traffic demand and level of service (LOS) metrics, CSS identifies critical contextual factors and uses this information to establish a more flexible framework for project development. For example, ITE's *Recommended Practice on Designing Walkable Urban Thoroughfares: A Context Sensitive Approach* uses the concept of context zones and a set of thoroughfare types consistent with the diverse characteristics found within urban areas as a guide to road design. [ITE, 2010] The more traditional functional classification of roads (that is, principal and minor arterials, collectors, and local roads) is tempered by the design criteria relating to thoroughfare types, which in turn reflect contextual factors. Context is defined both by the design of the thoroughfare itself and the adjacent buildings, land-use types, and surrounding district. The collaborative approach toward project planning and design flexibility uses multidisciplinary teams to reach a balance between safety, mobility, community, and environmental goals within the context of transportation goals and community needs.

FHWA [2007] has identified how the CSS process can relate to both transportation planning and project development. Table 9-3 shows those elements common to both and those that relate directly to planning.

A recent ITE *Recommended Practice on the Integration of Safety in the Project Development Process and Beyond: A Context Sensitive Approach* takes what it calls "the logical next step" in the evolution of the CSS process, which is to integrate safety into the project development process. By considering safety consequences as an important and integral part of the overall context, and applying context-sensitive and flexible design principles, the highway designer, safety engineer, planning team, and the general public can make more informed decisions with respect to community benefits. The *Recommended Practice* notes that new safety analysis tools have been developed in recent years providing planners with analysis capability to quantify safety benefits in project development to a level of detail not possible in the past (for example, using the *Highway Safety Manual*). The *Recommended Practice* provides information on how to use these tools and illustrates best practice applications. The intent is to achieve quantifiable safety impacts, similar to what has been done in the areas of traffic operations, economics, cost estimation, and environmental impacts (see chapter 23 on incorporating safety into the transportation planning process).

Table 9-3. The CSS Process and its Relationship to Transportation Planning and Project Development	
Transportation Planning	**Project Development**
Communication	
Communication with all stakeholders is open, honest, early, and continuous.	Communication with all stakeholders is open, honest, early, and continuous.
A full range of user-friendly tools for communicating transportation plan options are used to effectively present information and proactively solicit feedback.	A full range of tools for communication about project alternatives is used (for example, visualization).
Representative Disciplines	
The multidisciplinary team(s) is (are) fully representative of the human and natural environment as well as the communities' perspectives of a good quality of life and important issues.	A multidisciplinary team is established early, with disciplines based on the needs of the specific project, and with the inclusion of the public.
Consideration of Community and Natural Resources	
The landscape, community, and valued resources are understood before analysis of the transportation system begins or potential transportation solutions are explored.	The landscape, the community, and valued resources are understood before engineering design is started.
Process	
The transportation plan includes an upfront preplanning process that allows all formal partners, including, but not limited to, environmental agencies and community representatives, to participate in the early identification of issues that should be considered during the transportation planning process.	A full range of stakeholders is involved with transportation officials in the scoping phase. The purposes of the project are clearly defined, and consensus on the scope is forged before proceeding.
Evaluation	
The transportation plan evaluates multimodal, operational, and innovative strategies, and the recommended plan addresses all transportation needs, including, but not limited to, safety, access/mobility, and air-quality issues.	The highway development process is tailored to meet the circumstances. This process should examine multiple alternatives that will result in a consensus of approach methods.
Treatment of Context-Sensitive Solutions (CSS)	
The adopted transportation plan is a clear reflection of contextual factors and includes explicit support for CSS in all follow-on project development phases.	A commitment to the process from top agency officials and local leaders is secured.
Public Involvement	
The transportation planning process is based on a comprehensive public involvement/ participation plan that is based on meaningful opportunities for input.	The public involvement process, which includes informal meetings, is tailored to the project.
Communication Strategy	
A full range of user-friendly tools for communicating transportation plan options are used to effectively present information.	A full range of tools for communication about project alternatives is used (for example, visualization).

Source: Amended from FHWA, 2007

Readers are referred to ITE's context-sensitive website (http://ite.org/css), FHWA's website (http://www.fhwa.dot.gov/planning/csstp) and the Context Sensitive Solutions website (http://www.contextsensitivesolutions.org for the most up-to-date information on the latest guidance and research on CSS. Chapter 3 on land use and urban design also discusses CSS from the perspective of land use.

IV. TRAFFIC CALMING

A frequent mindset of traditional highway planners and engineers was that wider and straighter streets promoted safety, and that a minimum of two travel lanes, in addition to two parking lanes, was a reasonable minimum cross section to accommodate traffic in an unimpeded way. The unintended consequences of this approach, particularly on local residential streets, included various combinations of undesirable "cut-through" traffic and higher speeds that threatened vehicular and pedestrian safety. [Lockwood, 1997; Ewing, 1999] Traffic calming is a form of context-sensitive solutions. It is now widely accepted as a way of retrofitting "overdesigned" streets whose vehicular function is primarily to serve local access. Besides slowing vehicle speeds, traffic calming also serves to modify driver behavior.

Typical traffic calming measures include: speed humps, diverters/closures, roundabouts, chokers, and other engineering measures designed to slow vehicle speeds. The city of Chicago's *Tools for Safer Streets* provides a good example of the variety of traffic calming actions a community can consider. [Chicago Department of Transportation, 2013a] The city's guide includes:

Intersections and Corridors

- Marked crosswalks
- In-road "State Law Stop for Pedestrians" signs
- Pedestrian refuge islands
- Signals and beacons
- Accessible pedestrian signals
- Pedestrian countdown timers
- Leading pedestrian intervals
- Lagging left turns
- Road diets
- Speed feedback signs
- Roundabouts

Neighborhood Streets

- Chicanes
- Speed bumps
- Narrow street lanes
- Bumpouts
- Neighborhood traffic roundabouts

It is beyond the scope of this chapter to describe each of these in great detail. Such information is found in other publications and websites (see, for example, ITE, http://www.ite.org/traffic/tcdevices.asp; FHWA, http://safety.fhwa.dot.gov/speedmgt/traffic_calm.cfm; Project for Public Spaces http://www.pps.org/reference/livememtraffic/; and the traffic calming chapter in ITE's *Traffic Engineering Handbook*). [Gulden and De La Garza, 2016] However, to give some sense of the characteristics of traffic calming measures, two are highlighted here—roundabouts and road diets.

Roundabouts are large, raised, circular islands in the middle of intersections primarily aimed at slowing traffic while at the same time making the intersection work more efficiently. The benefits of roundabouts include:

- Creating a steady flow of traffic.
- Reducing conflict points, thus reducing crashes.
- Reducing vehicular speeds, which reduce the severity of crashes.
- Reducing the number of traffic signals required.

- Narrowing entrance streets allows safer pedestrian crossing.
- Providing streetscaping opportunities that enhance aesthetic appeal.
- Designing a sloping ramp around the perimeter of the raised island allows larger vehicle to navigate the intersection without mounting the curb. [PPS, 2015]

A great deal has been written on roundabouts, especially over the past 10 years. The reader is referred to the FHWA website on roundabouts as a good resource for the latest information http://safety.fhwa.dot.gov/intersection/roundabouts.

Road diets reallocate the cross-sectional space (travel lanes and shoulders) by restriping the road to provide more space to bicyclists and pedestrians by reducing the amount of road space for motor vehicles. To some, this is a controversial decision because it often entails removing through travel lanes in order to add space for walking and cycling, and removing left turns from through lanes (quite often with a two-way left turn lane); to others it provides a better context for the road itself and the function it is supposed to serve in the community. The benefits of road diets include:

- Narrowing lanes and widening sidewalks to provide safer walking space for pedestrians.
- Removing through lanes and adding bicycle lanes and turning lanes to provide safer and more convenient riding space to bicyclists and left turns.
- Narrowing street lanes to discourage speeding. [PPS, 2015]

As seen in these points, enhanced safety is one of the major benefits of road diets. A study of 14 road diets in Iowa found a 45 percent reduction in head-on crashes, 30 percent reduction in rear-end crashes, 74 percent reduction in angle/oncoming left-turn crashes, 41 percent reduction in broadside crashes, and 45 percent reduction in sideswipe-same direction crashes. [Stout, 2005] In Seattle, the overall change in crashes at 10 road diet locations ranged from 0 percent to a 60 percent reduction. [Lagerwey, 2005] Although the majority of before-and-after studies show a reduction in crashes, road diets are sometimes difficult to implement, primarily because of drivers who feel the road is becoming more difficult to drive on. Accordingly, implementing road diets requires a very careful and well-thought-out project planning process.

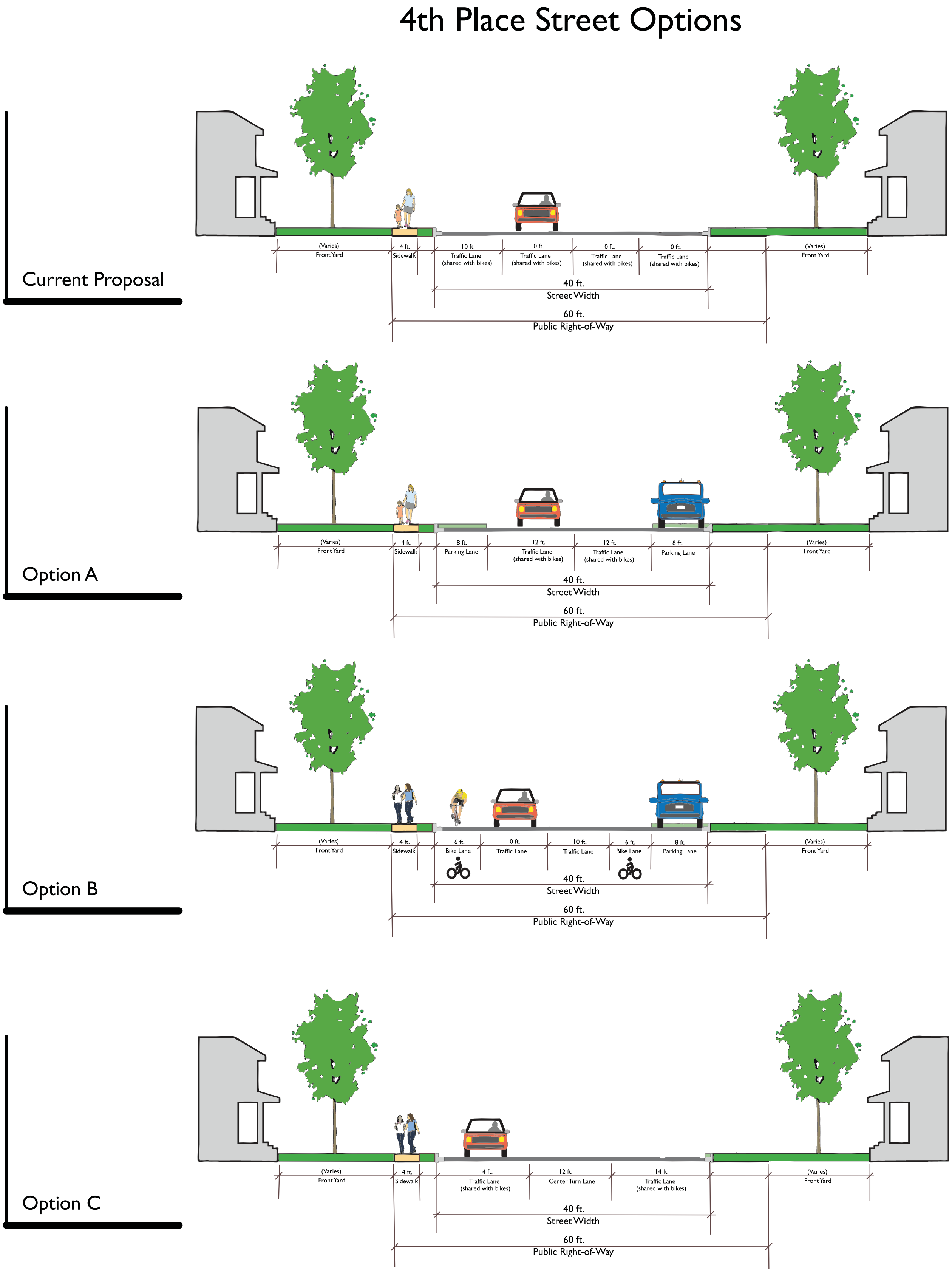
According to Rosales [2007], some guidelines for considering road diets in road planning include:

1) Consider road diet projects when a pavement reconstruction project or jurisdictional roadway transfer and other supporting conditions are present, such as the existences of an adjacent parallel route.
2) Consider community requests to evaluate and implement road diet projects. With technical evaluation and community involvement with stakeholder groups, road diet projects are more likely to be successful.
3) By implementing a road diet as a pilot project study, the effects on safety and operations can be measured before deciding to keep it permanently and/or to fund enhanced design features and a more permanent solution. However, a temporary solution may not provide all of the benefits of a permanent solution (this should be acknowledged and made clear to stakeholders upon implementation).
4) Coordinate with other corridor improvements.
5) Coordinate road diet projects with concurrent pavement overlay projects, if possible. A road diet striping plan on new pavement results in less driver confusion.

Figure 9-3 shows road diet project design options from Tulsa, Oklahoma.

The most up-to-date information on road diets can be found at the FHWA website http://www.fhwa.dot.gov/everydaycounts/edc-3/reconfiguration.cfm.

Figure 9-3. Example of a Road Diet Design, Tulsa, Oklahoma



Source: Courtesy of James Wagner, Indian Nations Council of Governments, Tulsa, Oklahoma

V. GREEN ROADS

As noted in chapter 1 and chapter 7 on evaluation, the concept of sustainability is one of the important societal trends influencing not only the transportation profession, but many other fields as well. With increasing consideration of the triple bottom line (TBL) of economic development, societal equity, and environmental quality (sometimes referred to as the "Three Pillars of Sustainability"), several project sustainability rating systems have been developed to rate individual projects on the degree to which they meet sustainability criteria. Five prominent rating systems in the United States include: FHWA's Infrastructure Voluntary Evaluation Sustainability Tool (INVEST), the Institute for Sustainable Infrastructure's Envision®, the Sustainable Transportation and Access Rating System (STARS), Greenroads™, and GreenLITES. Table 9-4 outlines high-level information on the development and structure of these systems.

Two of these rating systems, INVEST and Envision™, will be briefly discussed below to provide some sense of how they work, particularly in terms of road and highway planning.

Infrastructure Voluntary Evaluation Sustainability Tool (INVEST 1.1). INVEST is a voluntary, self-evaluation rating tool developed by the FHWA to measure the level of sustainability on roadway projects. The tool was developed with input from state and local transportation agency officials and staff, including those from the American Association of State Highway and Transportation Officials (AASHTO) and the American Society of Civil Engineers (ASCE).

INVEST includes three different evaluation systems: (1) system planning, (2) project development, and (3) operations and maintenance. System planning (SP) constitutes 17 potential credits. It is focused on agency-wide practices such as integrating long-range transportation plans (LRTPs) with economic, environmental, and community goals; linking planning with the environmental process; ensuring financial sustainability of the transportation system; and so on. The system planning criteria include:

SP-01: Integrated Planning: Economic Development and Land Use

SP-02: Integrated Planning: Natural Environment

SP-03: Integrated Planning: Social

SP-04: Integrated Planning: Bonus

SP-05: Access & Affordability

SP-06: Safety Planning

SP-07: Multimodal Transportation and Public Health

SP-08: Freight and Goods Movement

SP-09: Travel Demand Management

SP-10: Air Quality

SP-11: Energy and Fuels

SP-12: Financial Sustainability

SP-13: Analysis Methods

SP-14: Transportation Systems Management & Operations

SP-15: Linking Asset Management and Planning

SP-16: Infrastructure Resiliency

SP-17: Linking Planning and NEPA

Table 9-4. Green Project Rating Systems in the United States

System	Sponsor	Scope	Organization	Review/ Certification	Construction-Related Factors
Envision® Version 2.0	Institute for Sustainable Infrastructure	Infrastructure	60 credits in five categories (Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Risk); bonus point opportunity	Stage 1: Self-assessment and Stage 2: Fee-based review	13 credits focused on materials, energy, and water under Resource & Allocation Category
GreenLITES	New York State DOT	Highways	Design/Construction checklist includes 180 criteria, and other modules cover planning through operations and maintenance	Self-assessment	Credits interspersed throughout the checklist; focused within Water Quality, Materials and Resources, and Energy and Atmosphere
Greenroads™	Greenroads Foundation	Highways	11 Project Requirements; 37 Voluntary Credits; focused on design and construction	Fee-based review	8 credits in Construction Activities; 6 credits in Materials and Resources; 5 credits in Pavement Technologies
INVEST 1.1	FHWA	Highways	3 Checklists: System Planning (17 criteria), Project Development (29 criteria), and Operations and Maintenance (14 criteria)	Self-Assessment	Factors within Project Development scorecard include emission reduction, noise mitigation, quality control, warranties, etc.
STARS	North American Sustainable Transportation Council (STC)	Multimodal Transportation	STARS Project: 29 credits organized in 6 categories: Integrated Process, Access, Climate and Energy, Ecological Function, Cost Effectiveness Analysis, and Innovation. STARS Plan: 8 credits STARS Employer Programs: not yet developed	Fee-based review	2 credits in Climate and Energy and 3 credits in Ecological Function

Source: Parsons Brinckerhoff, 2014

As noted by the FHWA, INVEST can be used to evaluate and enhance transportation plans and programs, including:

- Retrospectively evaluating the sustainability of a completed program (or part of a program).
- Proactively setting goals, providing guidance, and measuring the sustainability of a developing program. INVEST can be used as a tool at this point to encourage broad participation, evaluate sustainability trade-offs, communicate benefits and goals, and reward excellence. Users can choose to what extent to measure success against the absolute scale of how many overall points are achieved by a given program or set an achievement level they would like to reach and use this tool to meet those goals.
- Assisting owners, stakeholders, and program teams with understanding new technologies and best practices in sustainability and helping them anticipate new, related requirements that may emerge.
- Estimating the sustainability of a System Planning program (including processes, procedures, policies, and practices) at a statewide, regional, or local level to facilitate the decision-making process. [FHWA, 2015b]

The operations and maintenance (OM) scorecard includes 14 potential credits with a focus on maintenance programs for bridges, pavement, traffic control, and infrastructure, among others. There is one scorecard each for the SP and OM modules. The project development (PD) scorecard includes a potential 29 credits and is focused on project-level sustainability decisions such as multimodal accommodations, life-cycle cost analyses, recycled materials, and construction practices, among others. The PD module includes six scorecard options, which vary based on project context and type (categories include paving, basic rural, basic urban, extended rural, extended urban, and custom).

Envision®. Envision was developed to be a sustainability-rating system for a wide range of infrastructure. According to the Envision website, it "offers a way of assessing the sustainability of infrastructure projects, not simply in individual improvements, but in terms of their overall contribution to the communities they serve." [Institute for Sustainable Development, 2015] Figure 9-4 shows the criteria that can be assigned to individual projects.

Although each project rating system has its unique characteristics, all focus on life cycle analysis, and rewarding project sponsors for making a project more sustainable by targeting project characteristics on the TBL goals.

VI. COMPLETE STREETS

Complete Streets are designed and operated to provide the safest achievable access for all users, including motorists, bicyclists, pedestrians, and transit riders. [ITE, 2010; Los Angeles County Metro, 2014] The concept of Complete Streets to some extent evolved from the context-sensitive solutions (CSS) approach to road planning and design, as well as experience in some communities that had adopted a more flexible approach to road design in the early 2000s. In addition, the urban planning profession during this time was championing the idea that streets were public spaces as well as a means for moving vehicles. The best example of this concept is the *Urban Street Design Guide* published by the National Association of City and Transportation Officials. [NACTO, 2013] As noted in the *Guide,* "Growing urban populations will demand that their streets serve not only as corridors for the conveyance of people, goods, and services, but as front yards, parks, playgrounds, and public spaces. Streets must accommodate an ever-expanding set of needs. They must be safe, sustainable, resilient, multimodal, and economically beneficial, all while accommodating traffic."

Similar in concept to context-sensitive solutions, the *Guide* states that street design depends on context, and defines 13 such contexts likely found in urban areas: downtown one-way street, downtown two-way street, downtown thoroughfare, neighborhood main street, neighborhood street, yield street, boulevard, residential boulevard, transit corridor, green alley, commercial alley, residential shared street, and a commercial shared street. Thus, for example, for a transit corridor, the *Guide* recommends:

- Transit corridor retrofits should be coordinated with land-use changes to maximize a corridor's potential for economic growth and transformation.
- A pedestrian-scale environment should be provided.

Figure 9-4. Envision® Sustainability Project Criteria

Credits and Categories

QUALITY OF LIFE
13 Credits

1 PURPOSE

QL1.1 Improve Community Quality of Life
QL1.2 Stimulate Sustainable Growth & Development
QL1.3 Develop Local Skills & Capabilities

2 WELLBEING

QL2.1 Enhance Public Health & Safety
QL2.2 Minimize Noise and Vibration
QL2.3 Minimize Light Pollution
QL2.4 Improve Community Mobility & Access
QL2.5 Encourage Alternative Modes of Transportation
QL2.6 Improve Site Accessibility, Safety, & Wayfinding

3 COMMUNITY

QL3.1 Preserve Historic & Cultural Resources
QL3.2 Preserve Views & Local Character
QL3.3 Enhance Public Space

QL0.0 Innovate or Exceed Credit Requirements

LEADERSHIP
10 Credits

1 COLLABORATION

LD1.1 Provide Effective Leadership & Commitment
LD1.2 Establish A Sustainability Management System
LD1.3 Foster Collaboration & Teamwork
LD1.4 Provide for Stakeholder Involvement

2 MANAGEMENT

LD2.1 Pursue By-Product Synergy Opportunities
LD2.2 Improve Infrastructure Integration

3 PLANNING

LD3.1 Plan For Long-Term Monitoring & Maintenance
LD3.2 Address Conflicting Regulations & Policies
LD3.3 Extend Useful Life

LD0.0 Innovate or Exceed Credit Requirements

RESOURCE ALLOCATION
14 Credits

1 MATERIALS

RA1.1 Reduce Net Embodied Energy
RA1.2 Support Sustainable Procurement Practices
RA1.3 Use Recycled Materials
RA1.4 Use Regional Materials
RA1.5 Divert Waste From Landfills
RA1.6 Reduce Excavated Materials Taken Off Site
RA1.7 Provide For Deconstruction & Recycling

2 ENERGY

RA2.1 Reduce Energy Consumption
RA2.2 Use Renewable Energy
RA2.3 Commission & Monitor Energy Systems

3 WATER

RA3.1 Protect Fresh Water Availability
RA3.2 Reduce Potable Water Consumption
RA3.3 Monitor Water Systems

RA0.0 Innovate or Exceed Credit Requirements

NATURAL WORLD
15 Credits

1 SITING

NW1.1 Preserve Prime Habitat
NW1.2 Protect Wetlands & Surface Water
NW1.3 Preserve Prime Farmland
NW1.4 Avoid Adverse Geology
NW1.5 Preserve Floodplain Functions
NW1.6 Avoid Unsuitable Development on Steep Slopes
NW1.7 Preserve Greenfields

2 LAND+WATER

NW2.1 Manage Stormwater
NW2.2 Reduce Pesticide & Fertilizer Impacts
NW2.3 Prevent Surface & Groundwater Contamination

3 BIODIVERSITY

NW3.1 Preserve Species Biodiversity
NW3.2 Control Invasive Species
NW3.3 Restore Disturbed Soils
NW3.4 Maintain Wetland & Surface Water Functions

NW0.0 Innovate or Exceed Credit Requirements

CLIMATE AND RISK
8 Credits

1 EMISSIONS

CR1.1 Reduce Greenhouse Gas Emissions
CR1.2 Reduce Air Pollutant Emissions

2 RESILIENCE

CR2.1 Assess Climate Threat
CR2.2 Avoid Traps & Vulnerabilities
CR2.3 Prepare For Long-Term Adaptability
CR2.4 Prepare For Short-Term Hazards
CR2.5 Manage Heat Island Effects

CR0.0 Innovate or Exceed Credit Requirements

Source: Institute for Sustainable Development, https://www.sustainableinfrastructure.org/downloads/Envision_Credit_List.pdf

- A raised cycle track on either side of the corridor promotes bicycle and transit use.
- If local transit service is obstructed by double parking and local traffic congestion, a BRT, streetcar, or light rail transit service should be considered if transit ridership supports it.
- Consider the trade-offs between shortening a traffic signal cycle length and providing sufficient time for pedestrians to cross the road.
- Consider off-board fare collection to improve transit speed.
- Design transit stops to reinforce the desired operation of the transit service.

Many state DOTs, MPOs, and cities have adopted Complete Streets principles as part of their planning and design guides. For example,

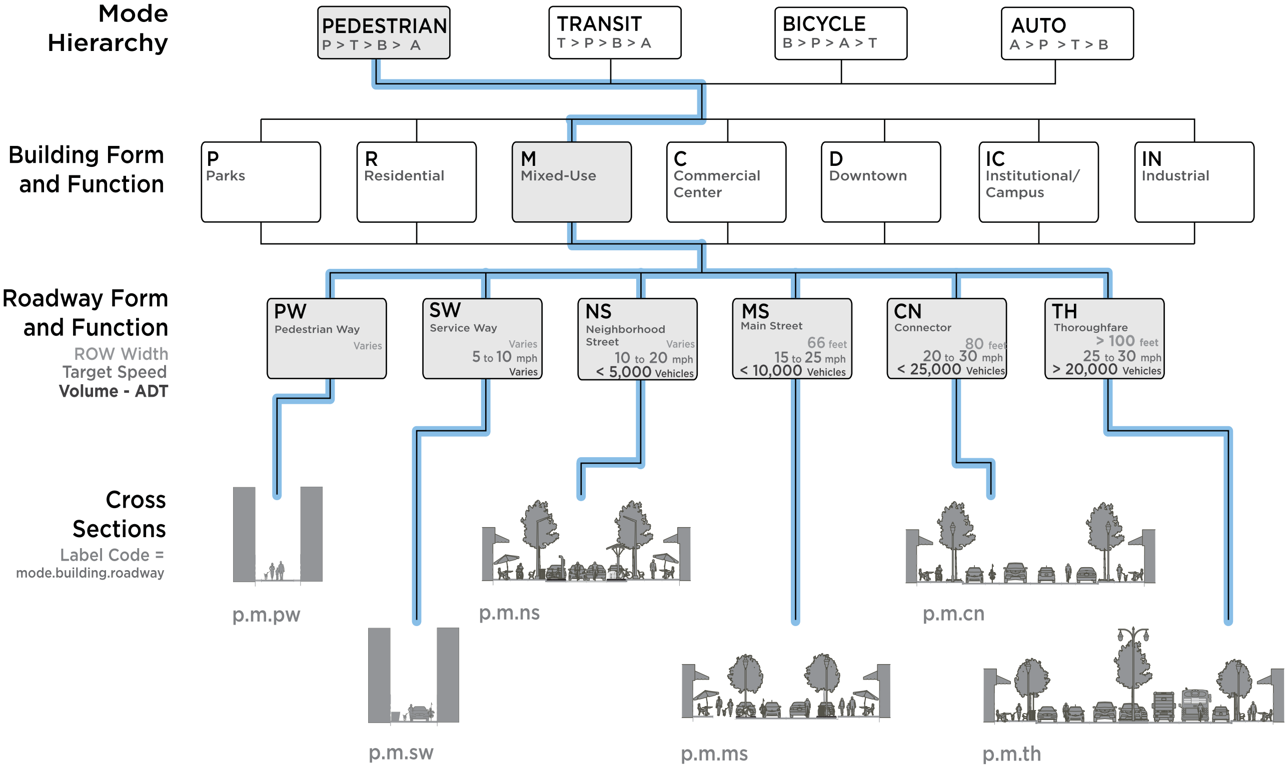
Chicago Department of Transportation [CDOT, 2013]

CDOT has adopted modal hierarchies to inform design and operation decisions. The default hierarchy is: Pedestrian > Transit > Bicycle > Automobile. These hierarchies not only inform street design, but they also provide planners with some sense of what type of road is appropriate in different contexts. For example, one could envision in a downtown transit corridor environment where Transit > Pedestrian > Bicycle > Automobile. On a parkway with no bus service, one might consider an Automobile > Pedestrian > Bicycle > Transit hierarchy. Figure 9-5 shows how many different combinations of mode hierarchy and building form and function could combine to end up with typical cross sections. Target speed in this case refers to the speed range that is desired after the street is constructed.

Minnesota DOT [MnDOT, 2014a]

In implementing its Complete Streets policy, MnDOT realized that road design standards could potentially be one of the key obstacles to flexible design. Accordingly, MnDOT revised its guidance on design elements to provide more flexible design opportunities. The design guidance for the following elements was revised: traveled lane width standards for state highways, bridge width standards for state highways, design speed guidance for state highways,

Figure 9-5. Modal Hierarchies as Part of a Complete Streets Policy, Chicago DOT



Source: Chicago DOT, 2013

superelevation and horizontal alignment design, maximum roadway design grades, vertical clearance requirements for new construction, traveled-way pavement cross slopes, and lateral offset to obstruction.

City of Decatur, Georgia

Decatur was one of the first cities to adopt a Complete Streets philosophy in its comprehensive transportation plan. A new street typology that looked at city streets by land-use context was used to identify key multimodal and economic development opportunities. As in other studies, level of service (LOS) measures were tied to the ability of facilities to handle current and expected demand. However, both the pedestrian and bicycle LOS measures included other factors relating to the quality of the travel experience, such as sidewalk width, pavement condition, and buffers between pedestrians/bicyclists and moving vehicles (a methodology found in the *Highway Capacity Manual* and described in chapter 13 on pedestrian and bicycle planning and chapter19 on site plan review and traffic impact analysis). Latent demand scores were used to account for the demand for bicycle and pedestrian travel to destinations (schools, retail stores, employment centers) that would likely increase with safer and more convenient ways of reaching the destination. Finally, the plan was one of the first in the United States to undergo a Health Impact Assessment (HIA) that examined how development patterns and transportation projects could affect public health. The concept of Complete Streets was one of the recommendations for improving community health.

Complete Streets as a policy or design guide will likely be an important characteristic of future transportation project development. It is important to transportation planners because the context of road development broadens the perspective of road design, feeding into planning concerns for land use, urban design, and sustainability. For updates on Complete Streets see National Complete Streets Coalition, http://www.smartgrowthamerica.org/complete-streets/changing-policy/model-policy.

VII. SYSTEM PERFORMANCE AND CAPACITY MEASURES

A. Traditional Measures

Of all the modes of transportation, roads and highways have been studied the most, and thus have the most well-developed concepts and relationships that define system and facility performance. This body of knowledge has been the basis for many of the manuals and technical guides directing road planning today (see [AASHTO, 2010, 2011, 2014] and [TRB, 2010, 2013, 2015]). Also, in many ways it has been the conflict between desired performance/capacity and community context that has led to the programs and initiatives described in the previous sections.

It is important to begin the discussion of performance and capacity with some understanding of what type of information and/or data are used in road and highway planning and roadway design. The following traffic characteristics are important inputs into the types of decisions that have to be made regarding roadway design and often in determining the priorities among different projects (see chapter 2 on travel characteristics and data provides a more detailed discussion of how traffic data are collected).

Average Daily Traffic—This is the most basic measure of traffic demand for a highway, and is estimated as the total volume during a given time period divided by the number of days in the time period. Although useful as an indicator of roadway use, ADT does not provide any indication of variation in demand by hour, day, week, or season, and is *not* an indicator of congestion.

Peak-Hour Traffic—In order to reflect better the operating conditions of a road or intersection during a day, planners collect information on peak hours and peak periods. Peak-hour counts provide input into performance assessments (when compared to capacity), and when further disaggregated into smaller time units, for example, 10- or 15-minute periods, are important inputs into traffic control strategies. Most highway agencies use the 30^{th} highest hourly volume of the year as the design control for a road.

Directional Distribution—The distribution of traffic by direction is important for road design (e.g., the number of lanes needed) and is used in transportation planning as input into modeled trip distributions and network assignments. For example, this information is a critical part of traffic impact studies (see chapter 19 on site planning and impact analysis).

Vehicle Classification—The vehicle fleet using the road system on a daily basis is quite diverse, especially for goods movement. Two general classes are used to group vehicles by operating characteristics: passenger cars (including automobiles, vans, pick-up trucks, and sport utility vehicles) and trucks (including single-unit and combination trucks, and recreational vehicles). The type of vehicle using a road or entering an intersection will have an effect on performance (for example, the more trucks, the more congestion). See chapter 2 on travel characteristics and data.

Speed—Speed is an important system characteristic to those who use the system. For transportation designers, it is a critical input into geometric design characteristics for roads and intersections. In recent years, the use of design speeds to justify design standards has been critiqued as resulting in unnecessarily wide and fast facilities. Two design concepts that have become of interest to planners and discussed earlier, traffic calming and road diets, are mostly intended to reduce the speed of vehicles on the road.

Vehicle (Person) Miles Traveled—The measure of network use is usually defined as either person or vehicle miles traveled (one person or vehicle traveling one mile). These measures result from travel demand models that predict the number of vehicles or persons using a road network, the trip lengths, and mode choice. VMT is an important variable for estimating motor vehicle-related pollutant emissions as well.

Volume/Capacity—This is a traditional measure that compares current or predicted volumes to the capacity of a facility to handle traffic. The closer this ratio gets to 1.0 (and in many modeling efforts, the ratio is much greater than 1.0), the more congested the road segment.

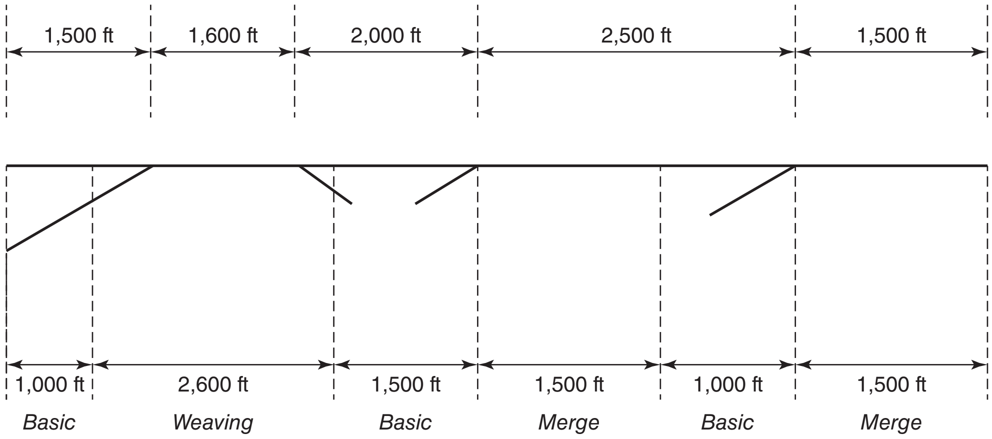
The Transportation Research Board's *Highway Capacity Manual* is the most widely used reference in determining the performance of existing roads and intersections, and for providing input into estimating future performance. [TRB, 2010] The *Manual* examines the performance characteristics of individual components of the highway network, with the logic being that the performance of the overall facility will vary dramatically depending on how each component operates. For example, freeway segments are different from intersections, which are different from an urban street, and so on. The *Manual's* procedures determine service measures that describe the performance of each system component. Table 9-5 shows the service measures that can be used for different facilities and system components. For example, signalized intersection performance can be assessed using vehicle delay (seconds/vehicle),

Table 9-5. Service Measures by System Element

System Element	Service Measures: Auto	Pedestrian	Bicycle	Transit	Systems Analysis
Freeway facility	Density	-	-	-	Speed
Basic freeway segment	Density	-	-	-	Speed
Freeway weaving segment	Density	-	-	-	Speed
Freeway merge/diverge segment	Density	-	-	-	Speed
Multilane highway	Density	-	LOS Score	-	Speed
Two-lane highway	% time spent following	-	LOS Score	-	Speed
Urban street facility	Speed	LOS Score	LOS Score	LOS Score	Speed
Urban street segment	Speed	LOS Score	LOS Score	LOS Score	Speed
Signalized intersection	Delay	LOS Score	LOS Score	-	Delay
Two-way stop	Delay	Delay	-	-	Delay
All-way stop	Delay	-	-	-	Delay
Roundabout	Delay	-	-	-	Delay
Interchange ramp terminal	Delay	-	-	-	Delay
Off-street pedestrian-bike facility	-	Space Bike/Ped Meeting Events	LOS Score	-	Speed

Source: TRB, 2010, Reproduced with permission of the Transportation Research Board.

Figure 9-6. Freeway Segments for Assessment of Performance

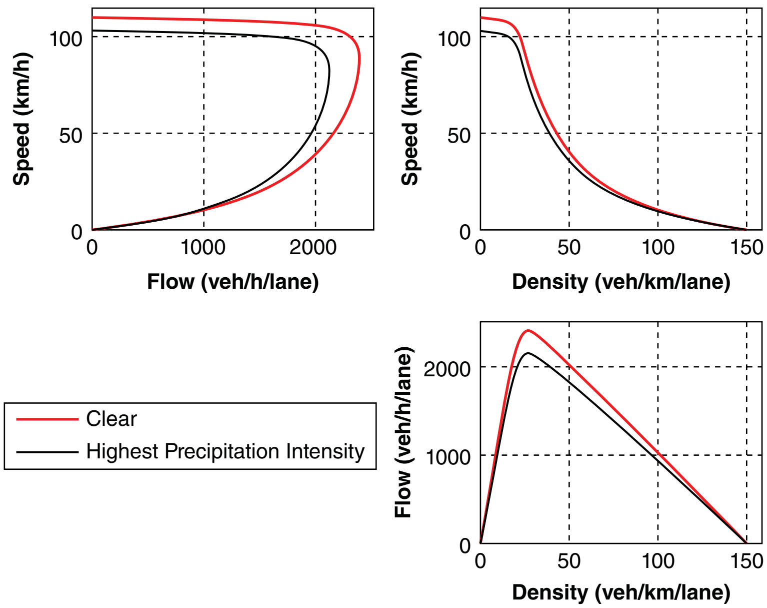


Source: TRB, 2010, Reproduced with permission of the Transportation Research Board.

whereas the assessment of the level of service for pedestrian and bicyclists at the same location would rely on level of service (LOS) scores. Another example is shown in Figure 9-6 where a freeway is divided into three segments—a basic segment and segments relating to weaving and ramp entrances. The methods for estimating performance are different for each segment (with the one having the least performance being the one that controls overall performance of the freeway).

The methods for estimating performance, in most cases defined as level of service, are fairly involved and readers are referred to the source documents for a detailed description of the recommended methods. However, some basic concepts need to be understood to place these methods in context. Figure 9-7 shows the fundamental relationships among traffic flow, density, and speed. These relationships are important because they define traffic-flow regimes where facility capacity is reached, that is, they define critical density (D_{cap}), maximum flow (V_m), and critical speed (S_{cap}). These relationships have been turned into levels of service metrics representing different facility operations levels. Figure 9-8, for example, shows the level-of-service thresholds for a flow versus speed comparison for a freeway. As levels of service progress from LOS A to LOS F, freeway users experience progressively worse conditions. One can see that speeds are quite low in the LOS F region.

Figure 9-7. Relationship among Traffic Flow, Density, Speed, and Impacts of Rain

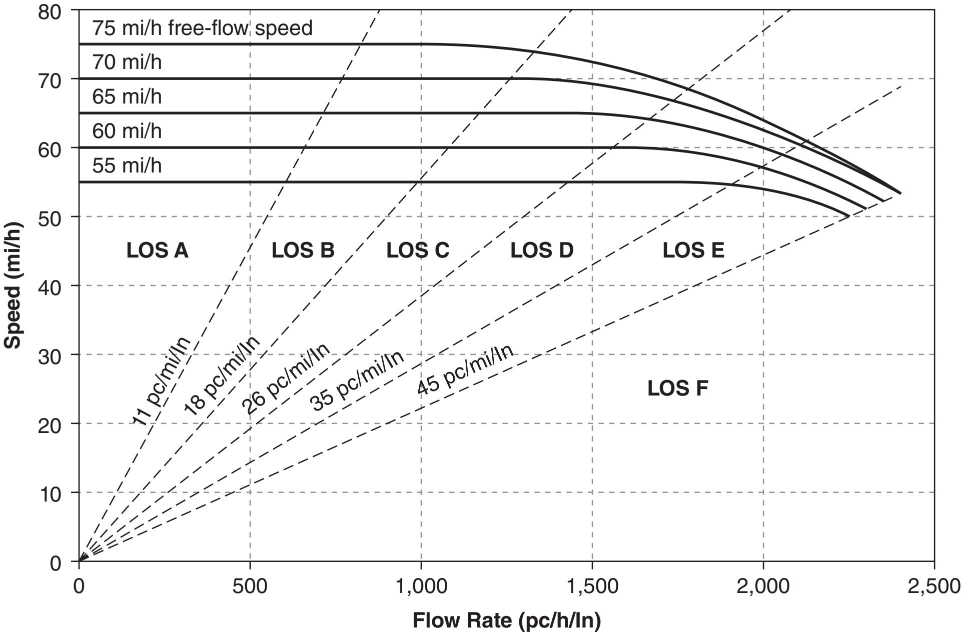


Source: Hranac et al., 2006

Table 9-6 shows the metrics that are used to define levels of service for a freeway. Transportation agencies often define their own threshold levels for determining unacceptable performance. In most cases, LOS E and F are considered to be heavily congested conditions. In more rural areas or smaller communities, the threshold might be higher (that is, LOS C or D) simply because the experience of exposing travelers to any level of congestion is considered to be an unacceptable deterioration of service. Similar concepts of level of service exist for pedestrian walkways and bicycle paths (see chapter 13).

In estimating level of service, most procedures start with an unadjusted estimate of speed assuming there are no factors that might cause speed to decline other than the amount of traffic on the road. In reality, of course, many different

Figure 9-8. Level of Service and Traffic Flow and Speed, Freeways



Source: TRB, 2010, Reproduced with permission of the Transportation Research Board.

Table 9-6. Level of Service for Freeways

Level of Service	Density (passenger cars/mile/lane)
A	≤ 11
B	> 11 – 18
C	> 18 – 26
D	> 26 – 35
E	> 35 – 45
F	> 45

Source: TRB, 2010, Reproduced with permission of the Transportation Research Board.

factors can affect vehicle speeds. Figure 9-9 shows how one starts with an estimated free-flow speed for a freeway, and then adjustments are made based on empirically established reductions in flow rates due to identified factors. For example, for intersections, saturation flow rates are adjusted based on different lane widths, number of heavy trucks in the traffic stream, approach grade, existence of a parking lane and parking activity adjacent to a lane group, local bus blocking potential, lane utilization, area type, left-turning and right-turning vehicles, pedestrians facing left-turning vehicles, and a pedestrian-bicycle adjustment for right-turning vehicles.

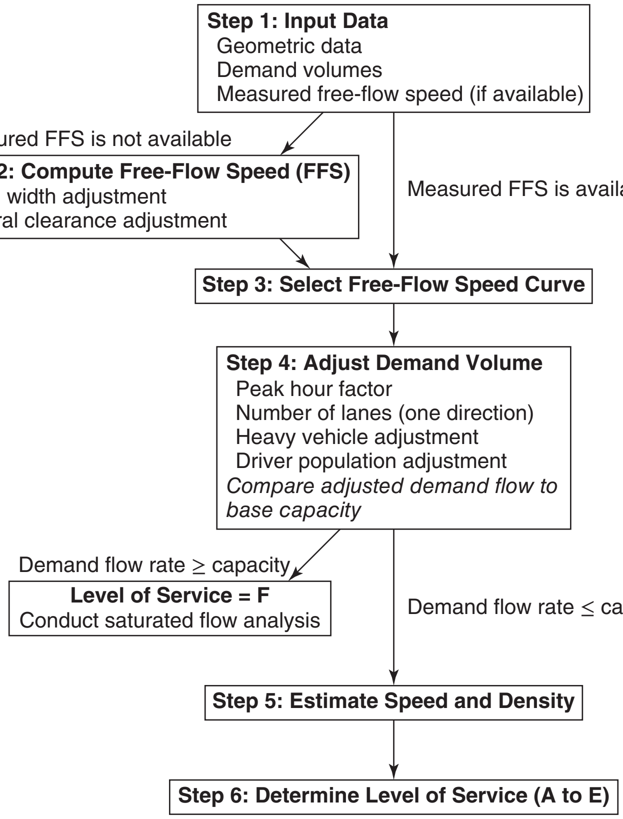
Given the legislative requirement to include performance measures in the transportation planning process in the United States (see chapter 1), transportation planners need to be aware of the latest methods and approaches for determining facility and system performance. For example, current federal legislation requires states and MPOs to report on a series of performance measures for the National Highway System (NHS), as well as condition measures (that will be discussed in the next section). These measures include:

- Performance of the interstate system and the remainder of the NHS
- Fatalities and serious injuries—both number and rate per vehicle mile traveled—on all public roads
- Traffic congestion
- On-road mobile source emissions

B. Multimodal Performance Measures

In keeping with the philosophy of Complete Streets, there has been a growing interest in the profession in defining performance measures that reflect the multimodal performance of a facility. In other words, planners should not just focus on the individual levels of service of a highway or a transit line or a pedestrian/bicycle facility, but rather what is the composite level of service for transportation using the facility? This is more difficult than it sounds. The major reason for this is the fundamentally different performance characteristics of the "vehicle" involved (in quotes because for walking the vehicle is the pedestrian). Attempting to integrate or link the performance of automobile flows with pedestrian flows in a road corridor, for example, raises questions on how the two can be compared fairly, and what type of measure(s) best reflect the experience of *all* users in the transportation corridor?

Figure 9-9. Level of Service Determination for Freeways with Adjustments



Source: TRB, 2010, Reproduced with permission of the Transportation Research Board.

The Florida DOT has developed multimodal planning software for both arterials and freeways that rely on the concepts in the *Highway Capacity Manual* (HCM) as well as the *Transit Capacity and Quality of Service Manual* (TCQSM). For example, ARTPLAN, FDOT's multimodal conceptual planning software for arterial facilities utilizes average travel speed solely as the service measure. [FDOT, 2013] For bicycles and pedestrians, ARTPLAN uses the planning application of the bicycle LOS methodology and the pedestrian methodologies in the HCM. For bus, ARTPLAN uses the conceptual planning application of the TCQSM methodology applied to bus route segments and roadway facilities. The multimodal level of service for a road segment is then presented as the individual LOS estimates for each individual mode—no attempt is made to combine or integrate the different measures. This is very similar to the urban streets multimodal measure of performance proposed in NCHRP Report 616. [Dowling et al., 2008] Other than these two efforts, very little has been done in developing a true multimodal system performance measure.

A recent study on multimodal performance measures at intersections adds caution on which approach is used and how the results are interpreted. Brozen, Black, and Liggett [2014] examined the use of three different approaches to assess the multimodal performance of an intersection: the HCM 2010 level of service analysis, a LOS protocol developed by the city of Charlotte, North Carolina, and a Bicycle Environmental Quality Index (BEQI) and Pedestrian Environmental Quality Index (PEQI) developed by the Department of Public Health in San Francisco. As noted in the paper, for bicycles, "the metrics were in complete disagreement in scoring intersections," and for pedestrians "despite grading on a completely different set of variables, the PEQI intersection grades were still reasonably close to grades assigned by the Charlotte LOS and HCM 2010 LOS approaches." The major differences in outcomes were explained by the different component variables constituting each method. As noted by the authors, the choice of method really depends on the goals of the study, "if the goal is to improve traveler satisfaction across all modes, the HCM 2010 LOS approach would be the best choice; improved safety or geometric design would be better evaluated through the Charlotte LOS approach; and the BEQI includes additional variables such as the availability of bicycle parking and presence of bicycle signage." [Brozen, Black, and Liggett, 2014]

In addition, it is important to note that some communities and the state of California have begun to remove LOS from consideration in traffic impact studies and replace it with VMT as the measure of record. The logic of doing so is that LOS is not conducive to transit and active transportation modes as solutions to mobility problems. It really focuses on reducing local congestion, but ignores the impacts of development-generated travel on the larger network. Given the range of values for each LOS level, even though a development is adding traffic to the network, the LOS might not change (and thus technically little mitigation is necessary). This issue is one that will likely receive more attention in the future.

As of the date of this handbook, the specific performance measures to be use by state DOTs and MPOs in transportation planning as per the U.S. DOT have not yet been chosen. However, it seems likely that the performance measures will clearly relate to the types of service measures described above. On-road mobile emissions, for example, are estimated from network models that produce VMT estimates as well as average vehicle speed. Traffic fatalities and serious injuries are also of great concern to transportation agencies and will be part of every performance measure reporting scheme (see chapter 23 on integrating safety into transportation planning).

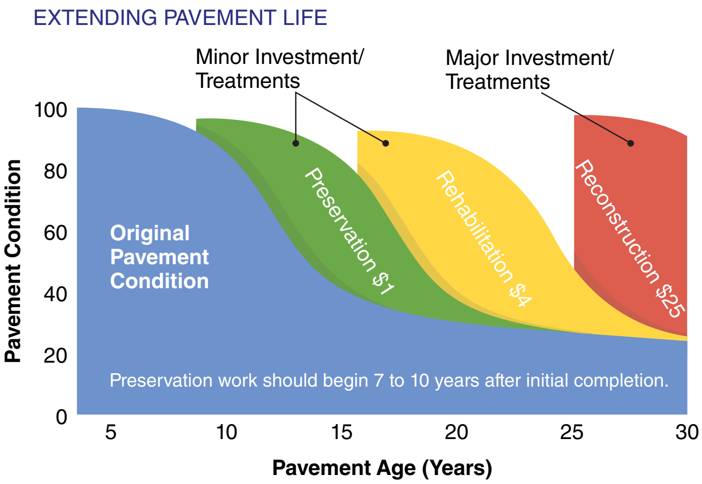
VIII. CONDITION MEASURES AND MANAGEMENT SYSTEMS

As noted above, federal transportation law in the United States requires state DOTs and MPOs to report on the condition of the National Highway System (NHS). Two condition measures were required as part of this legislation: (1) pavement condition on the interstate system and on the remainder of the NHS, and (2) bridge condition on the NHS. Both of these condition measures have been part of state DOTs' system management structure for years. In particular, all state DOTs have management systems capable of monitoring system condition and in most cases forecasting future asset conditions assuming investment levels. The most available management systems include pavement management, bridge management, road or inventory management, maintenance management, and asset management systems. Asset management systems are described in chapter 8 and thus are not repeated here.

A. Pavement Management Systems

A pavement management system is a "set of tools or methods that can assist decision makers in finding cost effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition. It provides the information necessary to make these decisions." [Oregon DOT, 2015a] Figure 9-10 represents the Utah DOT's philosophy on pavement management systems. The basic approach is that by keeping the pavement at a reasonable state of condition through preservation or minor reinvestment, the state DOT can avoid much more costly reconstruction in later years. As noted by the Utah DOT, "regular upkeep to prevent deterioration provides the best value at the lowest life-cycle cost. This preservation philosophy not only provides the best value for physical assets, it also provides additional safety benefits by ensuring that signs are well maintained, pavement striping is visible, and pavement provides adequate friction." [Utah DOT, 2014]

Figure 9-10. Extending Pavement Life, Utah DOT

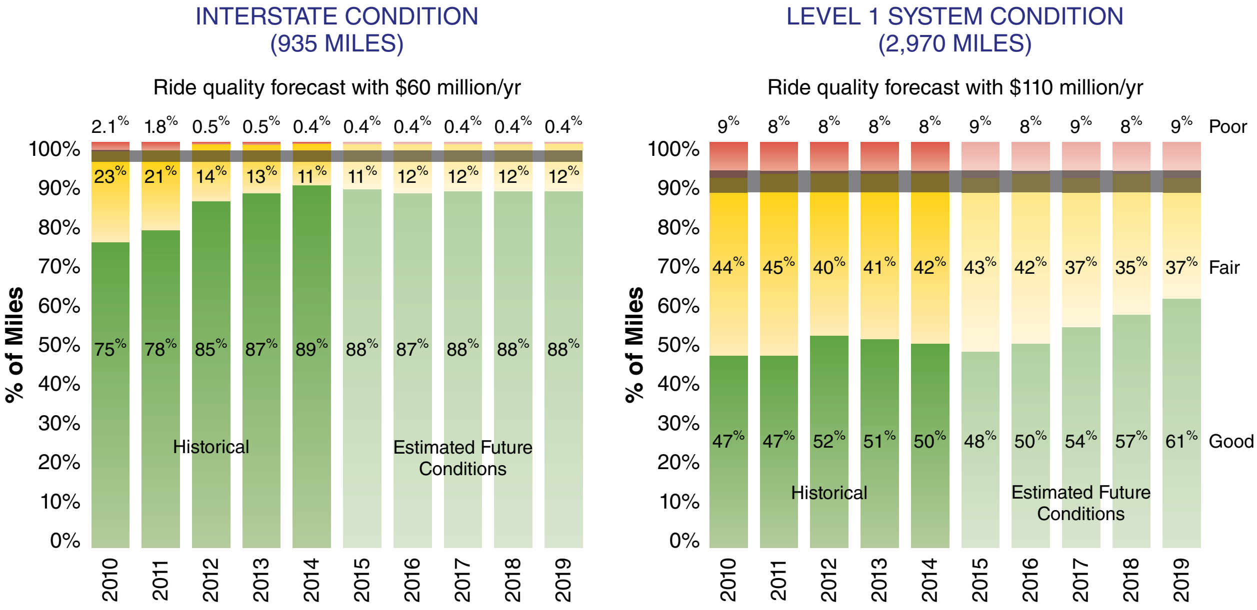


Source: Utah DOT, 2014

UDOT uses distress surveys and modeling techniques to forecast pavement conditions. Forecasting is conducted and reported by type of facility (for example, interstate, national highway system, urban, and rural), material (for example, concrete and asphalt), region, and available budget. Figure 9-11 shows how the pavement management system can be used to forecast future conditions by making assumptions on future traffic growth and the amount of funding available for pavement preservation.

Another example from the Oregon DOT is shown in Table 9-7. The table shows what is considered an "idealized" annual investment in pavement that will allow network pavement condition to reach a steady state. This is done by investing in an appropriate mix of preventive pavement maintenance, preservation, and rehabilitation projects.

Figure 9-11. Estimated Pavement Conditions, Interstate, and Other State Roads, Utah DOT



Source: Utah DOT, 2014

Table 9-7. Idealized Annual Pavement Investment Program, Oregon DOT

Pavement Condition	Activity	Annual Need (lane-miles)	Service Life (years)	Lane-Mile-Years*	Annual Need
Failed	*Reconstruction*				
	Concrete	20	40	800	$45 million
	Asphalt	25	20	500	
Poor	Structural Paving (multilayers)	250	20	5,000	$68 million
Fair	Nonstructural (thin paving)	400	10 to 15	5,000	$70 million
Good/Fair	Chip Seals	650	8	5,200	$17 million
All	Routine & Stop Gap Maintenance	500	2 to 5	1,500	Included in Maintenance Budget
Total					
Reconstruct		45		18,000	$200 million
Paving		650			
Seals		650			

*A lane-mile-year is one year's worth of deterioration for one mile of road lane

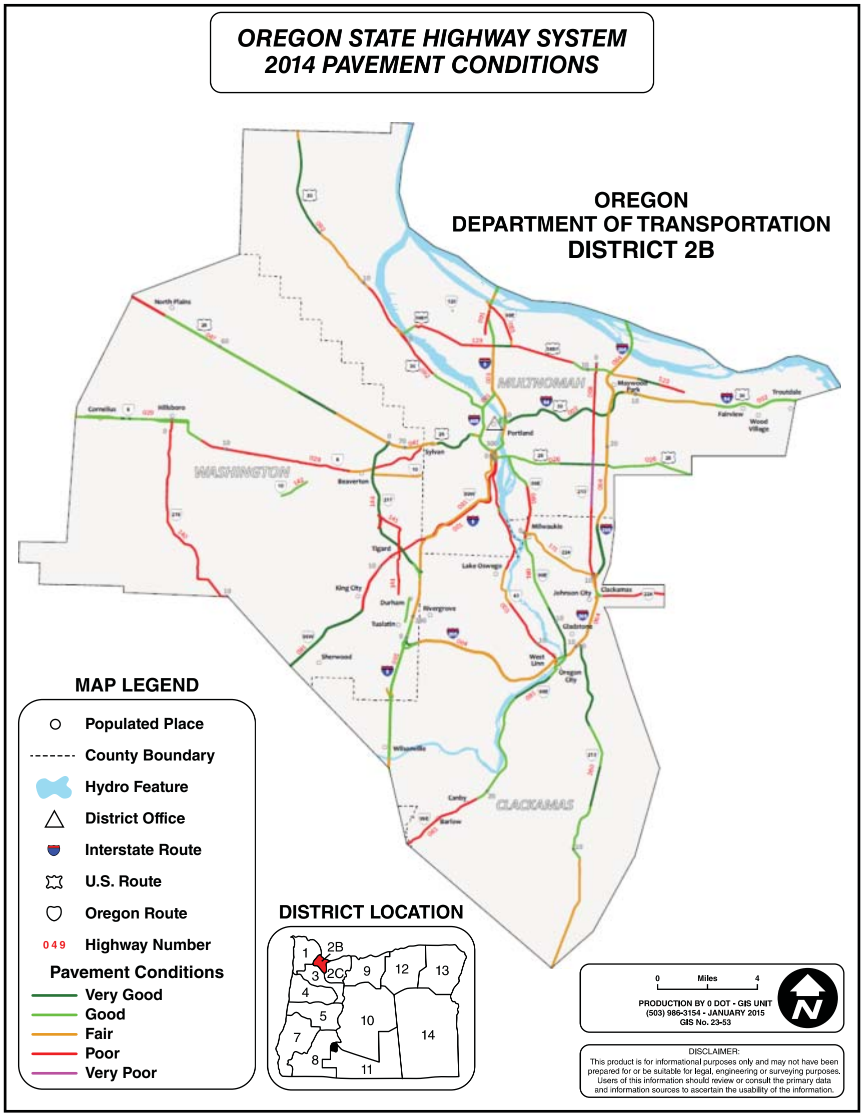
Source: Oregon DOT, 2015b

Annual rehabilitation and resurfacing mileage needs for the state highway network were approximated by pavement type by dividing the number of lane-miles by the typical life span of resurfacing and rehabilitation treatments. In theory, if Oregon DOT can keep up with this treatment cycle, pavement conditions would be in a sustainable "steady state," where each year the roads coming due for treatment would be programmed and there would be no backlog.

Pavement management systems not only provide an overall programmatic sense of investment needs, but they can also indicate where on the state highway system the needs are greatest. For example, Figure 9-12 shows a typical map for the Oregon DOT illustrating current pavement conditions on the state highway system for one district office.

Both the Utah DOT and Oregon DOT examples show how pavement management systems can be used for forecasting future needs with respect to pavement projects in a state or region. The outputs from such systems typically feed into the resource allocation and planning programs of state DOTs.

Figure 9-12. Pavement Condition Map, Oregon DOT



Source: Oregon DOT, 2015b

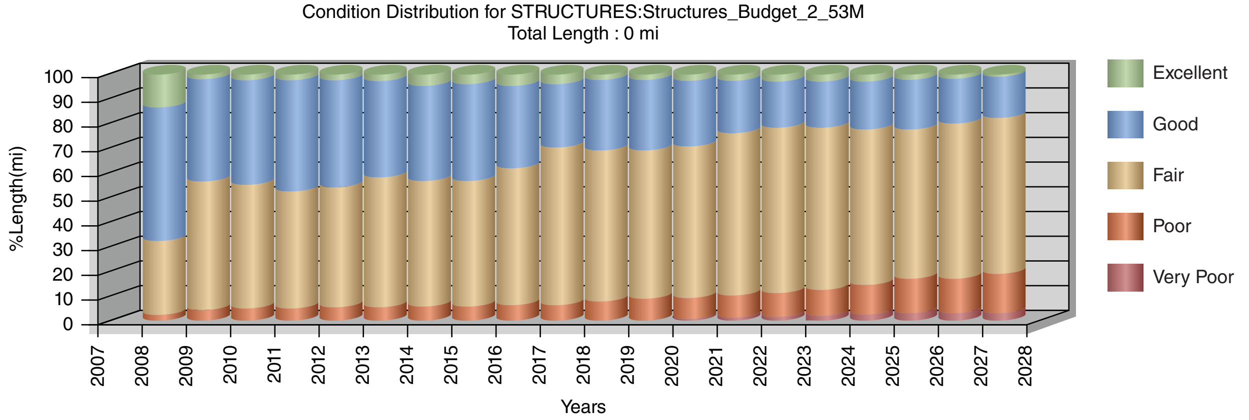
B. Bridge Management Systems

Bridge management systems for states are required by federal law. The outputs of these systems are placed into the National Bridge Inventory, a database supported by the FHWA. [Markow and Hyman, 2009] The key output of these systems is a sufficiency rating, which evaluates highway bridge data by calculating four separate factors, resulting in a numeric value of a bridge's condition to remain in service. The result is denoted in percentages, where 100 percent represents an entirely sufficient bridge and zero percent represents an entirely insufficient or deficient bridge. The input data describe a bridge's structural evaluation, functional obsolescence, and its essentiality to the public. A low sufficiency rating could thus be caused by structural defects, narrow lanes, low vertical clearance, or other possible issues.

Structural evaluation describes an overall rating of the condition of the bridge structure, which is a sum of separately rated conditions of the structural components of the bridge. Scores are given for bridge decks, superstructure, and substructure. The ratings are on a 1 to 9 scale where a 9 means excellent condition and a 1 means imminent failure. Commonly reported conditions include:

Functionally Obsolete—Functionally obsolete means a bridge is no longer by design functionally adequate for its task. Reasons could include not having enough lanes to accommodate traffic flow or having inadequate

Figure 9-13. Use of Bridge Management System to Forecast Future Bridge Conditions, Utah DOT



Source: Utah DOT, 2015b

emergency shoulders. A functionally obsolete bridge may be perfectly safe and structurally sound, but may be the source of traffic jams or may not have a high enough clearance to allow an oversized vehicle.

Structurally Deficient—Structurally deficient means a bridge has one or more structural defects that require attention.

Most state DOTs and many agencies in other countries use a bridge management software called AASHTOWare™, which is a product in AASHTO's BRIDGEWare™ suite of programs (previously referred to as Pontis). The program can be used for bridge inventories, managing inspections, conducting a needs assessment, and supporting project and program development.

Bridge management systems produce information very similar to that produced by pavement management systems. This includes the current condition status of a state's bridges. A bridge deterioration function allows state transportation officials to project into the future and estimate the status of the state's bridges given different levels of investment. Figure 9-13 shows the expected future conditions of bridges in Utah given current expected bridge investment revenues. In this figure, the percent length of bridges (in miles) in various levels of condition are projected to the year 2028 with currently budgeted investments. As shown, percent mileage in excellent or good condition declines over time, while the corresponding mileage in poor or fair condition increases. Similar figures can be created that show the expected improvement in bridge condition if extra investment occurs.

C. Road or Road Inventory Management System

Most states and many city/local government agencies have a road inventory or road management system that provides the base layer for all the other management systems used in the agency. For example, the Pennsylvania DOT (PennDOT) has a roadway management system (RMS) that defines and monitors the state-owned highway network. It represents an inventory of roadway features, conditions and characteristics, and provides decision makers with the information necessary for funding, business planning, project design, and maintenance programming. [PennDOT, 2015] Given that it serves as the geospatial reference for other management systems, there is a location reference system (LRS) tying data to roadway locations. Data stored and managed in the RMS includes roadway geometry information, traffic information, pavement and shoulder history, maintenance history, municipal and legislative boundaries, intersections, roadside features, structure locations, railroad crossings information, pavement testing, condition survey information (including guide rail and drainage features), and posting/bonding information.

As an indication of its importance to the agency, other users of the RMS include PennDOT units responsible for Automated Highway Occupancy Permits, Automated Permit Routing & Analysis, Bridge Management, Crash Recording, Engineering & Construction Management, Maintenance Operations & Resources Information, Multi-modal Project Management, Municipal Services Information Center, and Sign Inventory Management & Ordering.

Another example comes from Massachusetts where a road inventory file contains the spatial coordinates for all public, and a good portion of the private, roadways in Massachusetts. In addition, the file contains roadway attributes

Figure 9-14. Data Input for Maintenance Service Levels, Washington State DOT

Activity Number:	1A3		**Priority Rank**		28
Activity Name:	Shoulder Maintenance				
Survey Period:	Summer		**Detail Level:**		Area/Section
Indicator:	Paved shoulder with deficiencies.				
Outcome Measure:	Percent of paved shoulder area with deficiencies.				
Outcome Unit:	% SF				
Outcome Thresholds	**Service Level**				
	A	**B**	**C**	**D**	**F**
	0 – 2%	2.1% – 4%	4.1% – 8%	8.1% – 15%	> 15%
Comments:	Rolls up shoulder potholes, alligator cracking, longitudinal and transverse cracking, humps and sags, edge ravelling, and edge drop-off.				
Data Source	Field Surveys				

Source: WSDOT, 2014

covering the roadway classification, ownership, physical conditions, traffic volumes, pavement conditions, highway performance monitoring information, and more. [MassDOT 2015] The other layers in the MassDOT's GIS platform include a rail inventory, bicycle inventory, boundaries for the highway districts, interchanges, traffic count locations, rest areas, park and ride lots, toll booths, pipe outfalls, transit parking lots, train stations, freight rail yards, ferry routes, seaports, water taxi stops, airports, and National Highway System (NHS) terminals.

D. Maintenance Management Systems

State DOTs spend considerable dollars maintaining the state road system. In order to develop more productive maintenance programs, many state DOTs have adopted a maintenance management program usually supported with a maintenance management system.

Washington State DOT (WSDOT) provides a good example of a systematic and performance-driven approach to maintenance management. WSDOT developed a maintenance accountability program (MAP) with tools to link strategic planning, the budget, and maintenance service delivery. As noted in the maintenance plan, "the MAP, through its component pieces, provides WSDOT the means to clearly communicate to its key customers, the Legislature, the Governor, the Transportation Commission, and ultimately the tax paying public, the impact of policy and budget decisions on program service delivery." [WSDOT, 2012a]

The MAP uses outcome-based performance measures with a rating scale of A (best) to F (worst) for reporting the level of service provided. A performance measure is made up of a condition indicator (deficiency or condition to be measured), outcome measure (unit of measure), and thresholds for the five service levels for each MAP activity. A threshold is the range of allowable deficiencies or conditions for each service level. Figure 9-14 illustrates the type of data that is collected for each asset and the different gradations in service levels. These data are input into a management system, resulting in the outputs shown in Figure 9-15. This information has been influential in explaining the benefits of a maintenance program to legislators, and to show how a state DOT can be proactive in managing its maintenance program.

IX. STATE HIGHWAY PLANS AND CITY THOROUGHFARE PLANS

Notwithstanding the desire for roadway system planning to be multimodal and emphasizing context as discussed earlier, many transportation agencies develop highway system plans focusing exclusively on highway capital needs. In many cases, these agencies have also developed modal plans for aviation, rail, pedestrian/bicycles, and transit. The primary reasons for developing a highway-oriented plan are: (1) funding categories are often programmatically restricted to single modes, and thus it makes little sense developing a plan with elements that cannot be funded, (2) most transportation modes are very different in character, spatial extent, and overall impact (e.g., transit services

Figure 9-15. Maintenance Accountability Measurement, Washington State DOT

Maintenance Accountability Process
Activity Service Level Targets and Service Levels Delivered
CY 2014 - Statewide

	1.0		1.9	2.0		2.9	3.0		3.9	4.0		4.9	5.0		5.9
Activity	+	A	–	+	B	–	+	C	–	+	D	–	+	F	–
Group - 1 Roadway Maintenance and Operations															
1A1 Pavement Patching, Repair & Crack Seal*	Integrated with Pavement Management reporting - 93.3% of pavement in fair or better condition														
1A3 Shoulder Maintenance								✓	⦿						
1A4 Sweeping and Cleaning		✓⦿													
Group - 2 Drainage Maintenance and Slope Repair															
2A1 Maintain Ditches				✓⦿											
2A2 Maintain Culverts								✓			⦿				
2A3 Maintain Catch Basins and Inlets***	✓				⦿										
2A4 Maintain Stormwater Facilities								⦿							
2A5 Slope Repair		✓⦿													
Group - 3 Roadside and Vegetation Management															
3A1 Litter Pickup											✓⦿				
3A2 Noxious Weed Control				✓			⦿								
3A3 Nuisance Vegetation Control											✓	⦿			
3A4 Control of Vegetation Obstructions								✓⦿							
3A5 Landscape Maintenance											✓⦿				

Source: WSDOT, 2012b

are primarily in urban areas versus a state highway network that covers the entire state), and (3) it is often legislatively required.

This section provides two examples of highway plans—a statewide highway system plan for Minnesota, and a thoroughfare plan developed by the Atlanta Regional Commission (ARC). The approaches and methods used in these studies are very similar to those described in other chapters, especially chapter 6 on travel demand modeling, chapter 10 on network and facility operations planning, chapter 15 on statewide transportation planning, chapter 16 on metropolitan transportation planning, chapter 17 on corridor planning, and chapter 18 on local and activity center planning. These methods and approaches will not be repeated in the following sections. The examples that follow will simply highlight some of the key aspects of each planning study.

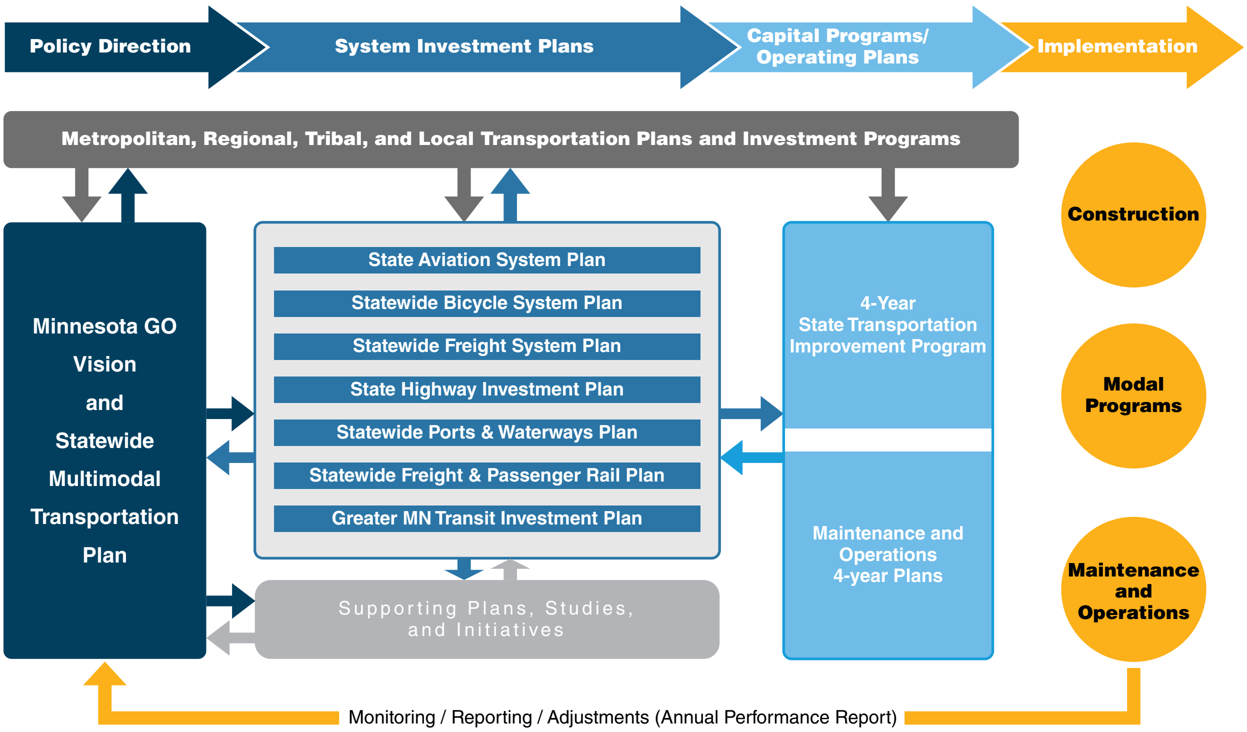
A. Minnesota DOT State Highway Investment Plan

The Minnesota 20-Year State Highway Investment Plan (MnSHIP) is "MnDOT's vehicle for deciding and communicating capital investment priorities for the system for the next 20 years." [MnDOT, 2013] The overall recommended investment budget in the plan was $18 billion (the so-called "constrained" budget), although the needs assessment identified a total of $30 billion in needed projects. MnDOT does have a statewide multimodal transportation plan that lays out the policy principles and guidelines for the modal plans that follow. Thus, the highway systems plan was developed within a multimodal transportation policy context (see chapter 15 on statewide transportation planning). Figure 9-16 shows the relationship among all of the plans prepared by Minnesota DOT.

The highway plan began by noting the trends likely affecting the future use of the state's transportation system, including:

- *An Aging Population*—Over the next 20 years, the peak of the baby boom generation will move past the age of 65. Although many will continue to drive personal vehicles, the frequency and destinations of their travel will likely change.
- *More Minnesotans Living in Urban Settings*—A greater percentage of Minnesota's population is living in urban areas. According to the 2010 U.S. Census, 70 percent of Minnesotans lived in towns and cities, with more than 50 percent of the state's population living in the Twin Cities metropolitan area.

Figure 9-16. Minnesota DOT's Statewide Planning Process



Source: MnDOT, 2013

- *Energy Shifts*—Due in large part to global demand, the price of gasoline in Minnesota has more than doubled since 2002, while the stability of supply and prices has become increasingly erratic. Drivers have adapted by driving less, switching to more efficient vehicles, or using different fuels.
- *Transportation Technology*—Technology for vehicles, traffic signals, transit systems, and other areas of transportation is improving and becoming more integrated. These improvements increase efficiency, improve safety, and reduce emissions.
- *Persistent Budget Challenges*—In the face of transportation funding challenges, MnDOT and its partners are placing more focus on innovative design, shared services, and other collaborative solutions to address and prioritize transportation needs.
- *Health Impacts*—Transportation choices, such as bicycling and walking, bring health benefits and are seeing increased popularity. Along with more Minnesotans living in urban settings, a focus on higher density, mixed-use development and changing travel demand are creating new opportunities to design for and encourage healthier transportation options.
- *Increased Global Competition*—An efficient transportation system enables Minnesota to support a diversified economy that offers the opportunity to compete globally, attract human capital, and maintain innovation and competitiveness.
- *Changing Work Environments, Telecommunications, and Access to Services*—Businesses are taking advantage of options for telecommuting and flexibility in work arrangements for employees.
- *Floods and Water Quality*—Flooding can dramatically damage roads and other transportation facilities, which, in turn, can result in costly detours and delays for users. During the past decade, Minnesota spent an average of almost $2 million a year fixing flood-damaged roads.

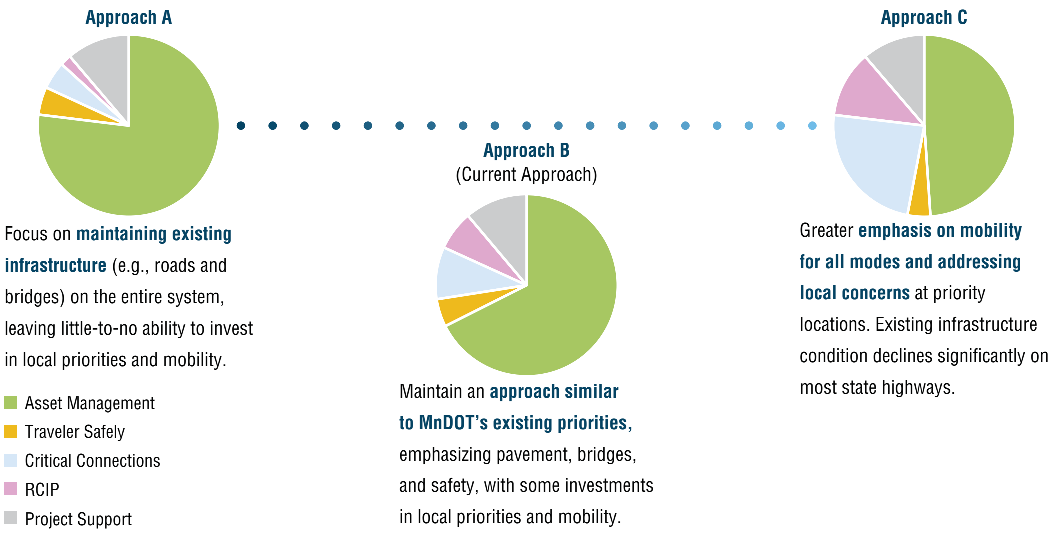
MnDOT identified five investment areas and categories of investment that were central to the plan's recommended investment strategy (see Table 9-8). Note that the asset management category depended primarily on pavement management and bridge management systems inputs.

Table 9-8. Minnesota DOT Investment Areas and Categories

Asset Management	Traveler Safety	Critical Connections	Regional & Community Improvement Priorities	Project Support
• Pavement Condition • Bridge Condition • Roadside Infrastructure Condition	Traveler Safety	• Twin Cities Mobility • Interregional Corridor Mobility • Bicycle Infrastructure • Accessible Pedestrian Infrastructure	Regional and Community Improvement Priorities	Project Support

Source: MnDOT, 2013

Figure 9-17. Scenarios Used in MnDOT's Highway Planning Process



Source: MnDOT, 2013

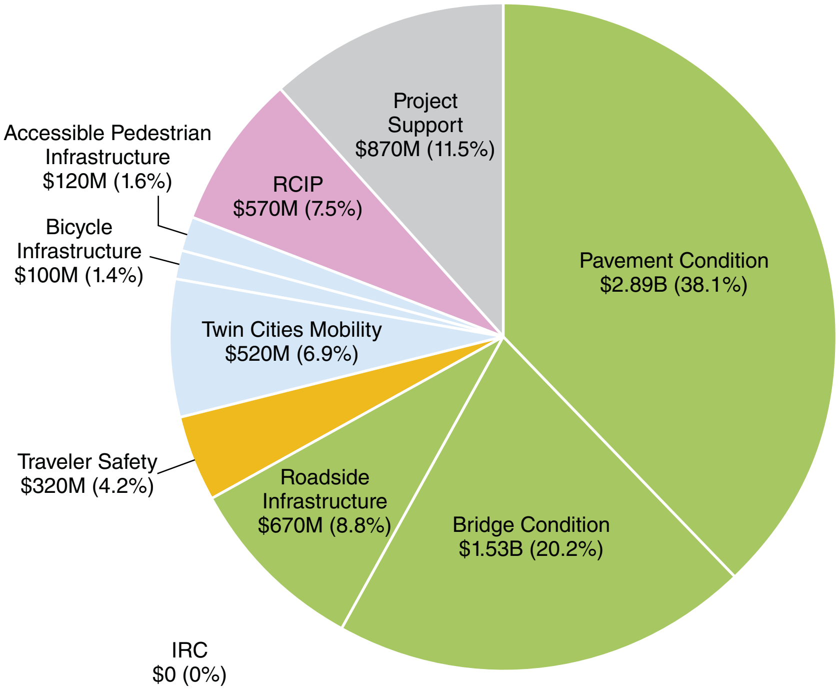
To illustrate the trade-offs associated with different ways of investing the expected $18 billion in the state highway system, MnDOT developed performance levels for each investment category and then packaged different performance levels from each category into three scenarios or "approaches." A two-month public outreach process including nine stakeholder engagement meetings and an online interactive scenario tool, and a one-and-a-half day internal workshop involving key MnDOT staff was used to assess the different scenarios. The online tool enabled participants to select their preferred scenario (Approach A, B, or C) and rank categories for increased or decreased investment. The scenarios used for this analysis are shown in Figure 9-17.

Based on the input from the public and stakeholders, and from its own management systems and other sources of data, MnDOT developed its $18 billion, 20-year plan. Figure 9-18 shows the distribution of the funds for the first 10 years of the plan. Of note in this planning process is the conscious identification of risks to the transportation program and to some of the investment priorities, and the mitigation of those risks by recommended actions in the plan (see Figure 9-19). This plan (and the planning process) is an excellent example of the state-of-practice highway system planning.

B. Atlanta Regional Commission (ARC) Strategic Thoroughfare Plan

The ARC's *Strategic Thoroughfare Plan* was intended to: (1) identify and classify a prioritized roadway component of the Regional Strategic Transportation System, (2) develop guidelines on the management and design of these roadways in relationship to area context and multimodal needs, and (3) create a geo-referenced dataset of roadway attributes,

Figure 9-18. Distribution of Investment Dollars for First 10 Years, Minnesota DOT



Source: MnDOT, 2013

including real-time truck movement data that would establish the overall framework for a future data clearinghouse. [ARC, 2011] The following criteria were used to screen potential thoroughfare candidates:

- *National Highway System designation*—Roadways important to the nation's economy, defense, and mobility.
- *Principal Arterial Designation*—Facilities that carry a large number of trips for long distances.
- *Regional Mobility Corridor Designation*: Corridors that demonstrate regional mobility based on the qualitative analysis. These facilities averaged over 10,000 trips per day (AADT) with an average trip length of 20 miles or more.
- *Regional Truck Route Designation*—Roadway segments designated as Regional Truck Routes on the Atlanta Strategic Truck Route Master Plan.
- *Premium Transit Roadway Alignment*—Roadway facilities identified for premium transit enhancements such as Bus Rapid Transit (BRT), Arterial Rapid Bus, etc.
- *Regional Traffic Operations Program (RTOP) Corridor Designation*—Cross-jurisdictional regional corridors identified by the state DOT for performance monitoring activities and prioritization of operational and maintenance improvements.

Table 9-9 shows the criteria that were then used to identify a more carefully defined set of thoroughfare candidates.

The regional travel demand model, which provided information for many of the mobility performance measures, the regional land-use database, the roadway crash database, the GIS bike/pedestrian network, and the truck route GIS network were used to identify performance measures and targets for the thoroughfare network (for more detail on the data sources used, see [ARC, 2010]). These are shown in Table 9-10.

The final recommended thoroughfare plan is shown in Figure 9-20. Note that the recommendations are organized in different "levels" to reflect the significance of the road to the region's road network.

Figure 9-19. Identification of Risk in Minnesota DOT's State Highway Plan

Key Capital Investment Risks	Mitigated Risk Through Year 10 (of 3 ✓)	Mitigated Risk Through Year 20 (of 3 ✓)
GASB 34: pavement and bridge conditions deteriorate, jeopardizing state bond rating	✓✓	✓
Federal policy: failure to achieve MAP-21 performance targets on NHS reduces funding flexibility	✓✓✓	✓
MnDOT policy: misalignment with Vision and Statewide Multimodal Transportation Plan results in loss of public trust	✓✓	✓
Bridges: deferring bridge investments viewed as an unwise/unsafe strategy	✓✓✓	✓✓
Responsiveness: rigid investment priorities limits ability to support local economic development and quality of life opportunities	✓✓	—
Operations budget: untimely or reduced capital investment leads to unsustainable maintenance costs	✓✓	✓
Public outreach: investment inconsistent with MnSHIP public outreach results in loss of public trust	✓✓	—

✓✓✓	*Adequately mitigated* MnDOT mitigates most or all of the risk through its investment priorities
✓✓	*Partially mitigated* MnDOT mitigates most of the risk through its investment priorities, but must accept some risk
✓ or —	*Unmanaged or inadequately mitigated* MnDOT is unable to mitigate the risk well, and must accept much of the risk or transfer it to another agency

Source: MnDOT, 2013

Table 9-9. Criteria Used to Classify Thoroughfare Candidates, Atlanta Region

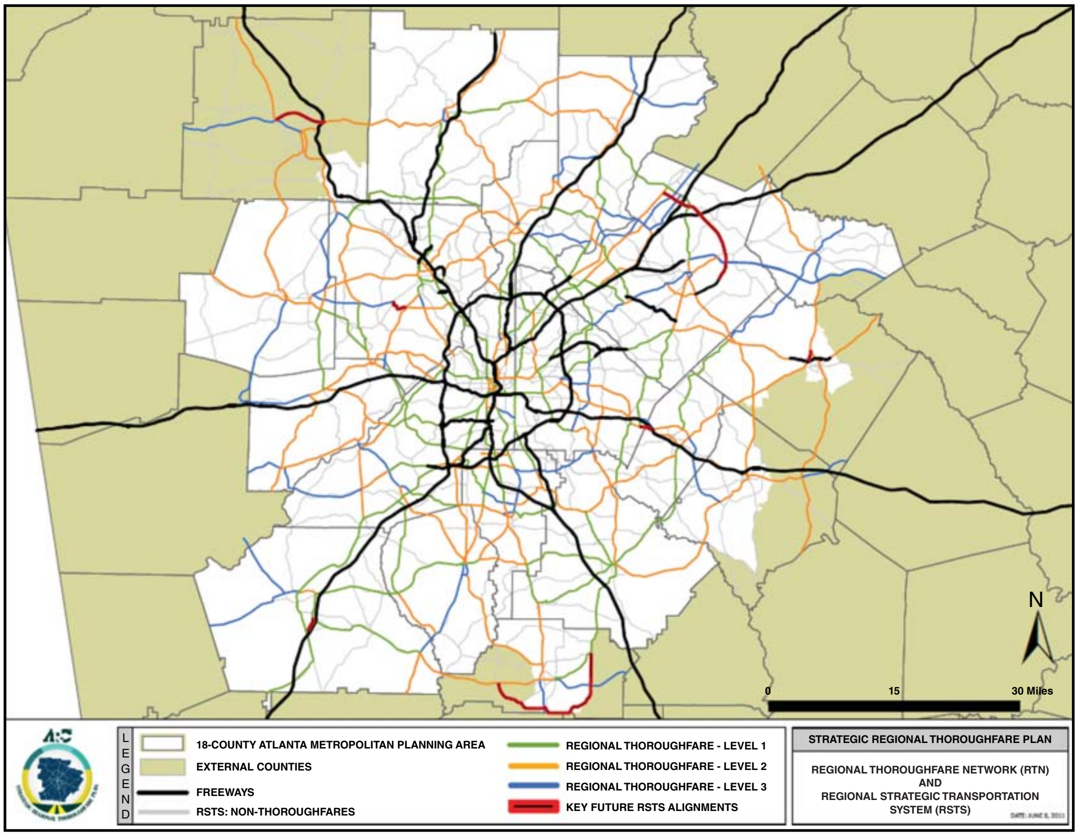
	Mobility of People and Freight	Land-Use Connectivity	Network Connectivity	Multimodal Functionality
Criteria	% of work trips and freight trips	# of regional attractors, regional areas, town centers, and/or industrial logistics areas	Type/Extent of connection	Type of transit served on segment
Level I	High	Primary—Serves 5 or more growth management areas	Freeway-to-freeway or interstate connector routes	High—Premium transit service on segment
Level II	Moderate	Intermediate—Serves 3 to 4 growth management areas	Freeway-to-activity center/town center connector	Moderate—Local transit service on segment
Level III	Low	Basic—Serves 0 to 2 growth management areas	Freeway-to-other limited access or U.S. route connector or other system connector	Basic—Paratransit or no transit on segment

Source: ARC, 2011

Table 9-10. Performance Measures and Network Targets for Thoroughfare Plan, Atlanta Region	
Performance Measure	**Target**
Average speed	> 25 mph
Crashes (all types)	100 crashes cutoff for top 25th percentile
Crashes (all types) per million VMT	Less than 10% of segments with greater than 15 crashes per million VMT
Premium transit within 2 miles of town center	25% of segments
Conventional transit within 2 miles of town center	75% of segments
Bike and pedestrian infrastructure within 2 miles of town centers	15% of segments
Conventional transit within 2 miles of regional center	75% of segments
Premium transit within 2 miles of regional center	25% of segments
Bike and pedestrian infrastructure within 2 miles of regional center	15% of segments
Freight corridor within 2 miles of industrial logistics centers	80% of segments

Source: ARC, 2011

Figure 9-20. Atlanta Region's Proposed Thoroughfare Plan



Source: ARC, 2012

X. ROAD INVESTMENT PROGRAMS AND PERFORMANCE MONITORING

The product of road and highway planning is almost always a capital program that prioritizes road projects over a specified number of years. For state DOTs, this capital program is the primary section of the statewide transportation improvement program (STIP). The STIP presents the prioritized list of road projects for an entire state and often then provides the list for individual DOT districts or regional offices. For city and municipal road planning, the list of projects is included in a capital investment plan or program (CIP). In both the statewide and local case, the list has to be approved by either the agency board of directors or a legislative body, and sometimes by both. Chapter 5 on transportation finance and funding presents more detail on the STIP and other program documents. The reader is referred to this chapter for further information.

Figure 9-21. Minnesota DOT's Monitoring of Progress

Minnesota 2012 Transportation Results Scorecard

● Meeting target | ▲ Moderately off target | ⬣ Seriously off target | — Target | MnDOT Primarily Responsible

Measure	Target	Result	Score	Multi-year Trend	Analysis
ACCOUNTABILITY, TRANSPARENCY & COMMUNICATION					
Public Trust: % of survey respondents agreeing with the statement "MnDOT can be relied upon to deliver Minnesota's transportation system"	Tracking Indicator	88% (2012)	N/A	Stable ('09-'12): 86, 85, 84, 88 (2009–2012); Better ↑	The vast majority of Minnesotans trust MnDOT's ability to deliver the transportation system. This result has been relatively stable over the last four years.
TRAVELER SAFETY					
Minnesota Traffic Fatalities: Total number of fatalities resulting from crashes involving a motor vehicle	350 by 2014	395 (2012)	▲	Improving ('08-'12): 455, 421, 411, 368, 395 (2008–2012); Better ↓	Fatalities resulting from vehicle crashes increased from 368 in 2011 to 395 in 2012. This increase represents a departure from the dramatic decline in recent years.
ASSET MANAGEMENT					
Ride Quality: Share of system with "Poor" ride quality in the travel lane	Inter-states ≤ 2%	2.4% (2012)	▲	Improving toward target ('09-'12): 5.0, 7.0, 3.4, 3.9, 2.4 (2008–2012); Better ↓	Ride quality improved on Interstates, the non-Interstate NHS, and all state highways in 2012. This improvement pushed ride quality on Interstates and the rest of the NHS to within 1 percentage point of statewide targets. Across all state highways, the number of miles of highway with Poor ride quality was comfortably within MnDOT's targeted range of 5-9 percent.
	Other NHS ≤ 4%	4.3% (2012)	▲	Stable and near target ('09-'12): 2.9, 5.0, 3.8, 5.1, 4.3 (2008–2012); Better ↓	**Outlook** — Without new sources of revenue, MnDOT expects ride quality to resume a long-term decline. By 2033, the share of non-Interstate NHS with Poor ride quality is projected to be 11-13%, roughly three times what it is today.
	All state highways 5-9%	5.6% (2012)	●	Meeting target: 4.6, 6.9, 5.2, 6.6, 5.6 (2008–2012); Better ↓	
Bridge Condition: NHS bridges in "Poor" condition as a percent of total NHS bridge deck area	≤ 2%	3.3% (2013)	▲	Stable and near target ('09-'13): 3.5, 3.2, 3.3, 4.7, 3.3 (2009–2013); Better ↓	Bridge condition improved in 2013 after a 2012 uptick in the percent of NHS bridge deck area on Poor condition bridges. This spike occurred when the Blatnik Bridge connecting Duluth and Superior was assigned a Poor rating following a 2011 inspection. MnDOT has since carried out a major rehabilitation that improved the bridge's condition and extended its useful life. **Outlook** — By 2033, the share of NHS bridge deck area in Poor condition is expected to approach the federally established threshold of 10 percent.
STATE HIGHWAY OPERATIONS					
Twin Cities Urban Freeway Congestion: % of metro-area freeway miles below 45 mph in AM or PM peak	Tracking Indicator	21.4% (2012)	N/A	Stable ('10-'12): 17.3, 18.2, 21.5, 21.0, 21.4 (2008–2012); Better ↓	After falling during the recession, the extent of congestion has been near its historic peak each of the last three years. **Outlook** — Congestion is expected to worsen as economic activity increases and the region continues to grow.
Interregional Corridor (IRC) Travel Speed: % of system miles performing more than 2 mph below corridor-level speed targets	≤ 5%	2% (2011)	●	Meeting target: 2.0, 2.0, 2.0, 2.0, 2.0 (2008–2012); Better ↓	98 percent of IRC system miles have performed at or above targeted speed each of the last 10 years. **Outlook** — Result expected to remain stable through 2023.
Snow and Ice Control: Frequency of achieving bare lanes within targeted number of hours	≥ 70%	82% (2012)	●	Meeting target: 68, 79, 79, 88, 82 (2008-9 – 2012-13); Better ↑	MnDOT has achieved its statewide snow and ice control target nine out of the last 10 winter seasons.

Source: MnDOT, 2014b

With today's emphasis on monitoring system performance many jurisdictions have developed a process for monitoring the achievement of transportation plans and programs. In Texas, for example, the legislature requires the Texas DOT to develop a 24-year long-range plan and the DOT must submit an annual report on the progress being made in achieving the plan's goals and targets. [Texas DOT, 2015] Minnesota DOT provides another example of the progress reporting that can occur for a state DOT. As seen in Figure 9-21, the performance measure values over the past five years are presented along with an indication of the trend in those statistics. This information provides state DOT officials with an indication of where extra effort might be necessary to achieve the goals of the plan.

XI. SUMMARY

Roads and highways are the backbone of a transportation system, and thus an important focus of the transportation planning process. Many of today's planning approaches and tools were in fact originally developed for highway planning. Historically, road and highway planning focused on the road itself: Whether and where should it be built? How much and what kind of traffic will it carry? How many lanes and access points should it have? And what are the environmental impacts on the adjacent community and natural resources? Much of the data collected as part of transportation data collection efforts are used by transportation planners in a wide range of multimodal planning applications. In fact, long-range highway planning at a systems level is almost always folded into a multimodal approach that emphasizes the right mix of modal alternatives.

Today, highway planning is evolving to reflect growing concerns for the context within which roads and highways are provided. Context-sensitive solutions, traffic calming, green roads, and Complete Streets policies that consider transit, pedestrian, and bicycle needs along with those of people in cars and goods in trucks exemplify road planning efforts that seek outcomes extending well beyond the movement of motor vehicles on roadways. In addition, with the emphasis on system performance, many of the traditional road performance measures that focus on congestion, delay, and asset condition are now being used as part of broader, multimodal system monitoring programs for states and metropolitan areas.

This chapter described the important role that road and highway planning have in a nation's, state's, or city's transportation system. The context within which roads are planned and designed has become a very important factor in decisions relating to both project plans and design concepts. In particular, the relationship between the urban context and the role of a road has been incorporated into many design guides, especially at the local community level. Principles of roadway systems planning include a concern for such a context and for multimodal integration at the network and site levels. In transportation, more states and cities are adopting a context-sensitive solutions, traffic calming, green roads, and Complete Streets approach to planning and design.

Even though these approaches are more sensitive to the context within which roads are planned, constructed, and operated, most road planning still relies on the performance and capacity measures that have been used for years in the profession. In addition, measures that reflect the condition of pavements, bridges, and other assets provide important input into the transportation investment decision-making process. Finally, the actual planning for roadway systems is very similar to other planning contexts, with an articulation of goals and objectives, the use of traffic and land-use data, the use of travel demand models and other means of forecasting future impacts, and finally a concern for the funding resources that will be necessary to implement the plan.

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Chapter 10

Transportation System Management and Operations[1]

I. INTRODUCTION

Transportation planning and operating the transportation system have historically been two relatively detached sets of activities with different requirements and varied agency responsibilities and cultures. Transportation planning, for example, has traditionally focused on creating the physical infrastructure and services needed to meet future travel demand. There was often very little consideration for short-term and ongoing operational issues. Conversely, the management and operation of the transportation system has typically involved a different set of practitioners often having a short-term or real-time focus on today's system operations, and giving little consideration to how their activities relate to regional transportation system goals and objectives. However, a safe, reliable, and secure transportation system requires more than just providing the highway and transit infrastructure to move people and freight. In the twenty-first century, it also requires efficient and coordinated operations to meet the public's performance expectations and those of elected and appointed decision makers. Transportation system management and operations (TSM&O) is a concept that allows this to happen.

The U.S. federal transportation legislation, Moving Ahead for Progress in the 21st Century Act (MAP-21), defined transportation systems management and operations (TSM&O) as "integrated strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services and projects." The most recent version of the Federal Highway Administration's (FHWA's) *Freeway Management and Operations Handbook* defines TSM&O as "a set of strategies to anticipate and manage traffic congestion, and minimize the other unpredictable causes of service disruption, delay, and crashes." [Noblis et al, 2015] For purposes of this chapter, the term "TSM&O" will be used as an overarching strategy or program of strategies having the intent as described in these definitions. The term "management and operations (M&O)" will be used to describe the types of strategies that are part of such a program.

Both of the above definitions relate to transportation planning in several ways. First, M&O strategies should be considered by planners as important strategies for improving transportation system performance (for example, many states and metropolitan areas are implementing a regional managed lanes strategy as the core investment strategy for future system performance). Many M&O strategies are also being viewed as viable options for state and metropolitan investment primarily because there is little likelihood of finding the dollars or public support for widening major highways, and thus some other means of enhancing system capacity is necessary.

Second, many M&O strategies have a regional focus and thus require cross-jurisdictional collaboration. The metropolitan planning organization (MPO) was created to provide such a forum for regional collaboration (see chapter 1). It should come as no surprise that metropolitan transportation plans produced by MPOs in Atlanta, Dallas–Ft. Worth, Los Angeles, San Francisco, Seattle, and Washington, DC have M&O strategies as one of the core investment strategies for improving transportation system performance in their regions.

Third, the transportation planning process is inclusive and open to the public, important stakeholders, and governmental agencies having some responsibility for actions that could influence, or be influenced by,

[1] The original chapter in Volume 3 of this handbook was written by Wayne Berman, Federal Highway Administration. Changes made to this updated chapter are solely the responsibility of the editor.

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transportation investment. Greater coordination and collaboration among planners and system operators could help focus attention on those investments that more effectively and efficiently address short-term and long-term system performance needs. Stronger coordination, therefore, helps both planners and operators do their jobs better.

Finally, given the focus of transportation planning on system performance (see chapter 1), M&O strategies can provide system-level benefits that relate to some of the most used performance measures, including:

Improved Travel-Time Reliability. Travelers and freight shippers are increasingly sensitive to unanticipated disruptions to tightly scheduled personal activities and manufacturing supply-chain processes. Travel times have become increasingly unpredictable due to the growth in nonrecurring congestion, such as unexpected or unusual delays caused by crashes, inclement weather, special events, or project construction. Growth in overall traffic volumes often means that even small disruptions can have a significant ripple effect on transportation system performance over a broad geographic area. Stronger connections between planners and operators help planners consider programs and strategies to address reliability, such as deploying technologies to rapidly detect incidents; utilizing variable message signs and other approaches for providing quick, reliable traffic information to the public and media outlets; and using roving incident response teams to quickly clear crash sites.

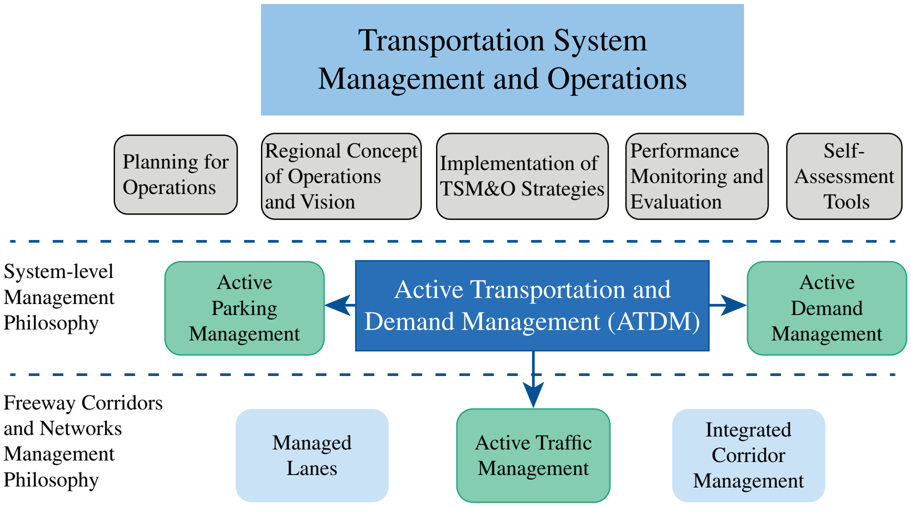
Improved System Resiliency. System operations is also an important focus for a resilient transportation system. States and regions that advance operational flexibility in their planning and investment prioritization are building capacity to address a myriad of emergency and security situations. In addition, sources of funding may be available specifically for activities that support transportation security and emergency preparedness, which can be used to support transportation TSM&O objectives.

Improved Environmental Quality. The FHWA has developed a self-assessment tool for transportation professionals to gauge the level to which actions they are undertaking help sustainability goals. The Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) is a web-based collection of voluntary best practices designed to help transportation agencies integrate sustainability into their programs (policies, processes, procedures, and practices) and projects. [FHWA, undated] Agency efforts are assigned points based on the practices currently undertaken. TSM&O is an area where points can be assigned. As noted by FHWA, "Improving the efficiency of the existing transportation system supports all of the Triple Bottom Line principles by improving mobility and reducing funding needs, congestion, and resource consumption." [FHWA, undated] Points can be scored if a TSM&O policy or plan exists, whether TSM&O performance measures are used for decision making, and the degree to which M&O strategies are being implemented.

A discussion of TSM&O necessarily entails an introduction to several other system operations concepts that are important activities in developing an effective transportation system. Figure 10-1, for example, shows how TSM&O as an overarching framework consists of several different efforts. For example, planning for operations and a regional concept of operations that includes system-level, real-time system management (for example, active parking management and active demand management), as well as targeted actions and approaches for different parts of the transportation system, in this case, for freeways are important processes that have a strong relationship to transportation planning. Figure 10-1 is used to structure much of this chapter.

In appreciating the benefits of TSM&O strategies, one must first understand transportation network and facility performance. The next section examines two characteristics of network and facility performance—road congestion and travel time reliability—that are often the focus of M&O strategies. The following section focuses on planning for operations and organizing for TSM&O in the context of agency capabilities. Following the framework laid out in Figure 10-1, the next section discusses active transportation and demand management, and how it helps meet TSM&O objectives. A description of M&O strategies for improving transportation system performance is presented in the next section. The following section then describes the opportunities for improving connections between the planning process and operations. It highlights how existing relationships can be strengthened, new ones developed, and how opportunities for greater coordination and collaboration can be exploited. It emphasizes the important role that both planners and operators can play in building stronger connections and the benefits of these relationships. The final section discusses emerging technologies—autonomous vehicles and connected vehicles (both vehicle-to-vehicle and vehicle-to-infrastructure technologies)—that are likely to have significant impacts on transportation system management and operations.

Figure 10-1. Transportation Systems Management and Operations Framework for Freeway Management



Source: Noblis et al., 2015

It is important to point out that many M&O strategies and actions happen outside of a statewide or metropolitan transportation planning process. For example, traffic incident management, road weather management, construction work zone management, and planned special events can happen anywhere in a state, and often do not include the participation of transportation planners. This chapter will focus on M&O strategies that have some link to transportation planning.

II. UNDERSTANDING NETWORK AND FACILITY PERFORMANCE

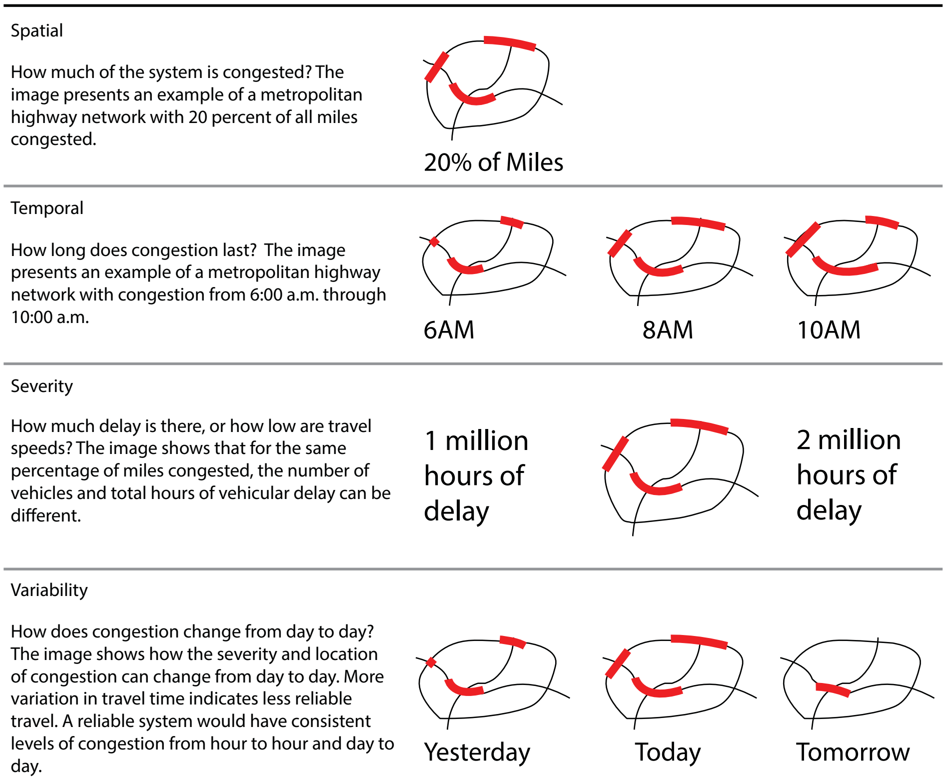
For a variety of reasons, the operational performance of the transportation system is of growing concern to transportation officials. For example, chapters 15, 16, and 17 describe current efforts to incorporate performance measures into the statewide, metropolitan, and corridor transportation planning processes. Two performance characteristics in particular—congestion and travel time reliability—are often at the top of the list when system performance is discussed, and thus transportation planners should understand some of the key issues associated with each. Note that the following sections focus on road performance; transit operations and bicycle/pedestrian operational issues are discussed in chapters 12 and 13, respectively. In addition, this chapter will not discuss some of the fundamental relationships among key variables such as traffic flow, speed, and density that in many ways define levels of service for road performance. Such information is presented in chapter 9 on road and highway planning.

A. Road Congestion

Road congestion is one of the most important characteristics associated with the performance of the transportation system, second only to safety. As discussed in chapters 2 and 9, congestion can be defined in several different ways, 1) spatially (how much of the system is congested?), 2) temporally (how long does congestion last?), 3) severity (how much delay is there or what are the average travel speeds?), and 4) variability (how does congestion change hour-by-hour and day-to-day?) (see Figure 10-2). The latter characteristic relates to travel time reliability, which is discussed in the next section.

The focus of many M&O strategies is on reducing the incidence and/or associated delay of congestion-causing elements of the transportation system. Road congestion results when there is inadequate capacity to handle traffic demand at a particular location and at a particular time. This can occur on a daily basis at the same location because the road design and resulting capacity are unable to handle demand. This is referred to as *recurring congestion*. Congestion can also occur due to crashes, other incidents, work zones, and weather. This is called *nonrecurring congestion*. Figure 10-3 shows an estimate of the incidence of different types of delay on the U.S. road network. As shown, an estimated 60 percent of delay is caused by events occurring on a nonrecurring basis.

Figure 10-2. Different Dimensions of Congestion

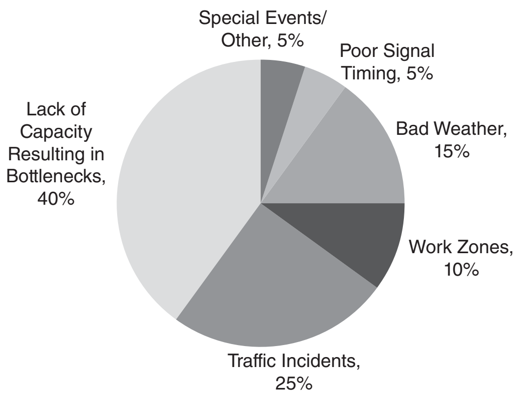


Source: Cambridge Systematics et al., 2013a

Figure 10-4 shows a typical map for the Atlanta strategic highway network that indicates key bottlenecks and congested routes in the study area. Note in this case that the different dimensions of congestion described earlier were used to identify congested locations.

A range of strategies can be used to reduce congestion levels, from long-term land-use policies to shorter-term improvements to road geometry. Table 10-1 shows the many types of strategies that could be considered as part of a congestion management process (CMP). The CMP, required of every metropolitan area over 200,000 population (called transportation management areas (TMAs)), focuses on congestion relief and is designed to be "flexible to allow MPOs to progress and adjust over time as goals and objectives change, new congestion issues arise, new information sources become available, and new strategies are identified and evaluated." [Grant et al, 2011] Note that M&O strategies are part of the strategy list in Table 10-1. Many of these strategies are discussed in other chapters of this handbook (chapter 3 on land use and urban design, chapter 11 on parking, chapter 12 on transit planning, chapter 13 on pedestrian and bicycle planning, and chapter 14 on travel demand management).

Figure 10-3. Causes of Delay on the U.S. Highway Network

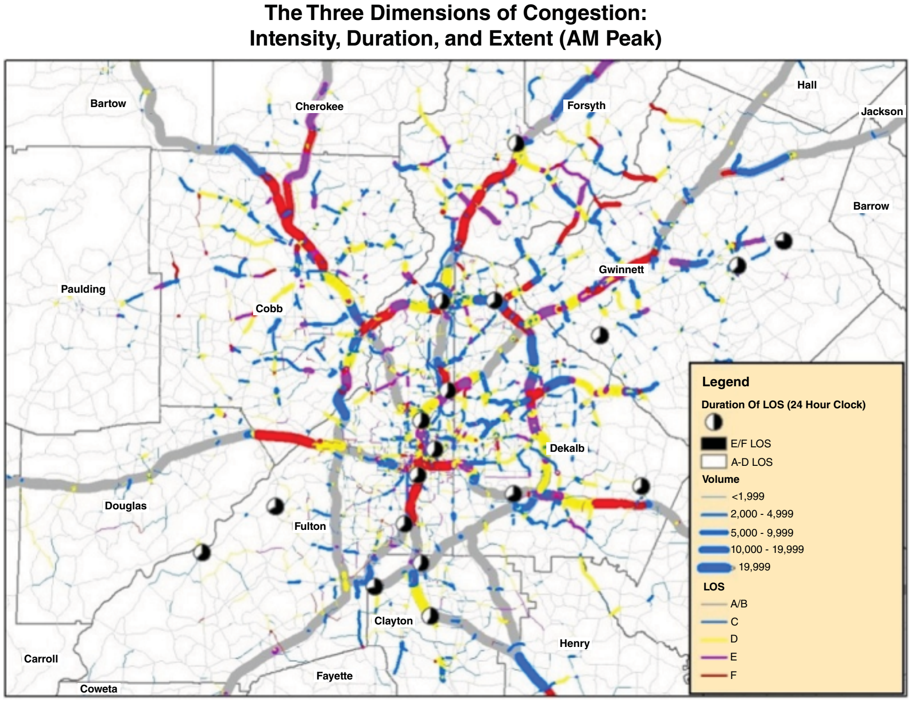


Source: Cambridge Systematics, 2014

B. Travel Time Reliability

Transportation system reliability has been a growing concern of transportation officials over the past decade. Simply put, reliability is a measure of the stability of system performance over time. Thus, if a trip takes 45 minutes on a particular day, a traveler would expect the same trip to take close to 45 minutes during the same time period the next day, all things being equal. Figure 10-5 shows this concept from the perspective of how one can measure performance of a single road link. The question arising from Figure 10-5 is which statistical measure for reliability makes most sense from a performance metric perspective?

Figure 10-4. Congestion Locations on the Atlanta Strategic Highway Network



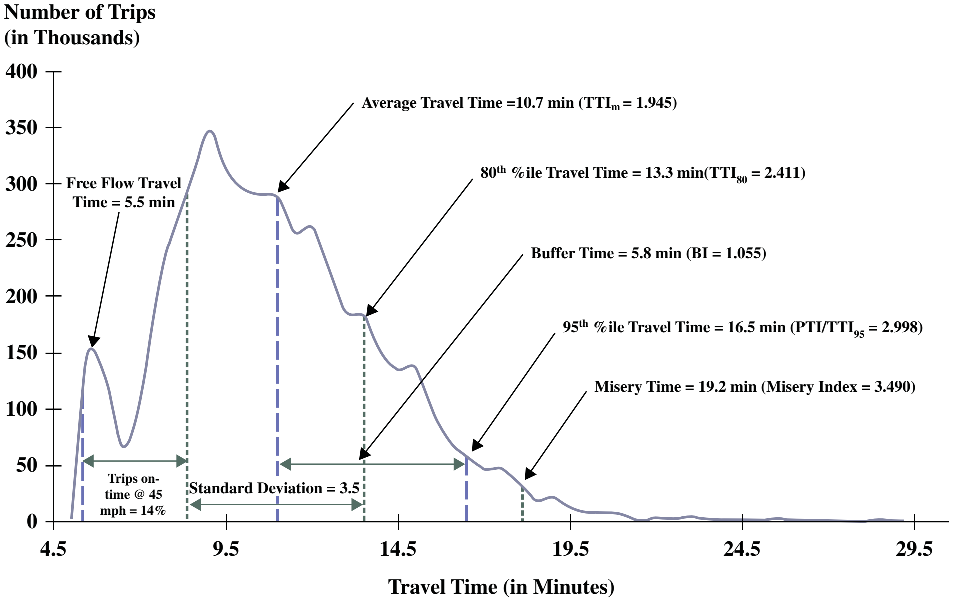
Source: ARC, 2015

Table 10-1. Types of Projects for Congestion Management Programs

Major Categories	Benefits	Costs	Examples
Access Management	Increase capacity, efficiency, and mobility; reduce travel time	Vary from low to high and include design, implementation, and maintenance costs	Turn restrictions, turn lanes, frontage roads, roundabout intersections
Active Transportation	Decrease auto mode share; reduce VMT; provide air quality benefits	Low to moderate	New sidewalks and bike lanes, improved facilities near transit stations, bike sharing; and exclusive rights of way
Highway	Increase capacity, mobility, and traffic flow	Vary from low to high depending on strategy; constructing new ROW results in higher cost than design improvements	High-occupancy vehicle (HOV) lanes, super street arterials, highway widening, acceleration and deceleration lanes, design improvements
Land Use	Decrease single occupant vehicle (SOV) trips; increase walk trips; increase transit mode share; air quality benefits	Low to moderate and involve establishing ordinances and may require economic incentives to encourage developer buy-in	Infill, transit oriented development (TOD), densification
Parking	Increase transit use; reduce VMT; generate revenue	Low to moderate, but require economic incentives to encourage developer buy-in	Preferential parking for HOVs, park and ride lots, advanced parking systems
Regulatory	Decrease VMT; air quality benefits; increase safety; generate revenue	Vary	Carbon pricing, VMT fee, pay-as-you-drive insurance, auto restriction zones, truck restrictions
Travel Demand Management	Reduce peak period travel; reduce SOV VMT	Low to moderate	Alternative work hours, telecommuting, road pricing, toll roads
Transit	Shift mode share; increase transit ridership; reduce VMT; provide air quality benefits	Vary from low to high depending on strategy; constructing new transit travel ways is higher cost than improving service frequencies	Increasing coverages and frequencies, new fixed guideway travel ways, employer incentive programs, signal priority, intelligent transit stops
TSM&O	Reduce travel time; reduce stops; reduce delays; increase safety; improve reliability	Vary, but tend to be low to moderate; large-scale projects involving new infrastructure and devices higher cost	Signal coordination, ramp metering, highway information systems, service patrols, incident management

Source: Cambridge Systematics, 2013a

Figure 10-5. Reliability Metrics for a Road Segment Travel Time Distribution



Source: Cambridge Systematics et al, 2014

Table 10-2 shows different types of measures that can be used to measure system reliability. As part of its national reporting on congestion conditions, the Texas A&M Transportation Institute (TTI) has developed a series of measures relating to Figure 10-5 (see chapter 2 and the following section on performance measures). These measures are reported biennially and often generate interest on travel reliability in different metropolitan areas.

M&O strategies can play a major role in improving travel time reliability by reducing the number of incidents that cause disruption to the system (for example, ramp metering), and by reducing the level of delay when such incidents occur (for example, incident management). The Strategic Highway Research Program, Phase 2 of the Transportation Research Board targeted travel time reliability as one of the key system characteristics whose improvement would have notable impact on system performance. Numerous research reports and practitioner guidance can be found at http://shrp2.transportation.org/Pages/Reliability.aspx.

Table 10-2. Definitions of Reliability Measures

Reliability Performance Metric	Definition	Units
Buffer Index	• The difference between the 95th percentile travel time and the average travel time normalized by the average travel time • The difference between the 95th percentile travel time and the median travel time, normalized by the median travel time	Percent
Planning Time Index	• 95th percentile travel time index (95th percentile travel time divided by the free-flow travel time)	None
Failure/On-Time Measures	• Percent of trips with travel time less than 1.1 × median travel time or 1.25 × median travel time • Percent of trips with space mean speed less than 50 mph, 45 mph, or 30 mph	Percent
80th Percentile Travel Time Index	• 80th percentile travel time divided by the free-flow travel time	None
Misery Index	• The average of the highest 5 percent of travel times divided by the free-flow travel time	None
Skew Statistic	• The ratio of (90th percentile travel time minus the median) divided by (the median minus the 10th percentile)	None
Standard Deviation	• Usual statistical definition	None

Source: Cambridge Systematics et al., 2014. Reproduced with permission of the Transportation Research Board.

III. PLANNING AND ORGANIZING FOR TSM&O

The TSM&O framework in Figure 10-1 shows a level of planning and organizing activities that often precede the implementation of M&O strategies, and that are used to provide feedback to existing programs so as to improve overall performance. Three efforts, in particular, merit some discussion—planning for operations, a regional concept for operations, and organizational capability (which includes the performance monitoring and self-assessment topics shown in the figure).

A. Planning for Operations

Planning for operations is defined by the FHWA as "a joint effort between planners and operators to support improved regional transportation system management and operations." [Grant et al., 2010] The concept includes a variety of activities to improve transportation system operations and hence transportation system performance. Included is the consideration of M&O strategies in the transportation planning process, as well as the need for collaboration among transportation system operators, transit agencies, highway agencies, toll authorities, local governments, and others to facilitate improved transportation system operations.

Planning for operations has a strong linkage to key components of the transportation planning process. For example, it means identifying goals, objectives, and performance measures that are system operations-focused; it means including management and operations strategies in the mix of projects and actions considered in the planning process; and it means using prioritization criteria that reflect the types of benefits that would occur with M&O strategies.

As noted earlier, U.S. federal law requires urbanized areas over 200,000 population to have a congestion management process (CMP) as part of their transportation planning process. The CMP, as defined in federal regulation, is intended to serve as "a systematic process that provides for safe and effective integrated management and operation of the multimodal transportation system." [Grant et al., 2011] Generally, the process includes:

- Developing congestion management objectives.
- Establishing measures of multimodal transportation system performance.
- Collecting data and using system performance monitoring to define the extent and duration of congestion, and determine the causes of congestion.
- Identifying congestion management strategies.
- Implementing activities, including developing an implementation schedule and identifying possible funding sources for each strategy.
- Evaluating the effectiveness of implemented strategies.

Because the CMP is a federal metropolitan planning requirement that emphasizes M&O strategies, it can serve as a strong foundation for integrated planning and operations. A CMP can take a variety of forms. At its core, a CMP should include a system for data collection and performance monitoring, a range of strategies for addressing congestion, performance measures or criteria for identifying when action is needed, and a system for prioritizing which congestion management strategies would be most effective.

A CMP can help raise awareness among the planning community of the system efficiencies that are possible with operational strategies. A CMP becomes an integral component of the planning and programming process when CMP performance measures and strategy evaluations are fully utilized in the development of the long-range plan and the transportation improvement program (TIP).

A CMP can expose MPOs to a broader range of strategies for addressing congestion. Federal regulations require that, through the CMP, planners give serious consideration to strategies that have a demonstrable impact on congestion and that CMPs include an assessment of the cost effectiveness of proposed strategies. Additionally, CMPs must consider strategies that "improve existing transportation system efficiency." M&O strategies are more likely to be included in a transportation plan if they are put forth as part of the CMP.

When a CMP is explicitly driven by regional goals and objectives and when operations managers are involved in the CMP development and implementation, it affords an opportunity for operations managers to recognize how their transportation strategies support the underlying objectives of the region's transportation planning and programming. In addition, the CMP can serve as a forum for interjurisdictional discussions on which strategies are most effective.

The CMP provides a good foundation for planning for operations. However, it tends to focus on congestion reduction, and there are many other objectives that M&O strategies can address, such as accessibility and travel time reliability. Including TSM&O considerations in the transportation planning process is discussed in more detail in a later section.

B. Regional Concept for Operations

A Regional Concept for Transportation Operations (RCTO) assists in the planning and implementing of M&O strategies in a collaborative and continuous manner. An RCTO should lead to a consensus of partner agencies on short-term TSM&O goals and how they are going to achieve them. [FHWA, 2015a]

The six key elements of an RCTO are:

- *Motivation ("Why")*—Reasons for developing an RCTO based on regional needs, goals, or operational concerns.
- *Operations Objective ("What")*—Desired near term outcome(s) in terms of transportation system performance and related performance measures.
- *Approach ("How")*—Overall description of how the operations objective will be achieved.
- *Relationships and Procedures*—Institutional arrangements, memoranda of understanding (MOUs), protocols, information sharing, and so on.
- *Physical Improvements*—Facilities, equipment, systems, and the like.
- *Resource Arrangements*—Sources and use of funding, staff, equipment, and so forth. [FHWA, 2015a]

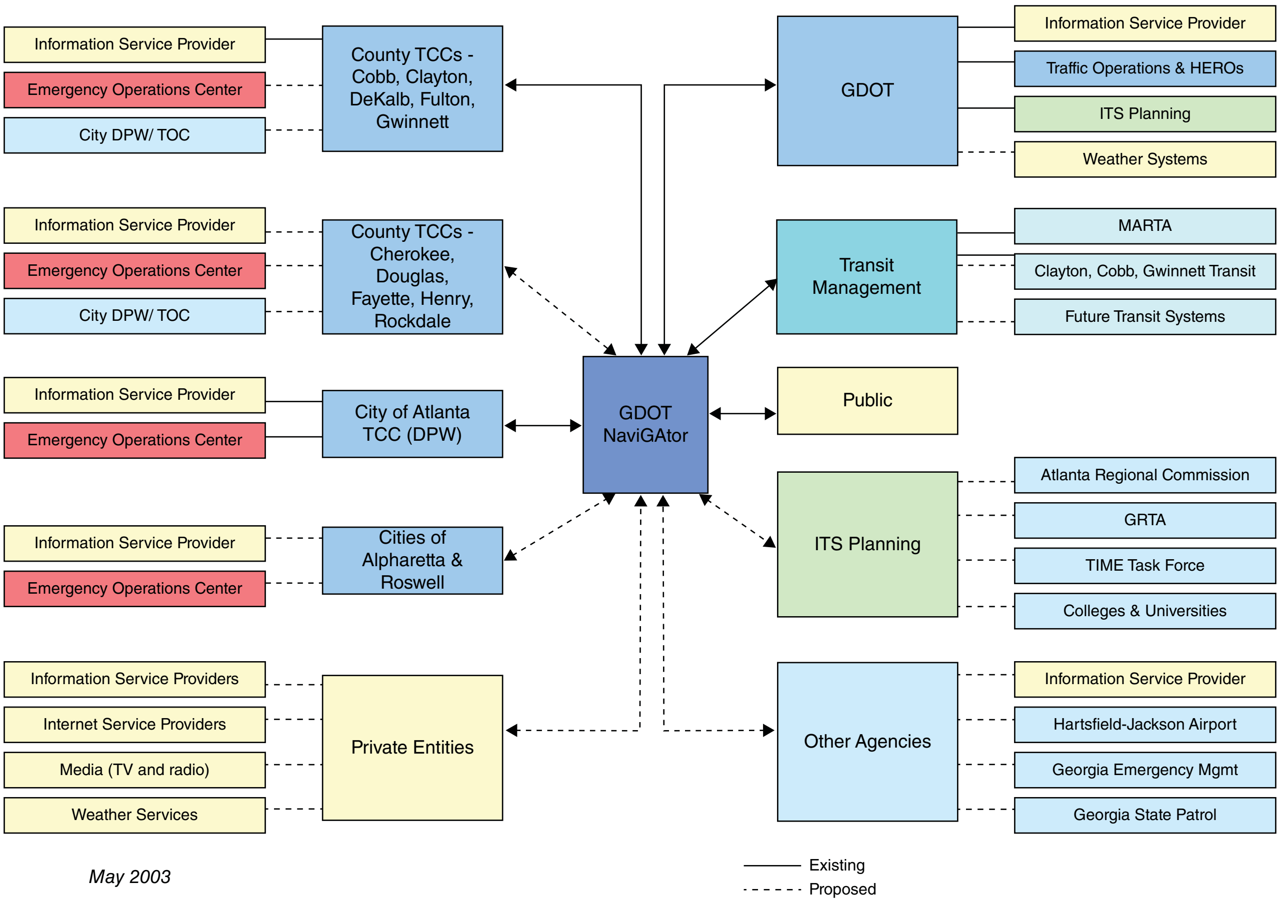
An example of a regional concept for operations comes from the Atlanta Regional Commission (ARC) in its development of the intelligent transportation system (ITS) architecture for the region (see below for more discussion on ITS). ARC formed an ITS Subcommittee with members from federal, state, and local agencies involved in ITS technology planning and deployment in the region. This subcommittee later became the Regional Management and Operations Subcommittee, which currently provides input into the development of the transportation plan and the Transportation Improvement Program (TIP), and provides a forum for information exchange relating to system operations.

The effort to develop an ITS strategy for the region began with a vision of what an ITS strategy could do for the region's transportation system. It was envisioned that the strategy would consist of:

- An extensive communications network that will provide direct, real–time information to any local and state transportation and incident response agency that participates in transportation operations within the 10-county Atlanta region.
- Real-time traveler information through various media to the public.
- An institutional environment that emphasizes efficient operations of the transportation system and that provides technological tools to enhance the operations of all transportation and incident response agencies.
- A process that monitors system performance and allows for system growth and enhancement.

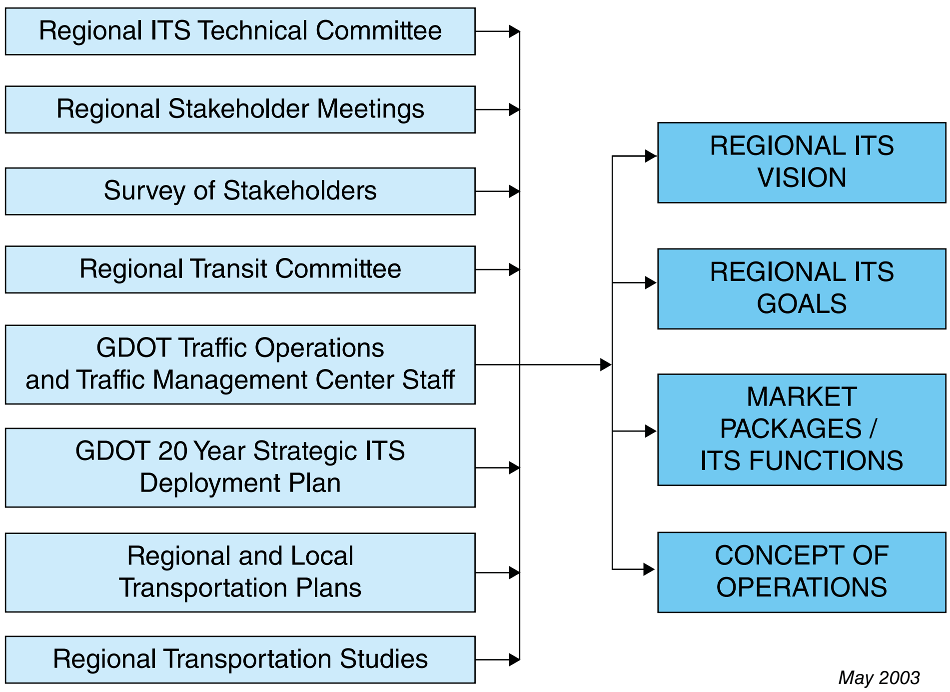
Figure 10-6 shows the ITS concept of operations developed to guide the development of an implementation plan. Georgia NaviGator is a regional traffic management center that disseminates information on real-time system performance. Note the large number of participants involved with the ITS strategy, which suggests the need for coordination and collaboration. Figure 10-7 shows the sources of input that contributed to the ITS strategy.

Figure 10-6. Atlanta's ITS Concept of Operations



Source: ARC, 2006 TOC = Traffic operations center TCC = Traffic control center

Figure 10-7. Sources of Input into ITS Strategy, Atlanta



Source: ARC, 2006

The regional ITS architecture includes an operational concept that defines the institutional relationships among the organizations involved in the deployment and operation of regionally integrated ITS systems. This operational concept serves as a starting place for linking planning and operations more broadly. Given that a region's ITS priorities and organizational approach need to evolve along with its travel patterns, available funding, and technological capabilities, the architecture was expected to mature in response to changes in the region's long-term goals and objectives.

C. Organizational Capacity

Developing the organizational capacity for creating and managing a TSM&O program is a key challenge to agencies responsible for system operations. A report by the Transportation Research Board's Strategic Highway Research Program (SHRP), *Guide to Improving Capability for Systems Operations and Management*, describes the steps to increase state DOT capability in managing a variety of M&O strategies, such as incident management in response to crashes, breakdowns, hazardous material spills, and other emergencies; integrated corridor management; road weather management; and work zone traffic management. [Parsons Brinckerhoff et al., 2011] This report is a good guide for those wanting to incorporate M&O strategies into their agency's activities.

The study concluded that the agencies with the most effective TSM&O activities were differentiated not by budgets or technical skills, but by the existence of critical processes and institutional arrangements tailored to the unique features of TSM&O applications.[FHWA, 2015b] In particular, six dimensions of the most successful efforts were considered critical for success: business processes, systems and technology, performance measurement; agency culture; organization and staffing; and collaboration. Three of the dimensions were process-oriented:

- Business processes, including planning, programming, and budgeting (resources).
- Systems and technology, including use of systems engineering, systems architecture standards, interoperability, and standardization.
- Performance measurement, including measures definition, data acquisition, and utilization.

Three dimensions were institutional:

- Culture, including technical understanding, leadership, outreach, and program legal authority.
- Organization and staffing, including programmatic status, organizational structure, staff development, and recruitment and retention.
- Collaboration, including relationships with public safety agencies, local governments, MPOs, and the private sector.

The study offered a "maturity" model that allows officials to first understand where their organization is with respect to TSM&O program characteristics, and to then identify what steps are necessary to advance to higher levels of "maturity." The American Association of State Highway and Transportation Officials (AASHTO) used the results of this study to develop a self-assessment tool that would identify types of actions for enhancing the TSM&O program. The levels of TSM&O maturity in this tool included:

- *Level 1*—Activities and relationships largely ad hoc, informal, and champion-driven, substantially outside the mainstream of other DOT activities.
- *Level 2*—Basic strategy applications understood; key processes support requirements identified and key technology and core capacities under development, but limited internal accountability and uneven alignment with external partners.
- *Level 3*—Standardized strategy applications implemented in priority contexts and managed for performance; TSM&O technical and business processes developed, documented, and integrated into DOT; partnerships aligned.
- *Level 4*—TSM&O as full, integrated, and sustainable core DOT program priority, established on the basis of continuous improvement with top-level management status and formal partnerships. [AASHTO, 2015a]

Table 10-3. TSM&O Capability Levels and Business Processes		
	Level of Capability Maturity	
Business Process	**Level 1: Ad Hoc**	**Level 4: Integrated**
Program Scoping	• Narrow and optimistic • Mission vague—ad hoc operations, activities based on regional initiatives, with limited central office support • Narrow/ITS-project based, low-hanging fruit • Absence of statewide service standards	• Full-range core program • Full-staged program of synergizing functionalities • Operations as key trade-off investment with other improvements in terms of mobility management • Program extended to lower jurisdictions
Technical Processes	• Informal, undocumented • Projects/issues handled on firefight basis with only modest formal regional/district planning (but no standard template) • Minimal concepts of operations and architecture, procedures ad hoc/no consistency • National Incident Management procedures compliance • No/limited documentation	• Integrated and documented • Integrated operations-related planning, budgeting, staffing, deployment, and maintenance both within operations and with statewide and metropolitan area planning • Full documentation of key concepts of operations, procedures, and protocols
Technology and Systems Development	• Qualitative, opportunistic • Technologies selected at project level ("big bang") • Limited understanding of operating platform needs • Mixed data items • Lack of appropriate procurement process	• Standardized, interoperable • Systematic evaluation/application of best available technology/procedure combinations with evolution • Standard technology platforms developed/maintained • Assets inventoried
Performance Measurement	• Outputs reported • Concept of continuous improvement absent • Projects lack objectives: measurement of outputs only with limited analysis/remediation • Output measures reported • Limited after-action analysis	• Performance accountability • Continuous improvement perspective adopted (requires intra- and interagency after-action analysis) • Accountability and benchmarking at unit and agency level via regular outcome performance reporting—internal and public

Source: Parsons Brinckerhoff et al, 2012. Permission granted by the Transportation Research Board.

Table 10-3 shows what different levels of maturity mean in terms of agency actions. In this case, only the first and fourth levels of maturity are shown simply to give a sense of the range of capability that might be found in TSM&O programs.

Providing a focus on M&O strategies in transportation planning and decision making can occur via the leadership of the MPO or state DOT, or it can evolve gradually as more agencies and stakeholders begin to realize the advantages of coordinated action. Several handbooks and guides have been developed to help transportation officials develop a comprehensive and collaborative TSM&O program in their state or region. Parsons Brinckerhoff et al. [2011] is the most comprehensive examination of the steps that can be taken to improve such programs, and as such is a good reference for those interested in enhancing their program.

The AASHTO self-assessment checklist mentioned above allows officials to determine not only the current position of their TSM&O program with respect to effectiveness, but shows possible directions for the program based on self-assessment questions. Five categories of questions relate to the organizational structure of the program, the process of making decisions, the products of the program, the allocation and utilization of resources, and the reporting of inputs to performance measurements. For those interested, the AASHTO self-assessment tool is found at: http://www.transportationops.org/tools/aashto-tsmo-guidance.

IV. ACTIVE TRANSPORTATION AND DEMAND MANAGEMENT

Figure 10-1 showed three system management "philosophies" under the topic of Active Transportation Demand Management (ATDM). ATDM is defined by FHWA as "the dynamic management, control, and influence of travel demand, traffic demand, and traffic flow of transportation facilities." [FHWA, 2012b] ATDM in turn consists of three major components—active traffic management, active demand management, and active parking management.

Active traffic management is "the ability to dynamically manage recurrent and nonrecurrent congestion based on prevailing and predicted traffic conditions. Focusing on trip reliability, it maximizes the effectiveness and efficiency of the facility." [FHWA, 2012b] Continuous monitoring of the transportation system is the foundation of active traffic management. Using archived data and or/predictive methods, an agency can make real-time changes to achieve or maintain system performance.

Typical Strategies

- *Dynamic Lane Use/Shoulder Control*—The dynamic opening of a shoulder lane to traffic or dynamic closure of travel lanes on a temporary basis in response to increasing congestion or incidents.
- *Dynamic Speed Limits*—The dynamic change in speed limits based on road, traffic, and weather conditions.
- *Queue Warning*—The dynamic display of warning signs to alert drivers that congestion and queues are ahead.
- *Adaptive Ramp Metering*—The dynamic adjustment of traffic signals at ramp entrances to proactively manage vehicle flow from local access roads.
- *Dynamic Rerouting*—The dynamic provision of alternate route information in response to increasing congestion at bottlenecks/incidents.
- *Dynamic Junction Control*—The provision of lane access based on highway traffic present and merging/diverging traffic to give priority to the facility higher volume to minimize the impact of the merging/diverging movement.
- *Adaptive Traffic Signal Control*—The optimization of signal timing plans based on prevailing conditions to increase throughput along an arterial. [FHWA, 2012b]

Typical Benefits

- Increase in throughput of 3 to 7 percent.
- Increase in overall capacity of 3 to 22 percent.
- Decrease in primary motor vehicle incidents of 3 to 30 percent.
- Decrease in secondary motor vehicle incidents of 40 to 50 percent.
- Overall harmonization of speeds.
- Increase in trip reliability. [FHWA, 2011]

Active demand management (ADM) uses "information and technology to dynamically manage demand, which could include redistributing travel to less congested times of the day or routes, or reducing overall vehicle trips by influencing a mode choice." [FHWA, 2012c]

Typical Strategies

- *Dynamic Fare Reduction*—The reduction in the fare for use of the transit system in a particular corridor as congestion or delay on that corridor increases. Fare changes are communicated in real-time to the traveling public, through general dissemination channels such as the transit website, as well as personalized messages to subscribers.

- *Dynamic High-Occupancy Vehicle (HOV)/Managed Lanes*—The dynamic change in the qualifications for driving in a high-occupancy vehicle (HOV) lane(s). The HOV lane qualifications are dynamically changed based on real-time or anticipated conditions on both the HOV and general-purpose lanes.
- *Dynamic Ridesharing*—The use of advanced technologies, such as smart phones and social networks, to arrange a short-notice, one-time, shared ride. This facilitates real-time and dynamic carpooling to reduce the number of auto trips/vehicles trying to use already congested roadways.
- *Dynamic Routing*—The use of variable destination messaging to disseminate information to make better use of roadway capacity by directing motorists to less congested facilities. Real-time and anticipated conditions can be used to provide route guidance and distribute the traffic spatially to improve overall system performance.
- *Dynamic Transit Capacity Assignment*—The restructuring of schedules and adjusting assignments of assets (for example, buses) based on real-time demand and patterns, to cover the most overcrowded sections of network. Real-time and predicted travel conditions can be used to determine the changes needed to the planned transit operations, thereby potentially reducing traffic demand and subsequent delays on roadway facilities.
- *On-Demand transit*—The traveler making real-time trip requests for services with flexible routes and schedules. This allows users to request a specific transit trip based on their individual trip origin/destination and desired departure or arrival time.
- *Predictive Traveler Information*—The use of a combination of real-time and historical transportation data to predict upcoming travel conditions and convey that information to travelers pre-trip and en route (such as in advance of strategic route choice locations) in an effort to influence travel behavior. Predictive traveler information is incorporated into a variety of traveler information mechanisms (for example, multimodal trip planning systems, 511 systems, dynamic message signs) to allow travelers to make better informed choices.
- *Transfer Connection Protection*—The improvement in the reliability of transfers from a high frequency transit service (for example, a train) to a low frequency transit service (for example, a bus) by dynamic management of operations. [FHWA, 2015c]

Typical Benefits

- Little evidence is reported in the literature relating to the quantifiable benefits of these strategies. However, they can contribute to the effectiveness of comprehensive travel demand management (TDM) programs (see chapter 14 on travel demand management).

Active parking management (APM) is "the dynamic management of parking facilities in a region to optimize performance and utilization of those facilities while influencing travel behavior at various stages along the trip making process, that is, from origin to destination." [FHWA, 2015d]

Typical Strategies

- *Dynamic Overflow Transit Parking*—The dynamic use of overflow parking facilities in the vicinity of transit stations and/or park-and-ride facilities when the existing parking facilities are at or near capacity. Parking demand and availability is continuously monitored and real-time determinations are made if overflow parking is needed, and accompanying dynamic routing information would be provided to travelers.
- *Dynamic Parking Reservation*—The use of technology to reserve a parking space at a destination facility on demand to ensure availability.
- *Dynamic Wayfinding*—The provision of real-time parking-related information to travelers associated with space availability and location so as to optimize the use of parking facilities and minimize the time spent searching for available parking. Parking availability is continuously monitored and routing information to the parking space is provided to the user.
- *Dynamically Priced Parking*—The use of parking fees that are dynamically varied based on demand and availability to influence trip timing choice and parking facility or location choice to more efficiently balance

parking supply and demand. Parking availability is continuously monitored and parking pricing is used as a means to influence travel and parking choices and dynamically manage the traffic demand. [FHWA, 2015d]

Typical Benefits

- *Travelers*—Easier access, reduced time spent looking for parking, and reduced frustration.
- *Venue Operators*—Increased accessibility and associated increase in patronage and customer satisfaction.
- *Parking Operators*—Increased space occupancy and associated increase in revenue.
- *The Jurisdiction and Nearby Neighborhoods*—Reduction in the number of patrons circulating through the street network looking for a parking space. [FHWA, 2007]

See chapter 11 on parking for further information on parking management strategies.

V. EXAMPLES OF MANAGEMENT AND OPERATIONS (M&O) STRATEGIES

The FHWA has created a reference library for M&O actions that provides the latest information on the following topics. See http://www.ops.fhwa.dot.gov/publications/publications.htm#eto.

- Active transportation and demand management
- Arterial management
- Congestion mitigation
- Corridor traffic management
- Emergency transportation operations
- Facilitating integrated ITS deployment
- Freeway management
- Freight operations and technology
- Freight vehicle size and weight
- Localized bottleneck reduction
- Operations asset management
- Planned special events traffic management
- Planning for operations
- Real-time system management information
- Real-time traveler information
- Road weather management
- Special events
- Tolling and pricing program
- Traffic incident management
- Travel demand management
- Work zone management

The following examples from this list are described in more detail to illustrate the potential of M&O strategies to enhance transportation system performance.

A. Emergency Transportation Operations

Agencies involved in M&O strategies are increasingly concerned with disaster preparedness planning and the coordination of regional emergency response. A number of regions have established an M&O committee focusing on day-to-day operations activities, with a transportation emergency preparedness subcommittee that focuses on longer-range planning and training programs related to emergency management. Arrangements such as these facilitate better coordination between planning and operations.

Extreme weather events have affected nearly every state in the United States, particularly in recent years. In 2012, a total of 133 disaster events occurred, resulting in $881 billion in damages. Events included hurricanes, droughts, heat waves, severe local storms, nontropical floods, winter storms, wildfires, and major dust storms. Transportation system managers and operators are often at the front line preparing for and managing the impacts of these events. In areas where natural disasters tend to occur, for example, hurricanes, earthquakes, and major floods, transportation agencies provide evacuation routes out of potentially affected areas, as well as access routes needed for emergency response.

AASHTO has developed guidance for transportation system managers in anticipating and handling system disruptions. [AASHTO, 2014] A "Top 10" list of suggestions for TSM&O managers and staff to better prepare for extreme weather included:

- *Contingency Plans*—Have contingency plans for power outages, detours, debris clearance, and routing for overweight or disabled trucks—to include preapproved contractors and funds.
- *Evacuation and Emergency Routes*—Operate effective evacuation routes in high-risk areas.
- *Traveler Information*—Develop effective public and traveler information systems/services to inform travelers of travel options (including social media tools, mobile apps, and collecting real time conditions through vehicle technology).
- *Drill and Test*—Use response to "routine emergencies" to test staffing, deployment, and communications. Also, coordinate in advance with partners at the local, state, and federal level in the event response is required.
- *Pre-Positioning Materials and Equipment*—Develop strategies for responding to transportation system disruptions due to weather-related events, including pre-positioning replacement materials (culverts, etc.) in vulnerable areas.
- *Backup Communications*—Prepare backup communications such as satellite phones, portable highway advisory radios, truck radios, and alternative networks.
- *Risk Reduction Strategies*—Identify facility locations vulnerable to risks (flooding, landslides, etc.), and develop appropriate strategies to minimize such risk.
- *Early Warning Indicators*—Incorporate "early warning indicators" for potential extreme weather-related risks into asset and maintenance management systems.
- *Harden the System*—Prepare for events with backup power generators, "hardened" — Sign structures and traffic signal wires, pre-positioned variable message sign boards and support vehicles trucks.
- *Workforce Protection*—Protect workers from extreme temperatures and weather during day-to-day and response activities. [AASHTO, 2014]

Several different kinds of M&O strategies can be used to handle emergencies. For example, Advanced Traveler Information Systems (ATIS) are important in conveying to the traveling public the conditions of the transportation system and the recommended routes to safety. In recent disasters, the means of communication have included toll-free telephone lines, websites, variable message signs, fixed portable highway advisory radio, and automatic messaging apps that provide warnings to travelers as conditions change. [Zimmerman et al, 2007]

The FHWA has conducted evacuation studies in many major U.S. metropolitan areas to identify the readiness and impediments for mass evacuations. These studies are good descriptions of the challenges metropolitan areas face in evacuations (see FHWA [2015e]). Table 10-4 shows the types of impediments facing successful evacuation efforts. [Vásconez and Kehrli. 2010] Notice that many of these impediments are the types of strategies and issues MPOs

Table 10-4. Perceived Impediments to Effective Evacuations in Selected U.S. Cities	
City	**Identified Evacuation Impediments**
Atlanta	Contraflow Constraints; Infrastructure Limitations; Arterial Road Systems with Overpasses Cannot Accommodate Trailer Heights; Bridge Weight Restrictions Impede Movements; and Traffic Data Is Scattered Throughout the Region
Baltimore	Evacuation Plan Needs Updating; Infrastructure Impediments-Roadways; and Region Lacks a Coordinated Signal Timing System
Boston	Contraflow Constraints; Shoulders May Not Be Able to Support Additional Evacuation Traffic; and No Place for Sheltering
Charleston	Infrastructure Constraint I-26; East-West Evacuation Routes; Lane Restrictions; ITS Capabilities along Evacuation Routes; and Incident Responder Coverage Along I-26, Charleston to Columbia
Chicago	Traffic Congestion; Emergency Vehicle Access; Railroad Crossing/Street Blockage; Contraflow Operations Would Impede Evacuations; and Real-Time Highway Information for Responders and Public
Dallas/Ft. Worth	Infrastructure Limitations; Lack of Cameras along Key Routes; and Evacuation Plans Do Not Exist
Denver	No Evacuation Plan; No Evacuation Routes Identified; No Lane Assignments for Emergency Services; Infrastructure Limitations; Traffic Flow Analysis on Evacuation Routes; and Weather Hindrances
Detroit	Infrastructure Conditions Impede Responder Operations; Congestion; and Bottlenecks on Freeways, including Narrow Freeway Lanes and Limited Shoulders
Hampton Roads	Traffic Signal Timing; Number of Water Crossings; Limited ITS Deployment Along Key Evacuation Routes; Flood-Prone Infrastructure; and Human Resources to Manage Evacuation Operations and Tools
Houston	Bottlenecks; Communications with the Public; Number/Type of Resources to Deploy; More CCTV Cameras; and Modeling Timeliness
Jacksonville	Work Zones; Limited Fueling Stations; No DMSs on Westbound I-10; and No ITS Deployment on Key Interstates
Las Vegas	Insufficient Lanes and Daily Congestion; Coordination with Other States on Evacuation Routes; Communications Systems Would Not Support Evacuation Operations; Deployable Traffic Signs and Evacuation Route Signage; and Traffic Flow Monitoring
Los Angeles	Congestion and Evacuation Route Capacity; Communications Capabilities; and Public Outreach and Understanding Evacuation Process
Miami	Insufficient Road Capacity; Damage to Critical Infrastructure; Work Zones on Major Routes; Traffic Signal Timing; and Lack of ITS Devices on Major Arterial Roads
Minneapolis-St. Paul	Infrastructure Capacity and Congestion; Lack of Coordinated Plan and Universal Agreement on the Benefits of Evacuation; Disconnected Transportation and Emergency Operations Centers; Need for More Signage and Public Education; Coordination of Signal Timing Plans; Address Equipment Gaps for Pedestrian Movements; and Develop Multiple Options for River Crossing
National Capital Region (DC, MD & northern VA)	Regional GIS Database; Traffic Signal Coordination on Arterials; Limited Roadway Capacity; Institutional Coordination; Communication Interoperability and Protocols; and VIP Movements and Security
New Orleans	Highway Flooding; Additional ITS Capacity; Insufficient Capacity; and Lack of Emergency Lanes
New York City	Infrastructure Condition and Limitations; Need Improved Coordination between State/Local Transportation Officials and Responders; Limited Deployment of ITS Impact on Sharing Situational Awareness Data; Weather Impacts; and Need for Public Information Campaign
Philadelphia	Expressway Congestion; Need for Situational Awareness; Emergency Signal Timing Coordination; Operational Coordination; and Toll Waivers
Phoenix	Communication Capabilities; Community Outreach and Education Program; Rural Evacuation Route Signing and Information (public outreach) Strategy; Mass Evacuation Regional Command and Control Center; and Evacuation Route Signing
Portland, OR	Bridge Vulnerability; Capacity and Infrastructure Limitations; Communications and Coordination with Neighboring Jurisdictions and the Public; Communications and ITS Technology for Incident Operations; Improved Traffic Management and Safety; More Robust Planning for Evacuation Operations; and Identification and Use of Resources
San Diego	Communication Capabilities; Evacuation Route Capacity; and Need Public Outreach Campaign
San Francisco	Communication Capabilities if Damaged; and Infrastructure (Roads, Bridges and Overpasses) along Evacuation Routes
Seattle	Congestion; Limited Infrastructure; and Insufficient Responder Resources to Manage an Evacuation
St. Louis	Limited Capacity; and Highway Capacity and Bridges
Tampa-St. Petersburg	Highway Infrastructure Capacity; Bridge Infrastructure Capacity; Bridge Vulnerability to Damage; Highway Vulnerability to Damage; and Limited Evacuation Routes due to Geographic Limitations

Source: Vásconez and Kehrli. 2010

consider as part of the planning process, for example, limited infrastructure, contraflow lane strategies, coordinated data collection and integration, congestion levels, and the like.

From an operations perspective, the major participants in anticipating and responding to disasters will be those who own and manage transportation systems. MPOs, as a region's leading convener of other agencies, can provide an important forum for discussions and collaboration to make sure the region is prepared.

Those interested in system disruptions are referred to [Meyer et al., 2014; AASHTO, 2013, 2014; Baglin, 2014]. Readers interested in evacuation planning are referred to FHWA's emergency operations website: http://www.ops.fhwa.dot.gov/publications/publications.htm#eto.

B. Facilitating Integrated ITS Deployment

ITS technology is defined as "the application of information technology to surface transportation in order to achieve enhanced safety and mobility while reducing the environmental impact of transportation." [USDOT, 2011] The U.S. DOT vision for a future transportation system includes one where:

- A fully connected, information-rich environment where travelers, freight managers, system operators, and other users are fully aware of all aspects of the transportation system's performance across all relevant modes.
- A cooperative system in which highway crashes and their tragic consequences are rare because vehicles of all types and roadside systems work together to:
  - Communicate the events and hazards happening around them.
  - Coordinate action and response among vehicles and their operators to avoid collisions.
- Travelers who have comprehensive and accurate information on travel options—transit travel times, schedules, cost, and real-time locations; driving travel times, routes, and travel costs; parking costs, availability, and ability to reserve a space; and the environmental footprint of each trip.
- System operators have full knowledge on the status of every transportation asset.
- Vehicles of all types that can communicate with traffic signals to eliminate unnecessary stops and help people drive in a more fuel-efficient manner.
- Vehicles that can communicate the status of on-board systems and provide information that can be used by travelers and system operators to mitigate the vehicle's impact on the environment and/or make more informed choices about travel modes. [USDOT, 2011]

ITS first began in the United States in the early 1990s, primarily in recognition of the rapid advance in technologies that could provide useful capabilities to managing transportation systems. In the United States, the federal government requires that regions have a regional ITS architecture, defined as, "a specific, tailored framework for ensuring institutional agreement and technical integration for the implementation of ITS projects or groups of projects in a particular region. It functionally defines what pieces of the system are linked to others and what information is exchanged between them." [FHWA, 2006] The linkage to long-range transportation planning as noted by FHWA includes:

- The services described in the Regional ITS Architecture can provide the basis for operational strategies to improve the transportation system to meet the region's vision and goals.
- The Regional ITS architecture can be used to support evaluation and prioritization of strategies in two ways. The first is through the definition in the architecture of archiving and data collection systems that support collecting the data needed for evaluation. The second is through the detailed definition of ITS projects and their sequencing that can be used to establish a long-range strategy of investment in a technology-focused system.
- The definition of an integrated transportation system described by the Regional ITS Architecture can support a key element of the transportation plan, for example, the element "operations and management of the transportation system."

- The process of developing and maintaining a Regional ITS Architecture can help to enhance the linkage between operations and planning through closer involvement of a wider array of stakeholders from both of these areas of transportation. [FHWA, 2006]

C. Freeway Management

Freeway traffic management and operations is the "set of activities that transportation agencies conduct to plan, design, develop, implement, operate, and maintain transportation infrastructure or assets on or near controlled-access freeways in order to best utilize the available freeway system capacity in cooperation with other regional transportation stakeholders and consistent with the region's vision and goals."[Noblis et al, 2015] Freeway M&O utilizes such strategies as ramp metering, traveler information systems, managed lanes, lane variable speed limits, pricing, and incident management programs to enhance the operational capacity of freeways and freeway corridors. The FHWA has developed the *Freeway Management and Operations Handbook* (FMOH) providing useful information on the many different types of M&O strategies that are part of freeway management. As of the writing of this transportation planning handbook, the FHWA in collaboration with the Transportation Research Board Committee on Freeway Operations was updating the FMOH. [Noblis et al., 2015] Interested readers should access the FHWA website on freeway management to review the latest version of the FMOH (http://ops.fhwa.dot.gov/freewaymgmt/frwy_ops.htm).

One freeway M&O strategy, in particular, has received much attention over the past 10 years and is being implemented in many U.S. metropolitan areas. Managed lanes are defined as highway facilities or a set of lanes where operational strategies are proactively implemented and managed in response to changing conditions. [FHWA, 2008a]. For example, high-occupancy vehicle (HOV) lanes have been used for decades in major freeways to encourage the use of transit and ridesharing. This early form of lane management was static, that is, the rules for using the HOV lanes were rigidly structured .... you either had two or more persons in the car (and thus could use the lane) or you did not. Several agencies realized that HOV lanes were often not used to their highest potential and that single occupant vehicles might be allowed in the underutilized lanes for a price. This price could change in real time depending on the volume in the HOV lane. For example, if an HOV lane was approaching capacity, allowing a single occupant vehicle into the lane could cause notable delays, and hence the price was high. If ample capacity was available, very little delay would result and the price was lowered (the term for such lanes was high-occupancy toll (HOT) lanes, now largely called managed lanes).

The concept of managed lanes and the use of pricing to provide enhanced freeway operations also became an important approach to financing freeways. Public/private partnerships for financing new freeway capacity rely on some source of funding for payments to the private entity willing to build and operate such a facility. In some cases, these facilities have been entire roads, while in others the concept was to use this financing strategy to build and operate managed lanes (see chapter 5 on transportation finance and funding as well as [FHWA, 2012d]). A good overview of managed lane projects can be found at Texas A&M Transportation Institute (http://managed-lanes.tamu.edu/projects).

Table 10-5 shows the range in system performance benefits for freeway management strategies. Although listed individually, most freeway management programs include a combination of many of the strategies listed in the table.

D. Regional Signal Coordination and Management

Traffic signal management is defined as "the planning, design, integration, maintenance, and proactive management of a traffic signal system in order to achieve policy based objectives to improve the efficiency, consistency, safety, and reliability of the traffic signal system." [Koonce et al., 2009] In particular, given the number of jurisdictions in a typical metropolitan area having responsibilities for signal design, operations, and maintenance, a regional signal management program often focuses on cross-jurisdictional collaboration and coordination. As noted in a FHWA study of coordinated traffic programs, the "regional" nature of such efforts can take many forms (and thus potential coordinating roles for state DOTs and/or MPOs):

- Establish different objectives and policies for varying arterial types, such as arterials within central business district or downtown, suburban, and rural areas. Objectives may vary depending on the type of land uses, travel patterns, travel speeds, and vehicle characteristics. An operations program should address these variations to maintain regional consistency.

Table 10-5. Benefits from Freeway Management and Operations (FMO) Strategies	
FMO Strategy Type	**Selected Findings**
Managed Lanes/Variable Speed Limit (VSL)	Field data collected over the last two decades show variable speed limit (VSL) systems can reduce crash potential by 8 to 30 percent.
Managed Lanes/VSL	A VSL system used to regulate traffic flow through work zones on a 7.5-mile section of I-495 saved motorists approximately 267 vehicle-hours of delay each day.
Managed Lanes/VSL	A VSL system on the I-270/I-255 loop around St. Louis reduced the crash rate by 4.5 to 8 percent, due to more homogenous traffic speed in congested areas and slower traffic speed upstream.
Active Traffic Management	Collisions on I-5 in Washington State have been reduced by 65–75 percent in a 7.5-mile corridor where an active traffic management system was deployed.
Integrated Corridor Management (ICM)	Decision support system scenarios modeled on the ICM Corridor in Dallas Texas show travel time savings of 9 percent on arterials when vehicles divert from the freeway.
Integrated Corridor Management	Transportation researchers have used analysis, modeling, and simulation (AMS) methodologies to estimate the impacts of proposed ICM solutions. Projected benefit-cost ratios for four cities range from 10:1 to 25:1 over a 10-year period, which include significant fuel savings and emissions reductions.
Ramp Metering	The Kansas City Scout program used ramp meters to improve safety on a 7-mile section of I-435; before and after data indicated that ramp meters decreased crashes by 64 percent.
Ramp Metering	The implementation of ramp metering in Kansas City increased corridor throughput by as much as 20 percent and improved incident clearance by an average of four minutes, with these benefits remaining consistent in the long term.
Traffic Incident Management	Northern Virginia's freeway safety service patrol assessment estimated an annual savings of $6.49 million in motorist delay and fuel consumption, resulting in a benefit-cost ratio estimate of 5.4:1.
Traffic Incident Management	Benefit-cost ratio for Georgia's HERO motorist assistance patrol program and NaviGAtor incident management activities estimated at 4.4:1.
Information Dissemination—Dynamic Message Signs (DMS)	Ninety-four percent of travelers took the action indicated by the DMSs in rural Missouri and drivers were very satisfied by the accuracy of the information provided.
Surveillance	NY State DOT TMC operators and NY State Thruway Authority staff were able to reduce traffic queues by 50 percent using vehicle probe data available through the I-95 Corridor Coalition.

Source: Noblis et al., 2015

- Establish a regional working group comprised of key stakeholders and a champion to lead the group in being responsible for traffic signal management and maintenance within the region.
- Develop the vision, goals, objectives, and performance measures for traffic signal management and operations in the region.
- Develop a regional traffic signal management concept of operations to identify high-level policies and plans needed to support plans and procedures for individual arterials. Such high-level policies should include:
    - Balancing major street throughput and average network/intersection delay.
    - Vehicle clearance times (yellow and all red).
    - Left-turn movement treatments (leading, lead-lag, lagging).
    - Pedestrian treatments (rest in walk, leading walk, recall, clearance times, etc.).
    - Signal timing monitoring and plan updates.
    - Intersection hardware maintenance.
- Identify information and resource sharing needs on a regional level (for example, identifying whether local agencies need to access and view freeway detector and closed circuit television [CCTV] cameras) for the purpose of traffic signal management and maintenance.

- Propose technology and ITS needs to support corridor traffic signal management and maintenance at a regional level.
- Assess and establish engineering and maintenance staffing needs and qualifications. [Koonce et al., 2009]

A good example of a regionally coordinated traffic signal program comes from Denver, where the MPO has established a traffic signal system improvement program. This program has two major components:

- A capital improvement program, providing equipment and installing communications links to improve system capabilities.
- A traffic signal timing improvement program, providing new traffic signal timing and coordination plans to demonstrate the benefits of the capital improvements. [DRCOG, 2014]

The focus of the program is on the following goal and objectives: [DRCOG, 2013]

Goal: The region's traffic signals systems will operate in a safe manner, making most efficient use of arterial street capacity.

Objective 1: Minimize arterial traveler stops.

Objective 2: Minimize traveler stop time at intersections.

Objective 3: Maximize traffic signal system equipment reliability.

The types of projects to accomplish this goal include: (1) upgrade and replace insufficient/unreliable communications for highway corridors/areas, (2) expand system control to key signals not on system, (3) improve the signal system efficiency, control, and the ability to monitor system operations performance, and (4) pilot advanced functions such as traffic adaptive control and advanced functions to support transit, bicycles, and pedestrians.

E. Traffic Incident Management

In many metropolitan areas, state DOTs and MPOs have taken the lead role in advancing coordinated incident response and freeway service patrol programs, collectively called traffic incident management (TIM). The primary goals of TIM programs are to: (1) reduce the duration and impacts of traffic incidents and (2) improve the safety of motorists, crash victims, and emergency responders. [Bauer et al., 2013] Because traffic incidents are responsible for such a large portion of regional congestion, many MPOs have coordinated the multijurisdictional challenges of putting such programs in place.

TIM activities are typically categorized into the following five functional areas:

- Detection and verification
- Traveler information
- Response
- Incident scene management and traffic control
- Quick clearance and recovery

Regional traffic management centers (TMCs) play an important role in each of these activities. In many cases, traffic incident management was the major motivation for the development of TMCs. They now serve as a foundation for broader cooperation in regional TSM&O efforts. TMCs, for example, provide a critical capability in monitoring managed lanes operations and of responding quickly to incidents. [Tantillo et al., 2014] Table 10-6 shows the different TIM roles that TMCs play in eight managed lanes projects in the United States. As shown, TMCs have an important

Table 10-6. Traffic Incident Management Best Practices, United States

	Long Island Exway HOV Lanes	I-35W Priced Dynamic Shoulder Lane, Minneapolis	Houston Katy Freeway Managed Lane	Miami I-95 Express Lanes	Boston I-93 Contraflow HOV Lane	San Diego I-15 Express Lanes	Atlanta I-85 Express Lanes	N. Virginia I-495 Express Lanes
Technology and Communications								
Establish protocols related to incident communications	√	√	√	√	√	√	√	√
Data sharing agreements among agencies	√		√	√		√	√	√
Interagency Relations and Coordination								
Interagency agreements established with response agencies	√	√	√	√	√	√	√	√
Interagency agreements established with other transportation agencies			√	√		√	√	√
Managed Lane Enforcement Patrols								
Manual enforcement/moving violations	√	√	√	√	√	√	√	√
Automated enforcement			√	√			√	√
Dedicated police patrols	√	√	√	√	√	√	√	√
Dedicated service patrols			√	√	√	√		√
TMC Resources								
Recovery of some TMC operating costs from toll revenue			√	√			√	√
Toll revenue fully supports TMC operating costs			√					√
TMC Operational Considerations are Incorporated into the Design of Managed Lanes								
Managed lane control software		√	√	√		√	√	√
Managed lane access and separation treatments	√	√	√	√		√		√
Planning Processes and Documents related to Managed Lanes								
TMC operational considerations incorporated into planning processes	√	√	√	√	√	√	√	√
Shared Operations Responsibilities								
Managed lanes/general purpose lanes operated by different transportation agency or entity			√				√	√
Multiple TMCs with TIM jurisdiction on corridor			√	√			√	√
Incident Detection and Verification								
Detect and verify incident from TMC	√	√	√	√	√	√	√	√
Incident Response								
Coordinate incident response from TMC	√	√	√	√	√	√	√	√
Pre-position response and recovery vehicles					√	√		
Dedicate safety patrols for managed lanes			√	√	√	√		√

(*continued*)

Table 10-6. (*Continued*)

	Long Island Exway HOV Lanes	I-35W Priced Dynamic Shoulder Lane, Minneapolis	Houston Katy Freeway Managed Lane	Miami I-95 Express Lanes	Boston I-93 Contraflow HOV Lane	San Diego I-15 Express Lanes	Atlanta I-85 Express Lanes	N. Virginia I-495 Express Lanes
Management of Vehicle Access during Incidents in Managed Lanes								
Adjust vehicle eligibility during incident		√				√	√	
Adjust pricing during incident		√		√		√	√	√
Close managed lanes remotely from TMC		√						
Remotely close access points from TMC		√	√	√	√	√	√	√
Scene Management								
Select location, establish/maintain incident scene	√	√	√	√	√	√	√	√
Coordinate interagency response to open access points to scene			√		√	√		√
Adjust or coordinate the adjustment off movable barriers to support needed traffic flow					√	√		
Open the use of special lanes such as HOV or shoulder lanes to improve traffic flow	√	√				√	√	
System and Corridor Management Strategies and Systems								
Lane control strategies		√				√		
Ramp metering	√	√		√		√	√	
Traveler information	√	√	√	√	√	√	√	√
Arterial signal timing	√		√					
Post diversion information on variable message signs	√	√	√	√	√	√	√	√
Post travel times	√	√	√	√		√	√	
Expand/relocate motorist assist patrols	√	√	√	√	√	√	√	√
Clearance and Recovery								
Coordinate with responders to support any needs for additional resources	√	√	√	√	√	√	√	√

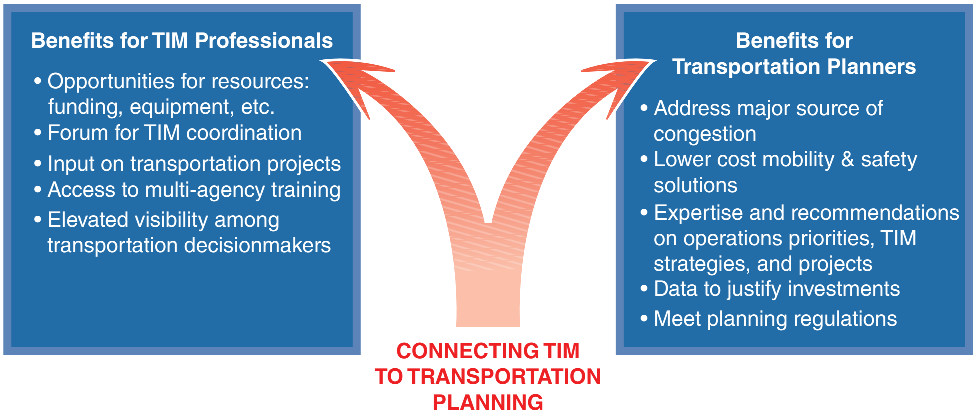
Source: Tantillo et al., 2014

role to play in all aspects of managing an incident on the road system. Figure 10-8 also shows the benefits to both TIM professionals and transportation planners of having a strong linkage between the two.

Transportation planners should also be aware that a group of organizations have created the National Traffic Incident Management Coalition (NTIMC) whose intent is to encourage safe and efficient management of incidents. A National Uniform Goal (NUG) has been adopted for TIM that relates to the following 18 different strategies.

- TIM Partnerships and Programs
- Multidisciplinary NIMS and TIM Training

Figure 10-8. Traffic Incident Management (TIM) Linkages to Transportation Planning



Source: Bauer et al., 2013

- Goals for Performance and Progress
- TIM Technology
- Effective TIM Policies
- Awareness and Education Partnerships
- Recommended Practices for Responder Safety
- Move Over/Slow Down Laws
- Driver Training and Awareness
- Multidisciplinary TIM Procedures
- Response and Clearance Time Goals
- 24/7 Availability
- Multidisciplinary Communications Practices and Procedures
- Prompt, Reliable Responder Notification
- Interoperable Voice and Data Networks
- Broadband Emergency Communications Systems
- Prompt, Reliable Traveler Information Systems
- Partnerships with News Media and Information Providers

Readers are encouraged to access the NTIMC website for the latest information on TIM strategies (http://ntimc.transportation.org/Pages/default.aspx).

F. Special Events

Cities of all sizes often host special events that could temporarily overwhelm the local transportation system. A FHWA study of special events planning and the potential role of ITS strategies concluded, "When planning is characterized by communication and active participation of stakeholders, the value of ITS tends to increase because there are more people who benefit from the wider access to timely and accurate information that ITS make possible. As a result, most of the lessons that successful planners have taken from their experiences with planned special events focus not so much on the technologies that work best for them, but the aspects of coordinating, planning, and implementing a transportation plan that lends value and usefulness to the information the technologies provide." [FHWA, 2008b] With respect to transportation planning issues, the report recommended:

- Coordinate with construction programs at the state, county, and local levels to ensure that there are no planned construction projects scheduled to occur on the day of event.

- When planning, remember the needs of local citizens as well as event attendees.
- When developing a traffic plan, consider establishing detours for commercial vehicles and other non-event-related vehicles around the area of the event venue.
- Put portable dynamic message signs in place several days prior to the start of a planned special event to inform motorists of the event and give them sufficient time to find and become familiar with alternate routes.
- While the event is actually underway and plans are being executed, have the same core members of the planning group available to modify the plan as necessary.
- Use state or regional motorist assistance vehicles to patrol the roadways around events, borrowing from other agencies if necessary.
- Develop an after-action review of each special event, both to identify shortcomings as well as to determine what worked well so successful practices can be expanded or used for other events. [FHWA, 2008b]

A special event can serve as a catalyst for the development of a new model for planning and operations coordination—a model that can potentially continue to function long after the event has occurred. To sustain and build upon the collaborative efforts common during special events, it is important that stakeholders consider in advance how to build from these events. Planners and operations representatives can work together to discuss opportunities to build from successful event coordination.

Readers interested in special events planning are referred to FHWA's emergency operations website: http://www.ops.fhwa.dot.gov/publications/publications.htm#eto. A useful handbook is found in [Latoski et al, 2003].

G. Some TSM&O Program Examples

State DOTs. Being the owner and operator of a state's major highway system, state DOTs are heavily engaged in M&O strategies. The Florida DOT (FDOT) provides a good example of a state's TSM&O effort. FDOT has used the following guiding principles as the foundation for its TSM&O strategy.

- *Definition of TSM&O*—TSM&O is an integrated program to optimize the performance of existing multimodal infrastructure through the implementation of systems, services, and projects to preserve capacity and improve the security, safety, and reliability of the transportation system.
- *System Vision*—To operate the transportation system at the highest level of cost-effective performance.
- *Expanded Vision for Arterial and Freeway Operations*—To operate the transportation system at the highest level of cost-effective performance, resulting in reduced excess delay on arterials and freeways, real-time management and traveler information for all modes, and seamless coordination with all operating agencies.
- *Agency Mission*—To deploy a customer-driven TSM&O program focused on mobility outcomes through real-time and effective management of the existing transportation system toward its maximum efficiency. [Florida DOT, 2013]

The different types of strategies, or as defined by FDOT, "focus areas," in the TSM&O strategic plan, include:

- *Ramp Signals*—Regulates the flow of traffic entering freeways.
- *Advanced Traffic Management System (ATMS)*—Enhances signal coordination.
- *Severe-Incident Response Vehicles*—Act as a central point of contact at major incidents.
- *Managed Lanes*—Manages roads in response to changing conditions, creating a more effective and efficient freeway.
- *Incident Management*—Improves safety for motorists and responders, reduces congestion, and improves safety.
- *Rapid Incident Scene Clearance*—Responds to major incidents using heavy wrecker performance-based contracts.
- *Traveler Information*—Improves traveler decision making in response to changing conditions.

- *Arterial Management*—Manages traffic on arterial roadways more effectively.
- *Work Zone Traffic Management*—Improves safety and enhanced traffic management in work zones.
- *Weather Information*—Provides advanced information for significant weather events and changing conditions.
- *Variable Speed Limits*—Promotes uniform traffic flows.
- *Hard Shoulder Running*—Increases corridor capacity.

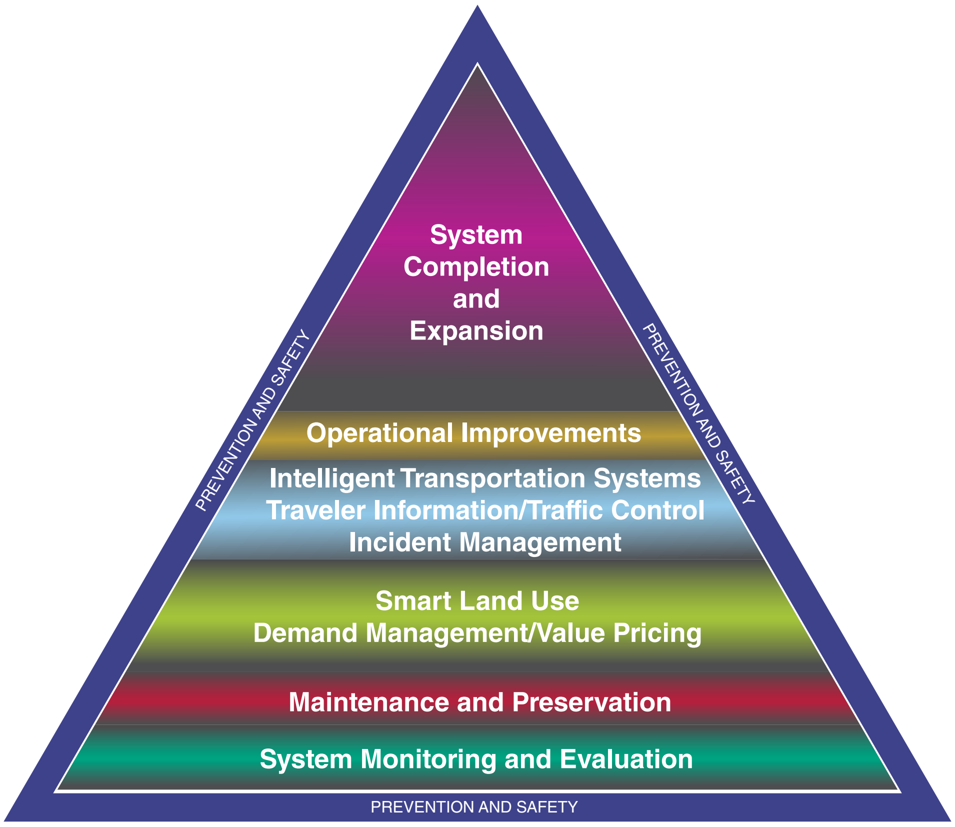
Because planning for operations means coordinating activities among transportation planners and managers having responsibility for day-to-day transportation operations, FDOT's strategic plan also lays out the organizational and management decisions to create TSM&O institutional capability within the agency.

Another state DOT example comes from California. Caltrans, California's state transportation agency, has been a national leader in TSM&O operations for decades, especially in the application of new technologies for system management. Figure 10-9 shows the types of efforts and actions that Caltrans is involved in, and illustrates the important foundation that operations provides to the agency's overall activities. [Bowen and Zhagari, 2015] One of the major reasons why Caltrans has placed emphasis on system management and operations is that the return on investment has been estimated to be much greater for these types of strategies than for others such as system expansion.

Another Caltrans initiative that illustrates well the application of advanced technology for system management is called "connected corridors," a program developed in collaboration with the University of California, Berkeley. The concept is to develop a coordinated system management approach of freeways, ramps, arterials, and other local roadways in a corridor to provide safe, reliable travel for all users in all modes, using: [Kuhl, 2014]

- Traffic management systems.
- Well-maintained infrastructure.

Figure 10-9. Caltrans' Mobility Pyramid



Source: Bowen and Zhagari, 2015

- Managed/priced lanes.
- Advanced ramp meter operations.
- Enhanced communication networks.
- Freeway service patrol and incident management strategies.
- Enhanced traveler information.
- Decision support systems.
- Approved concepts of operations with local and regional partners.

The goal is ultimately to "enable the coordination of existing transportation infrastructure and vehicles, deliver improved corridor performance, improve accountability, evolve Caltrans to real-time operations and management, and enhance regional, local, and private sector partnerships." [Kuhl, 2014]

MPOs. The types of TSM&O strategies and decisions facing transportation officials will vary by size of region, agency responsibilities, and transportation system components. Table 10-1, for example, showed the types of projects that a large MPO might consider as part of its congestion management process. A smaller MPO might have a very different perspective in terms of the types of projects or actions that would be considered. For example, Table 10-7 shows an assessment from Lawrence, Kansas, of the types of strategies that might be appropriate today and in the future.

The Pikes Peak Area Council of Governments (PPACOG), the MPO for the Colorado Springs, Colorado, metropolitan area and a medium-sized MPO, considers the following TSM&O strategies as most appropriate for its region: regional signalization; roadway channelization; intersection improvements; incident management; ramp metering; and an Intelligent Transportation System (ITS) program consisting of computerized signal systems, traffic control and surveillance equipment, and motorist information systems. [PPACOG, 2012]

FHWA [2012a], Baird and Noyes [2014], and AASHTO [2015b] provide a good description of state DOT TSM&O programs. A good overview of the types of TSM&O strategy candidates for MPOs is found in [IBI Group, 2009] and useful information is also provided in [Bauer et al., 2011].

Table 10-7. Operations and Management Strategies for a Small MPO: What's Right for Lawrence?

	Now		Future	
Strategy	**Yes**	**No**	**Yes**	**No**
Traffic synchronization	H		H	
Traffic signal priority	L		M	
Traffic signal priority for buses	L		M	
Dynamic traffic signal timing	L		L	
Reversible/changeable lanes		X		**X**
Dynamic message signs		X	L	
Intersection improvements	H		H	
Geometric improvements	H		H	
Peak period parking restrictions		X	L	
Access management	H		H	
Emergency response	L		M	
Regional multimodal traveler information	L		M	
Citywide fiber optic network	L		H	

H, M, L: High, medium, low priority X: Considered

Source: Lawrence/Douglas Counties MPO, 2008

VI. LINKING TRANSPORTATION PLANNING AND PLANNING FOR OPERATIONS

Many opportunities exist to foster collaboration between planners and operators and to incorporate M&O strategies into the transportation planning and decision-making process. FHWA calls for the development of an "objectives-driven, performance-based approach" for such collaboration. [Grant et al., 2010] The planning for operations discussion earlier provides a good framework for establishing linkages between operations and planning. In particular, there are seven areas where TSM&O concepts and M&O strategies can be incorporated into the transportation planning process:

- Incorporating system operations stakeholders into the transportation planning structure
- Establishing system operations goals and objectives
- Defining operations performance measures for the transportation planning process
- Using ITS technologies for data collection and sharing
- Using operations-oriented analysis tools
- Identifying TSM&O strategies to be included in the plan and TIP
- Sharing funding and resources

These are discussed in the following sections.

A. System Operations Stakeholders and Institutional Structures

The MPO serves as the regional agency coordinating transportation planning and programming among state and local agencies. For TSM&O, it can provide regional leadership by bringing operations managers in the region together to establish a decision-making framework for regional operations policies, plans, and programs. The inclusiveness of the planning process makes it a valuable tool for building regional collaboration for operations among a broader range of transportation managers. Because interagency and interjurisdictional collaboration is critical for effective regional transportation management, the regional planning process can be an important forum for addressing regional operations concerns.

A major event (hosting a national or global event or responding to a major natural disaster) could motivate planning and operating agencies to coordinate more effectively. Hosting the Olympics, for example, has been the focus of many studies on how federal, state, and local operating agencies can focus their collective resources on managing the host city's transportation system. New institutional arrangements might be created to oversee new programs (for example, ITS), to respond to new state or federal mandates, or to take advantage of new funding sources. Moreover, arrangements are often formed to focus on regional operations objectives, such as regional management of work zones, coordinated incident management, or ITS deployment. It is not uncommon for an initial committee or task force that is focused on a particular topic to broaden its mandate over time to include coordination among a range of regional M&O strategies. Some institutional arrangements are created to link planning and operations for a specific process (such as an interagency committee that oversees the development of performance measures). Many regions have other types of institutional arrangements that focus on TSM&O more broadly and can serve as a link to regional planning activities.

The circumstances that lead to institutional innovation may differ across regions. In Philadelphia, for example, an MPO Transportations Operations Task Force consists of the technical staff representatives from over 35 regional stakeholders and acts as a forum for agencies to share information on ITS deployments and incident management programs and develop a consensus on regional ITS issues. In Orlando, the Transportation Systems Management and Operations Committee can have up to 23 representatives from the three counties and the 16 cities in the MPO planning area, and eight representatives from regional transportation agencies. The Florida DOT is a nonvoting advisor. The Committee acts as an advisory group to the MPO policy board, and recommends TSM&O projects. In Atlanta, the Atlanta Regional Commission has formed the Regional Transit Committee to focus on regional transit planning, funding, and governance. This committee consists of 12 members representing political jurisdictions and transit operators in the MPO planning area. The committee often discusses issues concerning coordinated transit operations.

At the state level, most DOTs do not have advisory committees for TSM&O efforts, although they often have task forces or committees for specific topics such as work zone safety, ITS implementation, and the like.

The following recommendations highlight opportunities to better coordinate planning and operations and could help prompt agency managers to consider where new institutional arrangements might be needed:

Designate an MPO Stakeholder Committee or Task Force on Regional TSM&O. An increasing number of MPOs support interagency committees that deal directly and regularly with the management and operations of regional transportation systems. In hosting such committees, the MPO facilitates discussions on interjurisdictional coordination, funding strategies, and data sharing.

Include Stakeholders with Specific Concerns or Expertise on Regional Operations Programs. One way to achieve greater stakeholder participation in stakeholder forums is to focus the forum's discussions on issues of greatest concern to important stakeholders. For example, someone who manages first responders is more likely to attend a committee dealing with regional incident management than a committee dealing with the broad topic of regional TSM&O coordination. Freight transportation planning is an area where focused forums have also been successful. Such committees have managed to bring freight needs and perspectives to the planning process, helping promote a regional perspective on operations challenges (see chapter 22 on freight transportation).

Encourage Multi-Jurisdictional and Public/Private Sector Involvement in Regional Operations Strategies. Many states and regions have developed system operations capabilities, such as traffic management centers (TMCs), that offer opportunities for integrated operations independent of other regional bodies. These organizations may have specific mandates, such as running a regional incident management program, providing real-time traffic information, or coordinating emergency management plans. They often provide a unique opportunity to bring together the public safety and operations management communities and thus are well positioned to address broader operations issues. Regional transportation operations collaborations and TMCs can provide valuable input to the planning process. At the same time, state, and regional planners should ensure that these organizations are aware of the planning cycle and planning decisions that could influence regional initiatives.

Define an Organizational Structure for the MPO That Reflects the Importance of Regional Operations. MPOs have historically been organized around long-range planning and programming of capital projects. In recent years, many MPOs have expanded their role to include greater involvement in regional systems management issues. Some agencies have chosen to restructure to reflect a growing responsibility for regional system operations. MPOs should consider the potential benefits of an institutional structure that reflects a heightened focus on managing the regional network.

For those interested, the following references provide good examples of different institutional arrangements for TSM&O programs as well as guidance on how to organize such an effort. [FHWA, 2005; Grant et al., 2010; Balke and Vogt. 2011]

B. Goals and Objectives

The framing of a regional transportation vision and goals affords an opportunity to integrate operations agencies into processes that shape future transportation systems. Near-term goals and visions, important for engaging businesses and members of the public in setting priorities, should involve TSM&O practitioners. The region's or state's vision should emphasize efficient operations, as well as needed physical infrastructure investments. Figure 10-10 shows the relationship among vision, goals, and objectives as it relates to incorporating system reliability concerns into transportation decision making. Figure 10-11 shows a typical hierarchy of objectives as it relates to system reliability.

Some examples from state DOTs and MPOs are presented here.

1. State DOTs

Washington State DOT [2007]

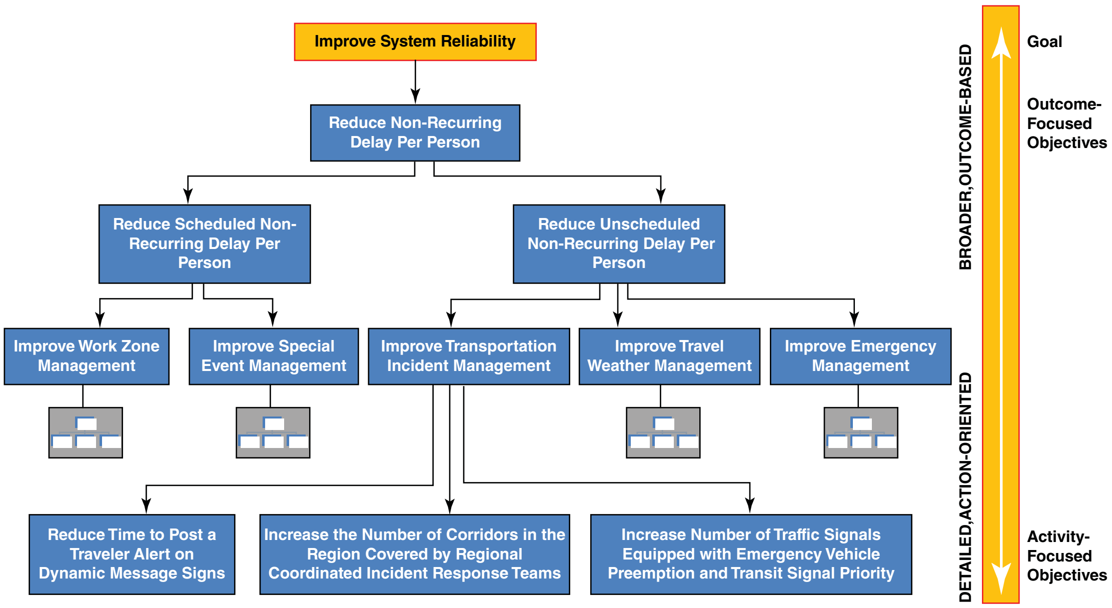
20-Year Transportation Vision—Washington's transportation system should serve citizens' safety and mobility, the state's economic productivity, communities' livability, and the ecosystem's viability.

Figure 10-10. Incorporating Reliability into Various Levels of Policy Statements

DESCRIPTION	ELEMENT	APPROACH TO INCORPORATING RELIABILITY
Broadest statement. Identifies the purpose of the organization	*Vision*	Reliability included only if it is a top agency priority
Broad statement that identifies how an agency delivers the vision	*Mission*	Reliability may be included if it is a major issue impeding the agency
Short statements describing a small set of the most critical issues that an agency is addressing	*Goals*	Reliability included if a significant issue
Additional specificity for the goals	*Objectives*	Reliability commonly addressed
Steps to implement the goals and objectives	*Policies, Strategies, Actions*	Actions to address reliability included

Source: Cambridge Systematics, 2014. Permission granted by the Transportation Research Board.

Figure 10-11. Objectives Hierarchy for Improving System Reliability



Source: Grant et al., 2013

Investment Guidelines

- *Preservation*—Preserve and extend prior investments in existing transportation facilities and the services they provide to people and commerce.
- *Safety*—Target construction projects, enforcement, and education to save lives, reduce injuries, and protect property.
- *Economic Vitality*—Improve freight movement and support economic sectors that rely on the transportation system, such as agriculture, tourism, and manufacturing.

- *Mobility*—Facilitate movement of people and goods to contribute to a strong economy and a better quality of life for citizens.
- *Environmental Quality and Health*—Bring benefits to the environment and our citizens' health by improving the existing transportation infrastructure.

South Carolina DOT [2014]

Vision—Provide safe, reliable surface transportation systems and infrastructure, and effective support for a healthy South Carolina economy through smart stewardship of all available resources.

Goals

- *Mobility and System Reliability*—Provide surface transportation infrastructure and services that will advance the efficient and reliable movement of people and goods throughout the state.
- *Safety and Security*—Improve the safety and security of the transportation system by implementing transportation improvements that reduce fatalities and serious injuries as well as enabling effective emergency management operations.
- *Infrastructure Condition*—Maintain surface transportation infrastructure assets in a state of good repair.
- *Economic and Community Vitality*—Provide an efficient and effective interconnected transportation system coordinated with state and local planning efforts to support thriving communities and South Carolina's economic competitiveness in global markets.
- *Environment*—Partner to sustain South Carolina's natural and cultural resources by minimizing and mitigating the impacts of state transportation improvements.
- *Equity*—Manage a transportation system that recognizes the diversity of the state and strives to accommodate the mobility needs of all of South Carolina's citizens.

2. MPOs

San Diego Association of Governments (SANDAG) [2011]

Vision: A transportation system that:

- Supports a prosperous economy; promotes a healthy and safe environment, including climate change protection; and provides a higher quality of life for all San Diego County residents.
- Better links jobs, homes, and major activity centers by enabling more people to use transit and to walk and bike; efficiently transports goods; and provides fast, convenient, and effective transportation options for all people.

Goals:

- *Mobility*—The transportation system should provide the general public and those who move goods with convenient travel options. The system also should operate in a way that maximizes productivity. It should reduce the time it takes to travel and the costs associated with travel.
- *Reliability*—The transportation system should be reliable. Travelers should expect relatively consistent travel times, from day to day, for the same trip and mode of transportation.
- *System Preservation and Safety*—The transportation system should be well-maintained to protect the public's investments in transportation. It is also critical to ensure a safe regional transportation system.

Charlotte Regional Transportation Planning Organization (CRTPO, Charlotte, North Carolina) [2014]. The following goals and objectives from Charlotte regional transportation plan are those relating mainly to system management and operations (a complete list is found in [CRTPO, 2014]).

Goal: Provide, manage, and maintain a safe, efficient and sustainable transportation system for all modes, intended to serve all segments of the population.

Objectives:

- Designate resources to maintain the existing transportation system.
- Minimize congestion within the existing transportation system.
- Develop an efficient street and highway network capable of providing an appropriate level of service for a variety of transportation modes.
- Encourage design features that minimize crash potential, severity, and frequency.
- Enable all users to choose a convenient and comfortable way to reach their destination, regardless of location, personal mobility level, age, or economic status.
- Promote future opportunities for interregional mobility through enhancements to intercity rail service and the provision of high-speed rail service.

Goal: Encourage walking, bicycling, and transit options, integrated with motor vehicle transportation, by providing a transportation system that serves the public with mobility choices.

Objectives:

- Increase the connectivity of the existing street network, including minimizing barriers and disconnections of the existing roadways, and improving access to activity centers.
- Improve the transportation system by developing streets and highways that are accessible to, or compatible with, multiple modes of transportation by utilizing design standards consistent with NCDOT's Complete Streets policy.
- Include sidewalks and bicycle facilities in the design of roadways to accommodate and encourage pedestrian and bicycle travel, and maximize linkages to off-road facilities and transit services.
- Support the operation of safe and efficient scheduled transit services that minimize travel times and distances.

Goal: Maximize travel and transportation opportunities for the movement of people and goods.

Objectives:

- Develop regionally significant streets and highways in a manner that manages congestion and minimizes travel times and distances.
- Promote the integration of, or coordination among, different transportation modes by supporting intermodal terminals that facilitate the movement of goods.
- Establish measures to enhance the intercity, interregional, and intraregional capacities of major transportation corridors.

Optimally, as regions strive to improve the efficiency, reliability, and safety of transportation systems, strategies that transcend jurisdictional boundaries will need to be developed and evaluated early in the planning process. In this manner, *solutions packages* that combine operations, infrastructure, and land-use strategies and projects can be formulated. Such a *transportation-as-a-system* perspective can help improve the quality and timeliness of transportation decisions because it inherently integrates operations into the planning process.

For further information on goals and objectives, see chapter 15 on state transportation planning and chapter 16 on metropolitan transportation planning.

C. Performance Measures

"What gets measured gets managed." This often-repeated maxim recognizes that performance measurement can focus the attention of decision makers, practitioners, and the public. Because they focus attention on the operating performance of the transportation system, performance measures are an important mechanism for increasing awareness of TSM&O approaches within the planning process. Performance measures provide a means of linking a transportation agency's perspective with the experience of those who use the transportation system. Defining performance measures and tracking performance often requires communication and coordination among those managing the operations of the transportation system (who often have data and expertise on real-time system performance), and those involved with planning and policy development (who can use this information to set goals, track progress, and make investment decisions).

Significant ways in which performance measures strengthen the planning-operations collaboration are:

Performance measures bring focus to customer-oriented outcomes. Performance measurement has traditionally been the realm of planners and policy analysts as part of the planning and investment prioritization process. Metrics tended to be those that could be modeled and used for long-term investment decision making, such as average travel times and miles of congested roadways. Examples of performance measures that focus on TSM&O included:

- Total or average hours of incident-related delay.
- Consistency of peak and off-peak travel times (that is, reliability).
- Average travel time by mode to designated regional centers.
- Commercial vehicle delay per mile.
- Extent of real-time information provision (for example, lane-miles or intersections for which information is available, number of ways to access such information, and so forth).
- Transit on-time performance.

Performance measures elevate the status of TSM&O approaches. Efforts to focus on system performance often result in better recognition of the value associated with TSM&O approaches. Use of performance measures and measuring the benefits of M&O strategies, such as traffic incident management and traveler information services, can help decision makers appreciate the value of such approaches for meeting both short- and long-term goals.

Performance measures help inform policy decisions. By focusing attention on system characteristics important to the traveling public, performance measures can help planners focus on the day-to-day experience of transportation system users. This provides important balance in settings where planners have been exclusively focused on very long-term development of the network. With greater focus on the day-to-day characteristics of the system, the issues faced by operators (such as incident response, work zone management, and provision of traveler information) take on greater importance. As a consequence, mid- and long-term planning can reflect greater consideration of TSM&O planning and investment needs. A greater understanding of operations issues by planning staff can also help in setting transportation policies.

A number of opportunities exist to use performance measurement to build stronger linkages between planning and operations. These include:

- Involve operations managers in the process of developing performance measures.
- Incorporate operational performance measures into strategic and long-range transportation plans.
- Use operations data for tracking performance in annual or quarterly reports.
- Use performance measures to motivate data and tool development.

Some examples of operations-oriented performance measures for different-sized jurisdictions include:

Florida DOT

- Percent travel in generally acceptable operating conditions during peak hour
- Hours of delay (passenger and trucks)
- Travel time reliability (passenger and trucks)
- Percent miles severely congested (passenger and trucks)

- Number of serious injuries and fatalities in motor vehicle crashes
- Fixed route transit incidents

Fredericksburg MPO, Virginia

- Annual hours of delay per peak period traveler
- Number of highway fatalities and fatality rate
- Number of highway crashes and crash rate
- Number of transit crashes, injuries and fatalities
- Number of aviation crashes and fatalities
- Mean travel time to work

Hampton Roads MPO, Virginia

- Annual delay, hours per peak auto commuter
- INRIX Index (extra time during peak period)
- Annual roadway fatalities, injuries and crashes and corresponding rates
- Annual transit fatalities, injuries and crashes and corresponding rates
- Annual highway-rail crossing crashes and rate (per million population)
- Annual aviation accidents
- On-time performance, Amtrak

Madison MPO, Wisconsin

- Miles of congested roadways (based on level of service)
- Freeway congestion duration
- Travel time to work (by mode)
- Miles of congestion on truck routes
- Total vehicle crashes by severity vs. VMT
- Metro transit bus crashes per 100,000 VMT
- Total bicycle and pedestrian crashes and fatalities
- Transit system on-time performance

Minnesota DOT

- Total number of fatalities resulting from crashes involving a motor vehicle
- Twin Cities urban freeway congestion: % of metro-area freeway miles below 45 mph in a.m. or p.m. peak periods
- Inter-Regional Corridor (IRC) travel speed: % of system miles performing more than 2 mph below corridor-level speed targets

Missouri DOT

- Average travel time and 95 percentile trip planning time for major metropolitan areas
- Miles of freeways in categories of percentile speed compared to free flow speed (for example, miles with 10 percent above free flow speed)

- Cost of congestion
- Average time to clear traffic incident
- Average time to meet winter storm performance requirements
- Work zone impact measure on traveling public

Performance measures should be periodically reexamined to make sure they are providing the information desired and needed by decision makers. The Minnesota DOT, for example, provided the following guidance on updating performance measures for its maintenance and asset management activities:

> *Continually improve reliability and credibility of performance measures*. The credibility of the measures is important in managing the asset and communicating the needs to the public and policy makers. It is imperative that good, reliable measures are developed and that data is tracked over time to establish historic patterns. This data can be used to evaluate current practices as well as predict impacts of changing investment levels or resources. Suggested actions include:
>
> - Continually improve data collection and methodology for performance measures (for example, pavement patching, guardrail, signing, and preventive bridge maintenance). As part of this process, consider independent review and verification of data.
> - Track historic data trends and report measures over time. Build trend-line data sets.
> - Forecast future performance and budget needs based on historic data.
> - Work to better define "winter severity" index and relationship of index to overall snow and ice removal cost. Track information over time to better compare snow and ice cost changes.
> - Compare standards and/or performance targets with applicable national standards from other available operations and maintenance plans.
> - Establish periodic audits of Highway System Operations Plan performance measures encompassing both performance and financial data. [MnDOT, 2005]

TSM&O professionals contribute a unique perspective on how to measure performance and can therefore add a great deal to the regional discussion about performance measurement at the system, corridor, or facility levels. Performance measures help determine whether resources are being prioritized properly to meet goals and objectives. Performance measurement can dramatically influence which regional needs are highlighted within the planning process and which are downplayed or ignored.

Good examples of performance measures that reflect system and facility operations are found in [Cambridge Systematics et al., 2008; Cambridge Systematics et al., 2010; Grant et al., 2013; and Cambridge Systematics et al., 2014].

D. Data Collection and Sharing

Data collection and interpretation have experienced significant changes over the past 10 years, and will likely see more in the future. With vehicle-to-vehicle and vehicle-to-infrastructure technologies becoming more commonplace, the data generated by travelers on an average day will far surpass data that was available to transportation planners in recent years (see later section on connected technologies). Much of this data will be useful for transportation planning. According to the FHWA, "the use of operations data is vital to the advancement of transportation planning as MPOs and state DOTs shift to a more performance-based planning process that requires system performance data to guide decision making." (http://www.ops.fhwa.dot.gov/plan4ops/focus_areas/analysis_p_measure/data_for_planning.htm).

The availability of data also has a great deal to do with the types of performance measures that can be adopted. Operations data address real-time performance of the transportation system, allowing for the development of measures that can better capture the experiences of users (such as travel time and travel time reliability). However, to access and properly apply real-time data, the planning process needs the resources and expertise of operations practitioners. [Shaw, 2003]

Using advanced technologies, it is now possible to collect and store vast amounts of data to support the planning and operation of transportation systems. Roadway loop detectors, for example, can provide real-time information about traffic volumes and speeds. Global positioning systems and radio/cellular phone triangulation can determine vehicle location and speed. Electronic fare collection and automatic vehicle location systems can record detailed information on transit service and use. These rich data sources may not only replace many more expensive, traditional data collection methods, such as manual traffic counts, surveys, and floating car studies, but they may also allow data to be combined across modes and operational environments in new ways. In doing so, they can create a more complete picture of how policy, infrastructure and service changes affect the reliability and performance of transportation systems.

Data sharing refers to a broad range of activities that support the full use of readily available transportation information. [Kittelson and Assocs. 2013; Pack and Ivanov, 2014] Many government and private organizations collect data that can inform the design and operation of transportation facilities and systems. First and foremost, data sharing implies awareness about such data sources and a fresh perspective in considering their potential value in new uses. Data sharing typically requires that organizations store data and make them available in usable formats. It may also involve a forum to coordinate with other organizations about potential data exchange opportunities. Table 10-8 shows different types of information technology strategies and typical applications.

Table 10-8. Information Technology and Data-Sharing Strategies

Strategy	Description or Application	Modes Affected	Impact on Reliability
Advanced automatic collision notification (AACN) systems in all vehicles	Crash notification within 1 min for all crashes; network of sensors in infrastructure to detect imminent or actual events or hazards	All (passenger vehicles, freight, transit, bikes, pedestrians)	High
Bus rapid transit and signal preemption	Vastly improved transit as a serious option	Transit	High
Combined sensors–computer–wireless link	Multiple information fusion methods combining data from multiple sensors and databases; data fusion nodes communicating on ad hoc wireless network	n.a.	Medium
Comprehensive real-time information	Real-time information available to all modes in an integrated fashion; pedestrians, bikes, and vehicles will have relevant information and options on how to proceed with trips	All (passenger vehicles, freight, transit, bikes, pedestrians)	High
Customized real-time routing	Tuned to driver preferences and driven by real-time congestion and reliability data, with predictive capability; what conditions will be at arrival	Passenger vehicles, freight, transit	High
Video coverage of networks	Can see picture of the road ahead in car, on phone, in TMC	All (passenger vehicles, freight, transit, bikes, pedestrians)	High
Rapid incident clearance	Automated scene assessment, damage assessment through total stations and digital imaging, rapid removal of damaged vehicles; ability to do on-scene accident investigation in minutes, not hours, with automated imaging technology	All (passenger vehicles, freight, transit, bikes, pedestrians)	High
Real-time condition monitoring to predict long-term infrastructure performance	Major elements self-monitoring on real-time basis; reports problems in advance	All (infrastructure)	High

(*continued*)

Table 10-8. (*Continued*)

Strategy	Description or Application	Modes Affected	Impact on Reliability
Real-time information on parking availability, roadway conditions, routing, rerouting	Time spent on parking significantly reduced; drivers will know parking availability ahead of time	Passenger vehicles	High
Reliance on roadside signs for driver information	Real-time messages directly to vehicles for information, routing, traffic management, incident management, etc.	Passenger vehicles, freight, transit	Medium
Universal fare instruments for transit and road pricing	Highly controlled to minimize transfer and waiting time; elimination of dwell times caused by fare collection	Passenger vehicles, freight, transit	High
Weather detection and response systems	Snow and ice management through chemical and nanotechnology applications; reduce reliability problems due to weather despite increasing extreme events	All (infrastructure)	Medium
Data from vehicle traces (for example, GPS tracking of trucks and containers)	Powerful source of reliability data; vastly improved ability to measure reliability makes it feasible to manage for reliability, to guard against performance degradation, to guarantee performance, etc.	Passenger vehicles, freight, transit	Medium
Data sharing	Barriers overcome through creative confidentiality agreements, technologies, and algorithms	n.a.	Medium
Fully implemented NG9-1-1	Full AACN telemetry data in actionable form pushed into NG9-1-1 system; image from inside vehicle automatically received at public-safety answering point after crash	All (passenger vehicles, freight, transit, bikes, pedestrians)	High
Hybrid wireless mesh networks	Mesh networks facilitating communication of VII and improving mobile interconnection; vehicle-to-vehicle and vehicle-to-infrastructure networks a reality	All (passenger vehicles, freight, transit, bikes, pedestrians)	High
Latest onboard technology	Fleet turnover inertia overcome with software upgrades rather than new vehicle purchases	Passenger vehicles, freight, transit	Medium
Multimodal routing, schedules, trip planning	Gives people travel options; same for freight (though to a large degree, this exists for freight through 3PL)	All (passenger vehicles, freight, transit, bikes, pedestrians)	Medium
Predictive models for real-time systems operation	Forecasting models supporting real-time systems operations and preventing possible breakdowns on the network	n.a.	Medium

Note: 3PL = third-party logistics; BRT = bus rapid transit; na = not applicable; AACN = advanced automated crash notification; NG9-1-1 = Next Generation 9-1-1.

Source: Kittelson and Assocs., 2013. Reproduced with permission of the Transportation Research Board.

Interest in data sharing is prompted in part by growing concern about the performance of transportation systems as well as the performance of individual facilities, and by the increased focus on M&O strategies to enhance transportation system performance. Efforts to improve travel time reliability and predictability require more detailed data than have traditionally been analyzed by planners. The system focus means that data on conditions are needed virtually everywhere in the transportation system across jurisdictions and modes. This contrasts with the typical hot-spot approach that has governed data collection and transportation management in the past.

The ITS architecture, that is, the strategy established to provide a coordinated approach to the application of advanced technologies to transportation system management, also encourages the identification of new data sharing opportunities. Information flow analysis is an important element of the national ITS architecture (and regional ITS architectures). An information flow analysis is typically diagramed in a way that illustrates the appropriate information flows between each major component of the transportation system, thereby highlighting potential data sharing options. A related element of the recommended national ITS architecture—the Archive Data User Service—was designed to facilitate alternative uses of ITS data, including use of data for transportation planning. The Archive Data User Service helps promote a regional data sharing approach consistent with current and anticipated technological capacity.

Organizations that receive data benefit from valuable information on transportation system demand and performance, often at little or no cost. Sharing data can benefit the organization providing data by building awareness of the agency's programs and creating a check on data accuracy. Data sharing may necessitate changes within the agencies receiving data, including a willingness to evaluate planning practices and operations strategies in light of more complete information.

Data sharing is often a first step toward broader coordination between planning and operations. Sharing data requires establishing new relationships with other agencies and building mechanisms to support sustained data exchange and storage. Data formats, accuracy, consistency, and appropriate use can complicate the process of establishing inter- and intra-agency data sharing programs, but there are many examples where such challenges have been met.

Data sharing can be used as a mechanism to link planning and operations in several ways:

- *Develop a regional data clearinghouse*. A central data clearinghouse can help facilitate access to the region's full range of transportation data for both planning and operating agencies.
- *Coordinate data resources with transit agencies*. As a result of ITS deployments, transit agencies are becoming more valuable data-sharing partners, enabling them to participate in regional planning activities in new ways.
- *Use special events to initiate new data partnerships*. Coordinating special events creates an opportunity to develop awareness of data that are available from other organizations.
- *Use operations data to develop more effective performance measures*. Operational data are also essential for the development of many performance measures.
- *Use operations data to improve planning analysis tools*. Data gathered through transportation systems operations activities can be valuable to transportation planners for improving travel demand models and developing other analytical tools. The availability of more detailed operations data can lead to better travel demand forecasting models, including models that are more sensitive to the effects of operations strategies.
- *Use archived data to inform TSM&O planning*. While archived data can be useful to transportation planning agencies, it can also help those responsible for M&O to internally plan and coordinate their activities for the most effective results.

Another type of data collection important in planning for operations focuses on evaluating strategies and actions that have been already been implemented to gauge their overall success and appropriateness for future application. In this case, the types of data collected would reflect the different possible outcomes of an implemented strategy. For example, Table 10-9 shows the types of data collection tools that would be considered in the evaluation of the strategies or actions listed. Chapter 7 on evaluation provides more information on ex post facto evaluation of projects.

E. Operations-Oriented Analysis Tools

Determining where transportation improvements are most needed is an important component of regional planning processes. Planning needs assessment traditionally has focused on additional roadway or transit capacity to improve mobility in particular corridors. As the focus of planning efforts extends beyond mobility to also address travel time reliability and accessibility, M&O strategies grow in importance, especially in light of environmental, community, and funding constraints on new physical infrastructure projects. The needs assessment phase, therefore, provides an important opportunity to more effectively engage TSM&O in the decision-making process. The need to better integrate TSM&O into regional needs assessment is heightened further by the increased focus on transportation security, which relies on effective operations planning and response to prepare for and respond to system disruptions.

Table 10-9. Data Collection Methods for Evaluating Transportation Strategies		
Strategies Being Evaluated	**Performance Measures**	**Data Collection Methods**
Incident management	• Average incident duration • Occurrence of secondary accidents • Incidence response time	• Log of incident duration (from dispatcher records) • Measurement of speeds from surveillance system
Traffic management	• Average speeds • Intersection delay	• Traffic volume counts • Moving car runs • Measurement of speeds from surveillance system
Traveler information	• Door-to-door trip time • Transit ridership • Mode share • On-time arrivals	• Trip logs (by regular commuters), for roads and/or transit • Traffic counts • Transit ridership counts • Mode shift survey
Transit operations	• Transit travel times • Transit ridership • Peak load factor • Schedule reliability • Transfer time/station delay or waiting time • Transit travel time • Roadway impacts (for example, vehicle delay, speeds) • Mode share	• Mean incidence clearance time
Travel demand management	• Mode share • VMT reduced	• Mode share survey • Traffic counts

Source: Grant et al., 2010

1. Analysis Tools and Methods

A variety of analysis tools and approaches are used to predict the effectiveness of M&O strategies. Figure 10-12 shows a typical range of analysis approaches and the level of precision associated with key characteristics. In many state DOTs and MPOs, network simulation is an important analysis tool for understanding network performance.

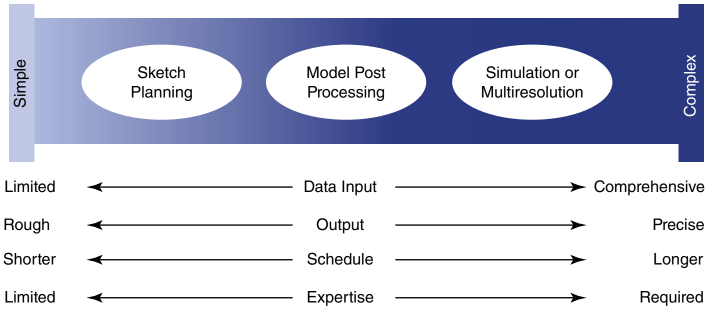
The different types of analysis tools that fit into this spectrum were defined by Cambridge Systematics et al., [2014] as:

Sketch-Planning Methods. Analysis methods intended to provide quick assessment of reliability (and the impacts of projects affecting reliability) using generally available data as inputs to the analysis. These are the least resource-intensive of the analysis methods and produce order-of-magnitude results that are often used in early planning stages.

Model Post-Processing Methods. Analysis methods focus on applying customized analysis routines to data from a regional travel demand model to generate more specific estimations of travel time reliability measurements. They benefit from the travel demand model's robust network and supply-and-demand conditions. The most common of these methods is based on analysis from the ITS Deployment Analysis System (IDAS) tool, developed by FHWA, which estimates incident-related congestion (a major component contributing to travel time variability).

Simulation or Multiresolution Methods. Methods that use an advanced traffic simulation model's ability to test and assess the driver's behavior and reactions to nonrecurring events. Multiresolution methods often take advantage of the integration of several standard modeling tools (for example, microsimulation and travel demand models) to combine different tools' abilities to assess shorter-range and longer-range impacts of various congestion mitigation strategies. For reliability assessments, these simulation and multiresolution methods are often combined with multi-scenario analysis, whereby models are run with several alternative conditions that represent logical variations in travel demand, weather conditions, incident occurrence, presence of work zones, or other factors influencing nonrecurring congestion.

Figure 10-12. Spectrum of Reliability Analysis Tools and Methods



Source: Cambridge Systematics et al., 2014. Reproduced with permission of the Transportation Research Board.

Monitoring and Management Tools and Methods. Tools and methods intended to provide analysis of real-time and archived traffic data. They differ from the aforementioned methods as they primarily target assessing past conditions rather than forecasting future conditions; however, these tools and methods may play a significant role in providing data for forecasting methods.

Table 10-10 identifies potential applications of different types of analysis tools and methods for different transportation planning needs. As shown in the table, performance metrics themselves are considered an analysis tool to understand system performance.

Table 10-10. Transportation Planning Needs and Operational Analysis Tools

	Operational Analysis Tools and Methods						
Transportation Planning Needs	**Sketch Planning Tools**	**Deterministic Models**	**Travel Demand Forecasting Models**	**Simulation**	**Archived Operations Data**	**Operations-oriented Performance Metrics**	**Traffic Signal Optimization Tools**
Needs Assessment/Deficiency Analysis		X	X	X	X	X	X
Preliminary Screening Assessments	X					X	
Alternatives Analysis	X		X	X		X	
Strategic ITS Planning	X		X			X	
Project Scoring/Ranking Prioritizing		X	X			X	
Corridor and Environmental Analysis		X	X	X		X	X
Planning for Nonrecurring Congestion	X		X	X	X	X	
Performance Monitoring		X			X	X	X
Evaluation of Implemented Projects	X				X	X	

Source: Jeannotte et al., 2009

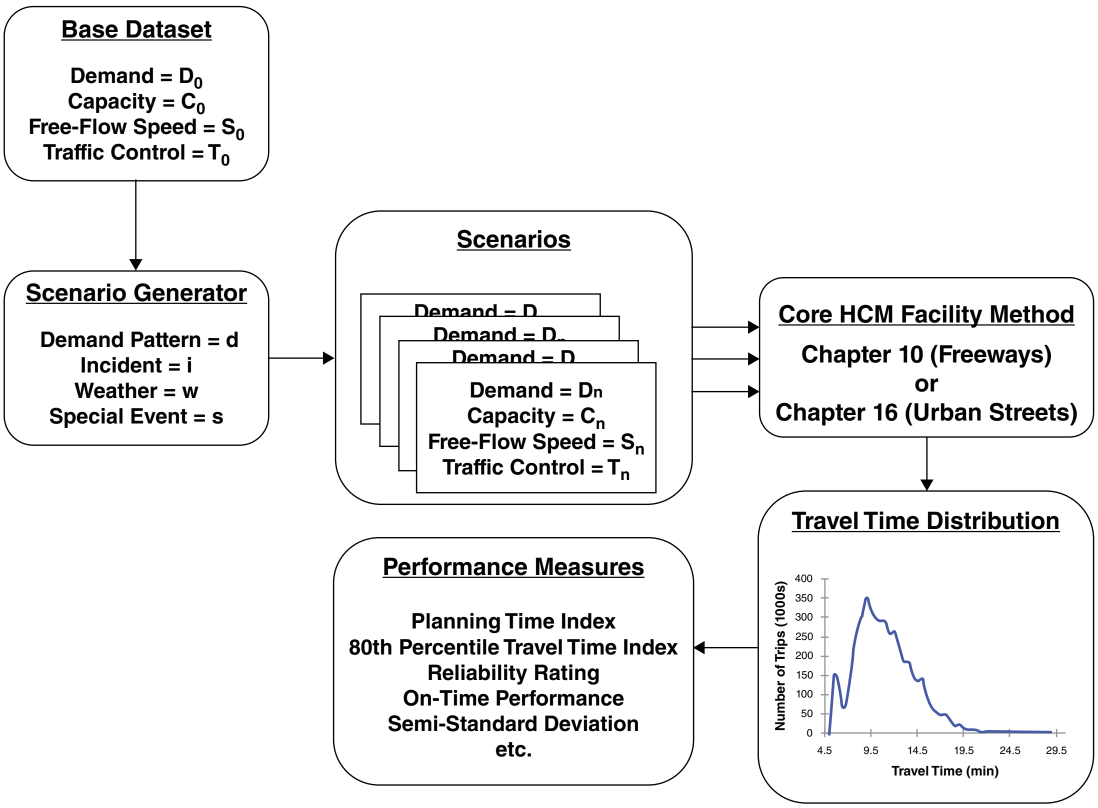
2. Scenarios

Many analysis efforts include two or more scenarios, often relating to particular themes. For example, a region may define one analysis scenario as all desired capital investments, while another scenario consists of whatever investment is needed simply to maintain the existing system. Or, alternatively, a scenario might be implementing what is already in the investment program, but putting all additional resources into M&O strategies. Developing an integrated M&O-focused alternative is an excellent opportunity for involving operations practitioners in the planning process. This is a chance to see how regional or state coordination of TSM&O efforts can address short- and midterm needs. Moreover, incorporating M&O strategies into all types of capacity enhancement projects is important for ensuring that the effective capacity of the system is achieved.

As of the publication of this handbook, there is a proposal to include in the *Highway Capacity Manual* two chapters that focus on nonrecurring congestion impacts on freeways and urban streets. The basis for the proposed methodology is the development of analysis scenarios reflecting different factors that could affect system or facility reliability, such as work zones, weather, incidents, and infrastructure design characteristics. Figure 10-13 shows the general concept of how scenarios are used to estimate the impact of nonrecurring events on facility reliability. In general, the scenario generation process includes the following steps:

- Adjusting the base demand to reflect day-of-week and month-of-year variations associated with a given scenario.
- Generating severe weather events based on their probability of occurrence in a given time of year, and adjusting capacities and free-flow speeds to reflect the effects of the weather events.
- Generating various types of incidents based on their probability of occurrence and adjusting capacities to reflect their effects.
- Incorporating user-supplied information about when and where work zones and special events occur, along with any corresponding changes to the base demand or geometry.

Figure 10-13. Proposed Process for Use of Scenarios in Estimating Impact on Freeway and Urban Street Reliability



Source: Ryus et al., 2013, Reproduced with permission of the Transportation Research Board.

Table 10-11. Benefits of Operations Strategy From Implemented Projects	
Operations Strategy	**Example Benefits**
Dynamic speed limits	Crashes reduced 10%–30% Secondary crashes reduced 50% Improved reliability
Dynamic shoulder running	Travel times reduced up to 25% No impact on safety
Ramp metering	Crashes reduced 15%–40% Travel times increased 10%+
Transit signal priority	Bus times improved 2%–15% Minimal impact to side streets
Adaptive signal control	Delay reduced 4%–40%
Integrated corridor	Estimated B/C of 5:1 to 10:1
Traffic signal control	Emissions reduced 3%–22%
Congestion mitigation strategies (for example, incident management)	CO_2 reduced 7%–12%
Variable speed displays	CO_2 reduced 10%–20%
Automated vehicle location/Computer aided dispatching	Improved schedule adherence by 9%–23%

Source: SHRP2, 2014, Reproduced with permission of the Transportation Research Board.

The results of the analysis will show what to expect in terms of change in performance characteristics. The specific impacts will vary by problem context, but to give some sense of the level of magnitude of such impacts, the information shown in Table 10-11 was gathered from a number of studies.

Those interested in the use of scenarios in analysis and evaluation should find the latest update on this effort to include a methodology in the *Highway Capacity Manual*.

F. M&O Strategies Included in the Plan and TIP

Many planning agencies have developed procedures for applying modeling techniques and economic assessments to choose among various capital investment options. This already challenging process becomes even more complex when transportation operations projects and programs are included within competing investment scenarios. For example, evaluation techniques can rarely weigh the benefit from a coordinated set of corridor traffic incident management strategies. Operations practitioner involvement in the analysis is critical to ensure that the full range of benefits of these operations programs is considered. Getting them involved at this stage can help them see the importance of their expertise within the transportation decision-making process. Ultimately, interaction in this evaluation process can lead to improved mutual understanding and often raises new coordination steps for subsequent updates to the transportation plan.

Estimating the benefits and costs associated with candidate alternatives is a critical element of any evaluation process. Table 10-12 shows the primary measures of effectiveness or evaluation criteria associated with different M&O strategies. Where an evaluation produces information on the relative merits of the alternatives being considered, the measures of effectiveness shown in Table 10-12 could be the basis of comparison (see chapter 7 on evaluation).

There are a variety of ways that M&O strategies can be evaluated and priorities established. Table 10-13 shows the approaches several MPOs use to evaluate M&O projects. Notice in some cases dollars are set aside before any assessment to ensure a minimum amount of investment is going to M&O strategies. Another important observation is that many MPOs rely on TSM&O committees or subcommittees for the prioritization of such strategies.

Table 10-12. Example Measures of Effectiveness for M&O Strategies/Projects

TSM&O Strategy	Mobility (Travel time savings)	Reliability (Total delay)	Safety (Number and severity of crashes)	Emissions	Energy (Fuel used)	Vehicle Operating Cost Savings	Agency Efficiency
Arterial Corridor Signal Coordination							
Preset timing Traffic actuated timing Centrally controlled timing Arterial transit vehicle signal priority	●	○	●	●	●	○	
Freeway Management Systems							
Ramp metering Preset timing Traffic actuated timing Centrally controlled timing	●	●	●	●	●	●	
Advanced Public Transportation Systems, Fixed-Route and Paratransit Systems							
Transit Automatic Vehicle Location Transit automated scheduling Paratransit systems	●	●	○	○	○	○	●
Incident Management Systems							
Freeway/arterial service patrols Incident detection and verification Incident response management	●	●	●	●	●	○	
Pre-trip Multimodal Traveler Information Systems							
Web-based 511 traveler information systems Phone-based 511 traveler information systems Kiosk-based traveler information systems	●	●	○	○	○		
En Route Multimodal Traveler Information Systems							
In-vehicle 511 traveler information system (PDA/web-based or telephone-based) Highway advisory radio Dynamic message boards Transit station traveler information systems	●	●	○	●	●		
Commercial Vehicle Operations							
Roadside electronic credential and safety screening	●		●	●	●	●	○
Traffic and Demand Management							
Congestion pricing and HOT lanes	●	●	○	○	○		
Speed harmonization	○	●	●	●	●		
Work zone management	●	●	●	●	●	●	●

● Primary Measure of Effectiveness ○ Secondary Measure of Effectiveness

Source: FHWA, 2013a

Table 10-13. Example Processes for Selecting TSM&O Projects	
TSM&O Project Selection Process Summary	
MPO	**Project Selection Process**
DRCOG (Denver)	Three program pools serve as the core mechanism for federal funding for operations in the region: ITS, TDM, and traffic signal system Improvements. There is a separate project selection process for each of three pools. Stakeholder groups apply a consensus-based scoring process with different selection criteria for each funding pool. Decisions are based on regional operations priorities in regional operations-focused planning documents.
GTC (Rochester, NY)	There are set-aside funds for the HELP (highway emergency local patrol) program and Regional Traffic Operations Center staffing. Other operations projects compete with all other projects for TIP funds. All projects are ranked using a set of common criteria and mode-specific criteria. TSM&O is a category with its own mode-specific criteria.
MAG (Phoenix)	Selection of ITS/operations projects is based on priorities set forth in the Regional ITS Strategic Plan using a competitive process with the following criteria: (1) relevance to regional ITS plan, (2) compliance with regional ITS architecture, (3) congestion mitigation potential, and (4) emissions reduction potential. ITS/operations projects do not compete with other transportation projects for funding. All proposed ITS projects are reviewed by the ITS committee. It provides project recommendations that are then reviewed by other committees.
MetroPlan (Orlando)	Once a year, an operations stakeholder committee meets to select TSMO projects to be funded by the TSMO set-aside, prioritize them, and set a schedule for implementation. The committee ranks projects based on expected system impact, cost-efficiency, coordination with the ITS system architecture, strategic -plan and geographic equity among MetroPlan's member local governments.
NCTCOG (Dallas-Ft. Worth)	NCTCOG uses separate project selection criteria for the following types of TSMO projects: (1) intersection improvements, (2) ITS, and (3) traffic signal improvements. NCTCOG staff then evaluate the merits of each project using criteria and weights identified in the call for projects. While most projects go through a competitive proposal and technical evaluation process, some projects are selected because they qualify for targeted, strategic state or local programs.
PPACG (Colorado Springs)	Projects are prioritized based on their ability to fulfill the goals of the RTP and to meet criteria specified for each specific funding program. TSM&O strategies compete for funding in the Maintenance & Operations and Congestion Mitigation Air Quality (CMAQ) funding program categories.
PSRC (Seattle)	Operations projects compete against all others in the TIP selection process. Operations project sponsors may apply for federal transportation funds from PSRC's programming process through either a regional competition or through one of four countywide competitions.
Portland Metro	Operations projects receive funding through the TSM&O Program funding set-aside and the open competitive process. The MPO works through its operations stakeholder group to evaluate and select projects for the TSM&O program funds; one-third of these funds go to regionwide projects and two-thirds go to corridor-level projects. The regionwide projects are selected by consensus whereas the corridor-level projects are selected using specific evaluation criteria and analysis.
SANDAG (San Diego)	The MPO applies a 100-point scoring process in the selection of TSM&O as well as other types of projects. The scoring criteria are grouped into three broad categories: serves travel needs (40 percent weight), network integration (20 percent weight), and addresses sustainability (40 percent weight). Many ITS and operations projects are incorporated into larger capital projects.

Source: FHWA, 2013b

There are several ways to determine the relative worth of one project over another (see chapter 7). The primary method is to conduct a benefit/cost analysis, where benefits are expressed in monetary terms. The FHWA has developed a simple spreadsheet-based benefit/cost tool called TOPS-BC that provides:

- The ability to investigate the expected range of impacts associated with previous deployments and analyze many M&O strategies.
- A screening mechanism to help identify appropriate tools and methodologies for conducting a B/C analysis based on analysis needs.

- A framework and default cost data to estimate the life-cycle costs (including capital, replacement, and continuing O&M costs) of various TSM&O strategies.
- A framework and suggested impact values for conducting simple sketch planning level B/C analysis for selected TSM&O strategies. [Sallman et al., 2013]

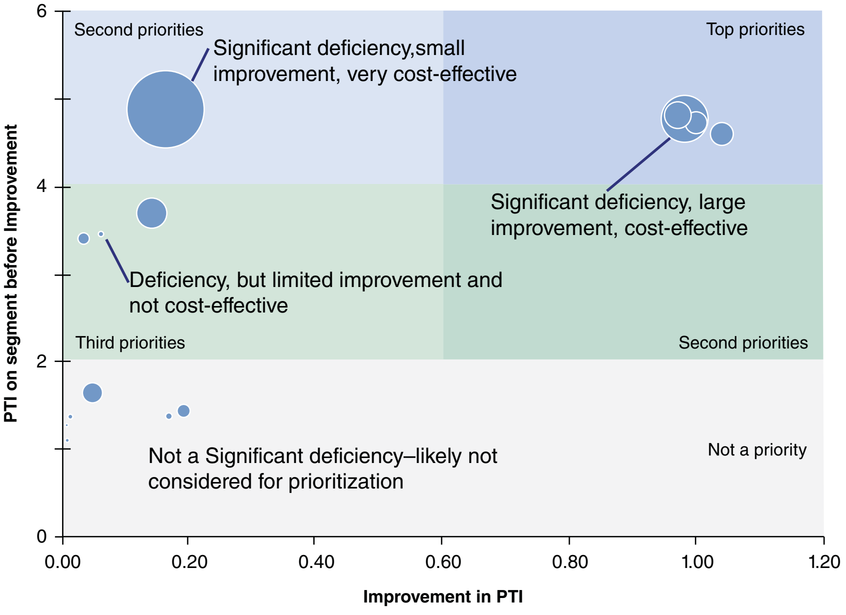
Compared to more traditional infrastructure improvements, M&O improvements typically exhibit a greater proportion of their costs as continuing operations and maintenance, as opposed to upfront capital costs. Thus, the tool provides a user with the capability to examine the total expected life-cycle costs of every strategy. The benefits of a strategy are associated with the expected effect on travel flow, for example, change in travel time, reduction in the number of crashes, improved travel-time reliability, and the like, with each criterion estimated monetarily (using appropriate economic value factors, such as the value of time and value of a human life).

Caltrans has developed a similar tool that provides users with outputs relating to life-cycle costs and benefits, net present value estimates, benefit/cost ratios, rate of return and payback values. [Caltrans, 2009] The benefits are estimated as travel time savings, vehicle operating cost savings, crash cost savings, and emission cost savings. The tool also produces results on person-hours of time saved, additional CO_2 emissions saved (in tons), and additional CO_2 emissions saved (in millions of dollars). The emphasis on CO_2 emissions comes from state laws that require state agencies to reduce greenhouse gas emissions.

Another interesting way of portraying the relative effectiveness of M&O strategies is called cost effectiveness. In this approach, the benefits are not monetized, but simply estimated with some quantifiable metric. The analysis then assesses the dollar expended per unit of benefit achieved. An example is shown in Figure 10-14 where the impact measure is the planning time index (PTI), a measure of the reliability of the system or facility (the larger the number, the worse the reliability). The x-axis in the figure shows the ratio in improvement in the PTI; the larger the ratio the greater the improvement. Thus, the strategies that are in the upper right quadrant of the figure are the "best" strategies because they have the largest deficiency in reliability and show the greatest improvement with respect to level of investment.

Readers interested in additional information on TSM&O evaluation and prioritization methods should refer to chapter 7 on evaluation and the FHWA Traffic Operations website at: http://www.ops.fhwa.dot.gov/plan4ops/news.htm.

Figure 10-14. Relative Effectiveness of TSM&O Strategies



Source: Cambridge Systematics, 2014. Reproduced with permission of the Transportation Research Board.

G. Shared Funding and Resources

In developing strategies to fund TSM&O activities, regions have an opportunity to promote new relationships and arrangements that support broad regional systems management perspectives and better link operations with regional planning. For example, a planning and programming process that places a high priority on inter-jurisdictional coordination can encourage normally independent practitioners to collaborate and identify opportunities for shared equipment and facilities. Funding strategies can also be used to help ensure implementation of TSM&O objectives developed through the planning process or to attract new operations stakeholders to planning forums.

Funding and resource sharing refers to a variety of arrangements by which transportation and other operating agencies collaborate to submit funding requests, develop pooled funding mechanisms, or share equipment and facilities. As a coordination opportunity, this also refers to efforts to coordinate between visions of transportation systems management that are discussed in plans and the regional funding policies and commitments that are needed to make those visions a reality.

The structure of resource sharing arrangements may evolve over time in response to changing regional needs and changing relationships among agencies. Initially, sharing may be limited to supplying staff, equipment, or facilities in support of regional meetings or other regional collaboration activities. If appropriate, participating public and private organizations may develop more formal sharing arrangements, including pooling of funds and other resources to sustain cooperative regional efforts. In some regions, agencies may provide funding to support a regional entity charged with leading regional collaboration or an entity that owns and operates regional transportation system assets.

There are several opportunities to coordinate planning and operations:

- *Link funding to planning goals and objectives*. Increasingly, local and regional transportation plans include language supporting improved transportation systems management, promoting more efficient use of existing infrastructure and adopting a more customer-oriented approach to transportation service provision. Yet the funding and staff resources to implement planning objectives are often lacking. Several approaches have been used to more closely link funding to operations goals. One approach is to have regional stakeholders determine minimum budget requirements to support long-range plan objectives in each program area.

- *Develop innovative operations funding sources*. New funding mechanisms can help create bridges between planners and operations managers. One strategy is to fund TSM&O efforts as part of the initial capital investment for a project. Planners and operators increasingly see that funds for TSM&O associated with a particular project or corridor are best secured in coordination allocations for major new construction or rehabilitation. Working together, planners and operators can make the case that proper management of new transportation facilities will maximize the long-term benefits of the initial investment.

- In the search for funding for system operations, some regions have turned to land developers. The practice of requiring developers to fund transportation improvements as a way to mitigate the transportation impacts of their projects is well established, but relying on this as a source of TSM&O improvements is relatively new. Developer concessions can provide an important source of revenue and can also encourage more detailed planning for TSM&O programs.

- *Build on emergency response funding needs to create regional opportunities for regional operations collaboration*. The recent focus on improving emergency preparedness and response has heightened the need for coordination between planning and operations.

- *Share office facilities*. Sharing office facilities inspires enhanced collaboration. In some cases, office sharing is arranged intentionally because there is recognition that transportation agencies working in the same space may do their job more effectively. A common example is a traffic management center (TMC) shared by traffic operators, transit staff, and public safety personnel.

- *Use the unified planning work program to define commitments to M&O planning*. Specific enumeration of regional M&O activities in the agency's Unified Planning Work Program (UPWP) is a way to ensure that such activities are implemented. This also builds the understanding that the MPO intends to take a leadership role on regional M&O issues.

VII. DISSEMINATION OF OPERATIONS DATA

The increasing application of sensors and advanced locational technologies has begun to change dramatically the types of data and information disseminated to the public. For example, Tables 10-14 to 10-16 show typical types of data collection methods, types of data, and means of dissemination that are now quite common.

The need for data such as that shown on the tables suggests some important characteristics for system monitoring programs. First, travel times are probably the most important piece of information desired by travelers. Second, the monitoring system should characterize the reliability of the transportation network during the time of travel. Third, the monitoring system should identify the sources of unreliability (for example, incidents or systemic design deficiencies), and finally the monitoring system should help owners and operators of transportation systems know what the impacts are of an unreliable system. [List et al., 2014]

VIII. THE CONNECTED TRANSPORTATION SYSTEM

Advancements in transportation follow, in many ways, the transformation of society that is caused by the creative use of information technologies. Many of the M&O strategies discussed in the previous sections rely on the use of surveillance and communications technologies. Transportation is arguably entering into one of the most transformative eras of personal mobility caused by the application of advanced technologies to both the vehicle and infrastructure. Autonomous vehicles, vehicle-to-vehicle (V2V) communications, and vehicle-to-infrastructure (V2I) sensing and communications are going to potentially revolutionize how transportation systems operate. These technologies are, in essence, enabling a connected transportation system, with significant impacts on TSM&O programs.

Table 10-14. Data Collection Methods for Operations Data

Data Collection Method	NavTeq[a]	Inrix[a]	TRANSCOM[b]	TransGuide[b]	TranStar[b]	AirSage[a]
Probe Vehicles						
E-ZPass tag readers			X			
GPS fleets	X	X				
Phone data (crowdsourcing)	X					
GPS enabled						X
Triangulation						X
Bluetooth data	X					
Proprietary services	X					
Government sensors	X	X[c]				
Incident data	X					
Event data	X					
Historical data	X	X				
Highway-embedded sensors		X				
Video monitors and cameras		X		X	X	
FM radio stations		X				
Local traffic monitoring centers		X				
Speed sensors					X	

Note: GPS = Global Positioning System.

[a]Private company.

[b]Public agency or consortium.

[c]Data collected via SmartDust network.

Source: List et al., 2014, Reproduced with permission of the Transportation Research Board.

Table 10-15. Types of Information Disseminated					
Types of Information	**NavTeq[a]**	**Inrix[a]**	**TRANSCOM[b]**	**TransGuide[b]**	**TranStar[b]**
Speeds	X				
Average speeds		X			
Travel times			X		
Origin-destination pairs			X		
Path			X		
Expected					X
Personalized updates					X
Map data	X	X			X
Incident data	X	X	X	X	X
Construction and work zone data			X	X	
Congestion and flow data	X	X		X	
Weather data					X
Real-time traffic data	X				X
Incident location					X
Quickest route to incident[c]					X
Stalled vehicle location[c]					X

Note:

[a]Private company.

[b]Public agency or consortium.

[c]Issued to emergency personnel.

Source: List et al., 2014, Reproduced with permission of the Transportation Research Board.

Table 10-16. Methods of Information Dissemination					
Method of Dissemination	**NavTeq[a]**	**Inrix[a]**	**TRANSCOM[b]**	**TransGuide[b]**	**TranStar[b]**
Internet	X		X	X	X
RSS feed					X
Twitter					X
E-mail					
Cell phone and mobile alerts					X
Low-power television stations				X	
Highway advisory radio					X
Dynamic message signs			X	X	X
AM/FM radio	X				
Satellite radio	X				
Broadcast and cable TV	X				
Wireless applications	X				
GPS navigation device for dynamic rerouting[c]		X			
In-car service for dynamic rerouting[d]		X			

Note:

[a]Private company.

[b]Public agency or consortium.

[c]Dash Express service, for example.

[d]BMWs and Minis, for example.

Source: List et al., 2014, Reproduced with permission of the Transportation Research Board.

A. Autonomous Vehicles

The National Highway Traffic Safety Administration (NHTSA) has proposed a five-level continuum of autonomous vehicles, with different benefits of the technology realized at different levels of automation:

- *No Automation (Level 0)*—The driver is in complete and sole control of the primary vehicle controls—brake, steering, throttle, and motive power—at all times.
- *Function-Specific Automation (Level 1)*—Automation at this level involves one or more specific control functions. Examples include electronic stability control or precharged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
- *Combined Function Automation (Level 2)*—This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.
- *Limited Self-Driving Automation (Level 3)*—Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.
- *Full Self-Driving Automation (Level 4)*—The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles. [NHTSA, 2013]

A report by the RAND Corporation identified the potential benefits of autonomous vehicles as being, (1) a dramatic reduction in the frequency of crashes, as much as one-third of fatalities and overall crashes simply by including forward crash avoidance and lane departure sensors; (2) increased mobility for the blind, disabled, or those too young to drive with a level 4 application; (3) a reduction in the costs associated with road congestion given that occupants of vehicles could undertake other activities with level 3 and above technology applications; (4) increased commuter willingness to travel longer distances to and from work, causing people to locate further from the urban core; and (5) a likely decrease in the cost of energy consumption and reduce emissions. [Anderson et al., 2014]

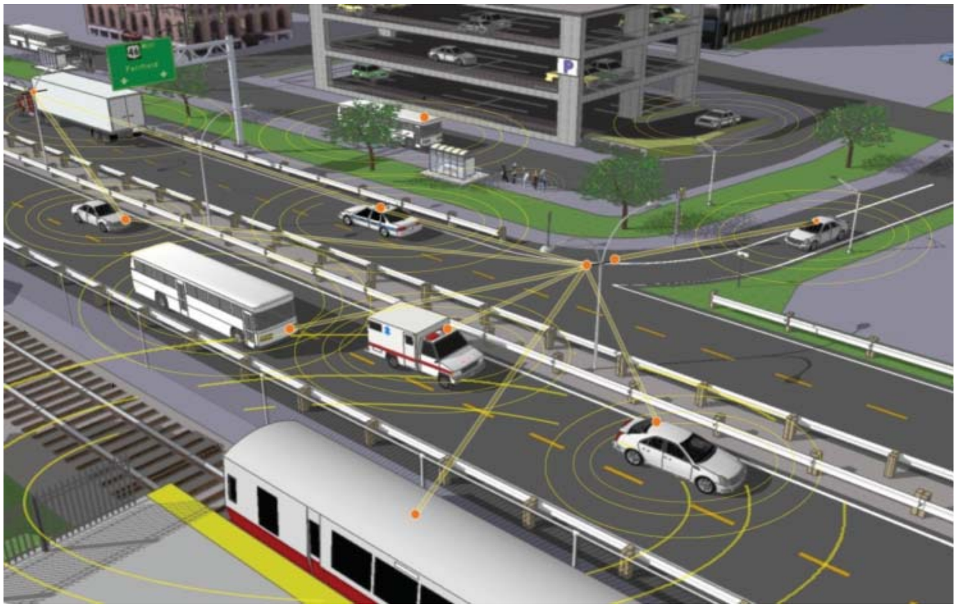
It seems likely that automobile manufacturers are already preparing the market for autonomous vehicles, and thus the future of personal mobility in the United States and other advanced countries will be tied to market acceptance of such vehicles and also how infrastructure is prepared to handle these vehicles. Test runs have already been made of autonomous vehicle operations in real-world conditions, and thus the concept has been shown to be feasible. However, an important challenge to transportation officials will be the transition from motor vehicles that do not have such technology to a fleet that is largely autonomous. For example, a likely scenario in this transition will be the use of lanes (perhaps the managed lanes of today?) for autonomous vehicles to separate their operation from traffic flows that are under manual control. This type of separation for high-speed operation could occur on the line-haul portion of a trip, and then mixed operations could occur at either end of the high-speed trip where speeds on local streets would be lower.

Autonomous vehicles also raise important questions relating to other parts of the transportation system. For example, what will be the impact of autonomous vehicles on transit service? Transportation for the elderly and mobility impaired? Teenage drivers? Freight movement? Parking? In the bigger picture, autonomous vehicles could result in more efficient utilization of existing highways, thus reducing the need for highway expansion. Why are we planning to build highways for the demands expected in 2040 when the very nature of how travelers make their trip could be different? What impact will this have on the construction industry? on local economies? Thus, while autonomous vehicle technologies provide tremendous benefits to travelers and to some parts of the economy, they raise important questions on the consequences and implications to many of the features of transportation system management and operations that we take for granted today.

B. Vehicle-to-Vehicle Technologies

Many of the technologies that are part of autonomous vehicle operations relate to technologies that enable communication and interaction among vehicles using the road network. [Harding et al., 2014] The major advancement in

Figure 10-15. Vehicle-to-Vehicle Technology Applications



Note: Vehicles "talk" to each other exchanging information such as vehicle size, position, speed, heading, lateral/longitudinal acceleration, yaw rate, throttle position, brake status, steering angle, wiper status, and turn signal status, enabling safety and mobility applications.

Source: Harding et al., 2014

this regard is the use of dedicated short-range communications (DSRC) technologies that allow vehicles to exchange information on position, infrastructure conditions, and vehicle operations. A visual representation of the V2V concept is shown in Figure 10-15.

A good example of the benefits of V2V technologies is the set of technologies that permit one vehicle to sense the potentially dangerous position and operations of another vehicle, and to bring the first vehicle to a stop if the likelihood of a crash is high. Figure 10-16 show the different types of crash situations where V2V applications could be instrumental in reducing the number of crashes.

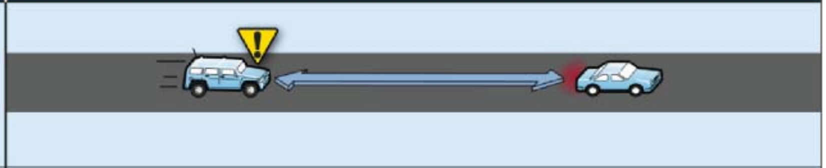
Based on 2004 to 2008 crash data, the U.S. DOT has concluded that a fully mature V2V system could potentially address 79 percent of all vehicle target crashes, 81 percent of all light-vehicle target crashes, and 81 percent of all heavy-truck target crashes annually. Improving the safety environment for motor vehicle operations is one of the major benefits of V2V applications.

V2V capabilities, already in place in newer vehicles, are likely to be implemented fleet-wide before full market penetration of autonomous vehicles. Thus, in the short term, defined as over the next 10 years, planners can expect greater use of V2V communications among vehicles on the roadway.

C. Vehicle-to-Infrastructure Technologies

The driver-infrastructure interface has been an important characteristic of road design since the first modern roads were constructed, most often taking the form of traffic signs and pavement markings. The likely future connected transportation system will include a combination of V2V and vehicle to infrastructure (V2I) communication. Similar in concept to V2V technologies, V2I capabilities provide a communications interface between vehicles and infrastructure, such as communications with traffic signals, warning messages, vehicle gap acceptance, vehicle position, construction work zone warnings, parking space occupancy, and traffic management centers that would allow transportation system managers to oversee the performance of a road network. [Anderson, 2013; FHWA, 2014] Figure 10-17 shows an example of V2I communications, in this case warning a driver that there are pedestrians in an upcoming crosswalk.

Figure 10-16. Vehicle-to Vehicle Technology Improved Safety Scenarios

Scenario and warning type		Scenario example
Rearend collision scenarios	**Forward collision warning** Approaching a vehicle that is decelerating or stopped.	
	Emergency electronic brake light warning Approaching a vehicle stopped in roadway but not visible due to obstructions.	
Lane change scenarios	**Blind spot warning** Beginning lane departure that could encroach on the travel lane of another vehicle traveling in the same direction; can detect vehicles not yet in blind spot.	
	Do not pass warning Encroaching onto the travel lane of another vehicle traveling in opposite direction; can detect moving vehicles not yet in blind spot.	
Intersection scenario	**Blind intersection warning** Encroaching onto the travel lane of another vehicle with whom driver is crossing paths at a blind intersection or an intersection without a traffic signal.	

Source: Harding et al., 2014

Figure 10-17. Example of Vehicle-to-Infrastructure Capability

Source: Walker, undated

Unlike autonomous vehicles and V2V technologies, which are primarily in the domain of private companies, the V2I emphasis on "smart" infrastructure leads to important roles for transportation agencies, in particular, state DOTs. Some of the leading state DOTs in this type of technology application, California, Colorado, Michigan, and Washington state, have placed great emphasis on understanding the future needs of V2I capabilities, in some cases, even creating department units focusing on system operations and technology applications. Over the next several years, more state DOTs are likely to join the ranks of agencies that are investing heavily in connected technologies.

IX. SUMMARY

Transportation system planning has traditionally focused on the road and transit facilities needed in the future to handle expected travel demands. This has led to a process heavily dominated by capital projects and methodologies aimed at expanding the physical capacity of the system. Starting in the 1970s, many transportation professionals became interested in examining strategies to enhance the performance of the transportation system through operational improvements. This chapter has examined this approach to operations planning. The process involves many different actors in a state or regional transportation system, from the providers of transportation services to those who plan and finance the system. With the advent of intelligent transportation system (ITS) technologies in the 1990s, many transportation agencies have implemented advanced surveillance and information technologies for managing system operations. This characteristic of transportation system operation will likely continue in future years.

Operations management has traditionally focused on "keeping the system(s) running by implementing a variety of projects to improve travel safety, reduce congestion, or increase capacity (traffic flow or throughput)." Given growth in traffic volumes, the lag time in getting construction projects online, the complexity of the operational improvements that are implemented and key societal trends, system operations must be thought of as more than just a project to resolve a problem. The operation of the transportation system is both a short-term project and a long-term strategy that will enable a continuous, high level of performance under varying conditions and demands. This concept extends well beyond thinking of operations as merely a project or a process that responds to a problem situation. To be effective in sustaining performance and efficiency as well as meeting user expectations, operations and the implementation of operational improvements must be recognized as essential strategies for system management, and they should be formally and strategically planned through the coordination between planning and operations.

As the operations community looks to expand its role in the regional transportation planning process, these multi-agency working relationships can be significant.

For *planners*, collaboration with operators can:

- Help them better understand how operational strategies can meet regional transportation goals.
- Provide access to systemwide, 24-hour travel data that can be used to better characterize existing system performance and travel conditions, identify the most critical transportation problems, and prioritize funding.
- Provide operations data and expertise to improve forecasts of future conditions, broaden the understanding of existing conditions, and analyze the effectiveness of alternative investments.
- Foster greater consideration of the day-to-day functioning of the transportation network and the real conditions facing travelers, which can help frame transportation goals, objectives, and priorities.
- Reveal how transportation plans can address issues such as reliability, security, and safety—issues that are difficult to address solely with traditional infrastructure investments.

For *operators*, collaboration and coordination with planners can:

- Help operators have a greater understanding of how the long-range planning process supports transportation system management and operations (TSM&O) activities and how such activities fit into the context of regional goals and objectives.
- Provide increased opportunities and incentives for getting involved in the planning process, thereby, helping shape system goals and objectives.
- Provide regional leadership and greater participation by stakeholders in regional TSM&O efforts.

- Clarify the role of operations in meeting the region's transportation vision and goals.
- Direct attention to the value of TSM&O strategies.
- Increase resources assigned to operations projects and programs.

Ultimately, greater coordination and collaboration among planners and operators improves transportation decision making and benefits the traveling public, businesses, and communities.

The ability to bring a multi-agency operations perspective to the planning table should enhance the decision-making process and result in increased system performance as, for example, when incidents get cleared in a timely and effective manner.

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Planning for Parking[1]

I. INTRODUCTION

Parking is an essential component of a community's transportation system. The number and use of parking spaces vary widely among activities in each community, reflecting the size, intensity, and location of specific land uses; availability of alternative means of travel; and community attitudes about environmental quality and economic development. Most often the number of spaces is dictated by local zoning requirements that require minimum amounts of parking for the type and intensity of use at a particular location.

The traditional and still widely held view is that adequate and convenient parking must be provided for commerce and a community to thrive. For example, the planning advisory service of the American Planning Association (APA) receives more requests on parking requirements than any other topic. The Colliers 2012 North American Parking Rate Survey found that 55 percent of the 56 North American cities surveyed considered the downtown parking garage supply as "fair" (60 to 80 percent full), while 32 percent indicated it was "limited" and only 13 percent said "abundant." [Colliers International, 2012]

Conversely, some have argued that the incorporation of minimum parking requirements in zoning ordinances and the provision of free parking are primary causes of suburban sprawl that makes it difficult to achieve travel demand management (TDM) objectives (see chapter 14 on travel demand management). Shoup, for example, states that parking requirements in zoning ordinances constitute "a great American planning disaster" because they "subsidize cars, distort transportation choices, warp urban form, increase housing costs, burden low-income households, debase urban design, damage the economy, and degrade the environment." [Shoup, 2005]

When land cost or availability triggers the need to use structured parking, developers are far more likely to question the required number of spaces. In such instances, they are much more amenable to develop shared parking or TDM solutions or pass along the cost of parking to the users via fees. [MAPC, 2007] The market largely decides how much new commercial space is developed downtown with paid parking as opposed to in the suburbs with free surface parking. Free parking, zoning requirements, land value, and density are so subtly intertwined in the market lease rate of new space in a particular locale that one cannot point to any one factor such as free parking or parking zoning requirements as the dominant cause of travel behavior.

The availability and price of parking are also key determinants in mode choice, which is a major focus of transportation planning and policy. The reliance on the personal automobile—and the need to park it at both ends of a trip—has increased in the last two decades even as TDM strategies and the reduction of single-occupant vehicle (SOV) trips have been a central focus of many transportation planners. In particular, the price of parking is an important factor in travelers' decisions to drive. Parking fees are generally below the actual cost of owning and operating the space due to market forces—when most of the other parking in the community is free, it is difficult to charge a user the full cost of providing a space. Two general exceptions are: (1) core areas of the largest cities where monthly parking charges exceed $300 per month, and (2) airport parking (parking revenues constitute one of the largest revenue sources for airports).

It is unlikely that any fundamental change in parking markets will occur without sustained government intervention. In the mid-1990s, an initiative by three federal agencies to lower the cap on tax-free employer-provided parking from $165 per month to $135 per month or less never found congressional support and languished without action.

[1] The original chapter in Volume 3 of this handbook was written by Mary S. Smith, Senior Vice President, Walker Parking Consultants Inc. Changes made to this updated chapter are solely the responsibility of the editor.

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Instead, in 1998, the Transportation Equity Act for the 21st Century (TEA-21) increased tax-favored benefits for employers and employees to a current (2015) $250 for parking and $130 transit and vanpooling. In 2012, only 16 U.S. cities had median monthly parking rates exceeding $175 per month. [Colliers International, 2012] Lowering the cap on employer-paid parking thus would only affect locations where parking is already market priced, and significant transit use and trip reduction already occur. In addition, lowering the parking benefit may encourage more tenants to move to the suburbs where parking is "free."

Unless and until government has the will to either mandate the unbundling of parking fees from all lease rates (that is, landlords charge parkers separately for parking spaces) and/or tax all employer-provided parking, which will require imputing a value of "free parking" in the suburbs, it is difficult to incorporate the real price of parking into a commuter's travel decision.

The next section describes typical organizational structures for parking management programs. The following section discusses parking zoning requirements, one of the most important factors in describing the amount and type of parking that is provided at all land uses. The types of strategies and decisions for parking supply options that reflect zoning and other factors and the combination of such strategies into parking management programs are discussed in the next two sections. The next three sections focus on the methodology for predicting parking demand and needs analysis, including the results associated with common land uses and a shared parking methodology. The next section discusses parking costs and how they are estimated as part of decision making, and the final section presents the key characteristics of parking finance.

II. PARKING MANAGEMENT ORGANIZATIONS

Parking responsibilities in many cities are often fragmented among numerous departments or agencies. In a municipal context (with institutional equivalents in parentheses), public works (building and grounds) may control most of the physical aspects, such as building and maintaining on- and off-street facilities, the police department (security) provides enforcement, and finance (business office) is responsible for revenue collection. Typically, parking is far down the list of concerns and priorities of each department. Parking is often politicized and lacks clarity of goals and attention to implementation.

A more successful model is a professional organization that is responsible for all or nearly all functions associated with parking management. Where it is necessary and appropriate to have separate functions (for example, planning and zoning will continue to administer parking requirements), the parking management organization should have a designated liaison to coordinate and contribute to policy decisions.

Common goals for parking programs include:

- Revenue should be tied to expenses and operations as closely as possible. For example, parking meter revenue should be compared to the expense of obtaining the revenue. This principle holds true for all parking management functions, even those that have less revenue than expenses. This is especially true in programs that have privatized parking operations.
- Budget preparation, analysis, allocation, and adjustment should be under the control of the parking management organization.
- The locations of parking management functions within the city governmental structure should reflect the importance of parking management issues as they are perceived in the city.
- Parking management often includes monitoring and environmental regulatory requirements. The structure and budget of the parking management organization should be flexible enough to meet these responsibilities.

A. Types of Parking Organizations

Most parking programs are part of a municipal transportation department. Parking enforcement is usually run by the transportation department as well, unless it is outsourced. This structure is particularly common for medium and small cities. However, for larger cities, three other types of parking organizations are often found—a parking authority, separate department, or a nonprofit organization. Each is described here.

Parking Authority

A parking authority offers more independence than a city department or division. Authorities are able to issue bonds for the construction of new parking facilities when empowered by state-enabling legislation. As part of the extended city government, an authority can have the same personnel policies (if desired), particularly if most or all of the personnel have been in city departments previously. This organizational structure allows considerable flexibility and the ability to respond to issues quickly.

Separate Department

Many cities have separated the transportation and parking functions from public works and have created a department devoted solely to parking. The primary advantage of such a structure is to emphasize the importance of transportation and parking issues for the city and its citizens. Generally, there will be less conflict of interest and more focus on these issues, and the coordination of parking and street traffic activities will be improved. Above all, there will be fewer layers between the parking manager and the municipal chief executive officer (CEO—mayor) and chief operating officer (COO—city manager). The creation of a new department would have to be based on municipal law.

Nonprofit Organization

One of the more recent institutional models for parking management is a nonprofit organization (NPO) charged with the specific needs and concerns of an activity center such as a downtown or suburban major employment center. Aside from the enabling legislation, the main difference between an NPO and a parking authority is that a nonprofit organization may have a broader perspective on transportation issues than a parking authority, which would be focused solely on parking. Both may be concerned with supporting and encouraging the economic vitality of an activity center, but the NPO might be involved in many more transportation and nontransportation activities.

Table 11-1 summarizes the strengths and weaknesses of these three options. It is important to note that many communities have moved to a privatized model of parking management. In this model, communities accept a tender for a private company to enforce parking meters and share in the revenues. The contract regulates parking rates, operating standards, and maintenance of all parking assets, but the actual operation (enforcement, for example) is the responsibility of the concessionaire. Even in these programs, however, the community needs to have some centralized parking policy and planning function in the government.

Parking Management as an Enterprise Fund

A parking management organization could operate as an enterprise fund under any of the previously discussed organizational structures. The defining characteristic of an enterprise fund organization is that it must generate sufficient revenue to cover its immediate expenses as well as for investment in necessary assets for the future as necessary. For parking, this means an enterprise fund would need to cover operating costs, debt service, debt service reserve funds (or any other required funds connected with bond issues) and sinking or reserve funds for significant future construction or maintenance.

A parking enterprise fund requires parking activities to be self-sufficient and that they be managed like a business, most importantly, generating income in excess of expenses. This does not mean that the primary purpose of parking management is to generate profit; rather, parking investment decisions need to consider the relationship between expected revenues and expenses. In some cases, the executive order or legislation creating an enterprise fund specifies the level of excess revenue that may remain in the enterprise fund and the disposition of any additional revenue.

III. ZONING REQUIREMENTS[2]

Community zoning and planning guidelines often require a minimum number of parking spaces for a proposed development, depending on the type of development and other means of accessing a site, for example, transit. Zoning standards typically include formulas for determining how many parking spaces must be provided for specific types of land uses. The intent of most local governments is to require property owners to provide sufficient off-street parking spaces without spillover demand, that is, overflow onto public streets or adjacent private property. An example of a parking zoning requirement from Eugene, Oregon, is shown in Table 11-2.

[2]Note that part of the following discussion was paraphrased by the original author from the Parking Consultants Council update of *Recommended Zoning Ordinance Provisions for Parking*, 2007.

Table 11-1. Strengths and Weaknesses of Parking Organizational Structures		
	Strengths	**Weaknesses**
Independent parking authority	• Parking functions are placed in an entity with one purpose—to deliver parking. • Can maintain some independence while also working closely with the city. • Requires a board of directors to set policy, maintain fiscal responsibility, and guide staff. • Easy to create new positions/set salary scales different from government and initiate rewards based on merit. • Can make decisions and implement programs quickly. • Has power to issue bonds to finance projects. • Can also benefit from city guarantee.	• Responsible for debt. • New legislation is often required (state and local). • Boards of directors can sometimes be unwieldy or cumbersome depending on requirements. • Civil service may make transferring employees difficult and cumbersome.
Nonprofit organization	• Parking functions are placed in an entity with one purpose—to deliver parking. • Can maintain some independence while also working closely with the city. • Flexibility regarding the size and characteristics of the board of directors. • Easy to create new positions, set salary scales different from government, and initiate rewards based on merit. • Can make decisions and implement programs quickly.	• The ability to issue bonds, while possible, may be more difficult and complex. • New legislation could be required to delegate functions. • Civil service may make transferring employees difficult and cumbersome.
City department	• Easy to transfer employees from other city departments. • New positions can be created under civil service regulations, which are less subject to political pressure. • Easy to earmark revenues for general fund activities.	• Parking gets buried in bureaucracy and does not receive the needed attention. • Parking policy more likely to remain the purview of staff and elected officials unless citizen advisory committee formed. • Civil service and budgeting process can be cumbersome and time consuming. • Financing for parking facilities must compete with other municipal projects if general obligation bonds are requested.

Zoning policies that require an excessive amount of parking spaces are inefficient and costly because the land area and resources devoted to parking spaces reduce the amount of development that could have occurred on the site. Based on studies of density before and after parking requirements were added to the zoning ordinance of Oakland, California, Shoup [2005] concluded that the parking requirements increased the cost per dwelling unit by 18 percent, decreased density by 30 percent, and lowered land values by 33 percent. A study by Willson [1997] estimated that increasing the parking requirement for an office building from 2.5 to 3.8 spaces/1,000 sq. feet (3.7 to 4.1 spaces/100 m^2) would reduce density by 18 percent and land values by 32 percent.

Excessive paved parking areas are also undesirable to the community from both an aesthetic and an environmental perspective.

Table 11-2. Example of a Parking Zoning Ordinance, Eugene, Oregon	
Required Off-Street Motor Vehicle Parking	
Uses	**Minimum Number of Required Off-Street Parking Spaces**
Residential Dwelling	
One-family dwelling	1 per dwelling
One-family dwelling – Flag lot	2 per dwelling
Secondary dwelling (either attached or detached from primary one-family dwelling on same lot)	1 per dwelling
Rowhouse (one-family on own lot attached or adjacent residence on separate lot with garage or carport access to rear of the lot)	1 per dwelling
Duplex (two-family attached on same lot)	1 per dwelling
Triplex (three-family attached on same lot)	1 per dwelling
Four-plex (four-family attached on same lot)	1 per dwelling
Multiple-family (three or more dwellings on same lot) not specifically addressed elsewhere	1 per dwelling
Multiple-family in the R-3 an R-4 zones within the boundaries of the City recognized West University Neighbors and South University Neighborhood Association.	1 space per each studio, 1 bedroom or 2 bedroom dwelling. 1.5 spaces for each 3 bedroom dwelling (0.5 spaces required for each additional bedroom beyond a three-bedroom dwelling). Fractions of 0.5 or more are rounded up to the next whole number. Rounding shall occur after the total number of minimum spaces is calculated for the multifamily development. One tandem space shall be counted as two parking spaces. Tandem spaces shall not be allowed for studio or 1- or 2-bedroom dwellings.
Multiple-family subsidized low-income housing in any area	0.67 per dwelling or 3 spaces, whichever is greater
Multiple-family subsidized low-income senior housing in any area	0.33 per dwelling or 3 spaces whichever is greater
Multiple-family subsidized low-income disabled housing in any area	0.33 per dwelling or 3 spaces, whichever is greater
Multiple-family subsidized low-income senior housing partial in any area	0.67 per dwelling or 3 spaces, whichever is greater
Multiple-family subsidized low-income specialized housing in any area	0.33 per dwelling or 3 spaces, whichever is greater
Manufactured home park	1 per dwelling
Controlled home and rent housing where density is above that usually permitted in the zoning, yet not to exceed 150%	1 per dwelling

Source: City of Eugene, 2009

A. Minimums or Maxima?

Many transportation professionals and city officials have debated whether parking ordinances should require a maximum or minimum amount of parking, or both. Some of the early recommendations reflected the proximity of transit services, for example, minimums and maxima could be provided for various land uses as a function of distance from transit stops. [Weant and Levinson, 1990] In Boston, for example, there is no required parking in the central business district (CBD) that is served with many transit lines, but there is a cap on total commercial parking spaces (implemented primarily for environmental quality reasons). All owners of parking, other than residential, must have a license for the number of spaces provided. Any developer wishing to develop new parking must buy out enough licenses to cover the number of spaces proposed, and the older facilities must close. There is also an extensive park-and-ride system in the area.

Other cities with maximum, rather than minimum, parking requirements include London and San Francisco. London changed its parking policy from minimums to maxima in the late 1960s; the new maximum ratios were generally less than half the former minimum values. San Francisco also limits parking in the CBD.

In Manhattan, land values are so high that new developments provide only the bare minimum of spaces necessary to finance and lease the building; in many cases, no parking is provided. The high market price of parking (the median for unreserved monthly parking in midtown and downtown Manhattan in 2012 was over $562/month) strongly influences the choice of using transit to commute to Manhattan. [Collier International. 2012] Reimbursement by employers for parking charges also affects the decision to drive and park. A 2007 study, for example, found that 38 percent of motorists parking in Midtown and Lower Manhattan have free parking provided or reimbursed by their employers, and an additional 19 percent park at unmetered on-street spaces. [Transportation Alternatives, 2007]

A study of residential parking in the Bronx and Brooklyn provided some interesting observations:

- Car ownership varied according to factors including geography, household characteristics, and building size, but not the amount of parking required by zoning.
- Vehicle ownership varied from building to building, making shared-parking resources important.
- In zoning districts, required parking is often waived for smaller buildings and sites, substantially lowering the effective parking requirement.
- Car-owning households make decisions about where to park based on the options available in their neighborhood, not just in their building.
- Inner Ring residents generally pay a fee for off-street parking, though the amount they pay varies.
- The often substantial costs of providing parking and the revenues generated by parking are important factors in developers' decisions about whether to build parking.
- Affordable housing is more susceptible than market-rate housing to the cost implications of requiring accessory parking, and its residents own fewer vehicles. [New York City, 2013]

Some have wondered if property developers would actually reduce parking if parking requirements were lowered or waived. For example, office developers, as well as their lenders and tenants, usually want to provide as much parking as other competitive buildings. This tends to perpetuate parking requirements based on *wants* rather than *needs*. Today, the number of spaces provided by competitors is often mandated by minimum parking requirements in the local zoning ordinance. However, history has shown that if there is justification for reductions, developers will embrace them. This is evident in the reduction of accepted parking ratios for shopping centers that has occurred over time. If the marketplace is allowed to establish a better, more natural equilibrium on how many spaces are required, and if shared parking, higher density, and better pedestrian connections are encouraged in zoning ordinances, parking ratios will likely decline over time.

In sum, parking zoning requirements need to trade off the problems of spillover parking because insufficient parking was provided and the potential negative impacts of over-requiring parking. As early as 1964, the American Society of Planning Officials (now known as the American Planning Association) was warning against employing a single standard for parking space requirements:

> *"No one set of standards, with the exception of off-street parking for industrial use, is recommended. The underlying assumptions used in drafting local regulations are often unknown and may not be applicable to other localities. The best approach, of course, is to develop off-street parking requirements based on local parking and traffic studies and the characteristics of the various zoning ordinance use districts." [Weant and Levinson, 1990]*

The suggestions were further outlined in a report from the American Planning Association called, *Flexible Parking Requirements* [Smith, 1983], which has been periodically updated to become one of the leading technical guides on parking standards. A more recent observation comes from Shoup [2014]:

> *"Minimum parking requirements limit urban development. They often force developers to provide more parking than necessary, or to construct smaller buildings than the zoning allows. Parking requirements promote an unsustainable city. If cities require ample off-street parking everywhere, most people will continue to drive everywhere …… cities get the traffic they plan for and the behavior they subsidize."*

It seems likely that as cities begin to adopt policies on sustainability and livable/walkable communities, removing the minimum requirement for parking will be part of the strategy.

B. Flexibility in Zoning Requirements

Parking in urban areas serves many different markets. Thus, parking demands will vary depending on the types and locations of land uses and activities that occur in a typical day. Key variables for a particular site include the size of buildings, access and distance to public transit, ridesharing patterns, shared parking, and applicable zoning requirements. If parking fees are charged in a CBD or activity center, the amount of required parking may be substantially different from an activity center having no fees. The traditional means of accommodating varying parking demands include using different parking requirements in different zoning districts, planned unit development permits, and special and conditional use permits (see chapter 3 on land use and urban design).

Zoning ordinances can be used to adjust parking requirements for different land use contexts. Some of the provisions by which cities are building flexibility into parking requirements include: (1) shared parking, (2) fees-in-lieu, (3) off-site parking, (4) credits for ridesharing programs, (5) credits for public transportation accessibility, and (6) accepting a credible parking study that evaluates the site-specific circumstances and expected demand.

The Parking Consultants Council's *Recommended Zoning Ordinance Provisions* [2007] recommends language to protect a city's interests while allowing flexibility to address the most common circumstances that influence parking demand. In addition to addressing changes in ownership and land use issues, certain adjustments to parking requirements can be handled by specifying a development credit that can routinely be taken if an analysis has been made of parking demand by a qualified parking or traffic consultant. Further, flexibility in zoning ordinances might require a developer or owner to provide additional parking in later years up to a certain threshold if the city finds that projected demand is exceeded. This *land bank* provision requires the developer to submit a plan detailing how additional spaces could later be provided in either surface lots or structures. The developer who does not wish to accept the land bank condition must go through the normal zoning variance procedure, usually appearing before a zoning board of appeals or a city council to receive a permanent, irrevocable reduction in the requirements. In some cases, land banking provides all parties with a necessary level of comfort for a lower parking ratio. The developer can provide more green space on the site initially and then apply to have the pledge released and/or a permanent variance issued after a period of successful operation at the lower ratio.

Some additional options for parking flexibility in zoning requirements include:

- *Captive Market*—A captive market is one where potential consumers face a very limited number of competitive suppliers, in this case, parking spaces. It often occurs among land uses that are not self-contained within a development. The captive market effect is one of the most significant determinants of parking demand in CBDs. Therefore, a zoning ordinance should allow parking requirements to be adjusted for captive market effects independent of shared parking effects.
- *Fees-in-lieu*. It may be in the best interests of a city to develop public parking in a densely developed activity center, rather than have property owners provide their own parking. With the high cost of constructing a parking structure and with the competing demands on city resources, a number of cities have asked developers (who will directly benefit with reduced parking space requirements) to pay some or all of the costs of developing parking in municipal facilities.
  - A problem with this strategy occurs when development is slow, small, or randomly located. If funds are available to develop parking in reasonable proximity to each development in a timely manner, a developer

might be willing to enter into such an agreement. However, a developer who has contributed $100,000 to a fund in lieu of 10 parking spaces does not want the funds to sit for five years waiting for more money to become available, or for it to be used to fund a parking structure six blocks away. Success is more likely when rapid development is expected in a defined area and when an off-street parking facility is or will be available on a set schedule and connected to the sites that are providing the funds.

- *Off-Site Parking*—Many cities have added clauses in their zoning that allow for off-site parking to be substituted for on-site parking under certain conditions.
- *Ridesharing*—Ridesharing generally refers to various forms of carpooling, vanpooling, and subscription bus service associated with employees' trips to and from work. Properly formulated ridesharing programs can reduce both traffic and parking demand. Zoning credits for ridesharing programs are a particularly effective means of achieving transportation management goals. Ridesharing credits are also a means of adjusting parking requirements for any development site that runs a dedicated shuttle. The most common application is hotels that cater to those wanting convenient access to an airport. However, other sites may also run shuttles and thus merit reduced parking requirements.
- *Right-Sizing Parking*—Parking rates are often available for development types that are not similar in context to what is being proposed. For example, suburban parking rates would likely be inappropriate for urban sites. Right-sizing of parking supply ties the amount of parking to the needs and parking goals of the site and community by conducting a parking demand study and linking the results to the types of needed strategies.
- *Shared Parking*—The Urban Land Institute's (ULI's) *Shared Parking* [Smith, 2005] provides a methodology for calculating shared parking effects without resorting to a single, catch-all formula (see later section on shared parking).
- *Transit*—Even smaller communities may have areas that are well served by public transit. A reasonable reduction in the parking requirements for developments within a certain distance of a regularly scheduled transit service might be appropriate.

An example of flexibility in zoning requirements comes from San Diego where local communities have used a variety of techniques as part of the region's Smart Growth policy. Here are some examples:

- The city of Carlsbad offers density bonus incentives to affordable housing developments. The following multifamily dwelling unit rates apply: 0- to 1-bedroom unit requires 1 parking space and a 2- to 3-bedroom unit requires 2 parking spaces.
- The city of Escondido reduces its standard retail parking requirements to 3 spaces per 1,000 square feet of gross floor area in the downtown retail core parking district.
- The city of El Cajon provides allowances for parking in smart growth settings within the downtown area.
- The city of La Mesa allows parking reductions in their Mixed-Use Urban Overlay Zone. They allow a minimum of 2 parking spaces per 1,000 square feet of commercial floor area.
- The city of San Diego offers parking reductions for developments located in the Transit Overlay Zone or developments that are deemed "very-low" income. Multifamily residential requirements are reduced as follows: studio units require 1 space, 1-bedroom units require 1.25 spaces, 2-bedroom units require 1.75 spaces, and 3-plus-bedroom units require 2 spaces. Commercial office requirements are reduced to 1.0–2.9 spaces per 1,000 square feet. Retail requirements are reduced to 1.0–4.3 spaces per 1,000 square feet.
- The city of Chula Vista details special parking requirements for their Urban Core Specific Plan area. Residential multifamily units in the transit focus area have the reduced requirement of 1 parking space per dwelling unit.
- The city of Coronado provides reduced parking requirements for the Orange Avenue Corridor Specific Plan. Commercial parking requirements are reduced to 1 parking space per 500 square feet of floor area. The city also provides reductions for affordable housing. [SANDAG, 2010]

Other examples are noted in [MAPC, 2010] and include: (1) Los Angeles allows a reduction of 0.5 spaces per unit for deed-restricted affordable units and additional reductions for units within 1,500 feet of a transit line;

(2) Eugene, Oregon, allows reduction of parking requirements on a case-by-case basis, subject to a parking study documenting that the reduced amount of parking will be sufficient; (3) Seattle grants reductions in minimum parking requirements for affordable housing (down to 0.5 to 1 space per unit, depending on income, location, and unit size), housing for seniors or people with disabilities, multi-family developments with car-sharing programs, and developments in dense, mixed-use neighborhoods; (4) Santa Monica, California, reduces parking from 2 spaces per unit to 1.5 for two bedroom affordable housing units; and (5) Hartford, Connecticut, allows reductions of up to 30 percent of required parking in exchange for implementing TDM programs such as discounted carpool parking, rideshare promotions, subsidized transit passes and shuttle services to off-site parking. See also [PSRC, undated].

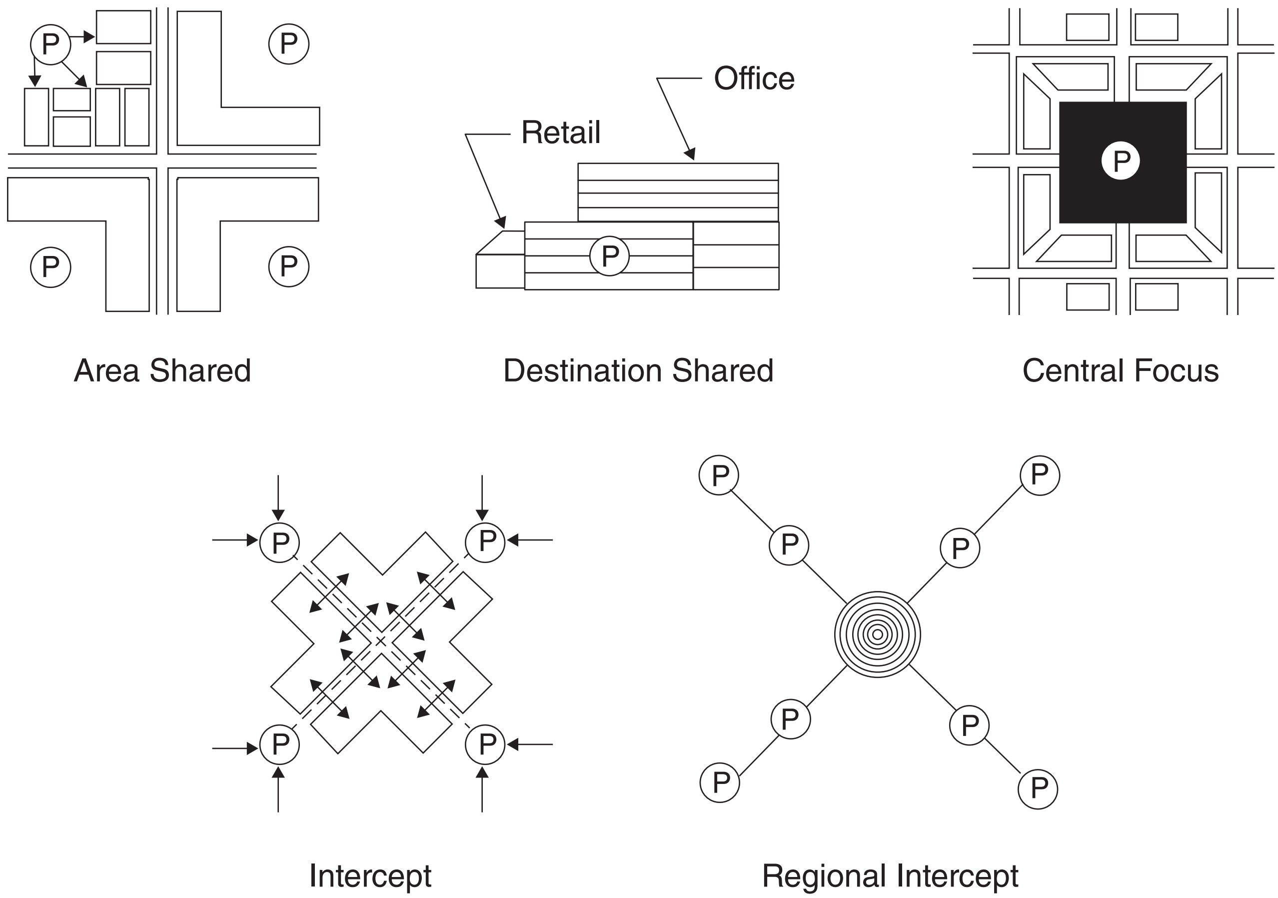
IV. STRATEGIES AND DECISIONS FOR PARKING SUPPLY OPTIONS

A. Parking Strategy Concepts

At a strategic level, a region or community can conceptualize parking strategies in very broad terms. For example, five conceptual models of parking development were defined and analyzed in a downtown parking study for Denver. [Walker Parking Consultants, 1992] Although dated, these models are still relevant today in terms of different parking supply strategies that might be considered by a community. They provide a useful means of evaluating alternatives for parking expansion. Note that different strategies may be required for long- and short-term parking. Figure 11-1 shows the five major parking management strategies that were considered in this study.

The study defined a base alternative, called a laissez-faire alternative, as a reference for the other alternatives. In this alternative, the private sector and financing requirements for new development dictated how much and what type of parking was provided for new and existing parking demand. Parking was neither required nor constrained by

Figure 11-1. Alternative Parking Development Scenarios, Denver



Source: Walker Parking Consultants, Inc., 1992

zoning, but was allowed as a use by right. The laissez faire model currently flourishes in many cities and suburban areas. The laissez faire solution is essentially market-driven and, therefore, parking locations are completely flexible and unplanned—the product of economic development, demolition of buildings, and parking needs as required by financial institutions and developers for new projects. This approach for both long- and short-term parking has been highly successful in such cities as Indianapolis, which had never required parking in its downtown. The city has not intervened in the private marketplace; it has only built public parking facilities for publicly financed projects. Instead, there is a flourishing private parking system that charges market rates for parking and offers multiple pricing options based on convenience to destinations in the CBD.

Area-Shared. An area-shared parking model provides parking for essentially all uses within a reasonable walking distance. This model is often employed by cities that provide parking for the CBD, but it is also found in commercial operations that provide parking for a particular area. Public/private joint ventures are also an option. An excellent example of an area-shared project is the Post Office Square facility in Boston. Developed by a public-private consortium, an inadequate and antiquated 750 space, above-ground parking structure was torn down and replaced by a 1,400-space underground garage. At street level, the top of the parking structure was a park themed as a public square.

Destination-Shared. Similar to the area-shared model, the destination-shared model targets a specific project or several uses near each other. This model suggests private-sector development rather than public investment. However, some destination-shared parking facilities might be joint public-private venture opportunities. Public-private partnerships could occur where a specific project receives a subsidy to build parking or where the city builds a parking structure and leases the air rights for a mixed-use development built by a private developer. An excellent example is the World of Wonders garage at Circle Centre in downtown Indianapolis. The World of Wonders garage not only serves Circle Centre but also the nearby Indiana Convention Center and RCA Dome.

The destination-shared model is intended to minimize parking occurring indiscriminately throughout the activity center. The model is based on the conventional development context, wherein each individual project is constructed with its own individual parking facilities. The difference between this model and the laissez-faire model is that the destination-shared concept specifically identifies where parking structures will be permitted, and these structures are built in such a manner as to permit sharing among a number of destinations.

Central Focus. The central focus model creates a large, centralized parking facility in the center of a zone with a pedestrian distribution system connecting the facility to many diverse destinations. A good example is the Grant Park underground parking facility in Chicago, which runs several blocks on the lakefront, providing substantial parking for many uses within the area that do not have their own parking facilities. The central focus parking concept could be a depressed, below-grade structure with either air rights development or park and green space on the top.

Good vehicular access in the center of activity is essential. Otherwise, by bringing all of the vehicles within a core area, a centralized parking facility could create additional congestion, result in air pollution, or produce other negative impacts.

Intercept. This model intercepts parkers at the perimeter of an activity center. In larger cities where the intercept would occur more than 1,000 ft from the core, the intercept model depends on a shuttle system to move the parker conveniently, quickly, and economically to destinations within the core. The intercept model is based on the philosophy that auto congestion within the core creates air pollution and unnecessary congestion, and that the environment within the activity center should be kept pedestrian in scale and free of auto traffic. Many university campuses, for example, have adopted a strategy of moving parking to the periphery to intercept traffic so that new buildings can be built on parking lots.

However, given the laissez-faire parking development policy in many activity centers today, there is simply too much parking to adopt the intercept concept. To encourage the use of intercept parking, parking rates must be considerably higher than those in the intercept lots. Simply providing intercept parking is not enough; the program must be accompanied by disincentives to park within the core. Likewise, the availability of surface parking lots and parking structures within the core must be reduced, so as to force long-term employee parking to the perimeter.

Shorter-term shopping trips or residential parking in close proximity to residential units do not work with intercept parking; therefore, the intercept concept generally is combined with short-term parking within the core and destination-shared parking near residential units. This is the model employed in larger cities such as Chicago where monthly parking rates for unreserved spaces in the central core are as high as $425 per month, but all day parking in the fringe is available for as low as $100 per month ($2015).

Regional Intercept. Much like the intercept model, the regional intercept model intercepts parkers farther away from the activity center. The benefits are similar to the intercept model, in addition to further improving air quality.

The key to a viable solution is a regional transportation system that offers rapid, reliable, and convenient access to the activity center. This approach offers close-in, destination-shared parking for short-term and residential parking needs, while employee long-term parking would be intercepted at regional facilities built along high-occupancy vehicle (HOV) and express transit corridors most often at freeway interchanges. Most cities that employ this strategy successfully have rail transit, including Atlanta, New York City, San Francisco, and Washington, DC. However, a few, such as Ottawa, Ontario, and Pittsburgh, are keyed to bus or busway systems.

Although the five models just described were presented individually, in reality, a combination of options can be applied in many cities. For example, Calgary, Alberta, has actively pursued *destination-shared* facilities for short-term parking and the *intercept model* for the employees either at the CBD or at dispersed regional locations to encourage transit use.

Table 11-3 shows how the various combinations of strategies support the strategy goals of a city, in this case, Denver. The options of interest to Denver officials were destination-shared facilities for short-term parking together with destination-shared or intercept options for long-term parking.

Table 11-3. Effect of Parking Development Scenarios on Mobility Goals

Short-Term Strategy	**Laissez-Faire**	**Destination-Shared**	**Destination-Shared**	**Destination-Shared**	**Destination-Shared**	**Destination-Shared**
Long-Term Strategy	**Laissez-Faire**	**Laissez-Faire**	**Area-Shared**	**Destination-Share**	**CBD-Intercept**	**Regional-Intercept**
Goals						
Facilitate access to downtown while meeting air quality goals, including strategies to promote transit and ridesharing.	o	o	√	o	√	•
Coordinate parking facility development with transportation systems (vehicular and pedestrian) to and within downtown.	o	o	•	o	•	•
Coordinate parking facility development with the development or redevelopment of other downtown property and desired density patterns.	o	o	•	√	•	•
Develop parking facilities which serve shared parking needs.	o	√	•	•	√	o
Integrate appropriately designed parking (structure and surface) as a suitable land use (permanent or temporary).	o	o	•	√	√	•
Create mechanisms to ensure that the appropriate amount of storage is provided for various classifications of vehicles (short-term parkers, long-term parkers, HOV, buses, etc.) that enter downtown.	o	o	•	•	•	•
Provide a financially self-supporting parking system.	o	√	√	•	√	√
Minimize impact on residential areas from parking generated from commercial land uses.	o	o	o	o	√	•

• supports goal o opposes goal √ neither supports nor opposes goal

Source: Walker Parking Consultants, Inc., 1992

B. Community and Parking Program Goals

The types of strategies included in a parking management program will reflect the community's overall goals and/or the specific goals for its parking program, if such have been articulated. The following list from the city of Ottawa illustrates typical goals for a parking management program:

- Provide and maintain an appropriate supply of affordable, secure, accessible, convenient, and appealing public parking.
- Provide and promote affordable short-term parking services, and fair and consistent enforcement services, that support local businesses, institutions, and tourism.
- Promote, establish, and maintain programs and facilities that encourage the use of alternative modes of transportation, including public transit, car/vanpooling, taxis, auto sharing, cycling, and walking.
- Support residential intensification and resolve parking problems within residential areas caused by significant traffic generators or conflicting uses of the roadway, including implementing on-street permit parking programs to relieve area residents and visitors from parking regulations directed at the nonresident.
- Ensure the revenues generated by the municipal parking program are sufficient to wholly recover all related operating and life-cycle maintenance expenditures; contribute to a reserve fund to finance future parking system development, operation, and promotion; and then assist in the funding of related initiatives to encourage the use of alternative modes of transportation. [City of Ottawa, 2009]

An example of parking goals and corresponding strategies from a small community comes from Corona del Mar, California, where a variety of parking management strategies were being considered. [Corona del Mar, undated] Table 11-4 shows the range of strategies and corresponding goals.

Master development plans often include more specific goals or principles that guide the consideration of parking actions in the development concept. For example, the following principles were used for the parking management plan for a major development in Chula Vista, California.

- Encourage a "park once, walk further" environment. Strategies seek to create and support a "park-once" district, in which people will be able to park once and use the extensive network of pedestrian facilities and walk further to multiple destinations.
- Parking should not be overprescribed and should be right-sized. The goal of the parking management plan (PMP) is to find the correct balance between providing adequate parking to support the requirements of an emerging planned commercial development while minimizing the negative aspects of excessive land area or resources devoted to parking.
- Total commercial parking demand will consider walkability, transit, and mixed-use reductions. Adjustments are made to account for the number of people who arrive at the project site by means other than a personal vehicle, who make other stops within the project by foot or bike after parking once, and to account for the mixed use character of the development. It is anticipated that these elements will be implemented in the project over time and that their benefits will be realized as the project is implemented.
- Shared parking, when feasible. Shared parking is the use of a parking space to serve two or more individual land uses without conflict or encroachment. The degree at which shared parking can be implemented will be dependent on the location, timing, and types of commercial land uses in the plan.
- Provide flexible and evolving PMP to accommodate uncertainty and change. The PMP responds to the fact that the proposed land uses will be market-driven and will require implementation strategies which are adaptable, based on evolving market conditions, and incentive-based.
- Conformity with the project and form based code requirements with alternative/refined parking ratios. Provide for monitoring of the parking supply by the master developer and future Parking District Council to refine the parking ratios over time. [Nelson Nygaard and Linscott, Law, and Greenspan, 2015]

No one action or tactic can simultaneously achieve all desired goals (minimize auto usage and traffic congestion, maximize transit patronage, provide adequate parking, foster economic growth, among others). This is partly because

Table 11-4. Example Strategies and Goals from Corona del Mar, California

Strategies	Goals	Components
Strategy 1 Short Term Revise the zoning code to create appropriate development standards.	• Parking Supply = Parking Demand in Corona del Mar • More flexible regulations • Empower creative solutions • Maximize use of existing parking supply • Increase convenience and attractiveness of biking	• All non residential uses = 2 spaces per 1,000 square feet • Exempt small add-ons and use changes (<5,000 square feet) from minimum parking requirements. • Establish an optional parking in-lieu fee to meet parking requirements. • Allow for shared parking among different land uses by right. • Establish bicycle parking requirements for all new non residential development.
Strategy 2 Short Term Extend the time limits on Highway 1 and adjust pricing in off-street lots.	• Add flexibility and convenience for visitors. • Ensure turnover and prevent long-term parking in most convenient spaces. • Encourage use of underutilized off-street lots.	• Extend time limit to two hours on Highway 1 from Avocado Avenue to Hazel Drive. • All existing public off-street lots retain 10-hour limits, but would become free of charge.
Strategy 3 Short Term Increase public parking supply through shared parking agreements with willing private property owners.	• Cost-effectively increase supply of public parking. • Encourage use of underutilized off-street lots/garages.	• Conduct additional outreach to property owners as a means to increase the supply of publicly available off-street parking. • Work with private parking lot owners to maximize the use and value of their parking lots. • Key issues for further study: displacement of current tenants, managing liability and insurance, maintenance and operations, and cost sharing.
Strategy 4 Short Term Better manage employee parking.	• Reduce employee parking spillover into residential neighborhoods. • Maximize use of existing parking supply.	• The city would designate specific off-street lots or garages for employee parking only during specific hours. • Employers could purchase permits on behalf of employees. • Additional incentives should be offered to employees to reduce driving.
Strategy 5 Short Term Restripe existing parking to maximize parking supply.	• Maximize use of existing parking supply.	• Review and restripe as feasible mid-block red curbs on highway. • Restripe existing lots to maximize parking supply.
Strategy 6 Short Term Increase supply of secure and convenient bicycle parking.	• Provide secure bicycle storage. • Create a more welcoming environment for potential bicycle riders. • Encourage bicycle trips as a way to reduce the demand for automobile parking.	• Install bicycle parking at high-volume locations. • Potential locations include: Clock Tower, Port Theater, Starbucks (East Coast Highway at Goldenrod), and Rose Bakery Café.

(*continued*)

Table 11-4. (*Continued*)		
Strategies	**Goals**	**Components**
Strategy 7 Short Term Improve awareness of and access to underutilized parking facilities with way finding improvements.	• Improve customer convenience. • Ensure awareness of existing parking resources. • Reduce congestion associated with searching for parking.	• Develop a coordinated way finding program for public and private lots. • Reduce the amount of unnecessary parking signage where feasible, especially in private lots. • Develop coordinated signage for use in private lots. • Supplement parking signage with area maps for pedestrians.
Strategy 8 Short Term Establish a monitoring and evaluation program.	• Facilitate timely adjustments to parking plan and strategies as parking conditions evolve.	• Collect annual parking occupancy data to calibrate parking demand in the area and determine whether ongoing adjustments are needed.
Strategy 9 Long Term If needed, implement pricing to ensure parking availability.	• More convenient and accessible for residents and visitors. • Generate adequate turnover.	• *Meter location*: Highway 1 (Avocado Avenue to Poppy Avenue), all public lots/garages • *Meter type*: Include credit cards, pay-by-phone, and wireless technology • *Target occupancy rates*: 85% (on-street) and 90% (off-street) • *Hours*: To be determined • *Pricing*: As low as needed to achieve target rates • *Parking revenue*: Net revenue reserved for local improvements
Strategy 10 Long Term If supported by residents, consider a residential permit program (RPP).	• Mitigate impacts of spillover parking into residential neighborhoods.	• *District initiation*: Only if spillover problem and strong community support • *District boundaries*: Limited to areas impacted by spillover parking • *Eligibility*: Restricted to district residents • *Hours of operation*: 2-hour parking, 8 a.m.–6 p.m., Monday–Saturday • *Permit type*: "Virtual" permits for residents, "hangtags" for guests/visitors • *Number of permits issued*: Limited number per household • *Guest parking*: One free annual pass, option to purchase temporary passes
Strategy 11 Long Term If needed, implement a free shuttle service to remote parking facilities.	• Manage parking impacts during periods of high demand.	• Provide a free shuttle service to ensure access for non-residents. • Potential routes to remote parking facilities at Fashion Island or City Hall • Could be limited to weekend and/or summer peak periods

Table 11-4. (*Continued*)		
Strategies	**Goals**	**Components**
Strategy 12 Long Term As needed, implement a peak period valet service.	• Facilitate convenient drop-off and pick-up in areas of high parking demand. • Enable more efficient use of parking supply.	• *Time of operation*: Holiday seasons; Friday evenings (6–10 p.m.), and Saturdays (12–10 p.m.) • *Cost, Option A*: Free, if locally subsidized • *Cost, Option B*: $6 w/o validation; $3 w/ validation • *Drop-off/pick-up locations*: Along Highway 1; Off-street lots within area • *Valet technology*: Customer convenience

Source: Corona del Mar, undated

fundamental conflicts arise among various goals. For example, tactics that increase the parking supply may reduce the incentive to use public transit. Some of these strategies may be quickly discarded for failure to meet the goals and objectives of a community or institution, while others require more detailed consideration.

C. Performance Measures and Definitions

The use of parking-related performance measures depends on decision-making circumstances. For example, at the facility or parking lot level, interest would be primarily on the productivity or utilization of the parking spaces. Some of the performance measures relevant at this level include:

Duration—The length of time a vehicle is parked. *Average stay* or *average duration* is the average length of time all vehicles are parked in a facility over a specific period. All-day parking refers to vehicles parked for the hours of a typical working day.

Parking Adequacy—The degree to which the supply of parking is adequate to handle the parking generation (demand). Where appropriate, an equally acceptable approach is to compare the peak parking generation rate (or demand) on the design day to the effective supply.

Parking Capacity—The number of vehicles that can be parked in a given facility; *parking supply* is the total number of spaces available to serve a destination.

Turnover—The number of different vehicles parked in a specific area or facility in a given period of time divided by the number of spaces. Turnover may be calculated during the course of an entire day or separately for daytime and evening parking. If parking spaces in a facility are underutilized, the turnover rate will be very low. A common misconception is that the average turnover can be calculated by dividing the time period by the average stay (for example, 8 hours/2 hours average = 4 turns per day). This is really the maximum or *potential turnover* possible in a given time period and can only be achieved when the spaces are 100 percent occupied throughout the time period. Employee parking typically turns over 1.1 to 1.2 times per day due to in and out activity, while most customer parking may turn over 2 to 7 times per day. Multiday parking, as occurs at airports and hotels, will turn over less than one time per day, while airport short-term parking may turn over 10 or more times per day if effective segregation of long- and short-term parkers is achieved.

Utilization—The usage of a space or facility over a given period of time. Parking occupancy may be measured and recorded at hourly intervals or only at the expected peak period.

At the program level, transportation officials would want to know about how a parking program is helping to achieve community goals, as well as how the parking program is perceived by residents. The following performance measures from the city of Victoria, British Columbia, illustrate the types of measures that can be used at this level of decision making. [City of Victoria, 2007] Note that those measures for which a baseline has to be established are denoted as "B;" the type of performance measure has also been indicated as: Percentage (%), Trend (T), or Descriptor (D).

Customer Service

- Percentage of citizens reporting satisfaction measured in the citizen survey and other surveys (B, %).
- State of new vision, mission, and values for parking officers (by fiscal quarter) (D).
- Parking Services staff to attend the specialized customer service training (100% attendance by 4th quarter 2007) (B, %).
- Establish new contract for parking officers (by fiscal quarter) (D).
- Enhance information of new Parking Services website (T).

Create Incentives to Position Downtown as the Destination of Choice

- Numbers of customers using alternatives payment methods (B, %).
- Number of holiday courtesy and warning tickets issued (B, %).
- Number of small vehicle parking spaces (20 spaces, % increased based on demand).
- Number of parking spaces for persons with disabilities (33 spaces, % increased based on demand).
- Number of van/car pool parking spaces (16 spaces, % increased based on demand).
- Number of bike lockers in parkades (60 lockers, % increased based on demand).

Promote a Safe and Inviting Downtown Parking Environment

- Complete safety and security improvements at each parkade and surface lot (4th quarter 2008) (D).
- Complete rehabilitation on all City-owned parkades (over 5 years) (D).
- Number of times the parkades and surface lots are cleaned (B, %).
- Condition of the parkades according to facility condition index (B, %).
- Provide 24 hr. security at all City parkades (4th quarter 2007).

Improve Parking Technology to Make It More User-Friendly

- Number of multipay ticket dispenser installed (over 5 years) (by fiscal quarter, %).
- Number of parkade ticket dispenser upgrades (completed).
- Percent of ticket dispenser signage upgraded (B, %).
- Number and type of signs related to parking identification and way-finding signs (D, B, %).
- Reduction in the number of tickets disputed and court cases (B, %).
- State of the advanced parking technologies (D).
- Numbers of parking card reload locations (B, %).
- Percentage of varying alternative payment methods (T, %).

Ensure the Parking System is Self-sufficient and Sustaining

- Increase in parking meter rates ($2.00/hr., review annually).
- Increase monthly parking rates in parkades ($110 Centennial Square. $140 Johnson Street; $160 Broughton Street; $160 Bastion Square $175 View Street, review annually).

- State of parking revenues versus expenses (T).
- Introduce longer metered zones in specific areas (D, based on demand).
- Increase in parking fines ($15.00 to $20.00 and so forth).

Ensure Parking Demands Are Addressed for Both Today and the Future Downtown Parking Assessment (Completed)

- Number of short-term parking spaces and usage (B, T, %).
- Number of long term parking spaces and usage (B, T, %).
- Parking and Transportation reserve fund (by fiscal quarter).

As can be seen in these performance measures, they can range from gauging customer satisfaction with the community's parking program to monitoring the parking supply in meeting future parking demands. Other communities have used performance measures relating to revenue generated and environmental impacts associated with the program.

D. Facility Location and Urban Design

Urban design considerations include the overall design of a building, its scale and mass, and the way that parking blends into the fabric of existing buildings. Of particular importance are the treatment of streetscape and whether the parking facility creates an intrusion into the overall scale and character of a given area. Another major concern is whether a parking structure is a singular use, auto-oriented facility, or whether it becomes a mixed-use project or part of a new redevelopment.

Parking facilities should be located so that:

- Entrance and exit points are placed where roadway access is clear, safe, and congestion free.
- Convenient pedestrian access is provided by minimizing walking distances.
- Site and design facilities blend with, rather than intrude upon, the surrounding environment.

A parking facility can become a catalyst for major public improvements such as the creation of a new public open space or park. Parking can provide a major visual statement about the type of land use that occurs at a particular site, such as parking structures at major sports facilities and airports. Within an urban activity center, parking can form a transition buffer between two different land uses, or it can define a major public space.

On the other hand, parking structures can also have some adverse effects by creating a wall of inhospitable, non-pedestrian space that creates imposing facades upon an otherwise pedestrian environment. This type of environment generally has been created along streets where parking structures have been built as a backside to major developments.

From an urban design perspective, surface parking creates several problems. A surface parking lot reduces streetscape continuity. The lots are generally not well landscaped and negatively affect the overall quality of environment. In addition, a proliferation of curb cuts can affect the pedestrian walkway system. Urban design guidelines can address these issues by governing the siting, design and construction of parking structures or surface parking lots, including:

- Extensive landscaping along the buffer of lots should be provided; landscaping needs must also recognize security and life safety concerns and avoid blind spots.
- The number of curb cuts cutting across pedestrian walkways should be limited.
- Existing buildings should not be torn down for the use of surface parking, unless it is an interim use leading to the construction of a new building.
- New parking structures within an activity center should include mixed-use development at the street level and design treatments to the building itself should be used to minimize its impact upon the local character. Height, massing, and the use of materials should be controlled through design standards.

- Parking structures should be prohibited from major pedestrian streets, and directed instead to secondary streets dedicated more to auto access. Parking access should be avoided from main shopping streets.
- Incentives should be provided to encourage below-grade parking structures, combined with mixed-use projects or public open space.
- Access to and from parking facilities should be coordinated with major access streets and the service roadways intended to carry major traffic into the city center or major activity center.
- Parking facilities should be located where they would offer the greatest opportunity to identify a given land use and provide a clear definition of form, linkages, and connections.
- Parking facilities should be located where they have a positive urban design effect on a given area, such as the infill of gaps in the streetscape.

Some developments may be occurring on city blocks where the full development potential has not yet occurred. This creates a challenge in the parking analysis for strategies such as shared parking in that the developer does not know what possibilities might exist in the future for these types of strategies. In some communities, where future development is expected to provide opportunities for shared parking, the development proposal must address the entire block on which the proposed project is located. Future shared parking strategies could then be reflected in the conceptual block planning process. The block layout would include parking for the maximum square footage allowed for the block.

V. PARKING MANAGEMENT

Parking management includes various parking policies and actions that can be used to manage the supply of, and demand for, parking. Most actions have occurred in major commercial and institutional activity centers. Litman [2006] identified three types of strategies that are usually found in a parking management program.

Strategies that increase parking facility efficiency

- Share parking.
- Regulate parking.
- Establish more accurate and flexible standards.
- Establishing parking maximums.
- Provide remote parking and shuttle services.
- Implement smart growth policies.
- Improve walking and cycling conditions.
- Increase capacity of existing parking facilities.

Strategies that reduce parking demand

- Implement mobility management.
- Price parking.
- Improve parking methods.
- Provide financial incentives.
- Unbundle parking.
- Reform parking taxes.
- Provide bicycle facilities.

Support strategies

- Improve user information and marketing.
- Improve enforcement and control.
- Establish transportation management associations and parking brokerage.
- Establish overflow parking plans.
- Address spillover problems.
- Improve parking facility design and operation.

The following sections describe five key characteristics of parking management programs: (1) pricing, (2) on-street supply, (3) enforcement and adjudication, (4) off-street supply within an activity center, and (5) marketing.

A. Pricing

Price is a major factor influencing travel behavior, and thus the price of parking could be an important influence on decisions to travel to a particular location by a certain mode. From a parking owner's perspective, a pricing strategy could be formulated for several reasons: generate revenue, control who parks where and when, and encourage the use of alternative modes of transportation. Parking pricing in municipally owned facilities is set by public officials, but it often is well below what the market would otherwise bear. Sometimes this is done with intent, for example, where the community wants to encourage business and commerce to locate in a particular area. In other cases, parking pricing may be closer to the market price simply to encourage drivers to shift modes. The cost of parking in real dollars consistently declines over time, making it more difficult (politically) to raise rates. Only when the parking system is required to finance capital expenditures or support restoration and repair of older structures does the community consider the cost and market value of providing parking. Meanwhile, because the pricing of privately owned and operated facilities is influenced and restrained by municipal parking rates, commercial parking may not be viable and the burden of providing parking falls increasingly on the shoulders of a municipality.

Most companies and agencies do not charge the full cost of parking to users. The ideal, of course, is to charge market rates for parking, raising them every year to keep pace with inflation and market factors, and to develop reserves to finance new projects, capital maintenance, and repair.

1. Short-Term Pricing

Visitor parking should generally be available close to destinations. The fee structure of a particular facility or system is often set to ensure that visitors' needs are met first. Short-term parkers usually are not as price sensitive as long-term parkers. In many cases, there is a compelling reason to go to a destination; the price of parking is not often a major concern, although if a competitive destination has equally acceptable products and services, short-term parking cost might be the tie breaker to the traveler.

A strong combination of retail with other land uses can also be a strong attraction affecting parking price sensitivity. When Circle Centre, a public-private joint venture retail and entertainment center in downtown Indianapolis, was about to open, there was much speculation about whether it could succeed with the relatively modest parking fee of $1 for a stay of up to 3 hours. The fee structure then jumped to $2 per hour, primarily to discourage parking longer than three hours to keep the more than 50,000 downtown employees from using the parking intended for visitors. In the end, the parking fee was a non-issue to shoppers, and shortly after opening the project was ranked among the top 5 percent of retail centers nationally in terms of annual sales per square feet.

Shoup [2005] has written extensively on the benefits of using *demand-responsive pricing* for on-street parking meters. He suggests that meter rates should be raised until the typical occupancy is 85 percent of capacity. He further recommends that the incremental revenue gained from raising meter rates be used for the benefit of the neighborhood served by the meters. For example, a rundown area of Pasadena, California, became a vibrant retail/dining district due in large part to raising meter rates and using the money initially to make capital improvements (repair sidewalks and develop pedestrian corridors through alleys) and, over the longer term, to clean streets and sidewalks and support police patrols. By promising to use the additional revenues from increased meter rates for these purposes, local businesses supported the meter rate increase. Importantly, the meter rate increase was not the only component of the city's plan; zoning requirements for required parking spaces that inhibited adaptive reuse of existing buildings were modified and the city developed a number of parking structures to serve the remainder of the short-term parking need as well as employee parking.

2. *Long-Term Pricing*

Parking price can and does play a major role in mode choice and in parking location choice by employees and other long-term parkers. In large activity centers like the CBD, parkers usually have a variety of options. If price is a concern, an employee can find reasonably priced, if not free, parking on the perimeter of the activity center and walk three or more blocks to his or her place of employment. Shuttle and park-and-ride programs may make low-cost perimeter parking more accessible in large CBDs.

Table 11-5 shows the pricing mix for parking in several large U.S. cities and London as of 2009. Although the prices will vary over time, the relative pricing among cities will not likely change that much. It is interesting to note the large differences in the number of on-street and off-street parking spaces in the different cities, as well as the differences in prices.

True market pricing generally only exists in the CBDs of cities where commercial parking constitutes the largest share of parking supply. Many properties in these areas were developed before the private automobile became the predominant mode of transportation and, therefore, do not provide adequate parking for tenant and customer needs by today's standards. Off-street commercial parking pricing is not overly influenced by on-street meter rates set by the municipality. Generally, if a commercial parking facility exists, it is because the on-street parking alone cannot serve the needs of the area.

Some communities have begun to use variable pricing as a means of efficiently operating their parking supply as well as encourage the use of alternate modes. In 2011, San Francisco implemented *SFpark*, a variable pricing program for on-street parking to achieve a target parking of one or two open spaces per block. Seven pilot zones were designated to install sensors in each curb space on every block with the goal to achieve an occupancy rate of between 60 and 80 percent through variable pricing throughout the day. Meter rates vary based on time of day and day of week, and rates are adjusted over time in response to demand. Rates are adjusted on a block-by-block basis, using occupancy

Table 11-5. Pricing in Major U.S. Cities and London, 2009

City	Pop.	Land Area (square miles)	Population Density (per square mile)	CBD (square miles)	Metered On-Street Parking Spaces	Off-Street Public Parking Spaces	Daily Parking Rate (median)	Monthly Unreserved Rate (median)
New York	8.1 million	305	26,557	9.3	85,930	102,000 (CBD)	$44.00 (Midtown)	$550.00 (Midtown)
Boston	617,000	48.4	12,748	N/A	7,300	134,000	$34.00	$402.50
Chicago	2.7 million	237	11,392	1.6	4,500	unknown	$31.00	$325.00
Milwaukee	595,000	96	6,198	1.5	6,400	25,000 (CBD)	$12.00	$110.00
Minneapolis	383,000	58	6,603	1	6,611	16,102	$17.25	$187.00
Philadelphia	1.5 million	135	11,111	1.5	N/A	N/A	$26.00	$314.00
Portland, OR	584,000	145	4,028	4.6	7,800	58,130	$9.00	$185.00
San Diego	1.3 million	342.5	3,796	2.27	N/A	N/A	$26.00	$180.00
San Francisco	805,000	47.6	16,912	0.53	25,000	15,000	$25.00	$350.00
Seattle	609,000	142.6	4,271	1.48	13,500	50,000	$28.00	$290.00
Washington DC	602,000	64	9,406	N/A	6,700	150,000	$14.00	$215.00
London	7.8 million	620	12,581	N/A	N/A	N/A	$56.68 (city)	$1,020.29 (city)

Source: US Census, 2010; Colliers International Global CBD Parking Rate Survey, 2009; as reported in New York City Department of City Planning, undated data from the parking sensors installed in most on-street parking spaces in the *SFpark* areas. The conclusions from a pilot study evaluation of the program noted: (1) average parking rates were lower, (2) parking availability improved, (3) it was easier to find a parking space, (4) it was easier to pay and avoid parking citations, (5) greenhouse gas emissions decreased, and (6) vehicle miles traveled decreased.

In 2010, Seattle adopted an ordinance that set rates for on-street parking between a minimum of $1.00 per hour and a maximum of $4.00 per hour. Rates are set per block over the 31 districts and are set once a year. All meters have the ability to use the PaybyPhoneParking app. The public response has been positive and is likely due to the data-driven decision-making process. The business community accepted the changes as city revenue was not the goal and the fact that data on utilization dictated the rates. [SFTCA, 2009]

One of the key characteristics of today's pricing schemes is the use of technology that aims to make the parking program more efficient and easier for those parking to pay. In downtown Los Angeles, for example, the city is using a smart parking platform to help drivers find available parking, using ground sensors to detect parking space vacancies that are communicated through smartphone apps as well as the city's website. The city can then change the price of parking in highly congested areas. Traffic congestion has dropped by 10 percent since the project was implemented. In Washington, DC, smart parking systems use sensors to determine availability of spaces. Just over 57 percent of all parking transactions in Washington, DC, are paid for via a mobile app. This type of technology can be an important capability in parking enforcement as well. Other technology trends that will likely take hold in the near future include: contactless payment systems, electric vehicle charging while the car is parked, more use of solar equipment, license plate sensing payment systems, and a host of mobile phone apps that will provide more information to potential parkers of where space is available and at what price. For a review of technology trends and applications globally, see. [Joshi et al., undated]

B. On-Street Parking

On-street parking, although limited in terms of capacity, is often a key resource to activity centers. Older CBDs and institutional activity centers have some streets intentionally designed to provide on-street parking in addition to moving traffic lanes. However, only 5 to 10 percent of the parking needs in a downtown are on-street. [Kuzmyak et al., 2003]

Managing on-street parking in essence means controlling who parks where and preventing spillover parking into adjacent neighborhoods. Parking management actions involving on-street supply include adding or removing spaces, changing the permitted time limit, restricting parking to certain times or users, and employing on-street spaces for preferential carpool parking.

1. Adding or Removing Spaces

In smaller towns and cities, adding on-street parking by providing angled parking stalls where parallel parking stalls previously existed may be the most cost-effective means for adding parking capacity. Going from parallel parking to 60-degree parking can double the number of spaces. Changing a street to one-way, or combining the width of parallel parking spaces on each side of the street to a single line of angled stalls, can often result in added parking solely for the cost of pavement markings and a few signs. Angled parking also has a traffic calming effect and is promoted by neo-traditionalist planners for that reason. Given that this approach would only be applied on streets where desired vehicle speeds are low, relatively narrow travel lanes may be appropriate. Generally, a shallower parking angle is preferred. Perpendicular parking, although more efficient, is usually avoided because of increased traffic conflicts.

Conversely, on-street parking does affect traffic movement and safety on streets used for through-traffic movement. Conflicts over the use of curb space for bus stops and deliveries can also be a significant concern. In larger cities, prohibiting parking in peak hours has often been used to serve peak-hour traffic needs while still providing convenient mid-day parking for storefront businesses.

It is also important for city parking officials to review on-street parking restrictions periodically to make sure they are still needed. A dedicated loading zone required for retail stores along the block may no longer be necessary when the use changes to office. Street traffic in an area may no longer require peak period prohibitions. For example, prior to opening Circle Center, the City of Indianapolis conducted a block-by-block review of on-street parking controls and removed 50 percent of the rush hour restrictions on on-street parking. The enforcement of meters was privatized.

These improvements reduced complaints about parking from 172 to 22 per month and reduced towing from 1,000 to 160 vehicles per month. However, with the growth of the downtown in subsequent years, the city found that double-parking of service vehicles was inhibiting movement. Therefore, in 1999 the city doubled the number of loading zones, removing some metered spaces, and doubled the fine for loading zone violations.

2. Metered and Time-Limit Parking

The most common parking management action for on-street spaces is metering the space. The primary purpose is to keep the spaces available for short-term parking. Although originally intended solely to cover the cost of enforcement, over time many cities have obtained significant revenues from parking meters (and why private concessionaires are interested in parking meter public/private partnerships).

More recently, as CBDs try to compete with suburban shopping centers, the parking meter has become a contentious issue. In many cases, downtown merchants do not want to impose additional costs on their customers. The short-term parker, however, is not price sensitive, but rather convenience sensitive. If there is any negative effect of parking in downtowns compared to the suburban shopping center, it is the lack of convenient parking, not the lack of free parking. The on-street parking immediately in front of a store is usually not available to serve thriving, storefront retail much less a restaurant. Removing meters does not solve this problem and only exacerbates the problem of financing off-street parking at rates reasonable to a public used to free on-street parking.

Given the political process, it is easy for the city to grant requests for special time limits: the 5-minute meter in front of the copy shop, or a 15-minute limit at the meat market. These limits are almost never enforced; moreover, the proliferation of multiple meter limits and fees only adds confusion and complication to the on-street parking system. Wherever possible, meter limits should be simplified to 1-hour or 2-hour limits for short-term parking with 10-hour limits for peripheral meters that can be used by employees.

A municipality should periodically review its meter and time-limit system for currency and efficiency. One possibility is performance-based pricing of metered parking in which prices are raised until occupancy typically is about 85 percent. Today's pay-and-display and pay-by-space meters allow different rate structures to be used at different times of the day, which provides even greater flexibility in managing on-street spaces. Moreover, by removing individual meters, more spaces are often accommodated naturally by parkers, and parking revenues are significantly increased. After three years in operation, Seattle found that its pay-and-display system had nearly doubled the revenue per parking space per day although half of that was from a rate increase.

3. Preferential Parking

Some cities, notably Portland, Oregon, have successfully adopted programs that reserve on-street parking (typically in peripheral areas that would otherwise be 10-hour meters) for carpools. Many corporations do the same in parking lots, as well as preserving spaces close to entrances for those awarded for exceptional service to the company ("employee of the month").

4. Residential Parking Permits

One of the most common consequences of parking shortages in activity centers is spillover parking into adjacent neighborhoods. Where these neighborhoods are residential, the residential parking permit (RPP) program is the most viable strategy for controlling the problem. Where the spillover is almost entirely employee parking, on-street spaces may be restricted to 1- or 2-hour parking or to those displaying a residential permit. The restrictions may apply during certain hours, such as 8:00 a.m. to 6:00 p.m. Area residents pay a modest fee for a residential permit that allows the vehicle to be parked on the street. The time limit allows short visits by service vehicles and guests of the residents; longer stays require the parker to obtain a visitor pass card from the resident and place it in the vehicle.

Targeting restrictions on a particular time period or for a particular group might not always work. For example, where the spillover is largely composed of university students parking for a single class or tourists visiting a local site, it makes sense to allow no parking by anyone without displaying a residential permit. The environment of the neighborhood is not only enhanced by the reduction of nonresident parking, but also by the reduction of vehicular traffic seeking a parking space. State or local enabling legislation may be required to implement a residential parking permit program.

Technology is also used in permit parking programs. Hoboken, New Jersey, has added radio frequency identification (RFID) technology (similar to that used in toll road prepaid tags) to its permits to allow enforcement officers to distinguish between residents and nonresidents and to identify counterfeit parking permits. Parking enforcement officers can read the information on the permit automatically. Citizens can renew permits online. Moreover, the electronic memory and communication of these systems allows for the collection of data on parking utilization, which helps not only with program management but also future parking planning as well.

C. Enforcement and Adjudication

Parking duration and turnover studies find substantial overtime parking at meters even with extensive enforcement. Illegal parking not only allows parkers to avoid paying for their use of scarce spaces, but also may negatively affect traffic flow on arterial streets. Experience in many cities has shown that strict enforcement more than pays for itself.

More recently, pay-and-display, pay-by-space meters, and RFID parking permits have improved enforcement capability by speeding the process of writing tickets that stand up to judicial review and of recording the data for use by the parking management office. Areas where violations are a problem can be identified and enforcement enhanced, rates and policies can be changed, and other strategies implemented.

A study of the relationship among parking revenues, fee schedules, fines, and enforcement practices indicated that the level of enforcement and the rate schedule are more important determinants of parking behavior than the fine schedule. [Adiv and Wan, 1987] Thus, while increasing fines will increase total revenues, strict enforcement and higher fees are more beneficial to the system as a whole. The study concluded that while about one in three users either parked for free or exceeded the time limit, the meters were effective in their major goal of keeping the spaces available for short-term parking.

The adjudication of disputed tickets can be another challenge to a parking management program. Parking tickets are often administered via the courts, which can consider them a nuisance. Some judges are known to routinely throw out tickets on almost any excuse; other agencies make little effort to collect outstanding tickets. As a result, the prompt voluntary payment of tickets is generally low, between 10 and 33 percent.

The most successful strategy for resolving problems in fine collection is to establish an in-house bureau dedicated to ticket collection or to retain a professional ticket collection firm to aggressively pursue ticket collection. Key components include towing and booting programs. As tickets are issued, the enforcement personnel check the license plate against a "hot list" of scofflaws. When a vehicle is identified as a frequent violator or associated with significant unpaid tickets, the vehicle is towed and impounded or immobilized via a "boot" applied to one wheel until outstanding tickets have been paid. In some states, such as California, vehicles cannot be re-registered if there are unpaid parking tickets.

Many communities have effectively decriminalized parking tickets by establishing a procedure for resolution at an administrative rather than court level. A trained paralegal officer or panel hears evidence in disputed ticket cases and has authority to determine fault and assess fines as appropriate. Generally, the procedure allows the parking ticket or the computerized ticket writer's log to be *prima facie* evidence and the ticket writer need not be present at the hearing. Enabling legislation for administrative adjudication is usually required. Some cities have made the process extremely citizen-friendly, allowing walk-in hearings, write-in explanations, periodic amnesty programs, and credit card payment of outstanding tickets and fines.

D. Off-Street Supply Actions

Communities can manage their off-street parking supply in various ways—expand or restrict parking supply, encourage shared parking, and build park-and-ride facilities. Some of the most common are discussed next.

1. Area-Wide Limits

CBD parking supply limits have been used in several cities, including Boston, New York, Portland, San Francisco, and Seattle. Institutional activity centers such as universities have also restricted parking supply to encourage use of alternative modes. In the early 1990s, the University of Illinois at Champaign-Urbana decided to stop building more parking, at least on an interim basis, and used the pressure of parking shortages to help develop an improved public transportation service. Rather than operating its own shuttle system, the university worked with the local transit agency to expand citywide transit and shuttle service between outlying commuter and student lots and campus buildings. All students were assessed a transportation fee as part of the students' annual fee payment and received a pass for free use of the entire transit system; faculty and staff can purchase a subsidized pass for the system as well. This type of fee system along with campus shuttles is now common at many universities.

2. *Shared Parking*

Shared parking is desirable from both a land development and a transportation perspective. The potential savings in paved parking area (both lots and structures) from shared parking and mixed-use developments are significantly greater than the savings that might occur from changing design days and effective supply factors for single-use land developments. This can be accomplished in most land developments of reasonable size, including greenfield development in suburban locations. In the left of Figure 11-2 is a site plan modeled from an actual development in a rapidly growing corridor in suburban Indianapolis. This development on former farmland is layered with a first row of buildings housing a pharmacy, restaurants, and banks; a second row with a shopping center; and then office buildings and a day-care center in the third layer from the highway. Parking is not shared; spaces used by the offices on weekdays sit vacant in the evenings and weekends, when parking at the retail and restaurant buildings peak, and vice versa. A patient visiting a doctor in one of the office buildings has to drive around the center to the pharmacy to pick up prescribed medications because there is no easy, attractive pedestrian path between the third row of buildings and the first.

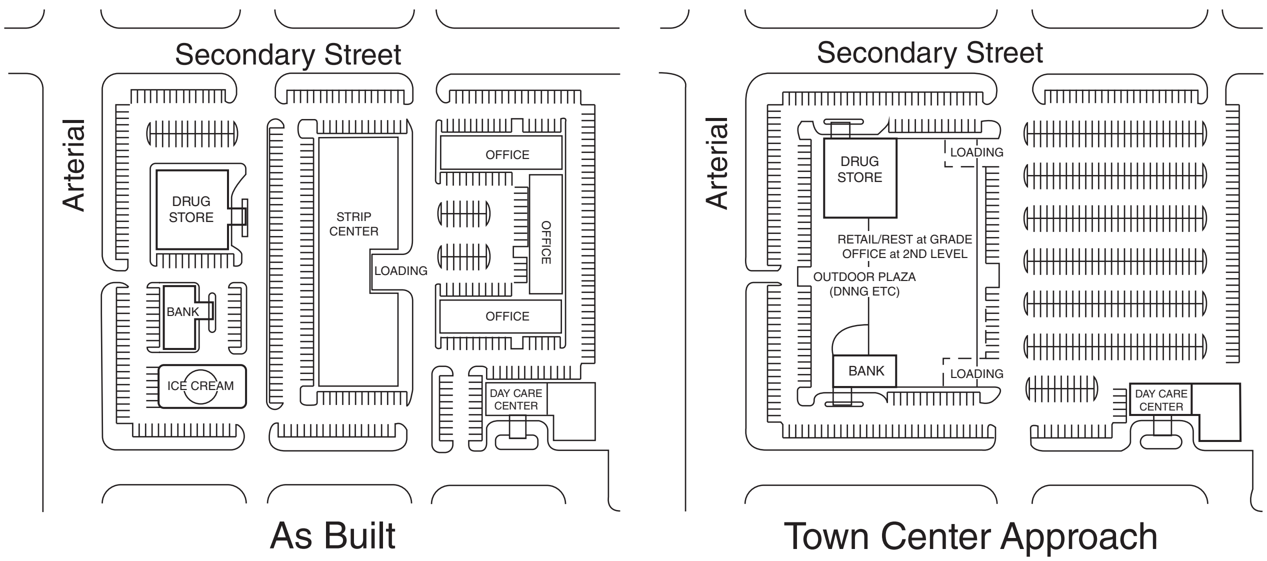
It would have been better to create a mini-town-center, like that shown on the right of Figure 11-2, with retail, banks, and restaurants at grade, and offices located on the second floor. The patient could also have stopped at the dry cleaners and the card shop in the center, as well as have had lunch at the sandwich shop. The buildings could have been pushed to the street, with nearly all parking behind creating a far better urban form and pedestrian environment. Furthermore, the town center approach would allow 50 percent more gross leasable area (GLA) to be developed, due to the efficiency of the site design and shared parking.

3. *New Technologies*

An evolving aspect of parking management is the use of new technologies for managing parking supply. Automated systems such as *parking availability displays* (PAD) and *individual space guidance* (ISG) systems can achieve some increase in required effective supply factors without excessive labor. PAD systems, as seen in Figure 11-3, help direct patrons to areas with available spaces, particularly on upper levels of parking structures. This system is cost-effective, costing less than $20 per stall (2006 dollars) where revenue control systems are otherwise provided, and less than $50 per stall where computers and software must be provided to operate the system. (The larger the number of spaces in each counting zone, the lower the cost per stall).

ISG systems monitor the occupancy of each stall and direct parkers to the nearest vacant stall. This system is in operation at several airports, including Baltimore-Washington International Airport, where it has been found to increase the effective supply factor to 93 to 95 percent as compared to 85 to 90 percent without ISG. It generally costs $500 per stall (2006 dollars) and is not typically considered cost-effective unless the number of spaces initially provided is reduced.

Figure 11-2. Comparison of Land Development with and without Shared Parking



Source: Walker Parking Consultants, Inc., 1992

For example, a 2,000-space structure costing $15,000 per space without ISG would cost $30 million. With ISG, the cost per space increases to $15,500 per space, but the proposed capacity will be reduced by 5 percent to 1,900 spaces and the construction cost reduced to $29.45 million. ISG must be regularly calibrated and maintained, but there is also a saving of the debt service and operating costs on the spaces eliminated. However, assuming 1,900 spaces could still be provided without ISG, there will be $1,500,000 in construction cost savings due to the elimination of ISG. This money would be available to pay for staff to direct parkers to available spaces in peak periods. In general, the more hours and more days that the parking generation rate exceeds the effective supply factor (for example, 93 percent of the spaces will be parked at the peak hour on many days of the year), the more cost-effective ISG will be.

These types of strategies can also be part of a much broader wayfinding strategy that guides motorist to available spots.

Figure 11-3. Parking Availability Displays

Photo Courtesy of Michael Meyer

E. Marketing

Marketing is an important part of parking management. While by itself it does not increase parking supply or reduce demand, it is valuable to publicize steps taken to improve parking in an activity center. The negative effect of increased parking fees on employee recruitment should be minimized by explaining the need for the increase and the overall benefits of changes in parking policies to the individual, the business, and the activity center.

An excellent marketing program in a CBD is maintained by Indianapolis Downtown, Inc. It provides information on parking policies downtown, a facility finder service that identifies parking facilities near a specific location and promotes a “Best Bargains” program comparing pricing of parking in many facilities to overcome a perception that parking has become expensive downtown due to events at the convention center and sports facilities. The home page for all these services is http://www.indydt.com/parking.cfm.

VI. PARKING DEMAND AND NEEDS ANALYSIS

The need for parking is closely related to the level of trip-making made for different purposes. According to the 2009 National Household Transportation Survey (NHTS), Americans averaged 1,385 trips per year, or 3.79 trips per person per day. [FHWA, 2013] Eighty-six percent of these trips were by personal vehicle. Only 15.6 percent of trips were commuting or work-related. However, as noted by Pisarski, commuter trips are more important in transportation planning than would be indicated by their proportion of total trips because of the impact they have on the economy, development within a community, congestion during peak hours, and air pollution. [Pisarski, 2006]

From a parking perspective, significantly more parking spaces are required per commuting trip than for shopping or other trip purposes because a commuter parking space serves one to two trips per day, whereas a customer space may serve 2 to 10 trips per day. Commuter parking is generally far less variable by time of day and season and thus more predictable. Commuter parking can be shared with evening and weekend customer parking, is generally far more price-sensitive than customer parking and is more easily influenced by local transit alternatives. One study found that increasing parking prices by 1 percent would decrease auto commuting trips by 8 percent, but customer use of the space by only 2 percent. [TRACE, 2005] Thus, the influence of parking pricing in commuting choices is four times as great as in visitor/customer trips.

Because trips are made to accomplish some activity at the end of the trip (called derived demand), trip-making and thus parking are strongly influenced by land-use characteristics. Parking demand varies widely among otherwise similar land uses. The variations reflect differences not only in the level of activity by a particular tenant, but also in the density of development, availability of public transportation, local policies, price of parking and local economic health. In areas with mixed land uses, such as the CBD, parking demand is often reduced because of the joint use of parking facilities for the different types of establishments found nearby.

Over the long-term, parking demand also varies as employment densities, transportation policies, and car ownership levels change. The density of employees per unit floor area in offices, for example, dropped from about six employees per 1,000 square (sq.) feet (or ksf) (6.5 employees per 100 meters^2 [m^2]) in the 1960s to below four employees per ksf (4.3 employees per 100 m^2) by 1985. [Weant and Levinson, 1990] The density of employees in downtown commercially developed office space declined from 3.9 employees per ksf (4.5 employees per 100 m^2) in 1985 to 3.5 employees per ksf (3.8 employees per 100 m^2) in 1995, but rebounded to 3.7 employees per ksf (4.0 employees per 100 m^2) by 2003. Similar patterns are found for suburban and governmental office space during the same timeframes.

A. Definitions

Many terms and concepts are used in parking analysis. Besides those introduced above in the section on performance measures, these include:

Activity Center—A relatively large concentration of development that is a major focus of activity within an urban area. While CBDs are historically the dominant form of activity center, the suburban activity center is the most prevalent form of commercial development in North America today. Suburban activity centers typically have multiple land uses and may consist of multiple mixed-use developments. Institutions such as major government centers, colleges, universities, and medical centers also create activity centers (see chapter 18 for more discussion on activity centers).

Central Business District (CBD)—The traditional core of the business, commercial, financial, and administrative activities of a community. A *CBD fringe* area may extend the CBD another two or three blocks in each direction. The fringe area often includes industrial and other lower-density uses and may have substantial on-street and surface parking serving the core area at lower rates.

Commercial Parking Facilities—Parking facilities that are operated for a profit, often by a professional parking operator. Commercial facilities are usually public; however, some commercial facilities may be entirely reserved (usually leased on a monthly basis) to a specific group of users and therefore are *private*.

Design Day—The level of parking demand that recurs frequently enough to justify providing parking spaces for daily use.

Effective Supply—The level of occupancy for optimum operating efficiency. A parking facility will be perceived as full at somewhat less than its actual capacity, generally in the range of 85 to 95 percent full, depending on various factors. A single facility also provides for flexibility in handling demand fluctuations; vehicle maneuvers and vacancies created by reserving spaces for specific users, such as disabled parking; losses due to misparked vehicles; or snow. In contrast, many small parking lots with many spaces reserved for specific users operate far less efficiently than a large single facility of comparable capacity with all spaces available to any user. The available spaces in a single large facility reduce the need to search many lots for the last few available spaces. Adding an effective supply cushion to the design day demand also provides for some flexibility in handling demand fluctuations.

Employee Parking—Parking provided for employees, most often long-term parking.

Intermodal—A characteristic of trip-making and of a transportation facility where a change of mode can occur. An *intermodal parking facility* allows a traveler to transfer from a private vehicle to some form of public transit. Parking facilities at airports, train stations, and other transportation transfer locations are intermodal terminals.

Long-Term Parking—Generally defined as parking for three hours or more.

Mechanical Parking Structures—Parking structures that employ elevators and other devices to move vehicles to parking stalls not accessible by pedestrians. This type of facility fell out of favor due to reliability problems and the high cost of maintenance as the facilities aged. Electronics and other technological advances have made these facilities feasible again since the 1990s, especially where there is no space for a traditional self-park structure. There are two types of mechanical access structures. The first is a simple *low rise* or *car stacker* that allows double or triple stacking of vehicles in a single parking space. The second type is a *high-rise* or *automated mechanical structure,* which uses lifts, elevators, or other mechanical devices to move vehicles to and from street level to an elevated space.

Mixed-Use Parking Structures—Parking structures that include retail and other uses, usually on the ground floor. This approach helps create a more pedestrian-friendly building façade at street level. Other uses may be built over parking structures, although usually at a substantial cost premium. In many urban areas, it is now quite common for parking structures to be developed in conjunction with other uses.

On-Street Parking—Parking that is provided on the street, either metered or free.

Off-Street Parking Facility—Parking facilities that are located on land adjacent to a street or road. Off-street parking facilities today range from driveways, carports, and multi-car garages at residences to parking structures in excess of 10,000 spaces.

Parking Demand—The number of spaces that should be provided to serve a use or group of uses under a specific set of circumstances, including pricing and effective supply considerations.

Parking Generation—An observed accumulation of vehicles. Traditionally, parking planners and industry publications select a design day, measure parking generation rates in the peak hour of parking accumulation on that day and then divide the expected number of parked vehicles by the effective supply factor to determine the recommended number of spaces (that is, parking demand) for that location or land use.

Parking Structures—A constructed facility for parking. Building codes distinguish *parking garages* (enclosed structures, often underground, that must have sprinklers and mechanical ventilation) from *open parking structures* (above-grade multistory parking facilities that are naturally ventilated). Owning and operating a space in a parking structure typically costs at least three times as much as a surface lot space, excluding land. There is more incentive for the owner or manager of the property to charge the user for parking in a structure. Regional variations in the terms used for parking are also quite common; for example, parking structures may be called parking *decks* or *ramps* in certain areas, while the British term is *car park*.

Private Parking Facilities—Parking facilities that are reserved for specific users.

Public Parking Facilities—Parking facilities that serve anyone who wishes to use them, often for a fee.

Self-Park Facilities—Parking facilities where the user parks the vehicle.

Short-Term Parking—Parking for less than three hours.

Surface Lots—Parking that is provided on at-grade lots and may be "free" to the user. The cost of building and operating "free parking" is either borne by the landowner or passed through to the tenants in the lease rate. The vast majority of parking supply in the United States is found in surface lots.

Valet Parking—Parking in which the vehicle is dropped off and is then parked by a parking lot operator. This has become more common in recent years as a customer service at locations with parking shortages or long walking distances.

Visitor Parking—Parking designated for visitors to a particular site. It is usually short term; however, it may be long term at an ambulatory surgery center, airport, or a hotel.

B. Parking Demand Formulas

Standard practice for estimating parking demand is to use equations that relate parking spaces to some quantitative measure of land use. The following paragraphs discuss some of the issues associated with the use of such formulas.

1. Units

Parking demand and generation rates are generally stated as a ratio of *x* spaces per *y* units, with the unit being an appropriate measure of a particular land use. In most cases, the land-use unit is building area (m^2 or $feet^2$ [ft^2]). Other units include dwelling units, hotel rooms, seats, or persons. The unit should be calculable at the time of planning. Demand ratios based on numbers of employees should generally be avoided since they may be variable over time. Similarly, although store sales may be a reliable predictor of parking demand for retail uses, it is difficult for planners to evaluate parking needs on this basis, because projected store sales are merely educated guesses of future activity levels. Airports generally use the number of passengers arriving and departing an airport for the design of terminals, but parking consultants typically use originating enplanements for parking planning because transferring passengers at hubs do not generate significant incremental parking demand.

In some cases, particularly those of assembly space such as auditoriums, a threshold capacity in allowable number of persons is licensed or posted and could serve as the basis for parking requirements. Certain land uses, specifically hospitals and universities, are variable due to age and mix of buildings such that it is difficult to determine a single consistent land use. A parking study specific to the institution is thus the only reliable way to evaluate parking demand. Similarly, there is a high degree of variability of parking demand for governmental buildings, except for buildings used primarily for office use.

In the past, parking ratios were sometimes stated as one space for each *x* square feet of usable space. However, most in the industry now prefer to use a ratio stated as *x* spaces per 1,000 sq ft (denoted as ksf). Therefore, the more recent studies of parking requirements, such as *Parking Generation* and *Shared Parking*, have generally employed spaces per 1,000 ft^2 or spaces per 100 m^2 (the remainder of the chapter will use the ksf rate). [ITE, 2010; Smith, 2005]

Another important aspect of area-based ratios is how they are defined. Because there is wide variation among both national standards and zoning ordinances on this issue, the modifiers *gross*, *net*, *leasable*, and *rentable* are frequently added to clarify the term *floor area* as follows:

Gross Floor Area (GFA)—Total floor area, including the exterior building walls, of all floors of a building or structure.

Gross Leasable Area (GLA)—Gross floor area that is available for leasing to a tenant.

Net Floor Area (NFA)—Total floor area, excluding exterior building walls.

Net Rentable Area (NRA)—Net floor area that is available to a tenant; also called net leasable area (NLA).

Vehicular parking and loading areas and the floor area occupied by mechanical, electrical, communications, and security equipment are deducted from either GFA or NFA, as these spaces do not contribute to parking demand. While older ordinances tended to use NFA, most industry standards today use GFA for nearly all land uses, with GLA being used for shopping centers and a few others (see, for example, *Dimensions of Parking* [ULI and National Parking Association, 2014]; *Parking Generation* [ITE, 2010], and the Parking Consultants Council's *Recommended Zoning Ordinance Provisions for Parking* [PCC, 2007]).

Generally, GLA is the GFA minus the floor area of elevator shafts and stair towers, public restrooms, permanently designed corridors, public lobbies, and common mall areas. Merely enclosing the space connecting tenant spaces does not add significantly to parking demand. For example, if the GLA is the same, the common mall areas of enclosed shopping centers do not generate significantly more demand than either a shopping center with open-air courtyards or a strip mall with all stores opening to the parking lot. Likewise, connecting the lobbies of a pair of office towers with an atrium does not generate additional parking demand, thus the atrium should be excluded from parking demand calculations. In smaller buildings, the difference between GLA and GFA is negligible.

Recommended parking ratios from *The Dimensions of Parking* [ULI and NPA, 2014] are shown in Table 11-6. Periodic parking surveys could also be conducted to help develop an adjustment factor for base parking rates to reflect actual parking behavior in the study area.

Table 11-6. Recommended Parking Ratios	
Use	**Parking Ratio**
Residences and Commercial Accommodations	
Single family dwelling unit (Dwelling Unit [DU])	• <2,000 sq. feet (186 sq. meters): 1/ DU • 2,000-3,000 sq. feet (186-279 sq meters): 2/DU • >3,000 sq. feet (279 sq meters): 3/DU
Multifamily DU	
Rented	1.65/DU
Owned	1.85/DU
Accessory	Add 1/accessory DU
Sleeping rooms	1/unit or room, plus 2 for owners /managers
Commercial lodgings	1.25/room plus 10/1,000 sq ft (10.8 per sq meters) of gross floor area for lounge and/or restaurant, plus conference/banquet facilities at the following rates: • <20 sq ft (1.86 sq meter): 0 • 20 sq. feet (1.86 sq meters)/room: 30/1,000 sq ft (32.3/100 sq meters) of GFA • 20 to 50 sq. ft (1.86 – 4.65 sq. meters)/room; scaled proportionally between 20 and 50 sq ft/room (1.86 to 4.65 sq meters) • >50 sq feet (4.65 sq meters)/room; 20/1,000 sq ft (21.5/100 sq meters) of GFA
Housing for seniors	0.5/DU
Congregate care or assisted living	0.35/DU
Group homes, convalescent homes, and nursing homes	0.5/bed
Retail Sales and Services (not in shopping center unless so noted)	
General and convenience retail	2.75/1,000 sq ft (2.96/100 sq meters) of GFA
Grocery stores	6.75/1,000 sq ft (7.26/100 sq meters) of GFA
Heavy/hard goods	2.5/1,000 sq ft (2.69/100 sq. meters) of GGA including outdoor sales areas
Discount superstores	5.5/1,000 sq ft (5.92/100 sq. meters) of GFA including outdoor sales areas
Specialty stores	4.5/1,000 sq ft (4.84/100 sq. meters) of GFA including outdoor sales areas
Shopping centers with not more than 10% of gross leasable area (GLA) in nonretail sales and service uses.	• <400,000 sq ft (37,160 sq. meters) of GLA; 4.0/1,000 sq. feet (4.3/100 sq meters) of GLA • 400,000–600,000 sq. feet (37,160–55,740 sq meters) of GLA: scaled proportionally between 4.0 and 4.5/1,000 sq ft (4.3 and 4.84/100 sq. meters) of GLA • >600,000 sq ft (>55,740 sq. meters) of GLA: 4.5/1,000 sq ft (4.84/100 sq. meters) of GLA
Shopping centers with more than 10% of GLA in nonretail sales and service uses.	Should be established in accordance with a shared parking study prepared specifically for the subject project
Food and Beverage Services	
Fine or casual dining (with bar)	20/1,000 sq ft (21.5/100 sq. meters) of GFA
Family restaurant (without bar)	15/1,000 sq ft (16/100 sq. meters) of GFA
Fast food restaurant	15/1,000 sq ft (16/100 sq. meters) of GFA
Night club	19/1,000 sq ft (20.5/100 sq. meters) of GFA

(*continued*)

Table 11-6. (*Continued*)

Use	Parking Ratio
Office and Business Services	
General business offices	• <25,000 sq ft (2,325 sq meters) of GFA: 3.8/1,000 sq ft (4.1/100 sq meters) of GFA • 25,000–100,000 sq ft (2,325 to 9,290 sq meters) of GFA: scaled proportionally between 3.8 and 3.4/1,000 sq ft (4.1 and 3.67/100 sq meters) of GFA • 100,000 sq ft (9,290 sq meters): 3.4/1,000 sq. feet (3.67/100 sq meters) of GFA • 100,000–500,000 sq. feet (9,290–46,450 sq. meters): scaled proportionally between 3.4 and 2.8/1,000 sq ft (3.67 to 3/100 sq meters) of GFA • >500,000 sq ft (>46,450 sq. meters): 2.8/1,000 sq ft ((3.0/100 sq meters) of GFA
Consumer services offices	4.6/1,000 sq ft (5/100 sq. meters) of GFA
Data processing, telemarketing, or operations office	6/1,000 sq ft (6.5/100 sq meters) of GFA
Medical offices that are not part of a hospital campus	4.5/1,000 sq ft (4.8/100 sq meters) of GFA
Medical offices within a hospital campus	4/1,000 sq ft (4.3/100 sq meters) of GFA
Government facilities	Should be established in accordance with a study of parking needs prepared specifically for the subject property
Industrial, Storage, or Wholesale Facilities	
Manufacturing or industrial	1.85/1,000 sq. feet (1.99/100 sq. meters) of GFA, plus required parking spaces for office, sales, or similar uses where those uses exceed 10% of GFA.
Storage or wholesale	0.67/1,000 sq. feet (0.72/100 sq. meters) of GFA
Mini-warehouse	1.75/100 units
Educational or Institutional Uses	
College or university	Should be established in accordance with a study of parking needs prepared specifically for the subject institution
Daycare center	0.3/person, based on licensed enrollment capacity
Hospital or medical center	Should be established in accordance with a study of parking needs prepared specifically for the subject institution
Arts, Recreation and Entertainment Uses	
Convention centers or meeting and banquet facilities that are not within a hotel but that exceed 100 sq ft (9.3 sq meters) per sleeping room	• <25,000 sq ft (2,320 sq meters: 30/1,000 sq ft (32.3/100 sq meters) of GFA • 25,000–50,000 sq ft (2,320-4,645 sq meters): proportionally scaled between 30 and 20/1,000 sq ft (32.3 and 21.5/100 sq meters) of GFA • 50,000 sq ft (4,645 sq. meters): 20/1,000 sq ft (21.5/100 sq meters) of GFA • 50,000–100,000 sq. feet (4,645–9,290 sq. meters): scaled proportionally between 20 and 10/1,000 sq feet (21.5 and 10.8/100 sq meters) of GFA • 100,000 sq ft (9,290 sq meters): 10/1,000 sq ft (10.8/100 sq meters) of GFA • 100,000–250,000 sq feet (9,290–23,225 sq. meters): scaled proportionally between 10/1,000 and 6/1,000 sq feet (10.8 and 6.5/100 sq. meters) of GFA • >250,000 sq feet (>23,225 sq meters): 6/1,000 sq ft (6.5/100 sq meters) of GFA
Health club	7/1,000 sq ft (7.5/100 sq meters) of GFA

Table 11-6. (*Continued*)	
Use	**Parking Ratio**
Cinema	• 1 screen: 0.5/seat • 2–5 screens: 0.33/seat • 5–10 screens: 0.3/seat • >10 screens: 0.27/seat
Theater (live performance), house of worship, or religious center	0.4/seat
Arena	0.33/seat
Football stadium	0.31/seat
Baseball stadium	0.35/seat
All other public assembly spaces	Where not seated, 0.25/person, based on permitted capacity Where seated, 0.3/seat

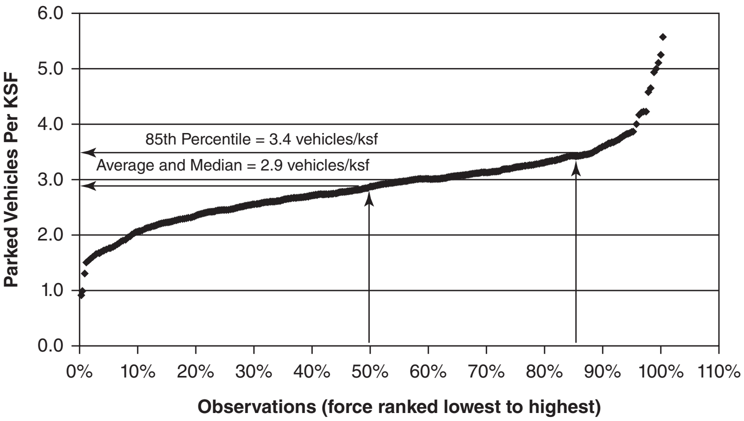
Source: ULI and NPA, 2010

2. *Design Day and Design Hour*

The design day is typically selected from among the top 10 to 20 activity days per year. Unfortunately, *shopping center* is the only land use for which data on parking needs throughout the year have been extensively studied to determine a design day and hour. For shopping centers, the 20th highest hour in the year is recommended as the design hour; this hour is usually the second or third busiest hour on the second Saturday before Christmas. [Urban Land Institute and International Council of Shopping Centers, 1999]

For other uses, ITE's *Parking Generation* presents regression curves for an average of the peak accumulations observed as well as 33rd and 85th percentile values. This text suggests that the average ratio may be acceptable for some uses, but not for others (see Figure 11-4). This database is simply the information that has been reported to ITE. The average ratio reported is simply the average of the peak accumulations observed. Moreover, in the vast majority of cases, there are less than 10 studies constituting the database, and the data set is not reliable from a statistical perspective. For this reason, many, including a 1990 ITE committee report, have suggested the 85th percentile in *Parking Generation* as an appropriate design standard. [ITE Technical Council, 1990] Most practitioners generally employ the 85th percentile, as does the Parking Consultants Council [2007].

Figure 11-4. Definition of 85th-Percentile Design Day



Source: Special sort of ITE Parking Generation Database for Land Use Code 701: Office

The 85th percentile means that 15 percent of the sites observed would require more parking than the specified value. The data reflect the observations submitted and are not counts on a generally accepted design day. Moreover, the vast majority of the studies occurred at sites with free, unconstrained parking and thus do not reflect the influence of parking price or transit use. In sum, care must be taken on applying ITE's data on parking generation rates. For a critique of parking generation rates, see Shoup [2005].

3. *Effective Supply*

When determining the adequacy of an existing multifacility parking system, a parking analyst will usually assign effective supply factors to each of the different facilities to determine the overall effective supply and then compare the effective parking supply with the design day parking generation. To provide the desired effective supply, the expected parking generation rate at the peak time on the design day is divided by the effective supply factor. For example, if 1,000 vehicles are expected to be parked at the peak hour on the design day with a 90 percent effective supply factor, 1000/0.90 = 1,111 spaces would be required for the system to work reasonably well in that hour.

This approach is not used when parking ratios are incorporated into zoning requirements and other planning standards; therefore, most industry publications suggest using effective supply factors in developing recommended parking ratios for the zoning code. The intent of the effective supply concept is that the system will work reasonably well on the design day, but there may be difficulty finding an available space in hours above the design hour. This is truly a practical need; for example, parking facilities with access and revenue controls are often closed before the parking facility becomes completely full, because it is just too difficult to find available space, and most of the remaining stalls are reserved for particular users, such as disabled parking. Users may perceive that there is a serious or even severe parking problem even though there may be spaces available somewhere in the system.

4. Size

The size of a development influences parking behavior. The peak accumulation of vehicles at a large multitenant building is more likely to fit a standard accumulation than is the peak accumulation of parking in a small building in the same land-use category. It is simply a case of probability. For example, among 50 small office buildings, a number will have a demand high enough to require 3.8 spaces/ksf. If the tenants of those 50 buildings move into a single, large building, the accumulation of vehicles will average out, and a 3.0 spaces/ksf (3.2 spaces/100 m^2) supply would be sufficient. It is appropriate, therefore, for a community to have a higher ratio for smaller concentrations of a specific land use than that required for larger buildings. However, single-tenant buildings, especially larger ones, may need special study. When there are multiple departments with different functions, the parking needs will be similar to a large multi-tenant building; however, a single-tenant building that houses one large function may have higher parking needs.

Size has the reverse impact on large shopping centers. Shopping center size usually reflects its primary markets—neighborhood, community, or regional—and thus differences in shopping and parking patterns. More specifically, the larger the center, the longer the length of stay, increasing the percentage of daily vehicles present at any one time (see Table 11-7).

5. Accessory Uses

Accessory uses are areas within a specific land use that are not the principal activity, but are necessary to the successful tenancy of that use. Examples include storage, stock, office, and kitchen spaces. Some believe that this floor area should be calculated at different rates for parking generation. However, most national standards have been based on studies wherein these areas have been considered as part of the floor area used to calculate parking ratios for the entire activity. Therefore, it is usually appropriate to include accessory areas in the parking-related floor area calculations for the primary use.

6. Complementary Uses

A complementary use is a space that is used or leased by a different land use, but designed to serve or enhance the primary use. Although the complementary use normally would have substantially different parking characteristics from those of the primary land use, the interrelationship with the primary use results in lowered parking demand, primarily through captive market effects. For example, a deli or sandwich shop that might otherwise require more parking spaces per unit of floor area can be allowed in an office building without increasing the ratio of the primary activity generator. An Urban Land Institute (ULI)/International Council of Shopping Centers (ICSC) study examined this issue and found that small concentrations of complementary uses do not change the parking requirements from those of the primary land uses. Thus, for small concentrations of complementary uses, the full GFA/GLA (that is, the sum of the primary and complementary uses generally) should be used in the projections of parking requirements using the ratio for the primary use.

The ULI/ICSC study found that where more than 10 percent of the GLA of a shopping center is occupied by restaurant or entertainment uses, the parking ratio should be increased, and that when more than 20 percent of the GLA is in restaurant/entertainment uses, shared-parking analysis should be employed. *Shared Parking* [Smith, 2005] and Parking Consultants Council updates recommend using shared-parking analysis when more than 10 percent of the GLA is occupied by complementary uses.

Table 11-7. ICSC Shopping Center Classification				
Type of Center	**Concept**	**Square Feet (including Anchors)**	**Sample Size**	**Type**
Malls				
Regional Center	General merchandise fashion (mall typically enclosed)	400,000–800,000	2 or more	Full-line department store; mass merchant; discount department store; fashion apparel
Super Regional Center	Similar to regional center but has more variety and assortment	800,000 +	3 or more	Full-line department store; junior department store; mass merchant; apparel
Open-Air Centers				
Neighborhood Center	Convenience	30,000–150,000	1 or more	Supermarket
Community Center	General merchandise; convenience	100,000–350,000	2 or more	Discount department store; drug; home improvements; large specialty/discount
Lifestyle Center	Upscale national chain specialty stores; dining and entertainment in outdoor setting	Typically 150,000–500,000, can be smaller or larger	0–2	Not usually anchored in the traditional sense, but may include book store; other large-format specialty retailers; multiplex cinema; small department store
Power Center	Category; dominant anchors; few small tenants	250,000–600,000	3 or more	Home improvement; discount department store; warehouse club; off-price
Theme/Festival Center	Leisure; tourist-oriented; retail and service	80,000–250,000	N/A	Restaurants; entertainment
Outlet Center	Manufacturers' outlet stores	50,000–400,000	N/A	Manufacturers' outlet stores

Source: Delisle, 2008

C. Sensitivity of Parking Recommendations

How much parking is enough? Quite simply, it depends. The following issues should be considered when developing an appropriate parking demand ratio for a land use.

1) How unified is the parking system? Is there one big facility or many scattered smaller facilities? Are spaces reserved for specific users that cannot be used by other parkers when vacant?

2) What is the level of confidence in the parking generation data (that is, predicted occupancy)? Where data are collected at an existing site and projected into the future, it is still appropriate to select a design day and employ an effective supply factor so that the system works reasonably well.

   When sources such as *Parking Generation* [ITE, 2010] are employed, the variation in density of activity occurring due to the specific tenants present must also be considered, along with the fact that tenants change over time. "Shopping center" is the only land use for which a large sample of data has been specifically collected in a widely accepted design hour; moreover, the accepted design hour (the 20th highest hour in the year) is relatively high. The level of confidence in office building parking ratios is also relatively high because the data sample in *Parking Generation* is large (178 study sites), the coefficient of variation is relatively low (26 percent) and there is not much variation in parking accumulation by season of the year (thus, when the data were collected is not a critical issue). For many other uses, coefficients of variation are high and the level of confidence is relatively low.

3) What is the shock absorber or failsafe when parking generation exceeds effective supply? Will there still be enough spaces if the operator manually directs parkers to the difficult-to-find spaces in those circumstances? Will automated systems be able to help parkers find spaces with less frustration? Is off-site temporary parking

available, and will it likely be available throughout the planning horizon? Is there the potential to share parking and use the parking resources more efficiently? Would spillover parking into an adjacent neighborhood be acceptable? Is it acceptable to turn some people away?

4) Will the knowledge of a likely tight supply modify visitation patterns or mode choices to the site? For example, a parking study at one shopping center that clearly needed more spaces than the generally accepted ratios in the design hour found that shoppers came earlier or later in the day to avoid the congestion in midafternoon. The media annually publicize the congestion at airports on peak holiday travel days, resulting in more travelers choosing to be picked up/dropped off at the airport rather than park for the length of the trip.

5) Is transit an alternative to automobile use? Is there a potential benefit to the community in limiting parking supply to encourage market pricing of parking and/or to encourage more use of alternate modes of travel?

6) With any of the above approaches, for hours exceeding the peak hour on the design day, how many times a year would this be acceptable to the business owner? To the users? To the community?

In many older references, the recommended parking demand ratio was based on the 85th percentile ratio and then factored up by dividing by an effective-supply factor to arrive at the ratio of spaces to be provided per unit of land use. This was never the case with the ratio for shopping centers. In the original 1978 study of shopping center parking demands, the 20^{th} highest hour was selected as the design hour, but the recommended parking ratio was set at the average of the observed accumulations across a large sample of data taken in that particular hour, without any additional effective-supply cushion. This approach recognizes that for the average center during 19 hours per year there will be no vacant spaces at all, and that in other hours there will be difficulty finding available space because there is no effective-supply cushion for these hours. Shopping centers that are more successful than the average center will have real and perceived parking shortages in more hours per year, while less successful centers may never have any perceived, much less real, parking shortages.

As previously discussed, there is growing acceptance in the industry that parking is often oversupplied when traditional zoning ratios are used. The second edition of *Shared Parking* used the 85th percentile accumulation with no additional effective-supply factor for recommended parking ratios. *Recommended Zoning Ordinance Provisions* adopted all of the *Shared Parking* ratios and added a number of ratios for other uses using the same philosophy. [Parking Consultants Council, 2007] These ratios are specifically intended to be the recommended *minimum* number of spaces to serve that quantity of that land use. If a community sets maxima in lieu of or in addition to minimum ratios, they should consider adding an effective-supply ratio to the minimum parking ratios found in these two publications to arrive at appropriate maximums. Fundamentally, this is a shift in thinking regarding how much parking a community should require.

An extra cushion of spaces for effective-supply considerations or even more spaces for leasing or other reasons might still be provided, but it should not be required by zoning or governmental approvals as the minimum number of spaces required to protect the community's interests. The provision of extra spaces should be a professional judgment made in consultation with the owner based on the advantages or disadvantages of a limited supply in peak hours at that particular site.

D. Reducing Parking Demand

There are many factors that can influence the demand for parking and thus the number of spaces that should be provided. Managing the supply and price of parking can have a significant effect on trip generation. Employee trips destined to work-related parking are just one of the target markets for parking management strategies. Those searching for parking spaces for other trip purposes, such as shopping, personal business, or recreation, could also be affected. For example, studies in several communities have shown that the amount of traffic on local streets engaged in searching for parking spaces can be quite high: 45 percent in Brooklyn, New York; 28 percent in Manhattan, New York; and 30 percent in Cambridge, Massachusetts. [City of Seattle, 2008]

Individual parking actions can have clearly identifiable effects on parking demand. For example, the impact on parking demand of increasing the price of parking can be estimated by using elasticity measures that reflect the demand-price relationship. However, for many communities where a parking program or strategy consists of many different actions,

Figure 11-5. Parking Management Actions Used by Cities

Place	Parking Cash-Out Required	Congestion Pricing	Unbundling of Parking Costs Required	Universal Transit Pass Program	Parking Tax	Low Minimum Parking Requirements	Eliminated Minimum Parking Requirements	Set Maximum Parking Requirements	Priced Parking	Shared Parking/Park Once	Residential Parking Permit Districts	Carpool/Ride Matching Services	Car Sharing	Bicycle Parking Requirements	Rail Transit	Bus Rapid Transit	
Arlington County, VA					✓	✓	✓		✓	✓	✓	✓	✓		✓		
Bellevue, WA (Downtown)			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Boulder, CO (Downtown)				✓		✓	✓		✓	✓	✓	✓	✓	✓			
Cambridge, MA						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Lloyd District, Portland, OR				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
London, Great Britain		✓					✓	✓	✓	✓	✓	✓	✓	✓	✓		
Portland, OR (Downtown)							✓	✓	✓	✓	✓		✓	✓	✓		
San Francisco, CA (Downtown)			✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		
Stockholm, Sweden		✓			✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Vancouver, B.C.				✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	

Source: City of Pasadena, 2006

it is often more difficult to assess the relationship between the parking program and the likely change in parking demand. For example, Figure 11-5 shows the types of actions that cities have used in developing a community-wide parking management strategy. Identifying the individual contribution of each action shown in this figure to overall trip reduction would be very challenging.

The town of Nantucket, Massachusetts, which faces many of the challenges of resort and tourist communities with both residents and visitors often vying for the same parking spaces, developed the following strategies and actions in order of priority. [Nelson Nygaard Consulting Associates, 2010]

- Remote parking
- Parking cash-outs or universal transit passes
- Handheld units
- Demand-responsive pricing
- Automated license plate reading technology
- Multispace pay and display
- In-car meters
- Valet
- Parking benefit district
- In-lieu fees
- Shared parking
- Residential parking benefit districts
- Reverse-angle parking
- Curbside sensors
- Pay with cell phone
- Zoning/parking maximums
- Unbundle parking
- Pay before you exit
- Real-time space availability displays

- Multispace pay by space
- Tandem and stackers
- Smart cards
- First few minutes free meter

The Nantucket study also provides excellent reference material for each of these proposed actions, especially as applied in smaller communities.

These examples of parking management programs illustrate the fact that communities often utilize many different actions and measures to manage their parking more efficiently and effectively. However, each community is different, and a wide variety of factors could affect parking demand. For example, ITE parking demand ratios reflect suburban sites where usually major land uses are separated, and there is little transit ridership or few walk-in patrons. In most cases, parking is free or low cost. Thus, they need downward adjustments where these conditions do not apply, especially in the CBDs. In addition, most planners today look at parking, especially in a suburban context, as part of a much larger mobility program. For example, Table 11-8 comes from a study that looked at parking programs in suburban downtowns in the Chicago metropolitan area. [Banks, 2011] As noted by the study, "To accommodate future growth and develop livable communities, with safe options for a variety of travel modes, we must take a proactive approach to managing parking so as to avoid the negative externalities and get the best and highest use out of our available land."

In parking analysis, factors that tend to dampen the demand for parking are incorporated into the analysis as adjustment factors. For example, in areas with high levels of transit use, the number of parking spaces could be reduced. Similarly, if shared parking opportunities exist in the development complex, the amount of parking required for each development could be reduced as well. Table 11-9 shows some of the adjustments that are typically made as part of parking demand analysis. In most cases, the allowable adjustments are codified in local zoning or planning requirements, or are established by the planning agency.

Table 11-8. Parking and Other Strategies for Suburban Downtowns, Chicago

Parking Management Tool	Description / Example
Context-sensitive solutions	Reduce minimums for senior and affordable housing.
Improve bicycling infrastructure and the pedestrian environment	Provide secure bike racks, improve crosswalk visibility, create bike lanes, etc.
Work with employers to incentivize carpooling, bicycling, walking	Employers can offer workers benefits such as: the cash equivalent of a parking space, access to a shared company vehicle, cash per mile ridden for bicyclists, etc.
Shared parking	Share parking facilities among multiple uses with disparate peak demand periods.
Land banking/land reserves	Require developers to provide parks and open space that could be converted to parking, if needed.
Paid parking, no time limits	Install meters or paid parking systems without time limits, as price should be influential enough to adjust behaviors.
Progressive parking pricing	To encourage turnover, the price is progressively higher per hour in high activity areas (for example, \$1 for the first hour, \$2 for the next hour, \$5 for each hour following).
Unbundled parking	Reduce parking requirements for developers who unbundle parking spaces from rents/mortgages; or require developers to unbundle parking.
Create a Parking Benefit District or Parking Management Authority	All paid parking revenue is deposited into a fund for the area where the meters are located, to be used for whatever the tenants and land-owners desire.
In-lieu fees	Charge developer fees in-lieu of providing required parking with funds dedicated to providing parking at a centralized garage/municipal lot, and/or improving the streetscape.
Eliminate parking minimums	With no parking minimums, developers will likely provide a more limited supply, and small businesses will have more incentive to open new locations.

Source: Banks, 2011

Table 11-9. Parking Requirement Adjustment Factors		
Factor	**Description**	**Typical Adjustments**
Geographic location	Vehicle ownership and use rates in an area.	Adjust parking requirements to reflect variations identified in census and travel survey data.
Residential density	Number of residents or housing units per acre/hectare.	Reduce requirements 1% for each resident per acre. Reduce requirements 15% where there are 15 residents per acre, and 30% if there are 30 residents per acre.
Employment density	Number of employees per acre.	Reduce requirements 10–15% in areas with 50 or more employees per gross acre.
Land-use mix	Range of land uses located within convenient walking distance.	Reduce requirements 5–10% in mixed-use developments. Additional reductions with shared parking.
Transit accessibility	Nearby transit service frequency and quality.	Reduce requirements 10% for housing and employment within 1/4 mile of frequent bus service, and 20% for housing and employment within 1/4 mile of a rail transit station.
Carsharing	Whether a carsharing service is located nearby.	Reduce residential requirements 5–10% if a carsharing service is located nearby, or reduce 4–8 parking spaces for each carshare vehicle in a residential building.
Walkability	Walking environment quality.	Reduce requirements 5–15% in walkable communities, and more if walkability allow more shared and off-site parking.
Demographics	Age and physical ability of residents or commuters.	Reduce requirements 20–40% for housing for young (under 30) elderly (over 65) or disabled people.
Income	Average income of residents or commuters.	Reduce requirements 10–20% for the 20% lowest income households, and 20–30% for the lowest 10%.
Housing tenure	Whether housing units are owned or rented.	Reduce requirements 20–40% for rental versus owner occupied housing.
Pricing	Parking that is priced, unbundled, or cashed out.	Reduce requirements 10–30% for cost-recovery pricing (i.e., parking priced to pay the full cost of parking facilities).
Unbundling parking	Parking sold or rented separately from building space.	Unbundling parking typically reduces vehicle ownership and parking demand 10–20%.
Parking & mobility management	Parking and mobility management programs are implemented at a site.	Reduce requirements 10–40% at worksites with effective parking and mobility management programs.
Design hour	Number of allowable annual hours a parking facility may fill.	Reduce requirements 10–20% if a 10th annual design hour is replaced by a 30th annual peak hour. Requires overflow plan.
Contingency-based planning	Use lower-bound requirements, and implement additional strategies if needed.	Reduce requirements 10–30%, and more if a comprehensive parking management program is implemented.

Source: Litman, 2013b, Reproduced with permission of Todd Litman.

Table 11-10 shows the types of actions that can be taken as part of a parking management program, the likely reduction in parking spaces associated with each action, and the likelihood that a notable traffic reduction will occur.

A more specific example comes from the city of Pasadena, which adopted a traffic reductions strategy aimed at reducing the amount of traffic in the city. [City of Pasadena, 2006] The strategy consisted of the following actions:

- *Charge the right price for curb parking*—Charge the lowest price that will leave one or two vacant spaces on each block—that is, performance-based pricing. This will eliminate the traffic congestion caused by drivers cruising for parking.
- *Return the meter revenue to the neighborhoods that generate it*—Revenue return will make performance-based prices for curb parking politically popular. Revenue will support, (a) additional commercial parking benefit districts, and (b) establish residential parking benefit districts.

Table 11-10. Potential Impacts of Parking Management Actions			
Action	**Description**	**Parking Space Reduction**	**Significant Traffic Impact**
Shared parking	Parking spaces serve multiple users and destinations.	10–30%	
Parking regulation	Regulations favor higher-value uses such as service vehicles, deliveries, customers, quick errands, and people with special needs.	10–30%	
More accurate and flexible standards	Adjust parking standards to more accurately reflect demand in a particular situation.	10–30%	
Parking maximums	Establish maximum parking standards.	10–30%	
Remote parking	Provide off-site or urban fringe parking facilities.	10–30%	
Smart growth	Encourage more compact, mixed-modal development to allow more parking sharing and use of alternative modes.	10–30%	√
Walking and cycling improvements	Improve walking and cycling conditions to expand the range of destinations served by a parking facility.	5–15%	√
Increase capacity of existing facilities	Increase parking supply by using otherwise wasted space, smaller stalls, car stackers, and valet parking.	5–15%	
Mobility management	Encourage more efficient travel patterns, including changes in mode, timing, destination, and vehicle trip frequency.	10-30%	√
Parking pricing	Charge motorists directly and efficiently for using parking facilities.	10–30%	√
Improve pricing methods	Use better charging techniques to make pricing more convenient and cost-effective.	Varies	√
Financial incentives	Provide financial incentives to shift mode such as parking cash-out.	10–30%	√
Unbundle parking	Rent or sell parking facilities separately from building space.	10–30%	√
Parking tax reform	Change tax policies to support parking management objectives.	5–15%	√
Bicycle facilities	Provide bicycle storage and changing facilities.	5–15%	√
Improve information and marketing	Provide convenient and accurate information on parking availability and price, using maps, signs, brochures, and the Internet.	5–15%	√
Improve enforcement	Ensure that regulation enforcement is efficient, considerate, and fair.	Varies	
Transportation management associations	Establish member-controlled organizations that provide transport and parking management services in a particular area.	Varies	√
Overflow parking plans	Establish plans to manage occasional peak parking demands.	Varies	
Address spillover problem	Use management, enforcement, and pricing to address spillover problems.	Varies	
Parking facility design and operation	Improve parking facility design and operations to help solve problems and support parking management.	Varies	

Source: Litman, 2013b, Reproduced with permission of Todd Litman.

- Invest in a portion of parking revenues in transportation demand management programs.
- Provide Universal Transit Passes.
- Require the unbundling of parking costs. Unbundle from housing costs, commercial leases, and from the costs of other goods and services.
- Require parking cash-out.
- Strengthen transportation demand management requirements.
- Improve transit.

- Improve bicycle and pedestrian facilities and programs.
- Remove minimum parking requirements for off-street parking.
- Set maximum parking requirements.
- Establish congestion pricing.

Given the importance of parking, it is not surprising that the Pasadena trip-reduction strategy targeted parking in 7 of its 12 actions.

Table 11-11 shows the expected impacts of the parking component of the trip-reduction strategy aimed at reducing trips by 10 percent. This presentation is very typical of most studies in that the impact of the primary measures as stand-alone actions are estimated along with the supporting measures that would be necessary for the full impact to occur.

The study also looked at the measures needed for a 25 percent reduction in trips. A $10.00 per workday parking cash-out program will reduce employee commute trips by approximately 40 percent; a $200 per month per parking space charge would result in a 20 to 40 percent reduction in household vehicle ownership and trips at the affected multifamily residences, and a charge of $6.00 per entry or exit will result in at least a 30 percent drop in peak hour entries and exits at Pasadena's borders.

In the United States, community- or area-wide parking management strategies are often part of transportation demand management (TDM) plans, which focus on reducing the use of the single occupant vehicle (SOV). Where the use of TDM strategies is contemplated, parking pricing is often critical to achieve program goals. Studies of TDM programs have consistently shown that free parking is the single largest deterrent to success. The following parking pricing options could be considered as part of TDM plans:

- *Fees for Parking*. A fairly high increase in cost is required to achieve a significant reduction in SOV commuting. Demand elasticity for parking appears to be situation dependent, reflecting the cost of alternative modes, commuting distances, and market pricing at competitive facilities.

Table 11-11. Sample Strategies for a 10 Percent Reduction in Traffic, Pasadena, California

Primary Measures	
Require parking cash-out, with a $5.00 per workday payment to non-drivers, for all employees at all worksites, both new and existing	Typical effect observed: a $5.00 per workday parking cash-out program will reduce employee commute trips by approximately 20 percent. Some additional reduction in non-work trips (e.g., shopping trips on the way home from work) would be expected as a result.
Require unbundling of parking costs from housing costs at all multi-family developments both new and existing, with a minimum price per parking space of $100 per month.	Typical effect observed: a $100 per month per parking space charge (offset by an equal reduction in rents) will result in a 15 to 30 percent reduction in household vehicle ownership and trips at the affected multi-family residences.
Institute congestion pricing at Pasadena's borders, with a minimum charge of $3.00 per entry or exit during peak hours.	Typical effect observed: a charge of $3.00 per entry or exit will result in at least a 20 percent drop in peak hour entries and exits at Pasadena's borders.
Supporting Measures	
Charge the right price for curb parking Return meter revenue to the neighborhoods that generate it Invest parking revenues in TDM programs Provide Universal Transit Passes Strengthen TDM requirements Improve bicycle/pedestrian facilities and programs Remove minimum parking requirements Set maximum parking requirements	

Source: City of Pasadena, 2006

- *Discounts for Ridesharing*. Discounts, if not elimination of parking charges, should be considered for carpools and vanpools. This strategy is most effective when combined with other non-pricing strategies, such as preferential locations and aggressive rideshare matching programs. The planner must also be concerned with the cost-effectiveness of such programs and their impacts on transit ridership. When the California Department of Transportation added a discount and preferential parking program for carpool parking, 90 percent of the spaces were used by existing pools, and two-thirds of the new pool participants switched from transit. Trips to the site actually increased and transit use declined by more than 200 persons per day. This finding suggests that it may be more beneficial to encourage transit use and park-and-ride than ridesharing, especially given reported decreases in ridesharing during the past few decades.
- *Transit Subsidies*. In addition to raising the cost of parking, lowering the cost of transit by either subsidizing or paying the full cost of transit can be a key component to a successful TDM plan. Again, the first in line for such subsidies will generally be those who already use transit, and it will be critical to combine this tactic with increasing the cost of SOV parking to achieve any real benefit.
- *Transportation Allowances*. Rather than target a single mode of transportation, a transportation allowance provides a cash payment to each employee to pay for the commute, whether by driving (and thus parking) or transit, or to be pocketed by walking or bicycling.
- *Cash-Out Programs*. Similar to the transportation allowance, the cash-out program provides a monthly payment equal to the monetary value of a previously free parking space. Employees can then spend it on parking at that rate, use it for other modes of transportation, or simply pocket it.
- *Parking Taxes or Surcharges*. In a community where commercial parking exists but fees are still not adequate to encourage alternative modes, parking taxes or surcharges can be used to force the market rates to a more acceptable level. However, it must be applied to a broad area. When Madison, Wisconsin, applied a peak period surcharge to four of its municipal garages, some commuters did switch to transit, but many more simply switched parking location. [VTPI, 2015]

Chapter 14 on transportation demand management provides more discussion on the use of parking strategies as part of a TDM program.

VII. COMMON LAND USES

Table 11-12 illustrates the types of data that is found in ITE's *Parking Generation* following the ITE land-use coding system. [ITE, 2010] In this case, codes 000 through the 500 series generally encompass transportation ports and terminals, industrial, residential, recreational, and lodging. The table also compares the ITE data with the recommended ratios in *Shared Parking* and *Recommended Zoning Ordinance Provisions*.

Parking Generation data represent the average peak of the observed accumulation and not necessarily *demand* or *required spaces* for zoning purposes. The information in the *Parking Generation* tables is only provided for the 73 land uses (out of 91) where ITE had enough data to present them graphically. Only about half of the graphical presentations have fitted curves where the regression analysis found a consistent relationship between the quantity of land use and parking generation. The tables include two of the statistical indices that assist in understanding the statistical reliability of the sample. The first is the coefficient of variation, which measures the reliability of the average ratio (the lower the percentage of variation the better); the other is the coefficient of determination (R^2) that measures the reliability of the regression equation (the higher the factor the better.)

Fitted curves are provided only where there were at least four study sites and R^2 exceeded 0.6. Generally, the coefficients of variation for those data sets were 50 percent or less (exceptions where the coefficients of variation were much higher were the relationship between parking spaces and employees for banks, ratios for airports on Saturdays, and ratios for warehouses on a GFA basis [see chapter 2 for a discussion of coefficient of variation]).

In some cases, the lack of a fitted curve, which is identifiable in Table 11-7 where no R^2 is listed, was simply because there were not enough study sites or enough variation in the size of the study sites for the regression analysis to determine a fitted curve. In other uses, such as restaurants, there is significant variation in parking generation, which

Table 11-12. Parking Generation and Recommended Parking Ratios for ITE Codes 021 through 495

ITE Code	Use		Period	# Studies	Coefficient of Variation	R^2	33rd Percentile		Average		85th Percentile		Unit	PCC *Recommended Zoning Ordinance Provisions* (2006)*
		ITE *Parking Generation* (Fourth Edition, 2010)					Parking Gen Rate in Peak Hour of Observations							
021	Commercial Airport	Daily	Weekday	16	45%	0.99	0.26		0.40		0.61		Enplanements	
		Daily	Saturday	9	71%	0.61	0.51		0.84		1.48		Enplanements	
		Daily	Sunday	7	54%		0.37		0.57		0.92		Enplanements	
093	Light Rail Transit with Parking	Suburban	Weekday	30	86%		0.07		0.14		0.21		Daily Boardings	
		Urban	Weekday	10	53%	0.64	0.04		0.06		0.09		Daily Boardings	
110	General Light Industrial		Weekday	7	44%	0.81	0.53	(0.49)	0.81	(0.75)	1.22	(1.13)	100 sq. m (ksf GFA)	1.99 /100 sq. m (1.85/ksf) GFA
			Weekday	5	32%	0.99	0.53		0.64		0.81		Employees	
130	Industrial Park		Weekday	11	49%		0.97	(0.90)	1.37	(1.27)	1.99	(1.85)	100 sq. m (ksf GFA)	
			Weekday	8	27%	0.66	0.83		0.89		0.98		Employees	
140	Manufacturing		Weekday	3	23%		0.99	(0.92)	1.10	(1.02)	1.27	(1.18)	100 sq. m (ksf GFA)	
			Weekday	3	24%		0.88		0.97		1.14		Employees	
150	Warehousing		Weekday	14	96%	0.87	0.31	(0.29)	0.55	(0.51)	0.87	(0.81)	100 sq. m (ksf GFA)	0.72/100 sq. m (0.67/ksf) GFA
			Weekday	13	33%	0.86	0.81		0.78		1.01		Employees	
151	Mini-Warehouse		Weekday	7	44%	0.86	0.12	(0.11)	0.15	(0.14)	0.18	(0.17)	100 sq. m (ksf GFA)	1.75/100 Units
			Weekday	6	25%	0.91	1.17		1.35		1.66		100 Storage Units	
210	Single-Family Detached Housing		Weekday	6	18%	0.69	1.67		1.83		2.14		Dwelling Units	2/dwelling unit
221	Low/Mid-Rise Apartment	Suburban	Weekday	21	21%	0.93	.68		1.23		1.94		Dwelling Units	*1.65/dwelling unit rental; 1.85/dwelling unit owned
		Urban	Weekday	40	35%	0.96	0.93		1.20		1.61		Dwelling Units	
		Urban	Saturday	8	19%	.99	0.93		1.03		1.14		Dwelling Units	
222	High-Rise Apartment	Cent City No	Weekday	7	11%	0.85	1.38		1.37		1.52		Dwelling Units	

(*continued*)

Table 11-12. (*Continued*)

			ITE *Parking Generation* (Fourth Edition, 2010)								
							Parking Gen Rate in Peak Hour of Observations				
ITE Code	Use		Period	# Studies	Coefficient of Variation	R^2	33rd Percentile	Average	85th Percentile	Unit	PCC *Recommended Zoning Ordinance Provisions* (2006)*
224	Rental Townhouse		Weekday	4	14%		1.67	1.62	1.76	Dwelling Units	
230	Condominium/ Townhouse	Suburban	Weekday	12	17%	0.95	1.28	1.38	1.52	Dwelling Units	
254	Assisted Living		Weekday	33	29%		0.34	0.41	0.54	Dwelling Units	0.35/dwelling unit
			Saturday	11	36%		0.23	0.24	0.30	Dwelling Units	
			Sunday	13	34%		0.27	0.34	0.47	Dwelling Units	
310	Hotel		Weekday	20	35%	0.74	0.72	0.89	1.08	Occupied Rooms	*1.25/room plus 10.8/100 sq. m (10/ksf) GFA for restaurant plus 32.3/100 sq. m (30/ksf) GFA for conf/ banquet if 215-540 sq. m (20-50 q ft) /room or 21.5/100 sq. m (20/ksf) GFA if >540 sq. m (50 ksf) /room
312	Business Hotel		Weekday	7	35%		0.56	0.60	0.75	Occupied Rooms	
			Saturday	3	13%		0.62	0.66	0.72	Occupied Rooms	
320	Motel		Weekday	7	26%	0.87	0.66	0.71	.85	Occupied Rooms	
330	Resort Hotel		Weekday	5	38%		1.05	1.29	1.59	Occupied Rooms	
430	Golf Course		Saturday	7	17%	0.90	8.38	8.68	9.83	Holes	9.8/hole
437	Bowling Alley	Suburban	Friday	4	14%	0.97	4.58	5.02	5.58	Lanes	5.5/lane
		Suburban	Mon-Thurs	4	20%	0.92	3.88	4.00	4.62	Lanes	
		Urban	Mon-Thurs	3	30%		2.79	3.13	3.78	Lanes	
441	Live Theater	Rural	Weekday	4	3%	0.99	0.38	0.38	0.39	Attendees	*0.4/seat
		Rural	Weekday	4	46%		0.19	0.25	0.32	Seats	

444	Movie Theater with Matinee		Friday	6	49%	0.65	0.21		0.26		0.36		Seats	1 screen: 0.5/seat; 2 to 5 screens: 0.33/seat; 5 to 10 screens: 0.3/seat; over 10 screens*: 0.27/seat
			Saturday	7	25%	0.72	0.20		0.19		0.23		Seats	
			Sunday	4	45%		0.10		0.11		0.15		Seats	
466	Snow Ski Area	Rural	Saturday	4	27%	0.86	1.02		1.31		1.62		Acres	
		Rural	Saturday	4	30%	0.91	0.20		0.25		0.31		Daily Lift Ticket	
491	Racquet/Tennis Club		Weekday	3	25%		3.05		3.56		4.13		Courts	4/court
492	Health/Fitness Club		Weekday	25	46%	0.60	4.23	(3.93)	5.67	(5.27)	9.10	(8.46)	100 sq. m (ksf GFA)	*7.5/100 sq. m (7/ksf) GFA
			Weekday	5	44%	0.97	0.10		0.13		0.16		Members	
493	Athletic Club		Weekday	11	41%		2.60	(2.42)	3.82	(3.55)	5.32	(4.94)	100 sq. m (ksf GFA)	
			Weekday	7	51%		0.05		0.07		0.12		Members	
495	Recreational Community Center	Suburban	Weekday	7	69%		1.96	(1.82)	3.44	(3.20)	5.41	(5.03)	100 sq. m (ksf GFA)	

*The same ratio is recommended in *Shared Parking*, Second Edition likely reflects the level of patronage of the restaurant. Even where there is a linear relationship, the sample may not be reliable. In many cases, the fitted curve is significantly different from the average ratio. Where the slope of the fitted curve is greater than the average ratio, parking generation ratios increase as the land use size increases; where it is less than the average ratio, generation rates decrease as land use size increases.

The following sections discuss special considerations for determining parking demand at some common land uses (note that not all uses are discussed).

A. Airports

ITE states its airport parking ratios in terms of parking spaces per daily enplanements (total number of passengers using a terminal), which is presumed to be average daily enplanements, not enplanements on the date studied. Many parking planners use originating enplanements (OE) instead of total enplanements, because this factors out transfer passengers, who do not generate public parking demand. Further, it is more common to use a ratio of parking spaces per 1,000 annual OE because most airports use annual enplanements in planning forecasts.

In a survey of parking supply at U.S. airports, Donoghue [1997] found a relationship between the size of the airport in terms of OE and parking supply, with generally lower ratios for larger airports. However, the range in spaces per 1,000 OE was very large. For example, the midsized airports with 900,000 to 3.5 million OE exhibited ratios ranging from 0.14 spaces/1,000 OE to 1.18 spaces/1,000 OE—nearly a factor of 10 between lowest and highest value. These are supply ratios, not demand ratios; many airports build parking for a planning horizon of 10 years or more (to avoid more frequent disruption of the airport parking system as enplanements grow) and may or may not have excess spaces at the time of study. Also, off-airport parking supplies at many airports accommodate some portion of the demand. Therefore, care should be taken in using published data on airport parking supply (for example, *Parking Generation* has 20 data points for airports, of which 15 are from Canadian airports in small markets).

Landrum & Brown et al. [2010] concluded that although there is a great deal of variation in parking demand for airports, a general rule of thumb is that parking supply should range from 900 to 1,400 spaces per million enplaned passengers, with 25 to 30 percent of the spaces designated for short-term parking.

Generally, airport parking is not controlled by local zoning and detailed parking studies are needed to project future parking needs. Airport parking demand is highly complex, being both a captive market and a lucrative one that has attracted competition from off-airport commercial providers. Because the revenue stream from parking is usually the second or third highest source of net revenue to the airport and because airport activities tend to increase over time, airport managers usually want to know in some detail what parking demand is likely to be. In addition, considerable data for parking projections are available from the revenue control systems used at airports. Therefore, while the following analysis of airport parking demand is not going to support an industry standard ratio of parking spaces/OE, it is generally beneficial for understanding the complexity of parking demand, design days, and effective supply considerations.

Airport parking demand is typically evaluated in four areas:

Hourly or short-term parking serves kiss-and-fly as well as "meeters and greeters" who stay 3 hours or less. The term *hourly* is preferred by many in the industry because the term *short term* is less understood by various parties, including the traveling public. Since the terrorist attacks of September 11, 2001, hourly parking, both in terms of annual parkers and spaces required, has decreased significantly. Security at airports has considerably increased, and nontravelers are no longer allowed to wait at gates. Therefore, the length of stay for hourly parking has significantly declined, increasing turnover factors. Cell phone lots where drivers who otherwise would have circled terminal roadways, waited at the terminal curb, or parked at the terminal parking facility to wait for arriving passengers, now allow meeters and greeters to wait in their vehicle at a more distant location and come to the terminal only when the passengers are ready to be picked up.

Daily parkers are typically willing to pay a relatively high daily rate for convenient terminal parking. The demand by this group is price sensitive, and differential pricing of economy lots and daily offerings can significantly affect demand for terminal parking.

Economy parking is generally provided for multi-day stays. Although those choosing economy parking may comprise only 10 to 20 percent of parkers, it may require 50 to 70 percent of the total parking supply—the reverse side of the 80/20 rule. The quantity of remote parking required at an airport can be greatly affected by commercial off-airport parking.

Employee parking is generally provided off-site with shuttle service. It is often difficult to keep employees out of terminal parking without relatively high daily parking rates and very tight revenue controls.

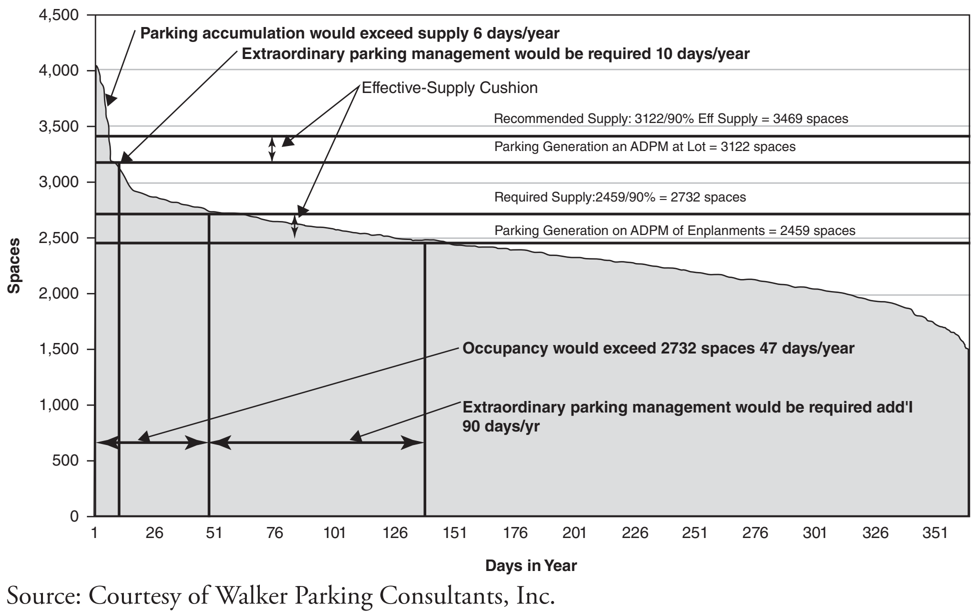
Once a pricing structure is in place, it is difficult to use spaces allocated for one group for another group, and because rates are often set by political bodies, it is difficult to change rates to accommodate the seasonal differences in travel that affect parking demand at different facilities. Therefore, it is important to look at the demand for parking at each parking service, rather than the overall number of spaces occupied on a design day. Also, because economy parking facilities peak at different times of the year than terminal parking, this further complicates issues relating to design day and effective-supply cushions. Figure 11-6 shows the peak hour of accumulation of parked vehicles at one airport's economy parking facility on each day in one year, in descending order.

Traditionally, the design day for airport terminal facilities is the *average day peak month* (ADPM) for enplanements. Often, this month may be in summer when business travel is at typical levels, but there is also a high level of leisure travel as opposed to the peak leisure travel period of Thanksgiving in an otherwise average month. A common standard for effective supply factors at airports is 85 percent for terminal parking and 90 percent for economy parking.

As an example, if the design day for an economy lot were to be the ADPM for enplanements (the design day for terminal design), and no effective-supply adjustment were provided, the parking generated at this lot would exceed the supply 47 days per year, and it would be so difficult to find spaces that extraordinary parking management strategies would be required on an additional 90 days per year (see Figure 11-6). Based on the airport's past practices, some cars would be allowed in and directed to available spaces, while other patrons would be directed to off-airport parking. If off-airport parking is reported to be full, patrons would be given coupons to park in terminal parking at economy rates. Because economy parking demand does not vary significantly from hour to hour throughout the course of the day, these strategies would be required in most hours of the $47 + 90 = 137$ days in a year. The delay in finding a space would be significant on more than one-third of the days, causing a perception of parking shortages at the airport. This in turn could result in local political pressure to "fix the parking problem."

If instead the occupancy on the ADPM for the lot is used and the lot is assumed to have a 90 percent effective supply factor, the number of hours or days when extraordinary parking management is required is significantly reduced. If the average peak-hour parking occupancy in the busiest month at this lot was 3,122 parking spaces, a lot with

Figure 11-6. Design Day and Effective-Supply Considerations at an Airport Economy Parking Lot



Source: Courtesy of Walker Parking Consultants, Inc.

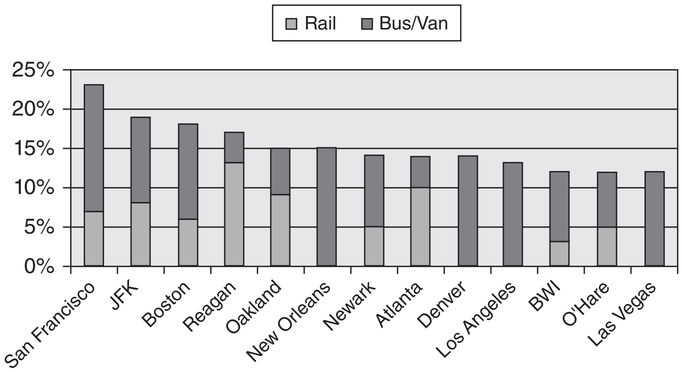
3,122/0.9 = 3,469 spaces would be required to accommodate the design day demand. With this design day, parking generation would exceed the capacity on only six days (all in either the peak Thanksgiving or Christmas travel periods when parking shortages are expected by the traveling public).

Special parking management strategies would be required on an additional four days per year. For this particular airport, using the ADPM for the economy parking with an effective supply factor of 90 percent was considered a far more acceptable design approach than using just the ADPM for enplanements overall. For terminal parking, the ADPM for the combination of daily and hourly parking, which occurred in a different month, was similarly employed with an 85-percent effective supply factor.

Another factor in estimating parking demand, especially at large airports, is the number of passengers and employees who will use transit to access the airport. Figure 11-7 shows the percentage or market share of those going to the airport in the 13 largest transit-oriented cities in the United States. As shown, when you have almost 24 percent of the trips into your airport coming via rail or bus/van (as in San Francisco), one must be very careful at estimating a parking demand simply using OEs as was described earlier.

In sum, the selection of design days and effective-supply factors is based primarily on professional judgment, which recognizes an owner's acceptance of extraordinary parking management actions that might be required. At airports, the specific combination of pricing, differing parking products, and off-airport availability further complicates parking planning.

Figure 11-7. Market Shares to Rail and Bus/Van in the 13 Most Transit-oriented U.S. Airports



Source: Coogan et al., 2008, Reproduced with permission of the Transportation Research Board.

B. Intermodal Parking

Intermodal parking lots and garages facilitate the transfer of users from one passenger vehicle to other modes of travel; park-and-ride facilities are the primary form of such terminals. Many rapid transit and commuter rail operators have developed parking facilities at stations to increase the convenience, attractiveness, and coverage of the service (the key constraint to expanding service is often the limited amount of parking at stations, rather than constraints related to the train service).

There are three basic types of park-and-ride facilities (adapted from the Technical Committee on Transport [2005]):

- *Local* park and ride lots that serve as collectors, such as parking facilities at express transit facilities, central bus terminals, and at stops along existing regional bus routes.
- *Remote* park-and-ride lots, intercepting automobile trips near their origin, generally along regional transportation corridors, with express bus or rail service to the CBD or activity center.
- *Peripheral* park-and-ride lots on the edge of activity centers, usually within 1.5 miles of the destination.

Park-and-ride lots are an important component of a region's transit strategy in that they provide a means of transferring from another mode to transit. Valley Metro, the transit agency for the Phoenix metropolitan area, conducted a study in 2013 of the utilization of its park-and-ride lots. [Valley Metro, 2013] The study concluded:

- Park-and-ride lots with express or rapid bus service served different travel markets than light rail park-and-ride lots.
    - Bus lots primarily served work trips (98 percent of total trips), while light rail lots tend to serve fewer work trips (53 percent) and more college or university trips (39 percent).
    - Light rail lots experienced higher parking utilization rates than bus lots.

    - Light rail lots had a 56 percent parking utilization rate compared to bus lots with a 46 percent utilization rate.
- Bus, light rail, and vanpool park-and-ride lot users predominantly accessed their lots by driving alone. However, light rail and vanpool lot users drove alone at a higher rate.
    - The survey found that 89 percent of vanpool lot users and 87 percent of light rail lot users drove alone, while 76 percent of bus lot users drove alone.
- A correlation between the number of cars parked at a light rail lot and the distance to downtown Phoenix was demonstrated by the survey data.
    - Analysis showed an almost direct 1:1 relationship between numbers of vehicles parked in light rail lot facilities and light rail lot distance to downtown Phoenix.
- On average, light rail park-and-ride lot users traveled farther to the lot than express and rapid bus lot users and vanpool users.
    - For light rail lot users, the average distance between their trip origin and lot is 5.1 miles while that distance was only 4.2 miles for vanpool lot users and 3.9 miles for bus lot users.
    - Lot facilities within 1.5 miles of a freeway were more utilized than those farther away. This typically resulted in the travel market sheds for lots near freeways to be larger.
    - Lots within 1.5 miles of a freeway averaged a 53 percent utilization rate while those at further distances averaged only a 28 percent utilization rate.
    - Lot users drove longer distances (4.3 miles) to lots within 1.5 miles of a freeway than to lots further from freeways (3.1 miles).
- Proximity to users' homes was the primary reason stated for choosing a park-and-ride lot, while the transit route that serves the lot facility was the second most common reason. (Survey respondents could select as many reasons for using their lot as applied.)
    - 75 percent of responses for users of all lots indicated that being close to home was a major reason. Bus lot users were more likely to list this as a reason (81 percent of responses) than light rail lot users (59 percent of responses).
    - 43 percent of responses for users of all lots indicated that a major reason was because their transit route serves it.
- The most-requested park-and-ride lot improvement was for covered parking, followed by real-time transit information.
    - Survey respondents could select up to two improvements they would most like to see. Approximately 25 percent of respondents requested covered parking, while just over 21 percent requested real-time transit information.
- A higher level of rapid bus service correlated with a higher number of cars parked in a lot.
    - An almost direct 1:1 relationship existed between the number of daily inbound rapid bus trips (HOV-based rapid service only) to the number of cars parked at a bus park-and-ride lot.
- Light rail park-and-ride lot users were 20 times more likely to be going to a university/college than bus lot users.
    - College/university trips comprised an average 39 percent of all trips for light rail park-and-ride users. For the four light rail lots closest to Arizona State University (ASU) and GateWay Community College, this trip purpose was much higher ranging between 43 percent and 65 percent of all trips. In contrast, college/university trips comprised less than 2 percent of all trips for bus lot users. An explanation of these results may be the expense of parking on the Arizona State University (ASU) campus. The two lots closest to ASU have 69 percent and 92 percent utilization ranking them the two most highly utilized of the light rail lots.
- Vanpool use at park-and-ride lots was greatest at highly visible lots adjacent to freeways.

- Five park-and-ride lots adjacent to the freeway had the highest vanpool utilization with five to eight vanpools (out of 45 vanpools responding to the survey) regularly using each.
- Vanpools used only 16 of the 29 lots surveyed. Limited utilization by vanpool commuters could be a result of lot geographic locations being inconsistent with trip origins, knowledge of lot facility locations, low visibility of lot facilities, and knowledge of authorization to use the lot facilities.

- The reason vanpool commuters most often chose their lot was because it is close to home. Other top reasons included availability of covered parking and being close to a freeway. The results indicate that convenience was a high priority for them.

Parking demand is generally stated as a ratio of spaces per boarding passenger on the average day of the peak month of ridership. The number of spaces per passenger at rapid transit stations varies substantially, depending on where the station is located. Characteristics for park-and-ride lots that may serve either rail or bus services are shown in Table 11-13. Table 11-14 shows characteristics of those who use park-and-ride lots, as seen in recent surveys of park-and-ride lot users representing a range of travel markets.

Ridership demand can be dramatically different at two successive stops on the same transit line because of the nature of the communities and market areas each station serves, as well as parking availability and the policies in place. One city may provide parking at a station for residents only; another station might allow parking for all users. Still others may have no parking at all. Railroad stations that serve long-distance routes have somewhat different parking demands than commuter rail stations given the differences in length of stay and in pick-up and drop-off characteristics. Many stations serve both on-site and kiss-and-ride demands; a parking study should consider both in the analysis. See [Turnbull et al., 2004] for a review of the impact on parking demand with changes in parking lot capacity.

A study that compares the competitive position of the target station with other stations is often necessary to estimate parking demand. In a metropolitan area, this is sometimes done through a regional travel demand model in which the availability and cost of parking and the characteristics of the transit operations serving the station help define the transportation network.

C. Residential Uses

Residential parking demand is influenced by neighborhood socioeconomic characteristics, development density, and the availability of public transit and pedestrian access. Each can influence household auto ownership levels. Therefore, unit residential parking demands are greatest in low-density, affluent suburban and exurban areas. Unbundling parking fees from rental/purchase of units also affects parking requirements and might be mandated in communities or districts where alternative transportation modes are encouraged.

Residential parking needs have increased during the past 50 years. In 1960, 21 percent of households in the United States had no vehicle, whereas the 2009 National Household Travel Survey found only 8.6 percent of households without vehicles. [FHWA, 2013] Moreover, a large share of households without vehicles is comprised of elderly women living alone, minority households, higher density neighborhoods, and low income households. Recent immigrants are also less likely to have vehicles available. Geographically, most households (59 percent) without vehicles are renters in central cities; the New York metropolitan area accounts for 20 percent of all zero-vehicle households.

The required number of parking spaces for owned units (single-family homes and condos) is usually higher than that for rental units. In the 2001 National Personal Transportation Survey, only 3 percent of owner households did not own vehicles as compared to 17.6 percent of rental households.

Many professionals believe that recommended parking demand ratios for multifamily housing units should be based on the number of bedrooms in the unit; however, there are few data in the literature to develop recommended ratios. Therefore, while [Smith, 2005] provides ratios solely based on number of dwelling units, Parking Consultants Council [2007] provides recommendations based on number of bedrooms in apartments and condos, and square feet of single-family dwellings. Adjustments should be made based on the socioeconomic characteristics of the tenants and on the availability of transit in the vicinity. Given the availability of data on vehicle ownership per household by census tracks in cities, ratios for local zoning ordinances generally should be based on local characteristics of home ownership.

Table 11-13. Parking Characteristics at Selected Rail Transit Stations				
Region	**Location**	**Boarding Passengers per Weekday**	**Off-Street Parking Spaces**	**Parking Spaces Available/Passenger Boarding**
Atlanta, GA	Avondale	9,700	1,180	0.12
	Eastlake	2,800	610	0.22
	Hightower	10,300	1,400	0.14
	Chamblee	8,000	1,520	0.19
	Brookhaven	4,200	1,700	0.40
	Lenox	10,900	800	0.07
	Lindbergh	11,100	1,470	0.13
	Lakewood	4,300	1,900	0.44
	College Park	7,700	2,120	0.28
Boston, MA	Wollaston	2,700	500	0.19
	North Quincy	2,400	800	0.33
	Quincy Center	7,500	930	0.12
	Commuter Rail—North (a)	11,000	3,360	0.31
	Commuter Rail—South (a)	3,800	2,640	0.69
Chicago, IL	Ashland	4,750	264	0.06
	Cicero-Berwyn	2,700	360	0.13
	Cumberland	5,500	828	0.15
	Dempster	3,200	594	0.19
	Des Plaines	4,750	596	0.13
	Howard	9,600	300	0.03
	Kimball	4,100	180	0.04
	Linden	3,500	456	0.13
	River Road	3,900	747	0.19
Cleveland, OH	West Side (5 stations)	20,000	6,400	0.32
	East Side (3 stations)	10,000	900	0.09
Philadelphia, PA	Bucks County (a)	4,000	1,800	0.45
	Chester County (a)	3,900	1,100	0.28
	Delaware County (a)	15,500	2,200	0.14
	Montgomery County (a)	19,500	4,300	0.22
	Lindenwold (New Jersey)	20,000	9,000	0.45
San Francisco, CA	Concord line (6 stations)	20,360	6,555	0.32
	Richmond line (5 stations)	9,130	3,381	0.37
	Alameda line (8 stations)	27,100	7,562	0.28
	Oakland line (3 stations)	7,300	1,087	0.15
	Daly City	8,860	1,877	0.21
Toronto, Ontario	Islington	23,500	1,300	0.06
	Warden	24,600	1,500	0.06

Source: *Transportation Planning Handbook*, *2nd Edition*. Edwards, J. (ed.). Washington, DC, USA: Institute of Transportation Engineers, 1999.

There are a number of various residential source data in ITE's *Parking Generation* for accessory units, a residential design that is increasingly popular in new urbanist developments. Recommendations are also made for sleeping rooms, which range from bed and breakfast and boarding house operations to convents and other group living arrangements in homes.

Assisted living or congregate care facilities include multi- or single-family dwelling units with centralized amenities such as dining, housekeeping, and transportation. Residents live relatively independently without constant supervision

Table 11-14. Travel Characteristics of Park and Ride Users

	Gainesville, GA	Hampton Roads, VA	Maine	Phoenix, Valley Metro	San Louis Obispo, CA
Year	2012	2014	2014	2013	2013
Character	Rural, Exurban, Highway	Urban, Transit	Rural, Turnpike-oriented	Urban, Transit	Small urban, Highway
Total spaces	-	2,162	2,303	28,860	518
% traveling > 4 miles	-	66%	100%	35%	39%
% using lots 5 days/week	53%	64%	68%	67%	55%
Access mode:					
—auto	100%	-	100%	79%	85%
—auto (drop-off)	-	-	-	11%	10%
—car/vanpool	-	-	-	5%	-
—transit	-	-	-	2%	-
—bike	-	-	-	2%	-
—ped	-	-	-	1%	5%
Purpose of trip					
—work/business	100%	99%	93%	87%	100%
—college	-	-	-	11%	-
—high/middle school	-	-	-	1%	-
—shop	-	-	6%	-	-
—leisure/recreation	-	-	2%	-	-
—medical	-	-	-	-	-
—other	-	1%	2%	2%	-

Source: Gainesville-Hall MPO. 2012; Jackson, C. 2014; Maine Department of Transportation. 2014; San Luis Obispo Council of Governments, 2013; Valley Metro, 2013

and care. These facilities bridge the gap between independent living and nursing home care and are defined by ITE in the 200 series of land-use codes with residential uses, rather than with nursing homes and other institutional care facilities in the 600 series. Although there are only 33 studies in ITE's *Parking Generation* database, the observed parking ratios were found to be statistically reliable. A minimum ratio of 0.34 spaces per dwelling unit is recommended.

D. Hotels

Determining parking demand for hotels is complicated by the variety of hotels in the marketplace, from low budget, no frills motels to the largest convention hotels. However, the demand for hotel parking can be shown to be directly related to the demand of the component uses of the particular hotel. Thus, parking demand can be determined through a shared parking analysis of the hotel and its particular components. The separation of hotels into multiple categories (hotels, business hotels, resort hotels, and motels) in ITE's *Parking Generation* suggests that there are sufficient data to estimate reliable parking ratios based on beds for business hotels and motels, both of which have only limited meeting and banquet facilities and may not have restaurants. There is more variation in the parking generation rates observed for full-service hotels. Resort hotels have significantly higher parking generation rates; in fact, the average ratio has been shown to be 1.3 spaces per room, with peak demand occurring between the hours of 2 and 3 p.m. due to check-in/check-out times. This is much higher daytime demand than other hotel types. This is likely true for a number of reasons, not the least of which is that resort visitors are more likely to stay many days and not check out in the early morning. Guests at resort hotels frequently store luggage after checkout time and continue to enjoy the resort, while others may arrive before check-in and also store luggage.

Parking generation at full-service hotels is also consistently higher than at business hotels (without restaurant and meeting/banquet space). Therefore, a shared parking analysis using separate ratios for the number of guestrooms, restaurant(s) and/or lounge(s), employees and convention or meeting rooms is recommended. This is a far easier way to adjust for the differences in hotel products than to try to define separate ratios for each hotel type. In ULI's *Shared Parking* [Smith, 2005], different ratios, time-of-day adjustments, and seasonal adjustments are also provided for guests at leisure and business hotels.

The parking ratio for restaurants in hotels is significantly lower than for stand-alone restaurants and should only be used if the restaurants are not expected to draw a significant number of non-hotel-guests. It is increasingly common for budget and business hotels (as classified by ITE) to have a branded, franchise restaurant on-site, serving guests as well as the surrounding area.

One refinement of ratios from older references is that different ratios are recommended for convention/meeting space depending on the amount of space provided. Below 20 ft^2 per guest room (or 215 m^2 of meeting space), no additional parking for the meeting space is required; different ratios are provided for GFA of 20 to 50 sq. ft. per guest room (215 to 540 m^2 of meeting space) and more than 50 ft^2 per guest room (540 m^2 of meeting space).

E. Recreational and Entertainment Uses

ITE's *Parking Generation* data for live-performance theatres come from an intensive study of four theaters in a resort area in rural Tennessee. Additional analysis of live theater venue attendance and scheduling in *Shared Parking* has led to a recommended ratio of 0.40 spaces per seat for live performing arts venues. Live-performance theaters are typically single auditoriums. Where multi-theater complexes exist, the parking ratio should be adjusted for likely simultaneous use.

Multiscreen cinema complexes providing thousands of seats were a significant development trend in the 1990s with parking needs that outpaced the available planning literature. The increasing size of cinemas and changing design practices, such as stadium seating, brand fast food and the like, makes a seats-based ratio the most appropriate. Parking spaces per screen is another ratio that is sometimes used, but seats per screen varies widely; multiscreen cinemas often have larger and smaller auditoriums in the same complex. If the number of seats is not available, a good rule of thumb for converting GFA to seats is 20 ft^2 (1.86 m^2) per seat.

A peak parking demand of one space for every two seats is appropriate for a single screen theater and one space per three seats is appropriate for a theater with up to five screens. This ratio can be reduced as the number of screens increases. *Shared Parking* now recommends a ratio of 0.29 spaces per seat for cinemas with more than 10 screens.

Parking Generation has no data on arenas and stadiums. The parking demand at arenas and stadiums is generally calculated by defining the design event as a busy regular season game if there is a franchise tenant. An appropriate adjustment for local transit service and charter bus service is taken, then the mode split to personal vehicle is divided by expected auto occupancy. Modes of arrival and vehicle occupancy at these facilities can vary substantially by type of event. After the design day is chosen, *Shared Parking* recommends 0.31 spaces per seat for football stadiums, 0.35 spaces per seat for baseball stadiums, and 0.33 spaces per seat for arenas.

Casinos (ITE land use code 473) are a relatively new phenomenon for parking studies. *Parking Generation* does not have parking generation ratios for this activity. Further complicating the issue is that most casinos are mixed-use developments with hotels, retail, and other land uses. While land-based casinos have relatively low turnover (30 percent or fewer of the spaces turn over in the peak hour), a ratio of parking spaces to licensed occupancy can be determined for similar existing casinos and applied. Riverboats may—or may not—have a significant overlap of gamblers arriving for the next cruise before those on the previous cruise depart. The degree of overlap is significantly influenced by the embarkation/debarkation procedures and the time in port. Additional factors are the percentage of users expected to arrive by charter bus and the existence of other attractions nearby.

F. Educational Institutions

The data in *Parking Generation* for elementary schools and urban high schools vary widely, while those for suburban high schools are more consistent. The Parking Consultants Council recommends the higher value of 0.2 spaces per auditorium or gym seat, or 0.25 spaces per student for elementary schools. Its recommendation for high schools is the higher total value of 0.3 spaces per auditorium or gym seat, or 0.3 spaces per student. *Parking Generation* suggests 85th-percentile parking demands of about 0.25 to 0.34 per school population, the traditional unit of measure. Another measure, spaces per registered vehicle, shows a range of 0.6 to 0.7 spaces per registered vehicle.

Similarly, Dorsett [1993] reviewed data from various parking studies and used regression analysis to determine how strong a relationship existed between total student/staff population and parking demand. He found that a regression line would have predicted the actual number of occupied parking spaces only 13 out of 22 times with a 20-percent margin of error. The remaining nine cases fell outside the 20-percent margin of error. Dorsett noted that city and campus transit services, student to staff ratios, parking policies, class schedules, and on-street parking in nearby neighborhoods influenced demand.

Given the combination of many different factors that could influence parking demand at a university, a parking study should be conducted when new parking facilities are being considered.

A relatively large sample of data on day care centers (37 studies) in *Parking Generation* provides an average ratio of 0.24 spaces per student and an 85th-percentile ratio of 0.34 spaces per student. There appears to be some reduction of parking needs in larger facilities. While there is slightly better statistical reliability exhibited in ratios based on employees rather than students (32 percent coefficient of variation on an employee basis versus 39 percent on a student basis), facilities are typically licensed for a particular number of students, and therefore, basing ratios on that figure appears to be most appropriate. The Parking Consultants Council recommends a ratio of 0.3 spaces per student in licensed capacity. *Parking Generation* data suggest a parking generation ratio of 0.4 spaces per seat for churches and other places of worship.

G. Medical Institutions

Whitlock [1982] concluded that a single parking generation ratio for hospitals based on the number of beds was not appropriate. He recommended four variables be considered for such an analysis—typical daily staff population, typical daily visitor population, percent of staff driving, and percent of visitors driving. Since this study, there has been a revolution in the delivery of health care shifting from inpatient to outpatient care, therefore making a single ratio of spaces per bed even less reliable.

Dorsett [1995] recommended studying four user groups—employees, physicians, visitors, and patients—and identifying when and in what numbers each user group would be on the medical campus and the mode share of each. This study also concluded that using only one ratio was inappropriate.

Many hospitals have several parking facilities, each reserved for specific users. Therefore, it is important to look at the demand in terms of user characteristics because the peak hour demand for each user group differs. Typically, the outpatient lot may need to be designed for parking demand at 10:00 a.m., and the employee lot for demand at the 3:00 p.m. shift change. Because of the site-specific characteristics of demand, the most reliable means of projecting parking demand at hospitals is to conduct a detailed parking study.

Parking Generation also found a high degree of data reliability for parking at medical clinics, which are defined as Medical-Dental Office facilities. A ratio of 4.27 spaces/ksf (5.1 spaces/100 m^2) is recommended for this use. Note that this ratio is not significantly different from the ratio for medical and dental office buildings. Therefore, a medical office building that has outpatient facilities as part of its space may consider both as complementary uses and not require adjustment of the base ratio for a medical office building.

H. Convention Centers

Parking demand varies significantly at convention facilities, reflecting the different types of events that occur. The facilities are constructed to draw regional if not national tourists for conventions. There are also differences between convention centers that have a combination of exhibit and meeting space, and exposition halls that are predominately exhibit halls. The parking demand for a regional event where many people drive in for the day will be considerably higher than for a large national event where most delegates arrive by taxi, shuttle from airports or rail stations, or walk from nearby hotels. Certain types of conferences may also have significantly higher parking demands, such as religious groups and franchise or distribution network meetings. However, the peak parking demand for a convention center almost always occurs when a public show is booked into the facility during periods of low convention activity. These events include boat and home shows that draw many local residents, most of whom drive and park.

There will be a relatively low turnover for a national convention (1.5 to 2 parkers or turns per day) with peak arrivals in the morning and peak departures in the afternoon; a boat show will have a higher turnover (three to five parkers per day) and in and out activity all day long.

By their very nature, convention centers have tended to be located in larger activity centers with convenient hotels. Thus, the convention center's dedicated parking may be designed for the needs of a moderate, mid-week national convention, with the greater needs of public shows on the weekend accommodated by other parking services in the vicinity. When a mega-show is scheduled, a parking and transportation management plan should be developed by the center's management and the show organizer to encourage alternative modes of travel to the center. Analysis of parking studies and event calendars in *Shared Parking* resulted in a recommendation of 6.0 spaces/ksf (6.5 spaces/100 m^2) of GLA for larger convention centers. In order to create a better transition from the *Shared Parking* ratios for convention spaces at hotels, the Parking Consultants Council has scaled ratios for quantities ranging from less than 25,000 sq. ft. (2,325 m^2) to more than 250,000 sq. ft. (23,225 m^2). (Note that by definition gross leasable space excludes the common areas, such as pre-function space, of these facilities.)

I. Office Space

Office space varies significantly by density of employees, location of facility, and type of office activity. A multi-tenant, general office building, originally class A office space but now older and dated compared to the newer market entries, will likely have a higher density of employees than a newer class A luxury building occupied by law and financial firms. This suggests that employee densities tend to increase over time as the building ages without substantial reinvestment. A building with a corporate headquarters as its single tenant will often have lower densities than a multi-tenant building of the same size; however, a building solely occupied by back-room operations such as data processing and telemarketing has significantly higher densities.

A study of 10 office buildings in Southern California in 1992 found employment densities ranging from 2.0 to 8.2 employees/ksf (2.2 to 8.8 employees/100 m^2). [Willson, 1992] The peak parking accumulation at buildings in the 2.7 to 3.2 employees/ksf (2.9 to 3.2 employees/100 m^2) density range had peak parking accumulations of 2.0 to 2.2 employees/ksf (2.2 to 2.4 spaces/100 m^2). There was considerable variation in the other results. A building with 2.0 employees/ksf (2.2 employees/100 m^2) had a peak demand of 1.8 spaces/ksf (1.9 spaces/100 m^2), while another with five employees/ksf (5.4 employees/100 m^2) had a demand of 1.4 spaces/ksf (1.5 spaces/100 m^2). The office use with higher total employment had significantly lower employee presence and parking needs, apparently due to multiple shifts.

The added presence of visitors further complicates the analysis. Medical office buildings may have more than one visitor per employee at any given time. The typical office building will have only five to seven visitors per 100 employees present at the typical peak hour for parking needs (late morning), while back room operations may have negligible visitor parking. Offices of consumer service providers—insurance and employment agencies, real estate offices and the retail bank branch—will have similar employment density but a different visitor demand profile than that of general offices and medical offices. The medical office data in *Parking Generation* have a range of 3.95 to 5.65 vehicles/ksf, where the 85th percentile figure is 4.27 vehicles/ksf and the 33rd percentile figure is 2.68 vehicles/ksf; the average is 3.20 vehicles/ksf.

Medical office parking may also vary by site. Space located on hospital campuses is more likely to be leased to physicians, such as surgeons, who have to spend significant time at the hospital and who have more restricted office hours than a doctor practicing at a neighborhood medical office.

It is recommended that office ratios be subdivided into discrete categories. ITE broke its data for *Parking Generation* into five categories: (general) office building, medical and dental offices, government office, post office, and judicial complexes. *Shared Parking* recommended parking ratios for general offices (with three size ranges), medical offices, data processing offices, and branch banks. The Parking Consultants Council adopted the same ratios and recommended using the bank ratio for all consumer service offices, such as insurance and real estate offices.

No ratio is provided in this chapter for government/post office/judicial offices. Rather, a shared parking analysis by type of offices is appropriate for these land uses. Areas where the public goes to receive services might be treated as consumer offices; areas generally used only by employees would be general offices; and meeting and assembly spaces would be evaluated based on design attendance and time of day factors.

Many office developers believe that parking demand is increasing at office buildings. Data collected by the Building Owners and Managers Association indicated that there has been a slight increase in the density of employees in office space since 1995, after a long period of decline. However, the density remains well below that of 1985. Also, these ratios are based on GFA (primarily because ITE uses GFA for its parking and traffic generation reports), while many in the office development community "think" in GLA or NRA. If NRA is 80 percent of GFA, the 3.8 spaces/ksf ratio for small office buildings is equivalent to 4.75 spaces/ksf NRA, and the 2.8 spaces/ksf ratio for buildings over 500,000 ft^2 is equivalent to 3.5 spaces/ksf NRA.

J. Retail Space

As previously noted, a shopping center is the only land use where there has been extensive study of parking accumulations during a design hour. *Parking Requirements for Shopping Centers* was first published by the Urban Land Institute in 1982 and updated in 1999. The currently recommended parking ratio varies from 4.0 spaces/ksf (4.3 spaces/100 m^2) of GLA for smaller centers to 4.5 spaces/ksf (4.8 spaces/100 m^2) for larger centers. *Shared Parking* contains additional recommendations regarding time of day and seasonality of shopping center demand.

Parking Requirements for Shopping Centers looked at the impact of limited amounts of entertainment uses (food court, cinema, and restaurant uses) on shopping center parking demand. It recommends that the above ratios be increased when dining and entertainment occupy 10 to 20 percent of the GLA and that shared parking analysis be employed where these uses comprise more than 20 percent of the GLA. *Shared Parking* further studied this issue and concluded that it may be more reliable to use shared parking analysis when entertainment uses exceed 10 percent of GLA because the specific mix of dining versus entertainment dramatically impacts the parking required. Table 11-15 summarizes desired shopping center parking ratios.

Because retail is not found only in shopping centers, *Recommended Zoning Ordinance Provisions for Parking* provides recommended parking ratios for some additional types of retail development. These ratios are recommended for freestanding buildings or when buildings in a development are spatially separated in such a way as to discourage the sharing of parking. *Shared Parking* in fact found that when more intense retail uses such as grocery stores are provided in convenience/ neighborhood centers with less intense uses such as dry cleaners or video stores, the overall parking ratios average out to be reasonably modeled by the recommended shopping center ratios.

K. Eating and Drinking Establishments

Restaurants have become significant uses in commercial developments since the early 1990s, a major driver being the changing U.S. household. In 1967, only 29 percent of a household's total food dollar was spent away from home; by 2010 this figure had climbed to 46 percent. [Thompson, 2013]

Parking Generation does not include regression equations for most data sets in this category, partly because there was not that much variation in size of use. One of the largest samples, family restaurants, had a size range of only 2,000 to 10,000 sq. ft. (186 to 930 m^2) with considerable scatter of data points.

While there are numerous variations in types of restaurants, the following classifications are used in *Shared Parking*. These groupings have reasonably similar parking demands. Given that parking planning may begin long before a particular restaurant tenant lays out seating areas, spaces per unit area is the most appropriate unit for parking demand ratios.

Casual and fine dining restaurants include two types of restaurants. One is the premier white tablecloth or gourmet restaurant serving food and beverages at relatively high cost. Some of these restaurants only serve dinner, and many do

Table 11-15. Shopping Center Parking Ratios

Gross Leasable Area (GLA) Not More Than 10% GLA in Non-Retail Uses	Recommended Spaces/100 m^2 GLA (/ksf)
<43,000 sq. m (400 ksf)	4.3/100 sq. m (4/ksf)
43,000–64,600 sq. m (400-600 ksf)	Scaled
>64,600 sq. m (600 ksf) GLA	4.8/100 sq. m (4.5/ksf)
Over 10% GLA in other uses	Shared parking analysis

Source: Smith, 2005

not have a significant bar area. However, when provided in mixed-use developments, some are likely to serve lunch. Casual restaurants bridge the gap between fine dining and family restaurants, with more moderately priced meals but extensive alcoholic beverage service. Many of these restaurants are heavily themed, following the Hard Rock Cafe model, with entertainment as part of the dining experience. Because they typically do not take reservations, there may be long waiting lines and heavy activity in the bar at busy times. While some have suggested separating the two categories, an analysis of the database in *Parking Generation* found that there was not a statistically significant difference in the parking ratios between these two groups. Therefore, the recommended base ratio for casual and fine dining restaurants (with full liquor service) is 20 spaces/ksf (22 spaces/100 m^2) of GFA.

Family restaurants usually serve breakfast as well as lunch and dinner, and they typically do not have a bar area. Alcoholic beverages, if served, are provided at dining tables only. With little or no waiting and no bar area, 15.0 spaces/ksf (16.0 spaces/100 m^2) of GLA is the recommended parking ratio.

Fast food restaurants generally have counter ordering with a self-serve seating area. Restaurants of this type usually have drive-through service. *Parking Generation* unfortunately subdivides fast food restaurants into multiple categories, weakening the overall reliability of its analysis. A review of the composite information by the *Shared Parking* update team determined that 15.0 spaces/ksf (16.0 spaces/100 m^2) of GLA is also the recommended parking ratio for fast food uses. However, fast food restaurants have peak parking needs on weekdays rather than weekends, hence the separation from family restaurants for shared parking analysis.

VIII. SHARED PARKING METHODOLOGY

Shared parking has two basic components: (1) some people visit a site while in the general area of a primary destination (for example, a restaurant in a large office building); and (2) some activities at a site peak at different times than others. An example of the latter is an entertainment complex located within a large shopping center where peak demands often occur at night and on the weekends.

Shared parking analysis, developed by the Urban Land Institute (ULI), examines parking characteristics relating to time of day, day of week, season, and the interaction of mixed-use developments to determine the peak accumulation of vehicles. [Smith, 2005] Parking demand for each component may peak at different days of the week or hours of the day; therefore, fewer parking spaces are generally needed than would be required if each component were a freestanding development. An example of this is parking demand for restaurants that primarily do business in the evening hours and thus can use the parking spaces of nearby office buildings whose employees have left for the day.

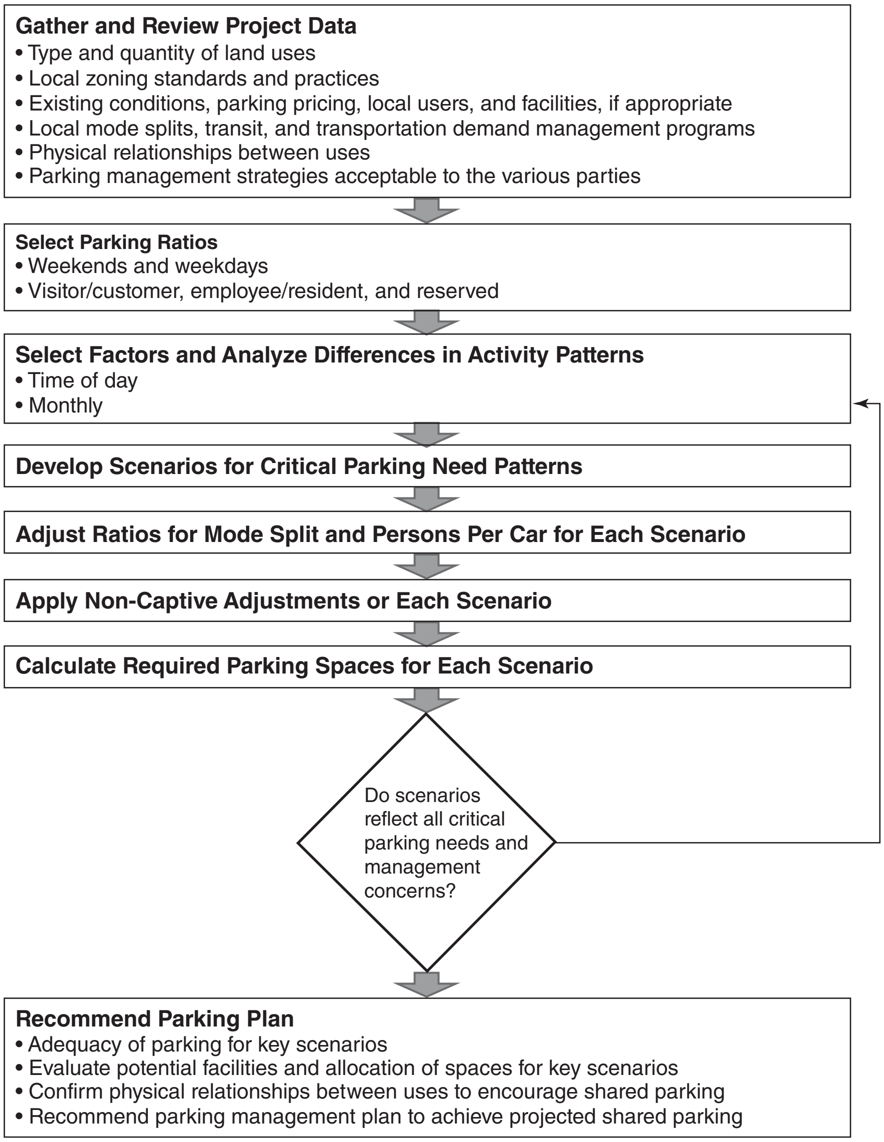
Shared Parking [Smith, 2005] quadrupled the number of land uses covered from an earlier edition and, more importantly, updated nearly all of the recommended default values for parking ratios, time-of-day, and seasonal adjustments. A significant change in methodology was the separation of parking ratios into visitor/customer, employee, and resident ratios, which facilitated the analysis of captive market and mode adjustments, and also parking management planning, which is critical to the success of shared parking plans. The methodology is presented in a flow chart shown in Figure 11-8.

Figure 11-9 presents the typical variation of parking needs by time of day for some of the more common uses occurring in shared parking situations. These variations differ according to whether it is a weekday or weekend. Figure 11-10 presents typical variations by month of year. Note that these exhibits have combined the separate factors for employee and customer parking in *Shared Parking* and represent the overall variation in parking demand at those land uses. The following sections discuss in brief the critical analysis assumptions in shared parking analysis.

A. Captive Market

The term captive market was originally borrowed from market researchers to describe people who are already present in the immediate vicinity of a development and are thus likely patrons of a new use. In shared parking analysis, it is used to reflect the adjustment of parking needs due to the interaction among land uses. Captive market effects not only accrue from onsite development, but also from nearby uses, such as office buildings. In parking analysis, planners use the complementary factor (that is, the noncaptive ratio), which is the percentage of users who are not already counted as being parked. Generally, the analyst considers a vehicle as being generated by the land use that was the primary trip purpose (or destination).

Figure 11-8. Shared Parking Methodology



Source: Smith, 2005

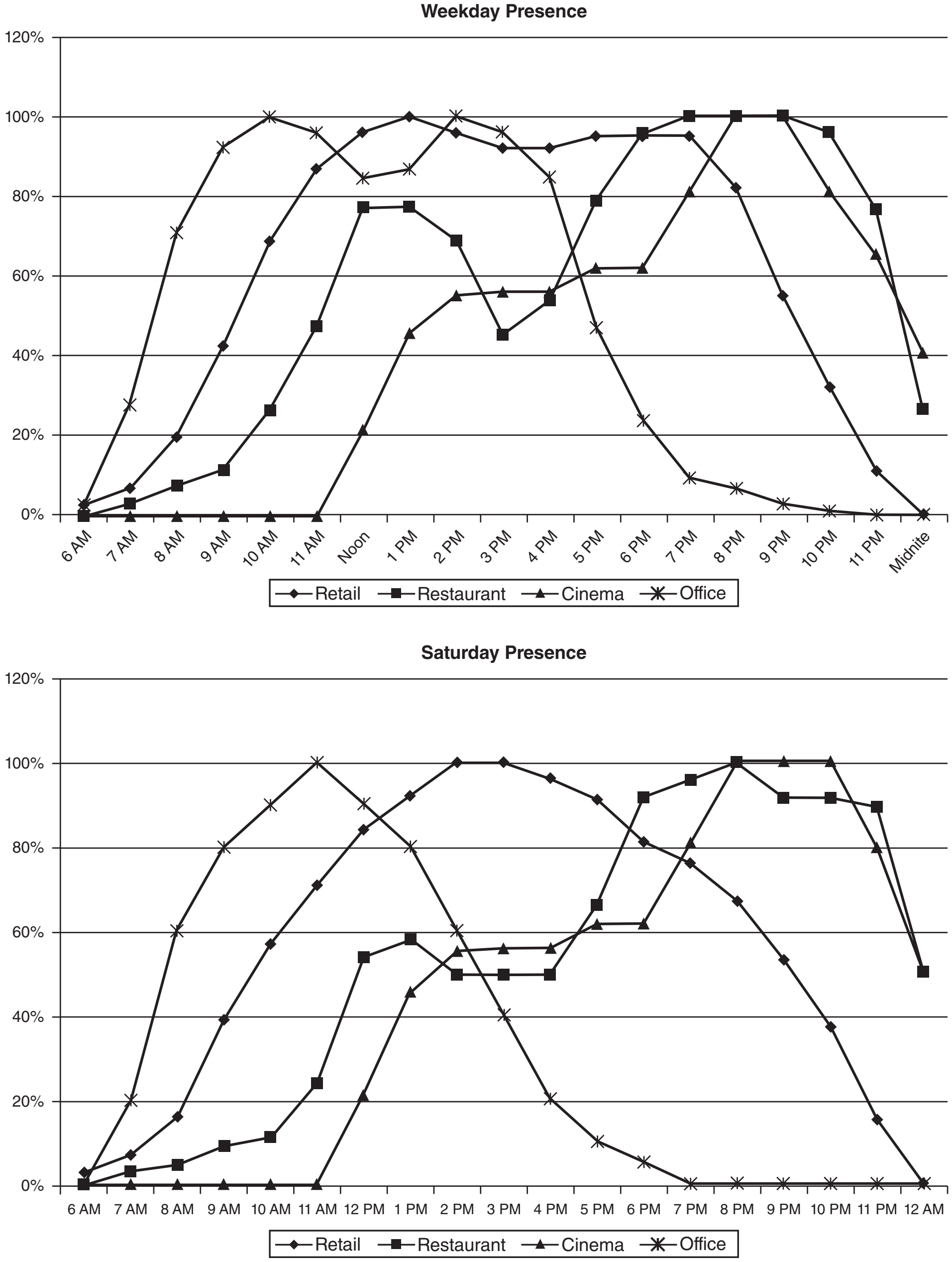
1. Development Synergy and Multipurpose Trips

Certain types of developments achieve much greater interaction among uses than others. When such synergy exists, a successful project may have lower parking demands than if the uses were built separately and will likely have a greater patronage than would otherwise be expected. For example, a restaurant may have greater noontime patronage than it would otherwise because it is located within walking distance of a large employment center. In other words, it may have more customers per day while having a lower noontime parking demand than stand-alone developments. Similarly, retail employees are a major component of those eating at a shopping center's food court.

Today's town center with significant dining and entertainment uses is predicated not only on the possibility of visiting multiple destinations on single trips, but also on multiple destinations being visited at the same time. A family visiting a town center may split up with the children going to the cinema, one parent going shopping and the other going to a bookstore. The length of stay is longer and the planner must consider the effects of sequential visits (which add to parking needs without generating vehicle trips) as well as simultaneous ones (which generate no additional parked vehicles or trips) in the parking analysis.

CBDs are among the best examples of successful shared parking. The CBD usually has the largest concentration of employment and commercial activity in a region. CBD (and outlying business districts) parking supply, demand, and

Figure 11-9. Variation of Parking Demand by Time of Day, Weekday and Saturday



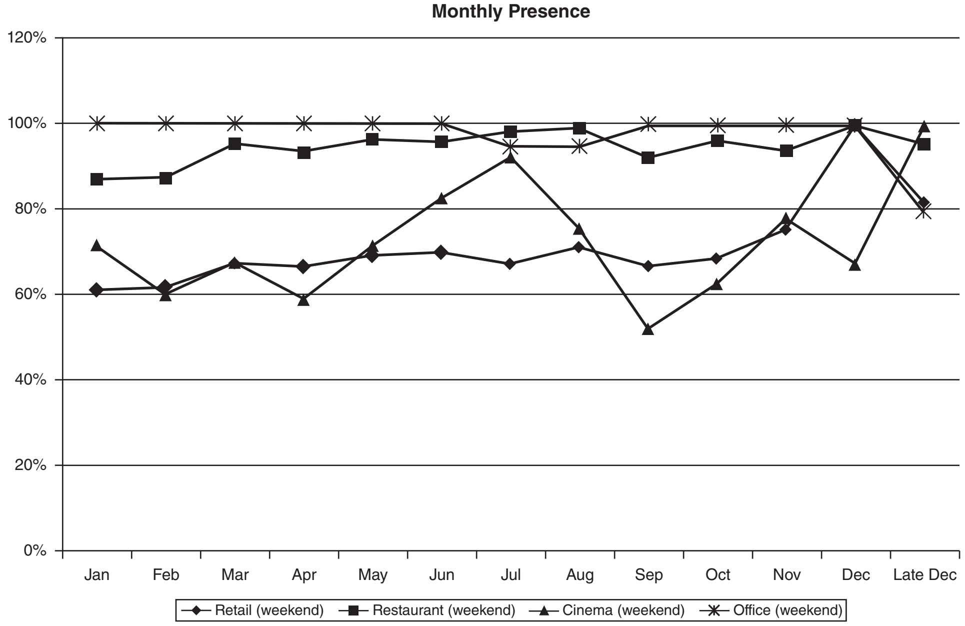
Source: Adapted from Smith, 2005

needs studies have been conducted for many years. The primary purposes for parking downtown in larger cities are (in relative importance)—work, business, and shopping. Because length of stay (parking duration) varies with trip purpose, every four work commutes result in three parked cars during peak parking demand, while four non-work parkers will generally need one space at peak occupancy. The peak occupancy (accumulation) occurs between 11:00 a.m. and 3:00 p.m.—about three-quarters of this accumulation represents motorists parked for work purposes.

CBD parking demand estimates are increasingly derived from land use-based approaches to avoid the costs of detailed parker interviews. The effective-parking supply is determined by analysis area. The peak accumulations of parkers are assumed to approximate the aggregate hour-to-hour downtown parking demand. This demand is then allocated to various subareas based on their share of downtown employment and other activities.

The ability to choose alternative modes is much greater in the CBD than in other parts of a metropolitan area. As a result, overall parking demand ratios in CBDs range from 1.4 to 3.3 spaces/ksf (1.5 to 3.5 spaces/100 m^2) with 1.9 to 2.3 spaces/ksf (2.0 to 2.5 spaces/100 m^2) being most common.

Figure 11-10. Variation in Demand for Parking by Month



Source: Smith, 2005

2. Mode Adjustment

A mode factor is applied to adjust the base ratio, which assumes virtually 100-percent arrival by automobile. Mode split, as used by the traffic engineering profession, is stated on a person basis; parking ratios require that the mode split be converted to a vehicle basis. This is accomplished by estimating the mode split and then dividing by the average persons per car. Some have called this a driving ratio, because it represents an adjustment to the number of vehicles driven to the site. The availability of local transit and the price of parking are primary considerations in determining the mode split at a particular site. Separating the parking ratios into employee and customer components allows for more accurate projections of parking needs, especially in light of the availability of local data on mode split and persons per car for commuters from the U.S. Census.

IX. PARKING COSTS

The cost of parking directly affects developers, landowners, and auto users, as well as influences the financial feasibility of a parking structure. Groups wanting to encourage alternative modes believe that the user should be charged the actual cost of using a parking space to make a fair comparison among mode choices. In other cases, institutions and communities have faced substantial "sticker shock" when looking at the cost of building structured parking to serve their users. An understanding of the cost of parking is thus important to the efficient use of parking resources, which may reduce or eliminate the need for new spaces.

Parking facility cost has two distinct components: the capital cost (or cost to own, which includes construction and financing) and the operational cost. The illustrative capital and operational costs discussed below help to compare different options and understand the order of magnitude of parking costs. They should be considered as a "snapshot in time" in that costs will vary over time due to inflationary pressures.

A. Capital Costs

Capital costs include all of the costs associated with constructing a project, including land acquisition, site preparation, construction, soft costs, and financing. The *construction cost* is the total amount paid to the contractor(s) for building a parking facility, including demolition and site preparation, and the so-called soft costs, beginning with the design fee and reimbursable expenses, the cost of surveys, geotechnical testing and materials testing during construction. Additional services not covered by the standard design contract, such as full-time on-site representation and feasibility studies, are also added into a project cost estimate. Finally, the cost of administering the construction contract as well as financing costs are included.

Construction costs for parking structures vary substantially by locality, reflecting labor costs and construction practices. The U.S. northeastern states have higher labor costs than the southeastern states, primarily because of union wages; Midwestern states have higher costs for material durability than the southwestern states. California and Florida lead the country in the delivery of parking projects by the design/build delivery system; this has allowed designers to put the lessons of construction efficiency into practice on traditional design/bid projects, resulting in generally lower costs.

Market factors also can cause significant cost variations even within one construction season. For example, after a period of relatively slow increases, parking construction costs increased 20 to 30 percent between 2003 and 2006, primarily because of increased material costs. Because 60 percent or more of a parking structure's cost will accrue in the concrete structural system and associated items such as expansion joints and sealers, the capabilities and workload of local cast-in-place and precast concrete contractors will have a substantial influence on the cost of the facility. Timing is crucial; if a structure is bid after most of the contractors have booked work for the season, the bids will likely exceed normal estimates. Table 11-16 shows the median parking structure cost in selected cities in the United States for 2014.

Table 11-16. Median Parking Structure Construction Costs 2014

	City Index	Cost/Space	Cost/SF
Atlanta	87.5	$15,783	$47.29
Baltimore	92.8	$16,739	$50.15
Boston	117.6	$21,212	$63.56
Charlotte	80.8	$14,575	$43.67
Chicago	117.6	$21,212	$63.56
Cleveland	99.4	$17,930	$53.72
Denver	93.3	$16,829	$50.42
Dallas	85.2	$15,368	$46.05
Detroit	102.8	$18,543	$55.56
Houston	86.6	$15,621	$46.80
Indianapolis	92.6	$16,703	$50.05
Kansas City	103.8	$18,723	$56.10
Los Angeles	107.3	$19,355	$57.99
Miami	87.6	$15,801	$47.34
Minneapolis	109.0	$19,661	$58.91
Nashville	87.5	$15,783	$47.29
New York	131.1	$23,648	$70.85
Philadelphia	113.9	$20,545	$61.56
Phoenix	88.7	$16,000	$47.94
Pittsburgh	102.3	$18,453	$55.29
Portland	99.1	$17,875	$53.56
Richmond	86.7	$15,639	$46.86
St. Louis	103.1	$18,597	$55.72
San Diego	104.1	$18,777	$56.26
San Francisco	122.5	$22,096	$66.21
Seattle	103.5	$18,669	$55.94
Washington, D.C.	97.2	$17,533	$52.53
National Average	100	$18,038	$54.05

Source: Cudney, 2014

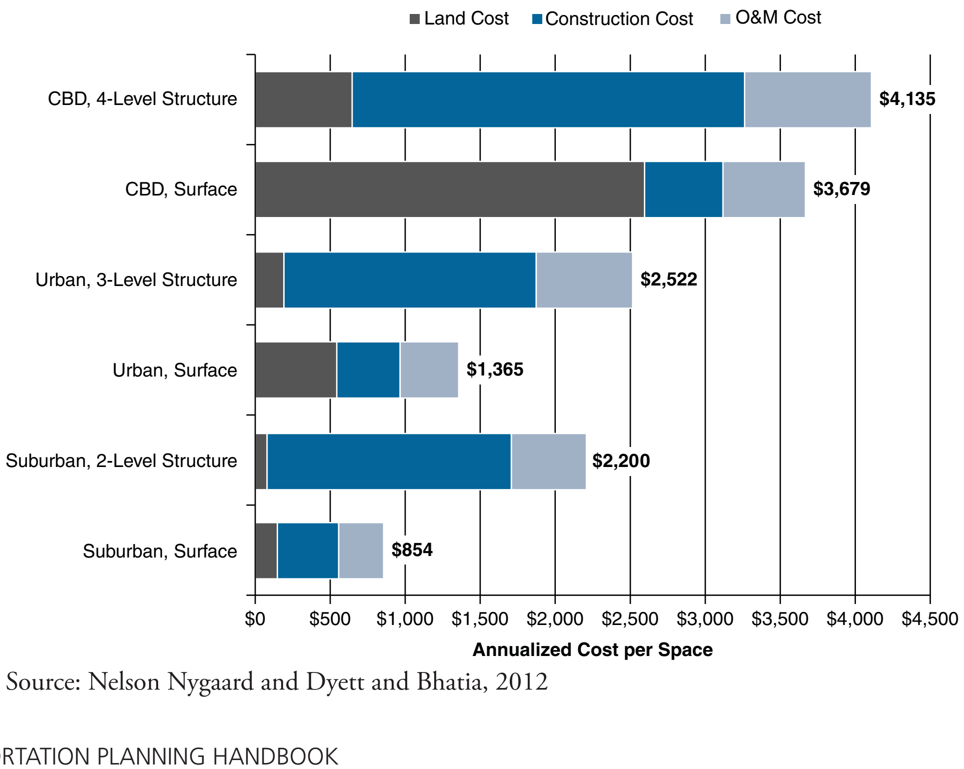
Parking construction costs are usually stated in cost per square feet (or square meter) and cost per space for comparison with industry norms and other projects. Cost per unit area gives an idea of the basic elements and amenities incorporated into the design—for want of a better term, the quality of the finished building.

The cost per space reflects the *efficiency* (sq. ft. or m^2 of parking area per space) of the parking design. In two different projects, the same level of architectural durability and engineering systems can result in a similar cost of say $35 per sq. ft. ($375 per m^2). However, if one achieves an efficiency of 300 sq. ft. per space (27.7 m^2 per space) versus 350 sq. ft. per space (32.3 m^2 per space), the more efficient design will cost $10,500 per space, or 14 percent less than the $12,250 per space cost of the less efficient design. Table 11-17 compares efficiency and cost per unit area to cost per space. Because construction cost per space is the most commonly used index, all tables presented relate other costs back to construction cost per space.

Surface lot parking is the least expensive to construct whereas underground parking costs vary widely because the number of floors below grade and the soil conditions affect the cost dramatically. This is seen in Table 11-17 and on an annualized basis in Figure 11-11. As shown in both, the importance of the cost of land is very evident, which is reflected in the location of the lot. In addition, parking garages, either vertical or in the subsurface, show dramatically different cost structures. The data shown in the table and figure would have to be adjusted for other areas, given that outside of New York City, the Bay Area has some of most expensive land in the United States.

The efficiency of parking designs varies widely. (Note: Any mixed-use areas, such as grade-level retail, should not be included in the efficiency calculation to avoid distorting comparisons.) A typical surface lot or structure with circulation through the parking areas can achieve efficiencies of 270 to 350 sq. ft. per space (25 to 33 m^2 per space). Efficiencies below 300 sq. ft. per space (28 m^2 per space) were almost never seen before the downsizing of the automobile in the 1970s and the subsequent development of compact-only stalls. In many locales, efficiencies of 300 to 325 sq. ft. per space (28 to 30 m^2 per space) are the goal of most designs today. Efficiencies of over 325 sq. ft. usually reflect a site constraint requiring short rows or single-loaded aisles and should be avoided where possible. Short-span garages (with columns between parking spaces rather than between bays) have efficiencies over 325 sq. ft. per space, but they may be dictated by mixed land uses above the parking facility. Facilities with special requirements for express ramps and loss of parking areas to toll plazas or other parking-related functions will also have efficiencies of 322 to 377 sq. ft. per space (30 to 35 m^2 per space). Table 11-18 shows the construction cost per space related to the amount of square feet (square meters) per space and the cost per square foot (meter). The values are in 2006 dollars, and illustrate the relationship between the factors that are part of the design process.

Figure 11-11. Land, Construction, and O&M Costs, by Location and Facility Type, San Francisco Bay Area, 2012



Source: Nelson Nygaard and Dyett and Bhatia, 2012

Table 11-17. Typical Parking Structure Costs, by Location and Facility Type, San Francisco Bay Area, 2012

	Land Costs			Construction Costs per Space				Total Capital Costs per Space	Annual O&M Costs per Space	Total per Space Costs, Annual
Type of Facility	Per Acre	Per Space	Annuallized	Hard	Soft	Total	Annualized			
Suburban, Surface, Free Land	$0	$0	$0	$5,000	$1,250	$6,250	$407	$6,250	$300	$707
Suburban, Surface	$250,000	$2,273	$148	$5,000	$1,250	$6,250	$407	$8,523	$300	$864
Suburban, 2-level Structure	$250,000	$1,136	$74	$20,000	$5,000	$25,000	$1,626	$26,136	$500	$2,200
Urban Surface	$1,000,000	$8,333	$542	$5,000	$1,500	$6,500	$423	$14,833	$400	$1,365
Urban, 3-level Structure	$1,000,000	$2,778	$181	$20,000	$6,000	$26,000	$1,691	$28,778	$650	$2,522
Urban, Underground	$1,000,000	$0	$0	$35.000	$10,500	$45,500	$2,960	$45,500	$650	$3,610
CBD, Surface	$5,000,000	$40,000	$2,602	$6,000	$2,100	$8,100	$527	$48,100	$550	$3,679
CBD, 4-level Structure	$5,000,000	$10,000	$651	$30,000	$10,500	$10,500	$2,635	$50,500	$850	$4,135
CBD, Underground	$5,000,000	$0	$0	$40,000	$14,000	$54,000	$3,513	$54,000	$850	$4,363

Source: Nelson Nygaard and Dyett and Bhatia, 2012

Table 11-18. Construction Cost per Parking Space								
	Sq. Ft./Space	**270.6**	**297.7**	**324.7**	**351.8**	**378.8**	**405.9**	**433.0**
	Sq. M/Space	**25.0**	**27.5**	**30.0**	**32.5**	**35.0**	**37.5**	**40.0**
Cost/Sq. ft.	**Cost/Sq. m.**							
Surface Lots								
$9.24	$100	$2,500	$2,750	$3,000	$3,250	$3,500	$3,750	$3,750
$11.55	$125	$3,125	$3,438	$3,750	$4,063	$4,375	$4,688	$4,688
$13.86	$150	$3,750	$4,125	$4,500	$4,875	$5,250	$5,625	$5,625
Above-Grade Structure								
$34.64	$375	$9,375	$10,313	$11,250	$12,188	$13,125	$14,063	$15,000
$36.95	$400	$10,000	$11,000	$12,000	$13,000	$14,000	$15,000	$16,000
$39.26	$425	$10,625	$11,688	$12,750	$13,813	$14,875	$15,938	$17,000
$41.57	$450	$11,250	$12,375	$13,500	$14,625	$15,750	$16,875	$18,000
$43.88	$475	$11,875	$13,063	$14,250	$15,438	$16,625	$17,813	$19,000
$46.19	$500	$12,500	$13,750	$15,000	$16,250	$17,500	$18,750	$20,000
Below-Grade Structure								
$46.19	$500	$12,500	$13,750	$15,000	$16,250	$17,500	$18,750	$20,000
$55.43	$600	$15,000	$16,500	$18,000	$19,500	$21,000	$22,500	$24,000
$64.67	$700	$17,500	$19,250	$21,000	$22,750	$24,500	$26,250	$28,000
$73.91	$800	$20,000	$22,000	$24,000	$26,000	$28,000	$30,000	$32,000
$83.15	$900	$22,500	$24,750	$27,000	$29,250	$31,500	$33,750	$36,000
$92.39	$1,000	$25,000	$27,500	$30,000	$32,500	$35,000	$37,500	$40,000

Source: Courtesy of Walker Parking Consultants

There has been significant publicity regarding high-rise, automated mechanical parking structures as an alternative to self-park structures. The advantages of these facilities include smaller site requirements, more spaces in a smaller building mass (height and footprint), significantly fewer security issues, and environmental advantages because vehicles are not searching for a space. However, the total completed construction and operating costs are often understated in marketing materials and media reports, particularly where turnover of spaces requires more than the minimum number of devices to move vehicles around in the facility. In addition, the savings in the footprint are often negated by access drives and queuing at the entrance and exit chambers where cars are surrendered by and returned to parkers, particularly for larger facilities with higher turnover. As a result, the construction cost of a high-rise, automated mechanical parking structure is 50 to 100 percent more than the cost of an above-grade parking structure and is similar to the cost of underground parking structures. [Monahan, 2001]

During the planning stage, the project budget for a parking facility of any type will include an *estimated construction cost* that represents an approximation of what a contractor would bid for the project based on the contract drawings plus *design contingencies* (for issues not yet addressed in the design) and a *field contingency* for unforeseen site conditions and design changes during construction. The design contingency is generally carried as 15 percent of the estimated cost at completion of the schematic phase, 10 percent at the end of design development, and 5 percent at the end of preparation of construction documents to allow for market conditions at the time of bid. Traditionally, once the project is bid and awarded, correction of minor errors and omissions in the design drawings are paid out of the field contingency. A study of design-caused changes concluded that the owner should anticipate and carry at least a 2-percent contingency for deficiencies in designs produced in accordance with customary architectural/engineering practices. This 2-percent design contingency is in addition to the normal 5-percent field contingency for unforeseen conditions and owner-initiated charges. The report notes that almost every design is unique and that it would be prohibitively expensive and time consuming to require the design team to produce perfect plans and specifications. This is not to say that the owner should not seek a designer with a superior track record in the quality area, which today is usually measured by monitoring design-caused change orders.

For budget purposes, the total project cost before any design occurs should be 35 percent greater than the construction cost. As design proceeds and is refined, the design contingency is reduced. Exclusive of land and financing costs, the project cost will typically be 10 to 15 percent greater than the construction cost at the completion of the project. As noted earlier, land costs can dramatically affect the capital cost.

B. Operating Costs

Several factors contribute to the variations in operating expenses among different parking facilities. The first consideration is the size of the facility. Larger facilities have lower costs per space resulting from economies of scale. A lot or structure that is part of a parking system, whether municipal, institutional, or private, will usually cost less to operate than an independent facility. Location is also an important consideration—above ground or below, warm climate or winter snow, high or low crime, high or low wage scale, and such. Hours of operation, ratio of contract parking patrons to daily parking patrons, automated payment versus cashiers, or whether fees for parking are charged also will influence operating expenses.

To determine operating expenses for parking facilities, first define what is included. The following categories are almost always included in operating expenses:

- Labor costs (wages and benefits)
- Management fees and costs
- Security costs
- Utilities
- Insurance
- Supplies and other miscellaneous expenses
- Maintenance, including routine maintenance, preventative maintenance, snow removal, and elevator and parking equipment maintenance

Taxes (for example, sales, property, parking, or some other type) are not included because of the wide range of taxes among facilities. A municipally owned structure, for instance, would pay no property tax, while a privately owned structure could have a substantial property tax bill. Some cities have a substantial parking tax, while others may have little or no tax. Debt service is also not included in these figures because it is not considered an operating expense.

Table 11-19 shows what goes into an estimate of O&M costs. The data in the table were gathered from a survey sent to operators of parking structures throughout the United States. [National Parking Association, 2006] The database included 156 parking structures. Additional unpublished data from 73 surface lots are also included (adjusted to 2006 dollars to be comparable). Many of the respondents reported little or no cost in one or more areas, presumably because accounting practices do not charge the parking system for those expenses.

The median values indicate an annual operating expense for a typical parking structure of $604 per space. Half of the operating costs are associated with revenue collection; revenue collection and security constituted nearly two-thirds of the total cost. The basic operating expense for an unattended facility with no security cost was $177 per space per year in 2006 dollars. Larger structures located in warm climates may have lower costs, but smaller structures located in the Snow Belt can expect to spend a greater amount per space, especially if an adequate amount is spent on structural maintenance.

The size and age of a structure influence costs, but hours of operation and type of use have the greatest impact on the bottom line. A facility with the primary purpose of providing parking for frequent events requires more cashiers than a general parking facility. If the cashiers are paid a higher wage and benefits, the increased hours of operation can increase expenses rapidly. Valet services also increase costs substantially.

Parking facility owners who fail to maintain parking facilities properly could incur significant capital repair expenses later in the life of the facility. Lending institutions, however, often require sinking funds for future repairs, which in turn require appropriate budgets for future structural repairs. Budget adjustments to the operating costs were thus made as shown in Table 11-19.

Car stackers have little operating cost, but they are considered somewhat inconvenient by many patrons. Given that the capital cost to stack two floors of cars in one floor with stackers is more than the cost to build two floors in a self-park structure, car stackers are generally only used to gain spaces in existing garages with high ceilings or as a temporary solution in parking lots.

Table 11-19. Operating Expenses for Parking Structures and Surface Lots (2006)				
	Parking Structures		Surface Lots	
	Median Cost/Space/Year	Rec'd Budget/Space/Year	Median Cost/Space/Year	Rec'd Budget/Space/Year
Expense Category				
Cashiering/Mgt.	$309	$309	$62	$62
PARCS replacement*	-	$31	-	$21
Total Cost of Revenue Collection	$309	$340	$62	$83
Security	$110	$110	$47	$47
Subtotal	$419	$450	$109	$130
Basic Operating Expense				
Utilities	$54	$54	$29	$29
Routine Maintenance	$50	$55	$8	$8
Prevent Maint.	$20	$36	-	$5
Uniforms, Supplies	$19	$19	$5	$5
Insurance	$19	$19	$5	$5
Miscellaneous	$15	$15	$2	$2
Subtotal Basic Operating Expense	$177	$198	$49	$54
Snow Removal	$8	$8	$3	$16
Total	$604	$656	$161	$200

*Sinking fund contribution for future periodic repair or replacement

Source: National Parking Association, 2006

C. Combined Costs

Combining the construction, financing, and operating costs for the various parking options gives a picture of the comparative overall annual costs per parking space (land costs are not included). The monthly revenue to break even gives a picture of necessary charges to users. Table 11-20 cross-tabulates construction cost per space versus annual operating cost per space to show the monthly revenues required per space to break even. This spreadsheet highlights 2006 figures for surface lots, aboveground structures, and underground structures. At the bottom is a conversion of monthly revenues to the hourly rates required for various combinations of days of revenue collection per year and turnover factors.

The Victoria Transport Policy Institute (VTPI) has developed a spreadsheet that planners can use to estimate the cost for parking spaces that includes both construction and O&M costs. The spreadsheet can be found at: www.vtpi.org/parking.xls.

D. Parking Scenario Comparisons

Table 11-21 compares seven alternative parking options to gain 500 spaces at a hospital located on the fringe of the CBD. It addresses two basic questions: How do project costs compare? What are the comparative costs per added space?

Financing costs in this table include the cost of obtaining the funds necessary for the project. Where conventional financing is obtained, the cost of financing typically would be added into the amount borrowed and is usually at least 10 to 15 percent of the project cost. For early project planning, a factor of 25 percent to 35 percent for design, financing, and miscellaneous project costs added to an estimate based on the typical construction cost per space is a reasonable budget figure. Financing methods are discussed later in this chapter.

However, for a more realistic comparison of the cost to own and operate parking facilities, a total project cost, including a 15 percent factor for all soft costs, was assumed to be financed at a cost of capital of 7 percent over 20 years for the structures and land acquisition, and over 10 years for lots. Parking facilities are rarely financed for longer terms because they typically begin to require significant restoration and refurbishing at that age. The cost of financing each

Table 11-20. Monthly Parking Revenue Required per Space

	Annual Operating Cost per Space												
Const. Cost	**$50**	**$100**	**$150**	**$200**	**$250**	**$300**	**$400**	**$500**	**$600**	**$700**	**$800**	**$900**	**$1000**
$1,000	$14	$18	$22	$26	$31	$35	$43	$51	$60	$68	$76	$85	$93
$2,000	$24	$28	$32	**$36**	$40	$45	$53	$61	$70	$78	$86	$95	$103
$3,000	$34	$38	$42	**$46**	$50	$54	$63	$71	$79	$88	$96	$104	$113
$4,000	$43	$48	$52	**$56**	$60	$64	$73	$81	$89	$98	$106	$114	$123
$5,000	$53	$57	$62	$66	$70	$74	$82	$91	$99	$107	$116	$124	$132
$6,000	$63	$67	$71	$76	$80	$84	$92	$101	$109	$117	$126	$134	$142
$7,000	$73	$77	$81	$85	$90	$94	$102	$110	$119	$127	$135	$144	$152
$8,000	$83	$87	$91	$95	$99	$104	$112	$120	$129	$137	$145	$154	$162
$9,000	$93	$97	$101	$105	$109	$113	$122	$130	$138	$147	$155	$163	$172
$10,000	$102	$107	$111	$115	$119	$123	$132	$140	**$148**	**$157**	$165	$173	$182
12,500	$127	$131	$135	$140	$144	$148	$156	$165	**$173**	**$181**	$190	$198	$206
$15,000	$152	$156	$160	$164	$168	$172	$181	$189	**$197**	**$206**	$214	$222	$231
$17,500	$176	$180	$185	$189	$193	$197	$205	$214	**$222**	**$230**	$239	$247	$255
$20,000	$201	$205	$209	$213	$217	$222	$230	$238	$247	$255	$263	$272	$280
$22,500	$225	$230	$234	$238	$242	$246	$255	$263	$271	$280	$288	$296	$305
$25,000	$250	$254	$258	$262	$267	$271	$279	$287	$296	$304	$312	$321	$329
$27,500	$275	$279	$283	$287	$291	$295	$304	$312	$320	**$329**	**$337**	$345	$354
$30,000	$299	$303	$307	$312	$316	$320	$328	$337	$345	**$353**	**$362**	$370	$378
$32,500	$324	$328	$332	$336	$340	$345	$353	$361	$370	**$378**	**$386**	$395	$403
$35,000	$348	$352	$357	$361	$365	$369	$377	$386	$394	**$402**	**$411**	$419	$427
$37,500	$373	$377	$381	$385	$390	$394	$402	$410	$419	**$427**	**$435**	$444	$452
$40,000	$397	$402	$406	$410	$414	$418	$427	$435	$443	**$452**	**$460**	$468	$477
$42,500	$422	$426	$430	$435	$439	$443	$451	$460	$468	$476	$485	$493	$501
$45,000	$447	$451	$455	$459	$463	$467	$476	$484	$492	$501	$509	$517	$526
$47,500	$471	$475	$480	$484	$488	$492	$500	$509	$517	$525	$534	$542	$550
$50,000	$496	$500	$504	$508	$512	$517	$525	$533	$542	$550	$558	$567	$575

Required Monthly Revenue/Space													
Hourly Rate Required	**Turns/ Day**	**Days/ Year**	**$25**	**$50**	**$75**	**$100**	**$150**	**$200**	**$250**	**$300**	**$350**	**$400**	**$450**
Weekday only	2	250	**$0.30**	**$0.60**	$0.90	$1.20	**$1.80**	**$2.40**	**$3.00**	$36.0	**$4.20**	**$4.80**	**$5.40**
	3	250	**$0.20**	**$0.40**	$0.60	$0.80	**$1.20**	**$1.20**	**$2.00**	$2.40	**$2.80**	**$3.20**	**$3.60**
Weekday and Saturdays	2	300	**$0.25**	**$0.50**	$0.75	$1.00	**$1.50**	**$1.50**	**$2.50**	$3.00	**$3.50**	**$4.00**	**$4.50**
	3	300	**$0.17**	**$0.33**	$0.50	$0.67	**$1.00**	**$1.00**	**$1.67**	$2.00	**$2.33**	**$2.67**	**$3.00**
7 Days per Week	2	360	**$0.21**	**$0.42**	$0.63	$0.83	**$1.25**	**$1.25**	**$2.08**	$2.50	**$2.92**	**$3.33**	**$3.75**
	3	360	**$0.14**	**$0.28**	$0.42	$0.56	**$0.83**	**$0.83**	**$1.39**	$1.67	**$1.94**	**$2.22**	**$2.50**
Average stay: 2 hours			**Surface Lot**				**Above-Grade Structure**				**Below-Grade Structure**		

Interest Rate = 7%

project has been added to Table 11-21. Note that both the annualized capital cost per space as well as the cost per added space is given along with the revenue that must be generated from each space.

Option A, building on a site already owned but without parking, is the most cost-effective at $3,450 per added space. Option B assembles a site by acquiring a full block of older tract housing and developing a 500-space surface lot. Land acquisition and demolition costs $14 per sq. ft. ($150 per m^2) and construction results in a cost per added space of

Table 11-21. Comparison of Parking Alternatives							
	Site A	**Site B1**	**Site B2**	**Site C**	**Site D**	**Site E**	**Site F**
Footprint (m)	80 m by 200 m	80 m by 200 m	80 m by 200 m	36.5 m by 76 m	36.5 m by 76 m	36.5 m by 76 m	24.5 m by 76 m
Footprint (ft.)	263' by 658'	263' by 658'	263' by 658'	263' by 658'	120' by 250'	120' by 250'	80' by 250'
Existing Parking	none	none	none	none	100	none	none
Land required?	no	yes	yes	no	no	yes	yes
# spaces	500	500	500	500	500	500	500
# floors	surface	surface	surface	6 levels	7 levels	6 levels	6 levels
Land Cost /sq. m		$150	$300	-		$300	
Land Cost /sq. ft.	-	$14	$28	-	-	$28	
Const. Cost/Space	$3,000	$3,000	$3,000	$12,500	$12,500	$12,500	$25,000
Const. Costs	$1,500,000	$1,500,000	$1,500,000	$6,250,000	$7,500,000	6,250,000	$12,500,00
Land Acquisition (site 10% larger)	-	$2,640,000	$5,280,000	-	-	$915,420	
Other Costs 15%	$225,000	$621,000	$1,017,000	$937,500	$1,125,000	$1,074,813	$1,875,000
Total Cost	**$1,725,000**	**$4,761,000**	**$7,797,000**	**$7,187,500**	**$8,625,000**	**$8,240,233**	**$14,375,000**
Cost Per Space	**$3,450**	**$9,522**	**$15,594**	**$14,375**	**$14,375**	**$16,480**	**$28,750**
Cost Per Added Space	**$3,450**	**$9,522**	**$15,594**	**$14,375**	**$17,250**	**$16,480**	**$28,750**
Financed Amount 10%	$1,897,500	$5,237,100	$8,576,700	$7,906,250	$9,487,500	$9,064,256	$15,812,500
Annual Cost of Project 7%	$270,161	$599,964	$929,767	$746,294	$895,553	$855,602	$1,492,588
Annual Capital Cost per Space	$540	$1,300	$1,860	$1,493	$1,492	$1,711	$2,985
Annual Operating Cost per Space	$200	$200	$200	$650	$650	$750	$400
Total Annual Cost per Space	$740	$1,400	$2,060	$2,143	$2,143	$2,461	$3,385
Monthly Revenue Per Space to Break Even	$62	$117	$172	$179	$179	$205	$282
Hourly Cost							
3 turns/day, avg. stay 1.5 hours, 250 days a year	$0.66	$1.24	$1.83	$1.90	$1.90	$2.19	$3.01
4 turns/day, avg. stay 1.5 hours, 300 days a year						$1.37	

about $9,500 for Option B1. If, instead, the land costs $28 per sq. ft. ($300 per m^2) as in B2, the cost per added space jumps to almost $15,600. Option C develops a structure on part of the surface parking in Option A; the cost per space and the cost per added space are identical at $14,375, and thus more cost-effective than buying the expensive property for a surface lot as in B2. Option D develops a structure on the site of an existing 100-space parking lot. A 600-space, seven-level structure would be required to add 500 spaces, at a project cost of $17,250 per added space, $2,875 more per added space than option C.

For illustrative purposes, two additional options have been included. The first is option E, acquiring a smaller portion of the B2 site, and building a six-level structure for 500 spaces with a land cost of $28 per sq. ft. ($300 per m^2).

This option has a project cost of almost $16,500 per added space, which is less than the cost per added space of D. If it is possible to use the deck in the evenings and weekends by customers of area businesses, the overall cost to the hospital for structured parking would be considerably reduced. Option F builds a high-rise, mechanical access garage on part of the site used in Option C, which is an owned, unused parcel. The cost per added space is nearly twice the cost of the self-park facility.

As noted, building surface parking on already owned vacant land is the most cost-effective, but it is often the least realistic; few owners with parking problems would likely have this much undeveloped land available. It might be easier to find a location on an existing medical campus for the structure in Option C, which is similarly the most cost-effective among the structure alternatives. Building a surface lot on low-cost land is also very cost-effective. It has the added advantage of "banking the land" for future expansion of the hospital. It is, however, more expensive to buy land at about $28 per sq. ft. ($300 per m^2) to build a lot than it is to build a 500-space structure per C, but it is more cost effective than D.

X. FINANCING PARKING FACILITIES

Parking facilities can be financed by public agencies, private sector investment groups, or a combination of public-private groups. Business improvement districts, or special benefit assessment districts, are sometimes used to finance parking improvements when authorized by law. Land for parking can be acquired by purchase, lease, condemnation, dedication by land developers or donation. Other means of land acquisition include reclamation, multiple use of public lands, and air rights.

Parking facilities are difficult to finance because they are specialized and uniquely subject to changes in the parking demand of the generators they serve, which in turn make them relatively high risks in the eyes of the financial markets. Lenders and investors are concerned with both the strength and the longevity of the intended market for facilities as well as the possible alternative users or uses of the facilities. In most cases, the general credit of the owner will be equally, if not more, important than the projected revenue and expenses of the parking facility itself.

When a parking facility is constructed as part of a private development, it is generally a relatively minor part of the project financing package. Lenders may be more interested in the number of spaces provided being adequate to market the retail or office space, for example, than in the line item projections for parking revenues and expenses in the project pro forma.

Few, if any, facilities financed with public bonds can show adequate coverage of the debt service to be secured solely by the parking revenues of the facility itself. These difficulties often necessitate approaches such as using general obligation (GO) bonds or system revenue bonds. The lenders will typically be far more interested in either the credit rating of the municipality (in the case of GO bonds) or the finances of the parking system as a whole (with revenue bonds) than in the projections of revenues and expenses for the parking facility itself.

Conversely, in those situations where a parking facility can be profitable, the financial markets have seen investment opportunity. Parking-centered real estate investment trusts have been established, and several commercial parking operators have done initial public offerings on the various stock exchanges. The key to these investments has been a careful assessment of the strength of the parking management team and the assets—both owned properties and long-term leases and contracts for managing properties.

The most likely sources of public funds to support a parking facility include:

- General fund/obligation of the city, county, or state.
- Revenue bonds secured by revenues from other parking facilities and meter revenues.
- In lieu and impact fees.
- Taxes, including:
  - Ad valorem (property taxes; most general fund pledges are ad valorem).
  - Special assessment district (where property owners are taxed to supply any deficits).

- Tax increment district (the additional sales and property taxes generated by private redevelopment in the district are dedicated to paying for associated municipal expenditures).
- Sales taxes in a defined or general area.
- Hotel and lodging taxes in a defined area.

Other revenue sources such as grade-level retail space income, development fees, or income from air rights can help to finance parking facilities.

A. Types of Public Financing

When public financing is contemplated, a key decision must be made on the type of bonds to be issued. Table 11-22 summarizes the four main types of public parking financing and some of the key issues related to each. The cost of financing with a GO bond—backed by the full faith and credit of the governmental entity—either as the sole pledge

Table 11-22. Municipal Bonds for Parking

	General Obligation Bonds	Revenue Bonds	General Obligation Revenue Bonds	Certificates of Participation
Definition	Pledge the full faith and credit and unlimited taxing power to pay debt service.	Pledge the revenues of a specified source to pay debt service. Additional assurances are covenanted within the bond documents.	Pledge specified revenues and the issuer's full faith and credit and unlimited taxing powers.	A government agency enters into an agreement with another party (lessor) to lease an asset. Lease payments are sufficient to pay the purchase price and associated interest cost of acquiring the asset.
Source of payment	Property taxes	Specified revenues	Specified revenues and property taxes	Tax revenues subject to annual appropriations (budget process)
Purposes	Projects that benefit the whole community	Projects that benefit specific users	Whole community and/or specific areas	
State law/Charter	Debt limit? Voter approval required?	Debt limit? Voter approval required?	Debt limit? Voter approval required?	Not subject to debt limit No voter approval required
Risk/Cost	Highest security-lowest cost	Higher than general obligations because of limited revenue stream. The degree of risk depends on the individual financing package. Investors require coverage usually in the range of 125% to 200%.	Same as general obligation bond	Higher than general obligation depending on essentiality of project/use.
Credit rating impact	Full impact	Credit rating is dependent on the degree of security the financing package has. The credit rating for a revenue bond is independent of an issuer's general obligation rating.	Usually a full impact on the credit rating. May be mitigated depending on the revenue stream.	Full impact, usually half grade to full grade lower than general obligation bond.

Source: Schaefer, T. "Municipal Bond Basics for Parking Providers," Springsted Public Finance Advisors or as a back-up to specified revenues will usually be significantly lower than with pure revenue bonds—backed solely by a specified stream of parking revenue.

In the former case, the lenders will be principally interested in the credit rating of the issuing municipality or entity. With revenue bonds, lenders typically require that there be coverage or a margin of safety by which either gross or net revenue exceeds the annual payment of debt service. Projected pledged net revenues after operating expenses generally must be 1.25 to 2 times the annual debt service to gain capital market access through revenue bond financing. Additionally, the lender may impose what can be significant covenants on parking revenue bonds, including:

- *Debt service reserve fund*—The entity is required to maintain a fund with an amount sufficient to pay one year's debt service (federal tax laws set a three-fold limit).
- *Operating reserve fund*—The entity is required to maintain a fund of two to three months' operating expenses.
- *Capital maintenance fund*—The entity is required to maintain a fund for periodic major maintenance and restoration so the parking facility can continue to generate sufficient revenue to repay the bonds.
- *Parking rate covenant*—Knowing that, historically, parking demand can be volatile and/or municipalities may have failed to raise rates sufficient enough to keep pace with inflation of costs, lenders may impose a requirement that rates will be adjusted as required to pay operating expenses and maintain all required reserve funds.

The disadvantages to GO bonds are that: (1) they often require voter approval and (2) most jurisdictions have many competing demands on their GO pledge from non-revenue-generating facilities (for example, local government services, schools, parks). Special assessment and tax-increment bonds may be attractive to the municipality and the general public because there is no burden placed on the typical homeowner; however, opposition from the affected taxpayers or tax receiving agencies (such as school districts) can make acceptance of these districts difficult.

A key concept of net revenue bonds is that operating expenses are paid first to protect the revenue-generating capacity of the facility. A gross revenue bond presumes a third party will guarantee the revenue generating capacity.

Cooperation between public agencies with bond authority may also be used to structure a financing strategy. Lease revenue and economic development bonds may be issued whereby one tax-exempt agency constructs the facility and leases it to the other, subject to statutory powers. The lease payments become a contingent liability on the leasing agency's balance sheet, contingent on the terms of the lease.

Certificates of participation (COPs) are a lease arrangement that still qualifies for tax-exempt bonds if the appropriate tests are met. The private entity is the developer, lessor, and nominal owner of the facility, while the public agency leases the facility for a specified term. The public agency may operate the facility or may retain a parking management firm to operate it. The title to the completed parking facility is in the name of the public agency and held by a trustee over the term of the lease. The purchasers or investors in the COPs provide the funds for the construction and are repaid from the lease payments. Generally, COPs are backed by a pledge of the public entity to pay the lease from general funds if parking revenues are insufficient to repay the bonds. While not a GO, the credit rating of the municipality would be seriously affected by a failure to appropriate funds to pay the lease. These bonds can achieve an investment grade rating with a great deal of flexibility and without the restrictions of GO bonds. They are, thus, an attractive form of public financing for parking facilities.

B. Tax-Exempt Bond Requirements

Another critical decision that must be made early is whether tax-exempt or taxable bonds can be used. While a bond counsel should review all proposed projects for conformance, the following outlines the general requirements that must be met to use tax-exempt bonds:

- Not less than 90 percent of the spaces must be available to the general public on a daily, monthly or yearly basis, excepting only governmental and not-for-profit institutional uses. If monthly spaces are offered on a first-come, first-served basis, but many or even most of them are leased by employees of a single corporation, this is still generally considered public use. Complications arise with agreements to lease parking spaces directly by a single corporation itself.

- Not less than 95 percent of the bond proceeds must be spent on the public parking facility. This test can be complicated where a public-private joint development occurs, and it is difficult to trace the uses of the funds. For example, a public parking facility is to be constructed with street-level retail leased to tenants and apartments built in the air-rights. The parking spaces are shared and serve area parkers in the daytime and the residents at night. How much of the land acquisition, foundation, and site utilities—much less the construction cost of the parking facility—can or should be allocated to the parking facility and how much to the private development components?
- No more than 10 percent of the annual debt service may be paid for or guaranteed by a corporate or non-public entity. Thus, when revenue from retail or air-rights development is expected to help repay the bonds, it may comprise no more than 10 percent of the total revenue stream to retain tax-exempt financing. Also, even if all spaces are to be used by the public on a daily fee basis, the bonds cannot be guaranteed by a corporation in excess of this threshold to reduce the municipal or investor risk without losing the tax-exempt status.
- Agreements for the management and operation of the facility may not exceed a 5-year term, must provide for payment to the operator by either a periodic fixed fee or fixed percentage of the gross revenue and must give the public entity the option to cancel at the end of any 2-year period. Because concession-style and long-term agreements cannot be used with tax-exempt financing, the interest in and viability of leaseback arrangements with commercial parking operators has been sharply reduced.

Obviously, the structure of the public/private partnership is critical to obtaining tax-exempt financing, which can carry an annual interest rate of as much as 2 percent less than taxable financing. Combinations of taxable and tax-exempt bonds can still be issued for public-private developments where the strict tests for tax-exempt bonds cannot be met (for example, a taxable series of bonds funds from a garage leased or reserved for a private entity, while the tax-exempt series goes toward the public portion of the garage). Also, tax increment districts with single- or limited-development projects may run afoul of the test relating to sources of funds for repayment of the bonds, jeopardizing tax-exempt financing.

C. Sizing a Bond Issue

The typical bond issue includes a number of different elements. As discussed previously, construction cost, land acquisition and related design fees, and miscellaneous expenses are considered part of the project cost. The total project cost will typically be 10 to 15 percent greater than the land and construction cost. There are also costs of issuance for counsel, printing, rating agency and trustee fees, and closing costs that are typically 0.05 to 1 percent of the amount financed. Other expenses related to the issuance include the underwriter's spread and bond insurance, which can help hold down the interest rate.

It is typical for bond issues to be sold before the start of construction. Much of the preparatory and design costs may have already been incurred; therefore, it is important to carefully track such expenses for incorporation in the bond amount. Because the first bond payment may occur during construction or before sufficient revenues occur to pay the first payment, it is common to structure the bond payments to defer principal payments for a year or two and to include in the bond an amount sufficient to make interest payments in that period. This is known as capitalized interest. When bonds are not sold early in the process, bond anticipation notes may be issued that provide the necessary funds for cash flow until the bonds are sold. Interest on this interim financing would then be included in the permanent financing.

Conversely, because the bond funds are paid to the municipality, they may be invested until required to pay contractors. A National Parking Association study found that owners should estimate the potential interest earned during the construction draw down using percentage curves given in the study rather than a straight-line monthly draw down. [Heeseler and Arons, 1984] Also, there would be interest earned during the first year on the debt service reserve and the capitalized interest. These deductions from the bond amount help to moderate the overall total of funds to be borrowed.

XI. SUMMARY

Parking is an essential complement to transportation systems and land development. The planning, design, and pricing of parking facilities have been concerns of communities, property owners, and providers of goods and services since the early days of travel. Planning parking facilities calls for addressing key questions, including where parking should be located, how much parking should be provided, what type of parking should be developed, what the costs will be, how the parking will be financed and managed, and how best to integrate parking facilities into the urban setting.

This chapter has presented material on the planning, operating, and financing of parking facilities. Of all the options available to public officials for influencing urban development and transportation strategy, managing the parking supply is the most influential—and likely the most controversial. Parking can be a significant portion of a development's cost, so strategies to reduce this cost are welcomed by developers, subject to the requirements related to the financial feasibility of the project. Transportation planners should understand the basic structure of the parking supply in a study area, the different types of policy and planning strategies that could influence the use of this parking and the degree to which changing parking will be politically feasible. There are many examples in the U.S. and in other countries where parking actions are integrated into much broader regional transportation and urban development strategies. The Puget Sound Regional Council (PSRC), for example, has developed a parking management checklist that planners can use to determine how parking fits into broader community goals (see [PSRC, 2003]). Such integration is the desired approach toward a comprehensive transportation strategy for a community or metropolitan area.

Litman [2006] has developed the following list of parking management principles that best summarize the major content of this chapter. The principles to support parking management include:

- *Consumer Choice*—People should have a variety of parking and travel options from which to choose.
- *User Information*—Motorists should have information on their parking and travel options.
- *Sharing*—Parking facilities should serve multiple users and destinations.
- *Efficient Utilization*—Parking facilities should be sized and managed so spaces are frequently occupied.
- *Flexibility*—Parking plans should accommodate uncertainty and change.
- *Prioritization*—The most desirable spaces should be managed to favor higher-priority uses.
- *Pricing*—As much as possible, users should pay directly for the parking facilities they use.
- *Peak Management*—Special efforts should be made to deal with peak demand.
- *Quality versus Quantity*—Parking facility quality should be considered as important as quantity, including convenience, comfort, aesthetics, and security.
- *Comprehensive analysis*—All significant costs and benefits should be considered in parking planning.

Some useful guides on parking management strategies include: [Willson, 2000; DVRPC, 2004; MTC, 2007, 2015; Litman, 2008, 2013a, 2013b, 2014, 2015; Weinberger et al., 2010; CMAP, 2013; Meier et al., 2015; Maryland Governor's Office of Smart Growth, Undated; U.S. EPA, undated]

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Transit Planning[1]

I. INTRODUCTION

Transit services provide mobility and accessibility in communities of all sizes. In large cities, transit services carry volumes of trips that could not be handled efficiently by other modes of transportation, especially to and from major activity centers such as central business districts (CBDs). Private cars, vans, or taxis would have great difficulty serving passenger travel effectively in cities like Toronto, Ontario; New York City; San Francisco, California; and Washington, DC, given the limited road network and the amount of travel, especially during peak periods. The presence of public transit can also affect land-use patterns and directly influence the quality of life in such cities. Vibrant urban areas like Denver, Colorado; Portland, Oregon; Salt Lake City, Utah; or Vancouver, British Columbia, are made viable by excellent transit systems that provide convenient transit service throughout the city. Large cities are livable and desirable places to live in part because of high-capacity transit systems.

In midsized cities, transit can play an important role in facilitating access to all major activity centers, thus reducing car dependency, traffic congestion, and parking demand. And in small U.S. and Canadian cities, where auto ownership rates are very high, transit can serve a social service function. In these communities, many riders who are physically or economically unable to travel by private automobile, such as the young, elderly, and low-income families, use transit as their sole means of mobility. Transit often provides the only means of reaching employment centers, educational opportunities, or life-essential activities such as health care.

Today, transit is increasingly recognized as an element of livability and economic progress in many cities. Federal, state, provincial, and local government investments in transit systems consider not only how many riders will be served, but also transit's role as a factor in the economic development and sustainability of cities. In addition, transit is often viewed as a means of reducing traffic congestion and parking demand in high-density areas.

Since the low point of public transportation ridership in the United States in 1970, the number of cities in the United States and Canada with rapid rail transit (RRT) systems has increased from 7 to 15, 20 cities have introduced new light rail transit (LRT) and modern streetcar systems, and many cities have upgraded bus systems, with at least 12 cities in the United States and 10 cities in Canada having bus rapid transit (BRT) services. In addition, a number of cities have constructed regional (commuter) rail systems, automated guided transit, and people movers, with the most common serving airports. New waterborne transit modes and a variety of demand-responsive services have also been implemented. The result of this investment in transit is that 2014 saw the highest level of public transit ridership in the United States since 1956.

Intermodal integration has been an important policy theme running throughout many of these investments. The concept of seamless travel—in time, space, fares, and information—through coordinated planning of modes and applications of new technologies is a recognized goal of today's comprehensive transit planning. The integration of different transit modes is supplemented by coordinating auto and transit trip interfaces, predominantly through park-and-ride and kiss-and-ride facilities, and by enhancing pedestrian and bicycle access.

The next section discusses different models of transit ownership and governance. This section is followed by a discussion on contemporary transit in North America, including an overview of how the transit industry has evolved over time. The following section provides statistics on transit service, including ridership, trip lengths, and

[1]The original chapter in Volume 3 of this handbook was written by Jeffrey M. Casello, Ph.D., P.E., Associate Professor, School of Planning and Department of Civil and Environmental Engineering, University of Waterloo, and Vukan R.Vuchic, UPS Foundation Professor of Transportation Engineering (retired), University of Pennsylvania. Changes made to this updated chapter are solely the responsibility of the editor.

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operating speeds. One of the distinguishing characteristics of transit planning is the many different modes of transit that are found around the world. The next section presents a classification of transit modes and their components. Costs are always important in any type of service provision, and the next section discusses the cost structure for transit service, followed by an overview of the ways in which system performance and quality of service can be analyzed. This section is followed by a description of typical transit planning procedures, including estimating transit ridership. Passenger stations and stops are an important component of transit systems, and the next two sections describe both the planning process and design approaches for passenger stations. The following section examines network structure and how individual transit lines are combined to form a system. This leads into a discussion of transit route planning and of analysis approaches for assessing route-level performance. The chapter ends with a section on future transit issues.

II. OWNERSHIP AND GOVERNANCE

Beginning in the late nineteenth century, as North American cities grew and expanded outward, walking distances also increased. This created a demand for some form of mass transportation. Because demand was very high, providing transit service became a lucrative and competitive private industry. Competition within the industry, however, had both positive and negative effects on transit system operation and passenger attraction. Service on the highest demand routes, and in the highest demand hours, was often excellent, with many providers competing to capture riders. In off-peak hours or on lightly used lines, service was often less frequent, less reliable, and therefore less desirable. Unregulated competition often resulted in the largest providers establishing unreasonably low fares to drive other providers out of business (cut-throat competition). When a company established a monopoly condition, it would raise fares to very high levels, which riders had to pay due to a lack of competition. Unregulated and competing services also often resulted in poor system integration. Transfers between lines were uncoordinated and inconvenient, requiring multiple wait times and often multiple fares.

By the 1960s, after decades of continued growth in automobile use, many cities had considered or had implemented public takeover of transit services. [Meyer and Gomez-Ibanez, 1981] For example, by 1974, 90 percent of transit trips in the United States were served by public agencies. [Muller, 2004] As with the public provision of many services, the movement toward public ownership of transit systems presented both opportunities and challenges that are still debated today. In principle, a single, public provider of transportation services can advance many of the community objectives inherent in urban passenger transportation. Consolidation leads to improved integration of services, including the formation of areawide transit networks that expand the range and convenience of travel by offering coordinated fares, routes, and schedules. Public ownership also makes government funds for investment in transit infrastructure easier to obtain and to use effectively (note: public ownership does not necessarily mean public day-to-day operation, which in many cases is contracted to private providers). Public ownership means that service decisions can be made with the public welfare in mind. Public ownership of transit service provision has taken many different institutional forms, as discussed below.

A. Local Agency

Some transit agencies are owned and operated by a city government. The benefits of city ownership are that planning, design, and operation are locally controlled and can therefore be better integrated with other municipal functions, such as land-use planning. Disadvantages include stronger budgetary competition for funding among municipal services and the inability to provide transit services outside of the city limits without some form of contracting arrangement.

Some transit agencies are owned and operated by county governments in the United States and regional governments in Canada. Higher-tier government structures have evolved from the need for coordinated transit services across many municipal jurisdictions. In Ontario, for example, a regional government operates the comprehensive and coordinated Grand River Transit system for several cities and townships with a total population of about 500,000.

In a few cases, states own and operate transit agencies outside of the traditional department of transportation. Examples of such statewide transit agencies in North America are found in Delaware, Maryland, New Jersey, and British Columbia.

B. Transit Authority or District

A regional transit authority or district is a more common model for multijurisdictional service in North America. These agencies, created by acts of state legislatures, are given the task of constructing and operating major transit systems. Examples of such systems in U.S. cities include Atlanta, Georgia (Metropolitan Atlanta Rapid Transit Authority [MARTA]); Denver, Colorado (Regional Transportation District [RTD]); Washington, DC (Washington Metropolitan Area Transit Authority [WMATA]) and Philadelphia, Pennsylvania (Southeastern Pennsylvania Transportation Authority [SEPTA]). In some cities, transportation authorities oversee other transportation agencies. New York City's Metropolitan Transportation Authority (MTA) is an example of this. It operates and manages New York City Transit, two regional rail systems (Long Island Rail Road and Metro North), and some major highway facilities. The underlying motivations for creating regional agencies are that they are better able to provide and coordinate multijurisdictional service to larger areas, and in some cases might be in a better position to raise regional funding to support the transit system.

Regional transit districts, such as San Francisco's Bay Area Rapid Transit District (BART), are similar to authorities in their formation and scope of their operations, but differ in one important regard. Districts are usually given the power to tax and thus directly raise revenue for capital investment.

C. Cooperative Arrangements

The need for coordinated and integrated services favors a single agency model for providing transit in a metropolitan area. Several organizational forms, however, are used to allow multiple operators in a region to cooperate and provide integrated services. Transit agencies that provide complementary or adjacent services within an area may form *tariff associations*, where contracts establish fares that are valid on both systems, and methods are agreed to redistribute jointly collected revenue. A *transit community* also offers joint fares that are valid on multiple systems, but extends the arrangement to include coordinated routing and schedules.

The most elaborate integration scheme is known as a *transit federation*. This concept, introduced in Germany in the 1960s, provides not only joint fares and operation among agencies, but also integrated planning of lines and networks. The transit federation may seek funding for capital investments in the systems of individual members. Operationally, members of the federation may jointly utilize their vehicle fleets. In Tokyo, Japan, such fleet-sharing is used extensively for the joint services between the Tokyo Rapid Transit Authority (TRTA) and several railway companies.

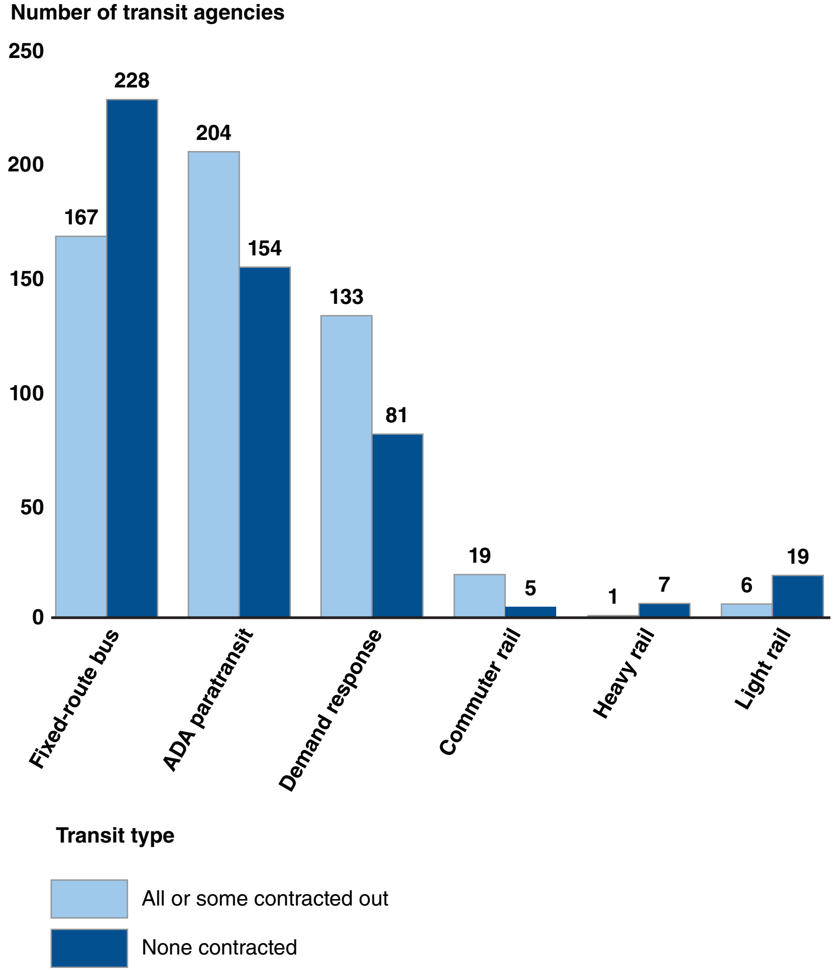
D. Privatization

Public transportation systems in many cities have introduced changes in organizational structure, management style, and labor relations to capture the positive aspects of private (competitive) contracting, while balancing the need for public oversight and the advancement of social goals. This has most often taken some form of privatization. For example, vehicle maintenance, some administrative functions, and most major planning and engineering studies are done by private contractors hired by the public agency. Private operation of paratransit or demand-responsive transit is also common.

More significantly, many transit agencies now use private contractors to provide fixed-route passenger (revenue) service. In 1980, for example, San Diego began using private operators to provide bus services; by 2001, 44 percent of San Diego's bus services were privately contracted. Similarly, Denver began private contracting for its bus service as a result of state legislation in 1988, which required that 20 percent of bus service be tendered. A survey conducted by the U.S. Government Accountability Office (GAO) [2013] identified 463 transit agencies in the United States that contracted out some aspect of their operations. By size of agency, 52 percent of small agencies, 69 percent of medium agencies, and 92 percent of large agencies had at least one service that had been contracted out (see Figure 12-1).

In Europe, competitive services are mandated by the European Commission. For example, Swedish transport law requires that all public transport services be openly bid, but the public agency may also bid to provide the service. Public objectives—service quality, fares and safety, for example—are specified as part of the bid documents. For a review of different privatized tendering practices, see [Hensher, 2007].

Figure 12-1. Contracted Services in U.S. Transit Agencies, 2013



Source: USGAO, 2013

The private contracting of fixed-route public transport has generally shown positive results. In most cases, operating costs have been reduced, though some studies note that the initial benefits of tendering have been later offset by increasing costs to the public agency. The source of the cost reductions is typically reductions in expenses associated with labor.

III. CONTEMPORARY TRANSIT IN NORTH AMERICA

A. Ridership

Transit ridership in the United States has increased since 1990 as measured in both passenger-miles traveled and unlinked passenger trips. Unlinked passenger trips are defined as the number of passengers who board public transportation vehicles no matter how many vehicles they use to travel from origin to destination. For example, a traveler who boards a bus and then transfers to a subway has taken two unlinked passenger trips. As seen in Table 12-1, the number of trips by bus and heavy rail (subways) declined in the first half of the 1990s, but has now recovered. All other modes have seen large gains in trips served in the same period, with the exception of trolleybuses. Commuter rail carried 50 percent more trips in 2014 than in 1990, demand-responsive transit trips grew by 111 percent, and light rail transit (LRT) trips grew by 267 percent in 24 years. Some of the trends contributing to ridership increase have included an increasing population, continued densification in city cores, continued investment in service and infrastructure by various levels of government, and recovery from economic recessions. The shaded areas in Table 12-1 indicate the years where economic recessions occurred in the United States as defined by the U.S. National Bureau

Table 12-1. Trends in U.S. Passenger Trips by Mode

Year	Total Ridership (000s)	Heavy Rail (000s)	Light Rail (000s)	Commuter Rail (000s)	Trolleybus (000s)	Bus (000s)	Demand Response (000s)	Other (000s)
1990	8,956,479	2,420,196	146,443	327,547	in Other	5,740,648	106,984	214,660
1991	8,483,877	2,182,759	170,726	325,186	in Other	5,526,171	72,108	206,927
1992	8,555,107	2,064,773	162,994	326,443	in Other	5,699,502	98,116	203,280
1993	8,452,120	2,172,905	168,451	329,591	125,464	5,487,952	94,119	73,639
1994	8,450,736	2,278,945	232,884	349,542	118,524	5,284,821	98,024	87,994
1995	8,490,116	2,181,997	243,403	352,312	116,759	5,416,852	94,533	84,261
1996	7,930,132	2,067,370	269,479	361,532	117,187	4,955,427	81,575	76,726
1997	8,106,214	2,201,070	261,619	368,198	118,573	4,992,529	83,513	80,713
1998	8,697,183	2,562,799	278,779	378,595	117,424	5,160,836	103,001	95,749
1999	9,057,962	2,685,998	286,671	393,662	126,469	5,360,392	107,791	96,864
2000	9,403,443	2,688,025	293,215	411,840	122,451	5,679,265	110,861	97,785
2001	9,504,693	2,729,836	310,612	420,680	112,253	5,719,321	112,639	99,172
2002	9,386,941	2,706,211	317,653	411,449	118,810	5,611,975	117,366	103,477
2003	9,427,056	2,651,271	321,239	406,802	108,113	5,711,407	123,205	105,019
2004	9,603,746	2,729,449	341,450	408,407	107,617	5,799,837	118,029	98,957
2005	9,708,337	2,742,403	362,689	423,323	104,554	5,842,240	117,844	115,284
2006	10,046,406	2,908,948	406,980	436,780	103,007	5,940,304	127,407	122,980
2007	10,270,589	3,450,429	429,765	455,118	102,868	5,429,322	210,650	192,437
2008	10,597,931	3,570,826	462,122	475,739	106,314	5,605,445	193,582	183,904
2009	10,257,889	3,476,969	457,118	451,879	99,925	5,370,880	189,434	211,685
2010	10,172,352	3,530,639	464,978	452,791	99,064	5,231,478	202,899	190,503
2011	10,394,405	3,672,244	490,462	470,405	97,962	5,272,503	191,906	198,922
2012	10,537,156	3,702,081	507,082	466,101	97,870	5,362,928	211,180	189,915
2013	10,656,570	3,808,781	518,911	476,233	92,623	5,358,779	212,024	189,219
2014	10,753,151	3,935,271	537,115	489,692	92,994	5,280,348	225,418	192,313

Note: The numbers are not contiguous for bus, demand response, and other from 2006 to 2007. A methodology change shifted trips from bus to demand response and other. Other includes aerial tramway, automated guideway, cable car, ferryboat, inclined plane, monorail, and vanpool.

Note: Areas shaded indicate economic recessions.

Source: APTA, http://www.apta.com/resources/statistics/Documents/Ridership/2014-q4-ridership-APTA.pdf, Reproduced with permission of the American Public Transportation Association.

of Economic Research. As shown, ridership is likely to decline during economic recessions as the number of people employed declines as well.

As shown in Table 12-2, total passenger-miles by rail increased between 1990 and 2013, with commuter rail increasing by 80 percent. LRT and demand-responsive (such as dial-a-ride) passenger-miles grew more rapidly, with LRT growing from 350 million in 1990 to more than 2.5 billion in 2013, for a total increase of 663 percent during the period. Passenger-miles traveled by demand-responsive modes grew from approximately 364 million in 1990 to nearly 852 million in 2012, a 134 percent increase.

Table 12-3 shows the number of passengers carried on an average weekday in the third quarter of 2015 for the top 12 transit systems in the United States and Canada. This table includes all of the systems in a particular metropolitan area that report ridership statistics to the American Public Transportation Association (APTA). About half of all transit trips in the United States are served by 10 major transit agencies, with transit services in the New York City metropolitan area having by far the largest transit ridership in North America.

Table 12-2. Trends in Total U.S. Passenger-Miles Traveled by Mode (Millions)

Year	Heavy Rail	Light Rail[a]	Commuter Rail	Trolley bus	Bus	Demand Response	Ferry	Other
1990	10,427	350	6,534	306	21,161	364	U	439
1995	10,668	833	7,996	187	18,832	577	260	232
2000	12,902	1,190	8,764	186	18,684	559	295	699
2005	14,418	1,700	9,470	173	19,425	738	359	842
2006	14,721	1,866	10,359	164	20,390	753	360	891
2007	16,138	1,930	11,137	156	20,388	778	381	966
2008	16,850	2,081	11,032	181	21,198	844	390	1,156
2009	16,805	2,196	11,129	168	21,100	881	365	1,254
2010	16,407	2,173	10,774	169	20,570	874	389	1,272
2011	17,317	2,363	11,314	160	20,559	879	389	1,347
2012 (R)	17,516	2,316	11,121	162	20,060	887	402	2,705
2013	18,005	2,565	11,736	156	18,796	852	402	3.966

KEY: N = data do not exist; R = revised; U = data are unavailable.

[a]Beginning in 2011, Light rail includes Light Rail, Street Car Rail, and Hybrid Rail.

Source: USDOT, Bureau of Transportation Statistics, http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_40.html.

Table 12-3. The Top 12 North American Transit Ridership Metropolitan Areas, Average Weekday Ridership, 3rd Quarter, 2015

Metropolitan Area Served	Average Weekday Ridership
New York City	12,027,000
Toronto	2,569,000
Chicago	1,958,000
Montreal	1,931,000
Los Angeles	1,426,000
Washington, DC	1,344,000
Boston	1,326,000
San Francisco	1,184,000
Vancouver, BC	1,172,000
Philadelphia	984,800
Calgary	545,900
Seattle	531,900

Note: Ridership is estimated from APTA reports for all systems in the city designated in the reports. Philadelphia, for example, had 6 different systems reporting for Philadelphia ridership.

Source: APTA, 2015 Ridership Statistics, http://www.apta.com/resources/statistics/Documents/Ridership/2015-q3-ridership-APTA.pdf. Reproduced with permission of the American Public Transportation Association.

B. Trip Lengths and Operating Speeds

Table 12-4 shows U.S. national characteristics for average trip lengths and vehicle operating speeds for all major transit modes. Operating speeds reflect the degree of right-of-way separation for the different modes as well as the time it takes passengers to get on and off the vehicle. Buses and trolleybuses, which operate in mixed traffic, have the lowest average operating speeds, 12.8 miles per hour (mph) (20.4 km/hr). LRT and BRT mostly use rights-of-way separated from general traffic, and therefore operate at a higher average operating speed, 15.7 mph (25.1 km/hr). Heavy-rail

Table 12-4. Average Trip Lengths and Operating Speeds for Major U.S. Modes, 2012		
	Average Trip Length (miles)	Revenue Service Speed (mph)
Bus	3.9	12.8
Trolleybus	1.6	7.1
Light Rail	5.2	15.7
Heavy Rail	4.7	20.0
Demand Response	8.3	15.3
Commuter Rail	23.7	32.8

Source: APTA, 2014a, Reproduced with permission of the American Public Transportation Association.

Table 12-5. Utilization Rates for U.S. Transit Modes, 2012		
Mode	**Passenger-Miles per Revenue Vehicle-Mile**	**Passenger-Miles per Revenue Vehicle-Hour**
Bus	10.4	132
Trolleybus	14.3	101
Light Rail	25.5	400
Heavy Rail	27.5	551
Demand Responsive	1.2	17
Commuter Rail	35.0	1153

Source: *APTA Fact Book*, http://staging.apta.com/resources/statistics/Documents/FactBook/2014-APTA-Fact-Book-Appendix-A.pdf, Reproduced with permission of the American Public Transportation Association.

systems operate on exclusive rights-of-way only, and have station spacings much farther apart than LRT and (often) BRT systems, and thus have an average operating speed of 20.0 mph (32.2 km/hr). Buses, light rail, and heavy rail serve trip lengths averaging 3.9, 5.2, and 4.7 miles (6.3, 7.4, and 7.6 km), respectively.

Demand-responsive systems serve much longer trips, averaging 8.3 miles (13.4 km), but at slightly lower speeds than heavy-rail or light-rail systems. Commuter rail networks, as is their function, serve longer trips (a 23.7 mile [38.1 km] average trip distance) at much higher speeds (an average speed of almost 33 mph or 53 km/hr).

The ratio of passenger-miles traveled to revenue vehicle-miles (or vehicle-hours) operated offers insight into vehicle loadings (utilization) and trip lengths. A revenue vehicle-mile is defined as a mile traveled while the vehicle was providing service (for example, this does not include dead-head miles to and from starting point). Table 12-5 shows these ratios for all modes using the average values from 2012. Demand-responsive transit services averaged approximately 1 passenger-mile per vehicle-mile and 17 passenger-miles (27.5 passenger-km) per revenue vehicle-hour. These utilization rates result from low vehicle capacities and dispersed origins and destinations. At the other end of the spectrum, commuter rail systems averaged 35 passenger-miles per vehicle-mile and 1,153 passenger-miles (1,856 passenger-km) per vehicle-hour because of the larger vehicle capacity, high operating speeds, and a more focused route structure. Other modes show utilization rates that are consistent with their typical vehicle capacities.

IV. CLASSIFICATION OF TRANSIT MODES AND THEIR COMPONENTS

Transit modes are defined by their rights-of-way, technologies, and operational characteristics.

Right-of-Way. In most cases, right-of-way interacts with transit technology and influences the type of service, costs, and performance characteristics of a transit mode. There are three basic categories of right-of-way (ROW):

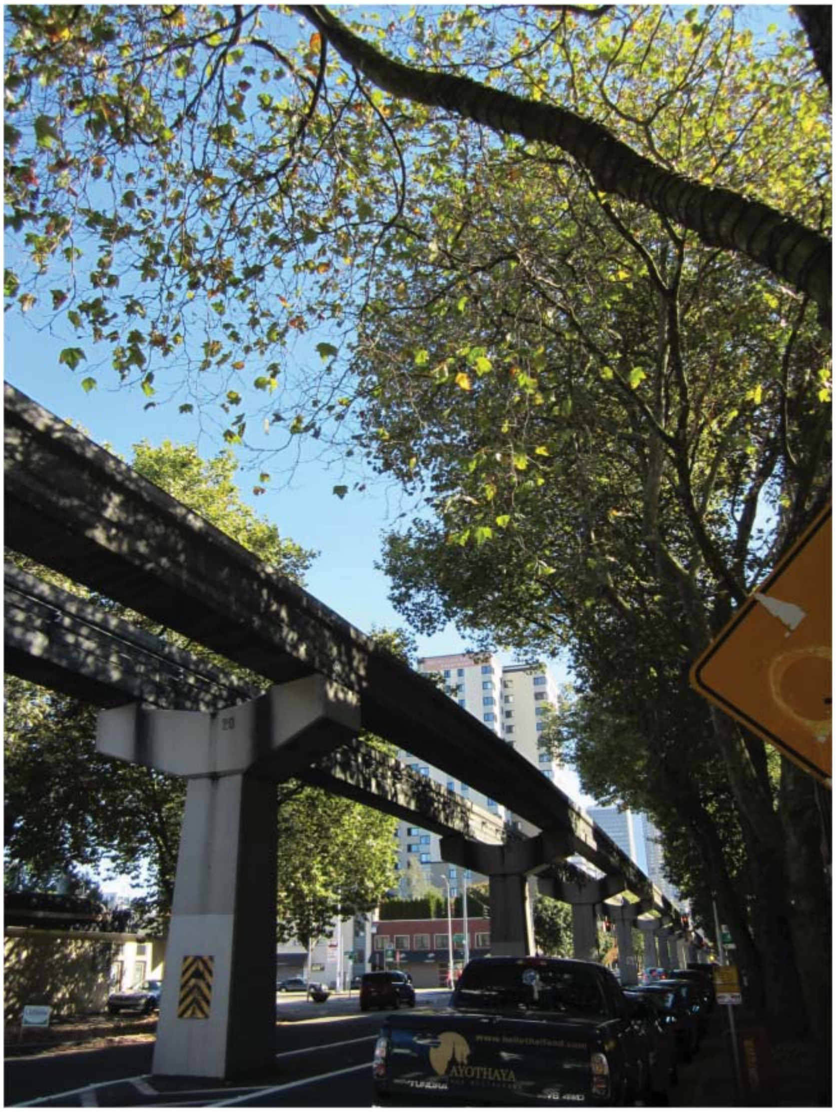
- Category A is defined as physically separated and fully access-controlled ROW without intersections or legal access by other vehicles or persons. These exclusive paths can be designed with alignments on aerial structures, in tunnels, or at-grade with physical separation from other travel flows (see Figure 12-2).
- Category B includes ways that are longitudinally separated from other traffic, as shown in Figure 12-3, but are subject to traffic controls at intersections. Pedestrians may also cross the transit right-of-way in some locations.

Figure 12-2. Types of Full Grade Separation, ROW Category A. (a) Transit tunnel in Seattle, (b) Automated transit in Dubai, (c) Light rail transit in Los Angeles, (d) Monorail in Seattle.

(a)

(b)

(c)



(d)

Photos 12a to c courtesy of Michael Meyer; Photo 12d courtesy of Amanda Wall Vandegrift

Figure 12-3. Longitudinally Separated Transit Way with Crossings Permitted, ROW Category B. (a) Tram in Rotterdam, Netherlands; (b) Streetcar in Portland, Oregon; (c) Bus in transit mall, Denver, Colorado

(a)

(b)

(c)

Figure 12-4. Mixed-Use Transit Right-of-Way, Category C. (a) Tram in Melbourne, Australia; (b) Streetcar in Amsterdam; (c) Light Rail in Portland, Oregon

(a) (b) (c)

Photos courtesy of Michael Meyer

- Category C represents transit operating on streets in mixed traffic (see Figure 12-4). It is the lowest cost and least impacting alternative, but because transit vehicle movement is dependent on the flow of general traffic, category C offers the lowest service performance. In some cases, category C performance may be improved by incorporating transit priority elements such as queue jump lanes (short lanes enabling transit vehicles to move past areas of congestion to more easily access intersections) and transit signal priority (enabling transit and emergency vehicles to hold green lights at intersections or truncate red lights).

As the degree of separation between travel modes increases from category C to category A, the performance (speed, capacity, and reliability) of the transit system improves, but investment costs also increase.

Glossary of Common Transit Terms

Transit planning uses some unique terms, many of which derive from transit's rail origins. Some common terms used in this chapter include:

- *Consist*—A consist includes more than one transit vehicle connected to provide a multi-vehicle train.
- *Deadhead*—When a vehicle travels not in service, most commonly between the transit storage facility and the start or end of service (garage deadhead) but sometimes between the terminus point of one route and the start of another (interline deadhead).
- *Dwell*—The time when a transit vehicle is in service but not moving. Sometimes used to describe time waiting at an intersection but more commonly used to refer to waiting time at a stop or station while passengers board or alight or the vehicle waits for the scheduled departure time.
- *Headway*—Literally the space or time between vehicles but often used to describe the frequency of service; a route operating on a "15-minute headway" has a service frequency of 15 minutes. Headway is the inverse of frequency. A 15-minute headway means a (60 mins/15 mins) or 4 buses per hour frequency.
- *Layover*—Also referred to as "recovery time," an additional buffer of time built into schedules at the end of trips (or at major midpoint transfer locations) to account for delays and ensure that the next trip or trip segment departs on time.

Technology. Transit mode technology refers to the physical components of vehicles and guideways. A vehicle or consist, a term that represents one or more vehicles coupled together, is the key supply-side unit of analysis. There are four fundamental technological components.

Support is the vertical contact between the vehicle and riding surface that supports the vehicle weight. Most commonly, vehicles are supported by rubber (pneumatic) tires on pavement or by steel wheels on steel rails.

The way in which vehicles are guided is described as their *guidance mechanism*. Buses and other highway vehicles are steered by a driver, while rail and other transit vehicles using fixed guideways are guided by their travel way and special guidance wheels.

The third component of transit technology is the *propulsion source* and the *transfer of tractive force*. Typically, transit vehicles are powered either by an internal combustion engine, usually diesel, or by electric motors. Compressed natural gas (CNG) and hybrid vehicles have been increasingly used during the past decade. The manner in which the motor force is transferred to move the vehicle is typically through friction between the rubber tires or steel wheels and the riding surface. Other propulsion technologies include linear induction motors, which use magnetic forces to accelerate the vehicle.

Vehicle control or the means for determining speeds and maintaining longitudinal spacing between vehicles/consists is the final technology component. Vehicles/consists may be controlled manually, subject only to the driver's judgment; manually, subject to fail-safe signal systems; or with varying levels of computerized control or feedback to maintain spacing (such as automated vehicle locator systems common on BRT routes). Fully automated, driverless vehicles/consists have preprogrammed computer-controlled acceleration, braking, and stopping. Automated vehicles/consists can only be used on category A rights-of-way.

Operational Characteristics. Transit service varies by the types of lines and trips. Short-haul lines usually operate with high frequency and serve high-density areas such as central business districts (CBDs), campuses, or neighborhoods. *City transit* encompasses most bus and rail lines serving the entire city; *suburban transit* mainly serves suburban areas, connecting them to the core and increasingly to each other; and *regional transit* serves entire metropolitan areas with long distances between stations and operating at high speeds.

Transit service can operate with different stop patterns. Lines that serve all stops/stations are defined as *local services*. For *skip-stop service*, each successive vehicle/consist stops at different stations on a predetermined basis to provide higher operating speed and shorter travel times. Finally, *express services* stop only at a few stations along a line, usually operating along the same path as local transit service, which serves all stations. Express service may have separate tracks/lanes or may use the same alignments as local service, but bypass vehicles/consists stopped at local stations.

Hours of operation is the final distinguishing operational characteristic of transit service. Regular transit usually operates for 16 to 18 hours per day. Commuter transit operates only in peak hours, usually serving highly directional travel. Irregular or special transit services operate only during special events or emergency situations.

A. Definition of Transit Modes

There is no rigorous definition of what differences in right-of-way category, technology, or type of service lead to a separately defined mode. However, it is common to consider systems that differ substantially in one or more performance characteristics as separate modes. For travel demand modeling, this is an important issue in that distinct transit modes must be defined in terms of operating characteristics in order to model traveler mode choice decisions (see chapter 6 on travel demand modeling). Modes are defined here first by right-of-way (ROW) category because the three right-of-way categories—A, B, and C—represent different sets of performance/investment cost packages.

Street transit is a generic classification of modes using ROW Category C. Although street transit includes first- and last-mile shuttles and local circulators, buses, trolleybuses, and streetcars/tramways, regular bus is the most widely considered street transit mode. Buses mainly use internal combustion engines, and employ visual/manual control. Double-deck and articulated buses may also be used for more route capacity. Streetcars/tramways are guided by rails, and streetcars may be coupled to create up to three- or four-vehicle consists, enhancing line capacity and labor productivity.

Semi-rapid transit is a second generic class of modes that mainly utilizes ROW category B, and on occasion, ROW A or C. As such, these modes exhibit a higher performance than street transit modes. Semi-rapid transit includes medium-capacity and medium-performance transit modes such as light rail transit (LRT), most forms of bus rapid transit (BRT), and a number of automated guided transit modes. (In some cities, these rail and bus modes are named rapid transit, although they technically belong in the semi-rapid transit category.)

Rapid transit operates only on category A, has large consists and line capacity, fast speed, great reliability, and enhanced safety. A logical extension of building an exclusive right-of-way for transit is to maximize its capacity and operating productivity through the use of large, electrically powered vehicles coupled in trains. As such, the dominant mode in this category is rapid rail transit (RRT), commonly referred to as metro or heavy rail. A second, much less common form, is a rubber-tired rapid transit system that uses a combination of rubber tires and conventional rails for support and guidance (used, for example, in Montreal; Mexico City; Santiago, Chile; and on several lines in Paris).

Regional rail, also known as commuter rail, is distinguished from RRT by the use of even larger vehicles and higher speeds made possible by operation on railroad alignments with longer interstation spacing. Light rail vehicles (LRVs) may also be used in rapid transit applications, often referred to as light rail rapid transit (LRRT). Examples of this mode with fully automatic operations include the SkyTrain in Vancouver, British Columbia; Metro in Dubai; and the Docklands Light Rail in London. In recent years, some LRT trains have operated on regional and intercity rail tracks for sections of their network.

Several electric rail transit systems operating on category A, including RRT, LRRT, and all automated guideway transit (AGT) services, are fully automated and operate without drivers. As such, AGT and automated people movers (APM) meet the definition of rapid transit by category, but they are not considered rapid transit because of their substantially smaller vehicles and lower line capacities.

Terrain-specialized modes use distinctly different technologies from conventional transit and are designed for operation on very steep terrain, traversing deep valleys and crossing water bodies. Most common forms include funiculars, cable cars, and ferries.

Paratransit services typically use smaller vehicles with low to medium capacity, often built on a truck chassis, which also enables easier procurement of maintenance services in smaller communities. They differ from regular transit because of variable schedules and routings to accommodate individual users' demands.

B. Bus Transit Modes

Bus transit modes consist of internal combustion engine-powered buses and electrically powered trolleybuses running on streets, highways, and sometimes on special rights-of-way. They can operate on most streets with very little special infrastructure. This allows buses, for example, to provide service over extensive road networks. Bus transit also enables service designs targeted to specific markets where rail lines do not exist (see market segmentation in chapter 2). However, buses are subject to traffic conditions and are generally noncompetitive with private cars with respect to service speed and reliability. In some cases, traffic engineering measures giving priorities to buses can be used to improve service reliability, especially at bottleneck points.

Because of their low investment costs, buses are the most economical mode to operate on moderate and lightly traveled transit lines. However, buses have fewer economies of scale than rail lines. With increasing passenger volumes, bus costs per passenger remain relatively constant, so that for heavy passenger volumes, buses become less economical, although many routes will likely have excess capacity during some periods during the day. They also often have a much lower public image and smaller influence on urban development than fixed-guideway systems. The increased infrastructure, passenger amenities, and branding associated with BRT can alleviate this somewhat.

1. Bus Systems

In 2012, there were 1,370 bus, trolley bus, and bus rapid transit systems in the United States, carrying nearly 5.3 billion unlinked trips, or 51.3 percent of all transit trips. [APTA, 2014b] Buses and trolleybuses accounted for about 36.7 percent of the passenger-miles carried on transit.

Buses can be classified by their propulsion systems, body type, size, capacity, and method of guidance (see Figure 12-5).

Propulsion System. The most common propulsion system for buses is the diesel motor. Just more than 67 percent of bus fuel consumption in 2012 was conventional diesel fuel. [APTA, 2013] However, in recent years, bus manufacturers and transit agencies have been attempting to reduce the negative environmental impacts associated with transit buses. [IAPT, 2013] These efforts have led to the addition of emission-reducing technologies to standard motors, including particulate filters for ultra-low sulfur fuels, as well as new propulsion systems and combinations of diesel and electric motors in so-called hybrid vehicles. Alternative fuel vehicles, including (in order of decreasing frequency of use) compressed natural gas (CNG), biodiesel, liquefied natural gas (LNG), propane, and electric (battery-powered) motors, now constitute about 32 percent of energy use for buses operated in the United States. Currently, the

Figure 12-5. Various Bus Vehicle Sizes and Configurations. (a) Articulated bus, Dubai; (b) Double articulated bus, Sweden; (c) Typical transit bus and bus shuttle, Atlanta, Georgia; (d) Double decker bus in Victoria, British Columbia

Photos 12-5a and b courtesy of Michael Meyer; photo 12c courtesy of Phillip Cherry; photo 12d courtesy of BC Transit.

technology exists to fast charge an electric bus for a limited amount of time in operations. In addition, more buses are being added to the fleet that use "clean" diesel fuel.

Trolleybuses are electrically powered buses having two overhead cables for power pick-up by trolley poles (see Figure 12-6). The poles allow buses to move up to 13 ft (4 m) laterally from the overhead wires, so that a trolleybus can use the lane under the cables as well as one adjacent lane to each side. Generally, trolleybuses can operate short distances off wire. Overall, trolleybuses represent an environmentally friendly transit mode that provides the lowest noise level of all transit modes, no exhaust, and effective operation on hilly streets. Due to these features, San Francisco; Seattle; Vancouver, British Columbia; and many cities in Switzerland, Greece, Russia, and East European countries have extensive trolleybus networks.

Vehicle Body Type, Size, and Capacity. A standard bus is typically a two-axle vehicle, 40 feet (ft) (12 m) long and 8.5 ft (2.5 m) wide. Its capacity may vary from 40 to 60 passengers, the lower number being with all passengers seated and the higher number including those standing. Many cities also use 30- and 35-ft (10- and 11-m) buses for lightly traveled routes. The entire family of transit buses includes minibus, 16 to 23 ft (5 to 7 m) with 12 to 20 seats and eight to 15 standing spaces; midi-bus, 26 to 33 ft (8 to 10 m); and extra-long 45-ft (15-m) two-axle buses, which require special permission to operate on specified routes. At 14 ft (4.3 m) tall, double-deck buses—most famously used in London and Hong Kong—are also used in a number of North American communities where they provide advantages in terms of a higher proportion of seats than articulated buses (making them a good choice for longer terminus-to-terminus trips) and better ability to serve older downtowns with short blocks.

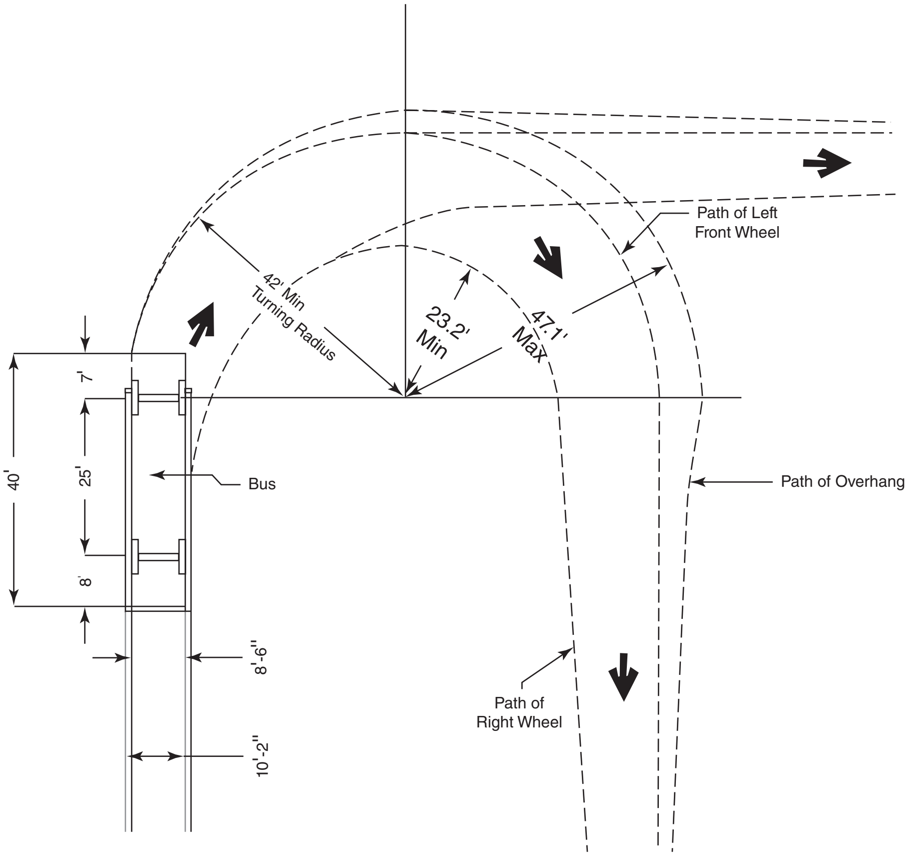
In addition to meeting passenger demand, a critical criterion in selecting vehicle length is its turning radius and clear turning path, shown with typical dimensions in Figure 12-7. Bicycle racks on the front of buses increase the minimum outside turning radius by a few feet.

An articulated bus is a three-axle vehicle, 52.5 to 59 ft (16 to 18 m) in length, with two body sections connected with a joint that allows horizontal and vertical "bending" of the vehicle in curves, while providing continuous interior for passenger accommodation. This bending effectively shortens the vehicle wheelbase, which permits these very long buses to travel where wide turning paths would otherwise prevent operation. Articulated buses typically have seating capacities of approximately 65 seats and an additional 35 to 50 standees for a total vehicle capacity of over 100 spaces. For heavy passenger loads (as in developing countries and cities such as New York City), articulated bus capacities of up to 125 spaces can be achieved by providing fewer seats and achieving higher standing passenger densities of 1.8 ft^2/persons (6 persons/m^2) instead of 2.2 or 2.7 ft^2/persons (5 or 4 persons/m^2) common for developed countries. Articulated buses usually show benefits of higher labor and vehicle productivity (passenger-mile per revenue-hour or per revenue-mile), but with some disadvantages in comfort and vehicle performance (lower acceleration and deceleration rates). Articulated buses were shown in Figure 12-5.

Figure 12-6. Modern Trolleybus, Seattle

Source: Courtesy of Metro King County Government

Figure 12-7. Typical Turning Dimensions for a 40-foot Bus



Source: Florida Planning and Development Lab, 2008

Low-floor buses with access points only 10 to 15 inches (25 to 35 cm) above the street surface are now used extensively in many cities around the world. The main purpose of this design is to provide easy boarding and alighting for disabled or mobility-impaired persons. An equally important benefit is easier and faster boarding for all passengers, decreased dwell times, and faster overall service. The vehicle's floor and aisle are at the same level in the front and usually rise by two steps or a sloped floor to accommodate the powered rear axle and engine compartment.

High-floor buses are also still common. Typically, access is via steps, but in a few cities platforms are being constructed to provide level access. High-platform boarding and alighting is commonly associated with the concept of BRT (see later section). High-floor buses without steps are limited to operation on lines with high platforms, usually on the left side. They cannot serve branch lines on regular streets where such platforms do not exist.

Bus Guidance. Several types of buses have the ability to be both steered or be guided on a guideway to combine the benefits of travel on streets with the safer and more reliable operation of a guided mode. The best known examples are the O-Bahn services in Essen, Germany, and a 7.5-mile (12-km) long line in Adelaide, Australia. Horizontal wheels run along 8-inch (0.2-m) high guiding curb surfaces on the bus track. When the bus leaves the guided section, the driver retracts the wheels and continues to drive the bus in the conventional steered mode. Compared to other guided modes, such as LRT, guided bus requires lower investment costs and is simpler to build, but cannot realize the advantages of labor productivity (through coupled vehicles) or electric traction as found in LRT. As such, few guided bus systems are currently in operation.

Recently, bus models with optical guidance have also been introduced, primarily on BRT lines with high platforms, to enable precise stopping of buses with a small gap between bus floor and a high platform edge. The vehicle is self-guided, utilizing front-mounted cameras and special pavement markings.

Bus Travelways: Most buses operate on urban streets in mixed traffic, along the right curb lane with little or no specialized infrastructure except for bus stop signs, shelters, and waiting facilities (in some cases, concrete bus pads are provided at high boarding stops). In cities that provide priority for bus services, buses also operate on different types of upgraded rights-of-way, as shown in Figure 12-8. Exclusive bus lanes on streets are dedicated to buses, and it is unlawful for nontransit vehicles to enter (see Figure 12-9). In some cases, bus systems use exclusive lanes in the opposite direction from all other traffic. These so-called contraflow bus lanes are most applicable for directionally dominated peak hour travel. However, the highest-quality bus service is obtained on bus lanes located in physically separated street medians (similar to typical LRT right-of-way). Left-turning traffic must be either separated by signals or eliminated.

Buses may also be operated on freeways for some portion of their routes. For freeway routes, stops are located at or immediately adjacent to interchanges. The most intensive use of a freeway for bus services is the approach to the New York City Lincoln Tunnel from New Jersey. This section carries about 700 buses per hour and serves the Port Authority Bus Terminal having more than 200 bus berths. In the morning peak, this section uses a contraflow lane on the outbound roadway.

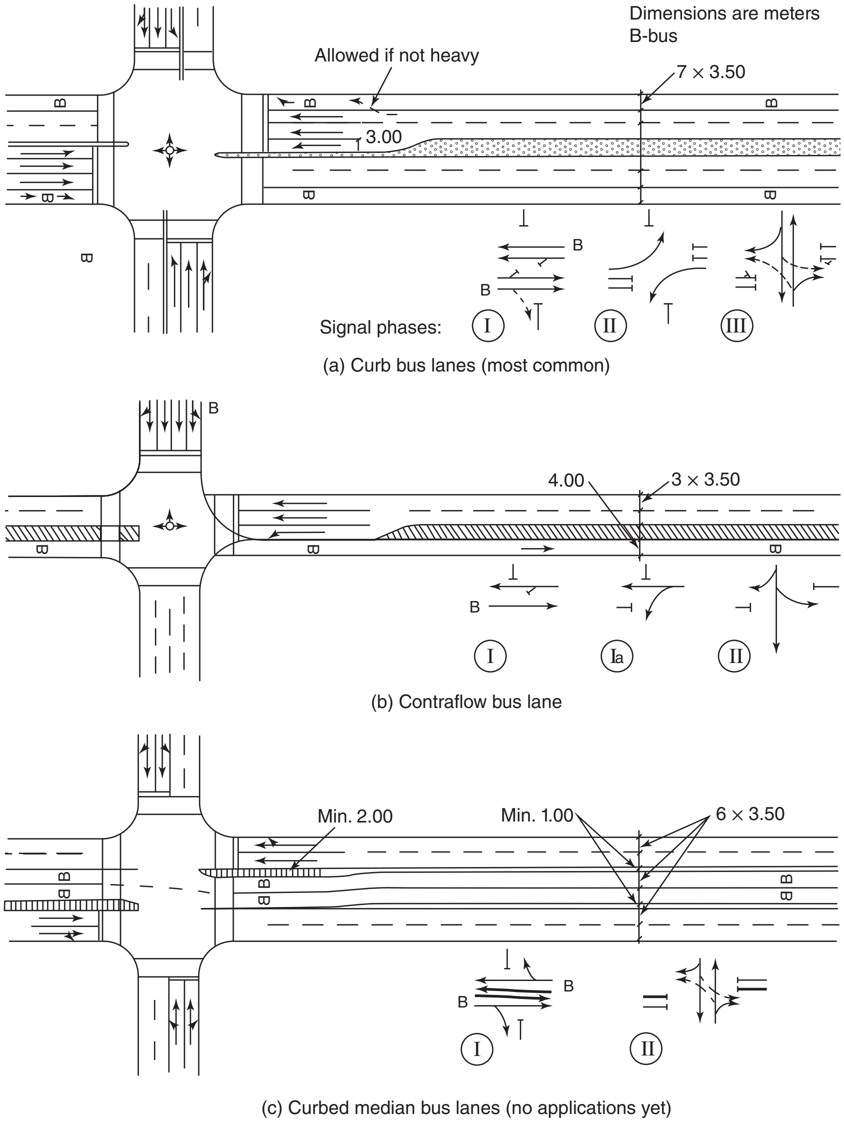
Busways: The highest performance bus rights-of-way are associated with busways, roadways dedicated to buses only. Busways are physically protected from other roadways, but usually have intersections with other streets or arterial roads. The most elaborate and best-known busways in North America are those in Ottawa, Canada, and in Pittsburgh, Pennsylvania. Ottawa's 17.4 mile (28 km) BRT network with 26 stations, integrated with a much more extensive network of regular bus lines, carries approximately 220,000 passengers daily. Pittsburgh's three busways serve 26 stations along 18.5 miles (29.8 km), serving approximately 22 percent of Pittsburgh's daily ridership. Examples of busways also include Miami's South Line and the Orange Line in Los Angeles.

In some cities, freeway shoulder lanes have been converted to bus use either during peak periods or in some cases during the entire day. Martin et al. [2012] provide a good overview of these types of facilities and the criteria that must be satisfied for their use.

2. Bus Rapid Transit (BRT)

The success of distinct bus networks with physically separated rights-of-way and busways in cities such as Bogota, Colombia, and São Paulo and Curitiba, Brazil, have stimulated interest and concerted efforts to define a distinctly upgraded bus mode. This mode, known popularly as Bus Rapid Transit (BRT), has been strongly promoted by the

Figure 12-8. Methods for Achieving Upgraded Right-of-Way for Bus Lanes



Source: Vuchic, 2007

U.S. Federal Transit Administration (FTA). A number of BRT services have been implemented in U.S. cities, with similar services in many other countries, particularly in South America.

System Definition and Characteristics. The family of BRT services encompasses a broad range of characteristics and performance levels, from BRT buses on arterial streets to distinct BRT networks separated from the road system. Experiences from many systems suggest that for a BRT service to improve bus speed, reliability, and identity, it must have the following elements: [Kittelson & Assocs., 2007]

- Partially or fully separated right-of-way (category B or A) on most of its length.
- Service during most daily hours with frequent and reliable service.

Figure 12-9. Providing Bus Lanes Allows Buses to Bypass Congested Road Segments

Photo courtesy of Michael Meyer

- Distinct stops and stations with passenger amenities.
- Spacious and distinctly designed vehicles with easy access (multiple door channels).
- Bus preferential treatment at most intersections.
- Monitoring, control and passenger information using intelligent transportation system (ITS) technology.

Vehicles. Many BRT systems use vehicles at least partially custom-designed for that specific line or system. Vehicle size and capacity depends on the passenger volume, but for heavily traveled lines, BRT systems commonly use 52.5- to 60-ft (16- to 18-m) articulated buses. In a few cases where lines are mostly on level terrain with few turns (Curitiba), 78.7-ft (24-m) long double-articulated buses are used. Total vehicle capacity, however, depends not only on vehicle dimensions, but also on several other factors.

First, a trade-off exists between seating capacity and total vehicle capacity. Maximum capacity is achieved with a minimum number of seats. However, if the goal is to offer high passenger comfort, a larger number of seats might be desired. Second, floor height and number of doors directly influence bus capacity because of differences in the design of entrances, steps, and aisles. In most cases, BRT buses should have multiple doors for faster passenger exchange and should eliminate the practice of passengers boarding through a single-channel door. Therefore, off-board payment technology at stations and/or other fare-related policies should also be considered for BRT systems to ensure faster passenger loading and reliability. Third, accommodations for the disabled require space for a lift, plate, ramp, and wheelchair placement. Finally, the standard used to compute standing capacity varies among industrialized countries, from systems in medium-sized cities in developing countries, 2.7 ft^2/person (4 persons per m^2) to very large cities, such as São Paulo and Bogota, 1.8 ft^2/person (6 persons per m^2). Four to five persons per m^2 are achieved under uncomfortable conditions, while six or seven persons per m^2 are unrealistic standards for most systems. In addition, crush loads almost always increase dwell times at stops, thus reducing the line capacity.

Vehicle appearance is part of a positive image or branding of the line, resulting in many new designs of vehicles for BRT systems. In some cases, however, excessive innovation and diversity in body design, propulsion, control, and even automatic driving and guidance have questionable applicability, leading to the production of extremely expensive vehicles, reaching a range of $1.5 to $2.0 million per vehicle. The trade-off between high comfort and appeal vs. purchase and operating costs should always be carefully considered.

Infrastructure. Physically protected roadways for BRT prevent entry by other vehicles. Appropriate design and enforcement are particularly important at intersections where other vehicles tend to enter bus lanes intentionally or by mistake. Intersection capacity can also be affected because a high-frequency bus line with signal priority may reduce the amount of traffic volume coming from the crossing street. Physically separated roadways and lanes are greatly superior to the lanes designated only by signs and markings. Physical separation also avoids traffic signals and city blocks (and numerous cross streets) that will reduce maximum bus flows.

Although physical separation is operationally feasible, such treatment can run into political pressures when bus lane capacity appears to be available in contrast to congested conditions on adjacent lanes. Such pressures have led to the abandonment of bus lines and degradation of BRT services in a number of cities.

BRT stops and stations must also be carefully planned to provide needed line capacity. BRT stations are spaced farther apart than conventional street bus stops, which promotes a fast and reliable bus service. For example, the street-running Metrobus lines in Los Angeles have been successful in attracting new passengers by having fewer stops and providing faster and more frequent service than conventional buses.

With single buses stopping at stations, a BRT line, even with high platform stations and articulated buses with four doors (for example, the Insurgentes Line in Mexico City), can carry about 6,000 passengers per hour. Higher capacities can be achieved with the operation of several buses in a group or platoon (São Paulo) with multiple station berths where several buses stop simultaneously. Another method to increase capacity is to design several sets of stops staggered along two-lane streets for buses only, which allows leapfrogging of buses (Portland, Oregon). It is also possible to provide two lanes at each station area, which allows express buses to pass. With these arrangements, line capacities may reach 15,000 to 20,000 passengers per hour or even higher.

The major operational features contributing to a greater passenger attraction to BRT relate to the design of lines and services. Instead of numerous overlapping lines with irregular services typical of many bus systems, BRT has few, but

Table 12-6. Costs for U.S. Bus Rapid Transit Projects

BRT System	Miles	Capital Costs ($ million)	Cost per Mile ($ million)	Federal Funding	State and Local Funding
Boston Silver Line, Washington St., Phase 1	2.4	$46.5	$19.4	0%	100%
Cleveland HealthLine	7.1	$197.1	$7.0	50%	50%
Boston Silver Line-Waterfront/Phase 2	8.8	$624.2	$89.1	77%	23%
Pittsburgh, MLK Jr. East Busway	9.1	$68.0	$20.0	50%	50%
Eugene EmX	4.0	$65.9	$16.4	80%	20%
Oakland San Pablo Rapid	14.0	$3.2	$0.23	N/A	N/A
Los Angeles Orange Line	14.2	$377.6	$25.0	7%	93%
Las Vegas, MAX and SDX	19.0	$51.6	$2.7	82%	18%
Kansas City MAX	12.0	$65.9	$5.5	63%	37%
Los Angeles Metro Rapid	400.0	$94.0	$0.24	77%	23%

Source: Lowe and La, 2012

very distinct lines with frequent and regular services. Thus, BRT is actually much less flexible than conventional bus networks, but is more similar to rail services with respect to its stronger image and reliable service with easy transfers to other lines. Exclusive busways also give BRT an image of greater permanence than bus operations in mixed traffic.

Other key characteristics of BRT service include off-vehicle fare collection and passenger information systems. These aspects of transit service are usually located at the BRT stops/stations so that the act of purchasing a fare or of determining schedules and arrival times will not delay the vehicle departure, thus enhancing service reliability and speed.

Capital costs for busway and BRT projects vary widely, depending on the amount of right-of-way, location, and technology specifications. Typical capital costs for some BRT projects in the United States are shown in Table 12-6. As can be seen, there is quite a range in costs, depending on facility characteristics.

Many of the system elements for upgraded BRT services, such as the provision of separate bus rights-of-way, faster services, and multiple doors, should be considered for conventional bus systems as well. The introduction of BRT requires a considerably greater effort, but it also results in a higher-performance system and associated positive land-use impacts. In essence, it represents a transit service option that fits between conventional bus and LRT services.

BRT usually has lower investment costs, faster implementation times, and simpler technology than LRT because it does not need tracks and line electrification. Generally, the greater extent of separated busways (and other features typical for LRT), the higher its level of service, but the smaller its advantage of lower investment costs over LRT. In extreme cases, such as bus tunnels in Seattle and Boston (Silver Line BRT), investment costs for busways have been comparable or higher than for LRT, while level of service is in most respects (speed, capacity, comfort) has been similar or lower. However, BRT can have many more branch lines and link more easily with other parts of the transit system. Ottawa, Ontario, for example, operates a "spider network" with many different route branches at each end of the BRT service, also common in Australia.

Present trends indicate that the need for medium-capacity transit modes, including mostly LRT and BRT, will be given increasing attention in the future, as cities want to increase the role of transit and decrease car dependency. In developing countries, BRT systems with high capacity, similar to those in São Paulo and Bogota, are likely to be introduced in more cities.

C. Rail and Other Guided Modes

Electric rail transit systems and other physically guided modes have many features that allow for diverse operations. The main features of most guided modes include:

- Rail systems, which operate the largest transit vehicles (except ferryboats) usually coupled in trains, result in much greater line capacity and labor productivity than that for buses and other transit modes.

- Guided modes require greater investment in transportation infrastructure, suggesting permanence of the service and creating strong identity for the system.
- Guidance systems allow use of narrower rights-of-way than for steered vehicles.
- Rail vehicles have higher riding comfort as a result of larger vehicles and their multiple vehicle suspensions.
- Most guided transit modes use electric traction, which has superior dynamic performance and little noise and air pollution, and enables operation in tunnels (although diesel commuter rail operations are not quiet).

Operationally, as a result of these features, guided modes usually utilize transit right-of-way categories A and B because of their high passenger capacity and operational scale of service. Independent travel ways ensure greater service reliability and provide stronger system image. Guided modes can better integrate into urban areas, due to their defined travel paths and minimal environmental impacts (in most cases). However, guided transit modes often incur very high investment costs, particularly for metro systems and other modes using category A rights-of-way. They can also present challenges to a transit agency when new technology is introduced into the system, often requiring specialized training of personnel and technology-specific support facilities. Although complex, they can also provide opportunities for intermodal integration with other modes in a network.

Four rail modes—streetcars/tramways, light rail transit (LRT), regional rapid transit (RRT) also known as metro or heavy rail, and regional or commuter rail—are the most common forms of rail transit. Several other guided technology modes, grouped as monorails and automated guided transit, are also part of the rail category.

1. Streetcars/Tramways

Streetcars were the dominant mode of street transit in many cities until the 1950s. With the increasing use of private automobiles, streetcar systems declined and most were replaced by bus service. In the United States, the number of streetcar systems in operation decreased dramatically after World War II, such that fewer than 10 cities retained major streetcar lines, including several that operated in tunnels in central cities, such as Philadelphia; San Francisco; Boston; and Newark, New Jersey. In Canada today, the Toronto Transit Commission operates an extensive streetcar system, by far the largest in North America.

Parallel with the development of LRT, there has been a renewed interest in recent years in conventional streetcars, predominantly as center city circulators. In 2001, Portland, Oregon, built a new streetcar line for such a purpose (see Figure 12-3). Memphis, Tennessee; New Orleans, Louisiana; Tacoma, Washington; Atlanta, Georgia (see Figure 12-10), and several other U.S. cities have built new streetcar lines in their central business districts (CBDs).

Streetcars are electrically powered vehicles, usually articulated, which can operate on any type of right-of-way (category A, B or C) as single vehicles or in transit consists of two to four vehicles. They usually receive their power via pantographs (historically, trolley poles were used) from overhead cables. New versions of streetcars allow operations without poles.

Figure 12-10. Atlanta Streetcar

Photo courtesy of Amanda Wall Vandegrift

Because streetcars and LRT share basic technological characteristics (rail technology, electric traction, and an ability to use any right-of-way category), the two names are often used interchangeably. However, significant differences exist. The most important distinction is the proportion of the respective lines operated on independent rights-of-way (A and B). Streetcars operate predominantly in mixed traffic and their performance depends on street design and traffic conditions. Light rail, mostly independent of traffic, has higher speed, reliability, safety, and passenger attraction.

Streetcar and LRT rolling stock can be four-axle, single-body vehicles with lengths between 46 and 52.5 ft (14 and 16 m). Modern LRT vehicles are typically articulated with lengths from 65.6 to 164 ft (20 to 50 m) and three to seven body sections. While many modern streetcars are unidirectional, LRT vehicles are bidirectional, which allows use of track crossovers and the operation of shortturn trains, simpler design of terminal stations (track loops are not needed), platforms on either side of the track and other design and operational flexibilities. In some cases, cities have opted for vintage, historic, and replica streetcars, whereas others are using more modern cars.

2. *Light Rail Transit (LRT)*

LRT is an electrically powered system that operates mostly on right-of-way category B, but can also use categories A and C. Reserved rights-of-way are, in most cases, in the medians of major arterial roads. In central cities, LRT may use either short tunnels (Boston, Massachusetts; Buffalo, New York; Edmonton, Alberta; and San Francisco, California), or be separated at-grade through auto-free zones (pedestrian and transit only), as demonstrated in Calgary, Alberta; Portland, Oregon, and many cities in Europe.

Contemporary LRT vehicles (LRVs) use a number of different trucks and axles including individually powered single axles and even single wheels instead of conventional two-wheel axles. These new designs often included the introduction of low-floor vehicles, which speed passenger boardings and alightings, reduce physical barriers to entry, and allow for better integration of stops in pedestrian areas (see Figure 12-11).

The capacity of LRVs varies widely based on the total length, width, and number of body sections. In North America, standing square feet, square feet per standee, and the number of seats are the usual determinants of service capacity. Manufacturers often provide different metrics that relate to crush loads, which in most North American cities would not be acceptable. Total capacities (seated and standees) for North American LRVs range from 90 to 225 spaces per vehicle.

Capital costs for light-rail systems vary mostly with the degree of right-of-way separation and the number of stations. Table 12-7 shows the capital costs for the LRT systems in the United States that have been constructed since 1990 ($2014). Note that the more expensive per mile systems included much higher levels of engineering and construction challenges.

In addition to operating on exclusive rights-of-way and on streets, LRT alignments can be integrated with urban arterial roads to provide convenient access for passengers with some reduction in line capacity (length of city blocks, for example, becomes an important factor in determining maximum consist flows). Figure 12-12 shows several possible right-of-way B alignments. In the first two diagrams, LRT is operated in the median of the arterial road, requiring right-of-way width of approximately 19.7 to 32.8 ft (6 to 10 m). In special cases, narrower rights-of-way may be used, as in San Francisco, California, where track centers are 11.6 ft (3.55 m) apart. Alternatively, LRT may be operated outside of auto lanes, with operation on two curbed lanes (diagram C) or with a combined alignment on a single side (diagram D).

The most common of these design alternatives is median operation. Typically, the LRVs move on the same traffic signal phase as the through roadway traffic. Figure 12-13 shows the geometric design and signal phasing for intersections with far-side LRT stops. A three-phase traffic signal is utilized: a left-turn phase for east-west vehicles that follows the through phase; a through phase for east-west vehicles and LRT; and a phase for all north-south movements. An example of preferential movement of LRT trains is shown in Figure 12-14.

The degree of right-of-way separation leads to many operational characteristics. For example, LRT may achieve speeds of 62 mph (100 km/hr) on exclusive rights-of-way, while in pedestrian zones typical maximum speeds are 10 to 15 mph (16 to 24 km/hr). Train control also varies. For example, LRT trains can be operated manually through CBD streets (San Diego and Sacramento, California; and others) and as trains come to sections of upgraded rights-of-way, they have barrier-protected crossings and fail-safe block signals, similar to metro systems and can thus move at faster speeds. In San Francisco, LRT trains converging into the center-city tunnel switch from manual driving to fully automated operation; the driver only initiates a preprogrammed train movement.

Figure 12-11. Light Rail Vehicles. (a) Five-body section articulated light rail vehicle in Jerusalem, Israel; (b) Docklands light rail, London; (c) Light rail in Portland, Oregon; (d) Light rail in Seattle, Washington, using a downtown transit tunnel.

(a) (b) (c) (d)

Photo 12(a) courtesy of Adam Rosbury; Photo 12(b) courtesy of William DeWitt; Photo 12(c) and 12(d) courtesy of Michael Meyer

This variety of vehicle design, right-of-way types, station configurations, and speeds presents many opportunities in the design of LRT lines. LRT lines can serve different functions, even within the same city. In Denver, Colorado, for example, LRT operates in contra-flow lanes in pedestrian-oriented downtown streets with transfers to buses and a pedestrian-mall bus shuttle. Outside of the downtown, the LRT service follows radial corridors in several directions, with speeds of 56 mph (90 km/hr) and sections of up to 5 miles (8 km) on fully separated rights-of-way. The system is well-integrated with suburban bus feeder lines and park-and-ride facilities. Similar arrangements exist in Calgary, Alberta; Dallas, Texas; St. Louis, Missouri; and other cities.

The number of LRT systems has grown very rapidly in North America, with 35 LRT/streetcar systems operating in the United States in 2012. As of 2014, there were another dozen LRT/streetcar systems in the procurement stage.

3. Rapid Rail Transit (RRT) (Metro)

RRT is an electrically powered system of trains operating only on exclusive rights-of-way and with fully access-controlled stations. RRT right-of-way is typically in tunnels within central cities, but aerial structure and separated, at-grade alignments are common in lower density areas. Rapid transit lines typically have 750–800 V power distribution via a third rail alongside the tracks (although the Cleveland line uses catenaries). Some recently built metros have 1,500 V power distributed by overhead cable (Hong Kong, Milan, most metro lines in Tokyo).

Table 12-7. Per Mile Cost of New U.S. Light Rail Transit Starter Systems since 1990 ($2014)				
System	**Year Opened**	**Initial Miles**	**$ M per mile ($2014)**	**Comments**
Baltimore	1992	22.5	$26.8	Mostly RR ROW and some CBD street track
Salt Lake City TRAX	1999	15.0	$30.7	Street track and RR ROW
Denver	1994	5.3	$37.3	Street track and RR ROW
St. Louis Metrolink	1993	18.1	$38.4	Mostly RR ROW and rehab tunnel & bridge, some elevated
Norfolk Tide	2011	7.4	$46.3	Mostly RR ROW and some street track
Houston MetroRail	2004	7.5	$55.0	Street track
Charlotte Blue Line	2007	9.6	$57.3	RR ROW
Dallas SART Red-Blue Lines	1996	20.7	$65.0	RR ROW, tunnel, subway station, elevated, viaduct
Hudson-Bergen (NJ	2006	21.0	$69.6	RR ROW, tunnel, subway station, some elevated
Phoenix Metro	2008	20.0	$79.2	Mostly street track, viaduct, RR ROW
Minneapolis Hiawatha	2004	11.6	$80.0	Mostly RR ROW, some tunnel, subway stations
Los Angeles Blue Line	1990	17.4	$91.2	Mostly RR ROW, some tunnel, subway stations
Seattle Link South Line	2009	14.0	$185.6	70% subway/elevated

Source: Light Rail Now. 2014. "New U.S. Light Rail Transit Starter Systems—Comparative Total Costs per Mile," May 6, Accessed Feb. 5, 2016, from, https://lightrailnow.wordpress.com/2014/05/06/new-u-s-light-rail-transit-starter-systems-comparative-total-costs-per-mile. Reproduced with permission of *LightRailNow!*

Train lengths are typically four to eight cars, but may be operated with 2- or 10-car consists. Access to the train is via high platform, each car having two to four, sometimes five, double-channel doors.

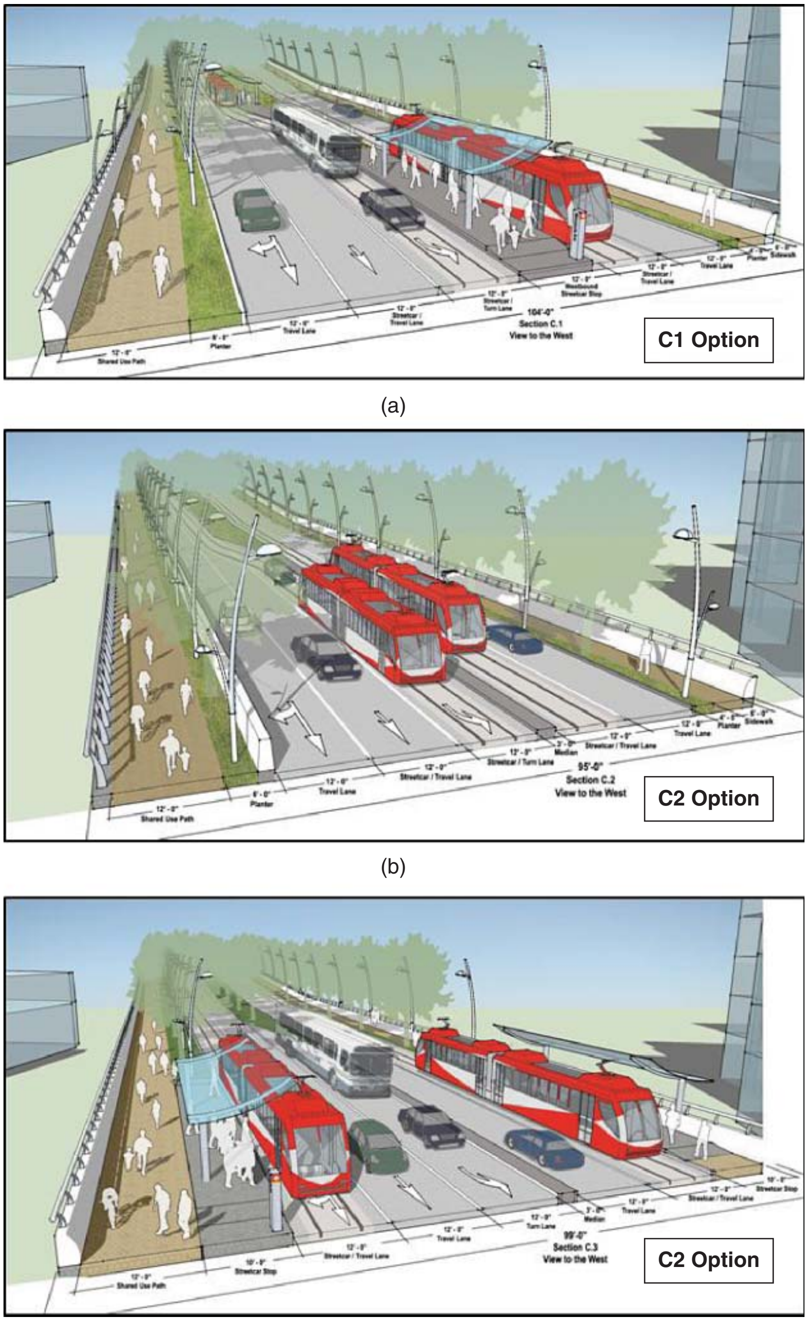
RRT systems use fail-safe train control systems, which consist of signals controlling occupancies of fixed sections of track, known as blocks. Fixed-block systems detect a train when it enters that section of track, and do not permit following trains to enter that block. This system, which is more than a century old, is known as automatic train protection (ATP). Signals, which may be wayside (located along the tracks) or cab signals displayed on driver's panel in the train, show the occupancy of the block the train is approaching.

To increase line capacity by operating shorter headways (the frequency of service or literally the space between vehicles), several new control systems have been implemented, which continuously record positions of each transit vehicle. This *moving block* technology, a form of communications-based train control (CBTC), differs from traditional control systems in that the locations of all trains are known exactly, rather than limited to a train's presence in a signal block section of track. With such CBTC systems, a centralized train control center monitors and controls the movements of all transit vehicles. This system is known as automated train control (ATC).

In some cases, the commands sent by the center are received and followed by vehicle operators. More commonly, particularly on recently built systems, ATC is used in conjunction with automatic train operation (ATO), where the trains have a series of operational performance levels (PLs) programs, consisting of different acceleration and braking rates, and maximum speeds for optimal travel between stations. PLs for each train can be changed for rail sections between stations.

Trains with ATO may have operators (drivers) whose responsibilities include starting the train at each station, making stop announcements, opening and closing doors, or acting as a point of contact for passengers in case of emergency. Several metro lines, such as the Paris Meteor line and the Singapore Northeast line, are driverless, meaning that no crew member is present on the train. Some systems use a hybrid approach. Vancouver's automated LRT, the SkyTrain, employs what are known as roaming conductors, who board the automated trains for several stops, then perform other duties at stations. The trains always operate without drivers.

Figure 12-12. (a) through (c): Alternative LRT Alignments



(a)

(b)

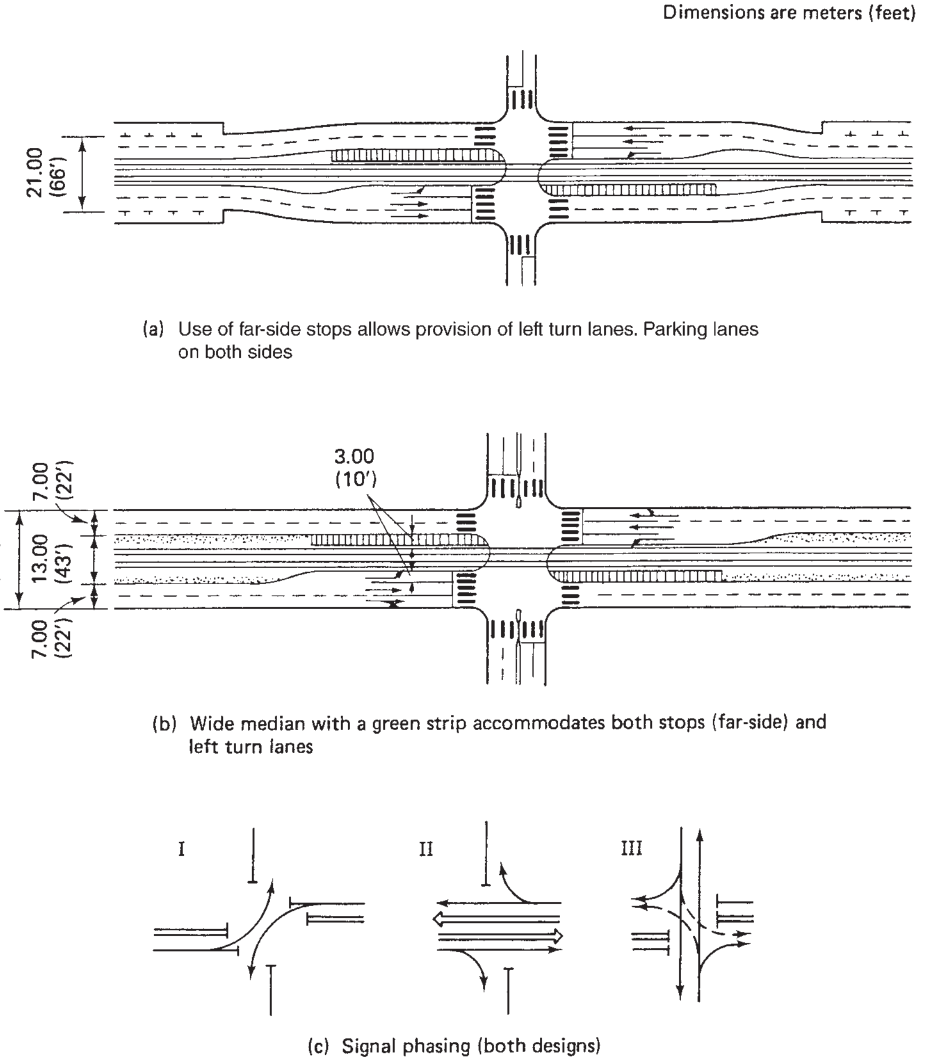
(c)

Source: District DOT, 2013

RRT vehicles vary in length from 49 to 75 ft (15 to 23 m) and in width from 8.2 ft (2.5 m) (rubber-tired metro vehicles) to 10.5 ft (3.2 m). Train consists range in length from 164 ft (50 m) in Lyon, France, to 710 ft (216 m) in San Francisco, California (BART). Capacities of vehicles are approximately 40 to 70 seats and can carry between 160 to 250 riders, depending on the car size and the willingness of riders to experience crush loads.

Rapid transit alignments can include tunnels, elevated sections, or at-grade operations. Tunnel sections are used in central cities and always provide full control of access. However, underground alignments require the greatest investment cost. Elevated alignments are often used outside of central cities along wide arterials or separate rights-of-way because of their considerably lower construction impacts. Modern aerial structures use pre-stressed concrete with small cross-sections that produce few negative impacts. Aerial structures are approximately 26 ft (8.0 m) in width with varying column heights. RRT systems operating at-grade are least expensive to construct, but require physical barriers

Figure 12-13. Station Locations and Signal Phasing for LRT Operation in the Median



Source: Adapted from Vuchic, 2007

to secure the track from illegal entry. At-grade systems also require that travel ways for intersecting modes (autos, pedestrians) be fully grade-separated.

Capital costs for RRT systems depend heavily on when the line was built and the method of achieving grade separation. San Francisco's Colma-Airport line (opened in 2003) was constructed with high aerial structures and a long tunnel, resulting in construction costs of approximately $256 million per mile ($159 million per km). At the other extreme is San Francisco's Dublin (1997) line, which utilized freeway median for much of its length. This line was constructed for $37 million per mile ($23.0 million per km). Typical values may be derived from Washington Metro's Green Line (2001)—6.5 miles (10.5 km) at $138 million per mile ($85.7 million per km), and San Juan's (Puerto Rico) Tren Urbano (2004)—10.7 miles (17.2 km) at $112 million per mile ($69.8 million per km). In some cities, such as New York City, London, and Berlin, the cost of building RRT is extremely expensive because of the difficulty in engineering and construction. In 2015, the Second Avenue Line extension in New York City was estimated to cost $2.7 billion per mile ($1.7 billion per km); in Paris a line extension is costing $403 million per mile ($250 million per km) and in Berlin $726 million per mile ($450 million per km).

RRT provides perhaps the best urban transit mode performance in terms of capacity, speed, frequency, reliability, safety, and impact on surrounding land use. The vehicle and platform design in combination with prepaid fares allows for rapid boarding and alighting and minimum station delays. Because the rights-of-way are protected, rapid transit lines can achieve speeds of 50 to 62 mph (80 to 100 km/hr), with exceptional cases of 81 mph (130 km/hr) (San Francisco BART). Average speed, which includes the time at stops, would be lower. Line capacities on rapid

Figure 12-14. Light Rail Trains in Rotterdam, Traffic Signal Coordination

Photo Courtesy of Michael Meyer

Table 12-8. Major Metro Systems' Characteristics			
City	**System Length (mi/km)**	**Stations**	**Approx. Annual Ridership (millions)**
Shanghai, China	321/548	337	2,500
Moscow, Russia	204/328	196	2,491
Tokyo, Japan Metro Corp.	199/320	179	2,351
New York (MTA)	660/1062	468	1,832
Mexico City, Mexico	141/226	195	1,685
Paris, France	137/220	303	1,527
London, England	250/402	270	1,362
Tokyo TOEI	66/106	106	866
Montreal	43/69	68	358
Washington, DC.	117/188	91	209

transit systems can theoretically reach 85,000 riders per hour per direction (recent passenger loads from Hong Kong), but typical maximum loads are about 40,000 riders per hour (average loads on most lines in the United States are much less).

Table 12-8 shows the characteristics of several major metro systems. The rapid transit system in Moscow consists of 12 lines and spans 204 miles (328 kms). The system carries more than 2.4 billion trips annually, or just over 6.5 million per day at an average operating speed of 9.7 mph (15.5 km/hr). Tokyo's system is composed of two companies providing service on 12 lines. Together these services also carry more than 6 million passengers daily. The average speed reported by the TOEI Corporation for its lines is approximately 20 mph (32 km/hr).

Rapid transit stations represent major infrastructure investments, and they often have major impacts on their surroundings. Several planning principles should be followed in their planning and design:

- Locate stations such that adequate area coverage is provided while maintaining sufficient spacing so that the line maintains desired operating speed.

- Provide efficient transfers among lines of each transit mode (complementing bus, streetcar networks, etc.) as well as for maximum integration of modes, including pedestrian, bicycle, street transit and, in outlying areas, kiss-and-ride and park-and-ride facilities, usually in this priority sequence.
- Include station planning for passenger movements into and out of stations through fare collection devices and between levels for transfers at grade-separated stations.
- Consider fire safety and other emergency evacuation requirements in both design and passenger information systems.
- Supply comprehensive information regarding the transit system, including a list of all routes served by the station, maps, and schedules for the line and network and, in contemporary systems, real-time information on transit vehicle arrivals and departures.
- Coordinate location with existing or future planned higher density destinations and mix of land uses in the station area.

Station planning and design for RRT systems are described in further detail in later sections.

4. Regional Rail

Regional rail, also known as commuter rail, is a system of electric or diesel-powered trains operating on railroad rights-of-way, providing very high-performance service on long lines, typically between central cities and the suburbs (see Figure 12-15). Regional rail systems usually have longer lines, higher operating speeds, and higher passenger comfort than rapid rail transit. Many regional rail networks have fully protected at-grade crossings in outlying suburban areas, but grade-separated tracks, often in tunnels or elevated structures, in central cities.

As a railroad-based system, regional rail uses signal control and the highest standards of alignment geometry, the longest station spacing (between 5 to 10 miles [8 to 10 km], typically) and, therefore, the highest operating speed of all transit modes. These elements make regional rail services highly competitive with longer distance auto travel. However, freight track is designed to standard gauges, and thus regional rail vehicles must be able to operate safely on such track. The mere existence of freight track should not be construed as meaning regional rail operations could be started without possibly costly upgrades.

Contemporary regional rail vehicles introduced in recent decades in cities like New York City (on all three systems: Long Island Rail Road, Metro North, and New Jersey Transit), Chicago, Philadelphia, and Boston, have maximum dimensions allowed by railway standards, which are (in most countries) a length of 85.3 ft (26 m) and a width of 10.5 ft (3.20 m). Such cars designed for maximum seating can have capacities of 110 to 128 seats. As trains of 5 to 10 cars could not provide sufficient seating in some cases, cities have introduced multilevel cars. In North America,

Figure 12-15. New Jersey Transit Multilevel Regional Rail Vehicles

Photo courtesy of Bombardier Transportation

Chicago's Metra and San Francisco's Caltrain have used multilevel cars for many decades. In recent years, the Long Island Railroad, Boston, New Jersey Transit as well as most regional rail systems opened since the 1970s (Toronto, Tri-Rail in Florida, Los Angeles Metrolink), have introduced different designs of multilevel cars with capacities of up to 150 seats and 200 spaces for standees. A similar trend toward multilevel cars has taken place in many other countries, including France, Germany, Spain, and Australia.

Most regional rail systems in North America are diesel powered with a locomotive pulling 5 to 10 trailer cars. Such trains are designed as push-pull units, with the locomotive driven by an engineer at the head of the train, while in the reverse direction, the train operator drives from a cabin at the opposite end of the train, remotely controlling the locomotive that pushes the train.

Because regional rail systems are operated in corridors with active freight and intercity railroads, rail cars in North America are required to be designed with sufficient vehicle buffering strength to meet federal railroad safety criteria in the event of an accident. These requirements result in very heavy regional rail vehicles. They also allow LRVs to use railroad tracks only when these two types of services are separated in time as they are in San Diego, for example. Some European cities have relaxed this constraint to allow LRVs to operate on intercity railway tracks. This arrangement was reached by designing the train control system so as to prevent any possibility of collisions, as well as in the United States where a focus has been on minimizing the damage when collisions occur.

Most regional rail systems in North America have high-floor vehicles and low platforms, with passengers negotiating up to four steps. A design with high-floor vehicles and high-platform stations is operationally much better, since it allows much faster boarding/alighting and accessibility. This design requires different solutions when freight train profiles must be provided for at each station. Another design is where suburban stations have low platforms and require cars with steps, while center-city stations have high platforms, as is the case in Philadelphia on SEPTA's regional rail system. This arrangement with manual control of step covers requires the train crew to move the plates above the steps, thus, requiring large train crews.

Stations on most regional rail systems in North America have open fare access and involve low maintenance cost, but old systems still use labor-intensive fare collection on trains. Recently opened regional rail systems, such as Los Angeles' Metrolink, use a much more efficient self-service fare collection system.

With their heavily commuter-oriented ridership, most regional rail systems depend on station access in suburbs via kiss-and-ride and park-and-ride modes. [Coffel et al., 2012] For this reason, regional rail systems have constructed park-and-ride lots and garages at many stations. The investment in such parking facilities from a systems point of view is very effective because the provision of station parking in remote suburbs more effective from a public policy perspective than longer distance travel by car.

The capital costs of regional rail systems will vary by the degree to which additional infrastructure will be necessary over and above what is provided by the freight rail track. In Nashville, Tennessee, the cost for new service with very little incremental investment was $1.3 million per mile; in Seattle with more investment in track and stations, the cost was $26 million per mile. The Federal Railroad Administration, for example, in an effort to mitigate the effects of train horn noise, requires "quiet zones" around crossings where trains are not allowed to sound their horn when approaching public highway-rail grade crossings, except in emergency situations. In order to maintain the safety of vehicle and pedestrians/bicyclists crossing at such locations, investment must be made in medians or four-quadrant gates.

5. Monorails

Monorails represent a fundamentally different technology from conventional rail. Like conventional rail, monorails are both supported and guided by a guideway. However, they run along a single beam, which may have several different designs, but is always on an elevated structure. There are two primary configurations for monorails—vehicles may be supported (ride above the guiding beam) or may be suspended (ride below the beam or rail) as is found in the Oakland Airport connector. In both cases, the vehicle is powered by electric motors that transfer their force via rubber tires running along the beam or steel wheels running along a single rail. Typically, horizontally aligned rubber tires provide the horizontal stability for the vehicle. Various configurations exist in the number and alignment of rubber tires used as well as the shape of beam on which the monorails are operated. The supported types require a lower structure than suspended ones, and they are more common. Figure 12-16 shows a monorail in Dubai.

Monorail vehicles vary in size, configuration, and capacities. Jacksonville, Florida; Las Vegas, Nevada; and Seattle, Washington are the only cities in the United States operating monorail transit systems in revenue service.

Figure 12-16. Monorail in Dubai

Photo courtesy of Michael Meyer

Outside of North America, a number of cities operate monorail transit systems, with the most developed systems being in Japan. Tokyo, Osaka, cities in Okinawa, and several other cities have several heavily used public transit monorail systems. It is difficult to compare the loading capacity of monorail vehicles from Japanese cities with the U.S. market because passenger load factors are much higher than in North America. However, using a North American standard of 2.7 ft^2/person (3 persons per m^2), the capacities of small, standard, and large four-car monorails are approximately 190, 350, and 420 passengers, respectively.

Fixed infrastructure costs can range from about $44 million to $118 million per mile ($27 million to $73 million per km) with an additional $25 million to $55 million for equipment and rolling stock. Proponents claim that monorails may operate with headways of 90 to 120 seconds. The minimum headways operated in practice are on the Tokyo monorail at 3 minutes 20 seconds, producing a line capacity of about 10,500 passengers per hour. Benefits include electric traction, the quieter operation of rubber tires, the ability to traverse steeper grades, and a smaller footprint for elevated sections. The disadvantages of monorails include the ability to run only on elevated sections, complicated switching, and greater operational complexity than rail systems.

6. Automated Systems

For most transit agencies—and especially in North America—labor costs account for a very large share of operating costs. This cost structure creates pressure on transit operators to provide service with large transit vehicles (high productivity of the driver) at long headways, instead of smaller transit vehicles running at short headways, which would likely be most attractive to passengers. Fully automated trains without drivers allow the transit agency to utilize its fleet such that more frequent consists using automated train operations (ATO) are operated at the same cost as fewer consists at longer headways. This is particularly beneficial because high frequency operation becomes economically feasible during off-peak periods. ATO can also achieve benefits of higher operating efficiency (lower energy consumption and vehicle wear and tear) and greater riding comfort.

Driverless operation can be used only on guided systems with fully controlled right-of-way. There are several dozen fully automated systems in many countries, and they can be classified in three categories—automated people movers, automated guideway transit, and automated metros.

Automated People Movers. The most common use of fully automated transit systems is for shuttle-type operation (short lines with two or several stations and frequent service) in high-density areas such as airports, sport complexes, fairgrounds, or hospital complexes. These systems, usually known as automated people movers (APMs), typically consist of rubber-tired vehicles with capacities of between 40 and 100 spaces, mostly for standees, sometimes operated in two- to three-car consists. They usually provide frequent services (headways of 3 to 5 minutes). In many situations they represent internal circulators where no fares are charged. In such cases, APMs are not planned and evaluated in relation to the number of passengers they are expected to serve and fare revenues, as is typical for planning of regular transit lines. Rather, they are planned as integral parts of the developments they serve.

APMs are operated in an increasing number of airports. Among some 30 such systems in operation, the Atlanta Hartsfield-Jackson Airport people mover is an example of an APM as it is the main connector between terminal buildings, serving about 225,000 passengers per day.

Automated Guided Transit (AGT). Automated guided transit (AGT) is a fully automated (driverless) system consisting of electrically powered, guided, rubber-tired or rail vehicles operating on exclusive right-of-way. AGT systems utilize medium-capacity (80 to 120 spaces) vehicles operated as one- to six-car consists. These systems are often used to provide circulation in dense urban areas such as downtown people movers (DPM) in Detroit (rail system) and Miami (rubber-tired guided system). The Miami system has 21 stations throughout its CBD, and they are well integrated with the city's heavy rail and many local and regional bus lines. This DPM, locally known as Metromover, serves as a collector-distributor to the Metro and regional bus lines, as well as for many intra-CBD trips, reducing the demand for provision of large parking garages and contributing to its pedestrian atmosphere and livability.

Since the 1980s, several AGT lines have been built as major transit lines in their respective cities. The VAL system, consisting of two rubber-tired, married-pair vehicles, has served two lines in Lille, France, which carry over 100,000 passengers per day. The same technology has been used by several other French cities and by one line in Taipei, Taiwan. Several Japanese cities operate four- and six-car rubber-tired AGT consists on regular transit lines.

A particularly successful AGT system has been Vancouver's 32-mile (52-km) SkyTrain network. It consists of two-, four-, and six-car automated rail consists operating at high frequencies throughout the day. During most hours, headways of 3 minutes are provided; during the peaks and night hours the headways are shortened and lengthened. This frequent, fast, and reliable service attracts 69 million riders annually.

Shortcomings of full automation include, (1) higher investment cost in the system; (2) much more complicated control technology, requiring higher skills of operating personnel; (3) the need for extra supervision of the tracks and stations; (4) organization of special procedures for handling emergencies; and (5) the need for fully protected rights-of-way. The decision to introduce driverless train systems is complex and must be based on careful analysis of all the advantages and disadvantages for each specific planned transit line or network.

Automated Metros. As previously discussed, automation with driverless trains is particularly beneficial for transit lines requiring medium-capacity systems because short headways are feasible even on lines with moderate passenger volumes. Many metro systems have high ridership, which makes operation of short headways with conventional technologies feasible during most daily hours. As a result, the benefits of full automation are not as significant on metro systems. However, the feasibility of providing frequent services at all times, as well as the other benefits of driverless operation, such as the adaptability of services to changes in demand or operations, improved communications and supervision systems, make driverless operation of conventional metro systems justified and attractive in certain conditions.

The implementation of driverless metros has been slow, and it is still limited to new metro lines only. The best known examples of driverless metro lines have been the Line 14, Meteor of the Paris Metro, the Northeast Line of the Singapore Metro, and several others. Paradoxically, most fully automated metros, as well as AGT systems, do not utilize the option of tailoring consist lengths to changes in passenger volume, one of the potentially most significant benefits of driverless operation. The SkyTrain in Vancouver is one of a few automated systems adopting this strategy.

Despite these difficulties in introducing transit systems with driverless trains, their number is expected to increase in the foreseeable future, mostly as APM systems, but also as AGTs and automated conventional metros.

A major issue in North America with the automation of metro systems may be the resulting loss of jobs for train operators. One solution has been to reassign drivers to other duties within the transit agency. A second concern is that potential riders may perceive driverless operation to be less safe (in terms of vehicle operations) and less secure (in terms of crime). However, experiences with fully automated systems in Asia, North America, and Europe have shown that ridership increases over time as riders experience the system.

D. Paratransit and Specialized Services

Paratransit or demand-responsive transit differs from conventional transit in that demand-responsive transit routing and scheduling are adaptable to individual users' desires in varying degrees. Trip times, origins, and destinations are coordinated between the user and the providing agency, and charges are usually based on trip duration and length. In many cases, paratransit services may not be available to the general public.

Paratransit services are classified in two categories:

- *Semi-public paratransit*, available to certain categories of users, such as members of a specific community, university or hospital complex, or to subscribers of specified vehicle uses. Subscription vans or buses as well as car sharing programs are examples.
- *Public paratransit*, available to any individual or group of persons. Examples are taxi and jitney services, as well as buses that operate "flexible service" by deviating off route in a variety of ways.

Paratransit's flexible or personalized operation greatly increases passenger convenience and attraction. It provides necessary accessibility for disabled passengers and for the public. It can make transit services more competitive or feasible in areas where ridership has been traditionally low.

Paratransit systems are increasingly being integrated with traditional or fixed-route services. Their use as complementary services has potential to increase ridership throughout a transit system. In developing countries, the regulation and coordination of paratransit services with upgraded regular transit systems are major tasks for transit planners, which involves not only technical planning but also political and financing decisions.

Different modes of paratransit have important roles in urban areas, providing services that exhibit characteristics between those of private auto and transit. However, all paratransit consists of organizationally different types of services and very little, if any, infrastructure. Therefore, paratransit does not require long-range, comprehensive planning of facilities, but only its consideration in transportation policies, which determine the respective roles of different modes in urban transportation. General characteristics of major paratransit modes are discussed below.

1. Semi-Public Paratransit

Semi-public paratransit can be grouped into three categories:

Vanpools. Many offices, factories, or institutions with large numbers of employees who commute by car encourage vanpool travel by purchasing or leasing 7- to 15-seat vans and assisting groups of employees to commute together. Vans have much lower per-commuter costs and require less parking area per commuter. Vanpools should be considered as part of a broader transportation demand management strategy and as complementary strategies for such initiatives as high-occupancy lanes, lower parking charges, and preferential parking locations (see chapter 14 on travel demand management). Shortcomings are high turnover of participants and the need for continuous organization and supervision of their operations.

Subscription Buses. When there are a large number of commuters traveling between two areas or along certain corridors, subscription buses may be more economical and efficient than vanpools. This service is organized either by large employers or by a group of residents who hire bus services with fixed routings and schedules. Subscription bus commuters have a larger choice of stops, routings, and departure times than vanpools, which only offer a single departure between two points during every peak period.

Car Sharing. Beginning in the 1990s, a new type of car rental organization was introduced in many North American and European cities. These car-sharing organizations provide a fleet of vehicles at a number of locations in a city, which may be used by individuals who subscribe to the service. Vehicles are picked up and left at any of the system's locations within the city. In addition to their fixed subscription fee, users are charged on the basis of time and distance traveled.

Experiences in different cities have shown that car sharing is more complementary than competitive with transit services. A number of auto owners in central cities find that by supplementing transit service with car sharing, they are able to give up their personal cars, thus eliminating parking and maintenance costs.

2. *Public Paratransit*

The three major modes of public paratransit—taxis/Uber/Lyft, jitneys, and flexible transit services—take various forms and could have significant roles in cities.

Taxis/Uber/Lyft. Taxis have traditionally been the major means of providing personalized, for-hire service, transporting either individuals or groups of up to five persons from an origin to a desired destination for fares that depend on travel time and distance traveled. In recent years, services such as Uber and Lyft have entered the market, competing with taxi services. The role of taxis and Uber/Lyft services is to provide individualized service for trips when transit services cannot offer adequate service, such as trips from airports to suburban locations, often trips within downtowns, or trips made with luggage. Generally, in medium-sized cities, taxis meet the need for travel of people who do not own autos; in large cities, taxis and Uber/Lyft replace many private auto trips because they are more easily obtained and require no parking. Many transit systems also use taxis to provide a portion of service, and some have begun to explore how Uber/Lyft-type services could provide the "last mile" connectivity to destinations that are not directly connected to line haul transit services. Conventional transit—particularly in smaller or suburban systems—may use taxis to provide service in lower-density areas or at lower demand times of the day. Demand responsive services for people with a disability may also dispatch a portion of trips to taxi providers.

Jitneys. Jitneys are privately owned and operated vehicles with capacities of 5 to 15 passengers, usually providing service on fixed routes. In many developing country cities, jitneys provide a significant portion of available transit services. They may also compete directly with publicly provided fixed-route transit, offering a different type of service. Usually, jitneys operate more frequently and have higher speeds than buses because jitneys do not stop at all stops. They offer seats to passengers, but often accept more passengers than seats. Their safety features are regulated in some cities (Hong Kong and Istanbul, Turkey), but in many cities their safety record is far below the standards of transit systems. Jitney vehicles are designed with small seats, offer little structural protection in accidents, and may even operate with open doors. On lightly traveled routes and times, jitney service is irregular, and on longer routes they may depart only when all seats are filled. The fares charged by jitney operators are typically regulated, but instances of overcharging may occur.

Jitneys are known under different names, such as *publicos* in San Juan, Puerto Rico; *por puestos* in Caracas, Venezuela; *jeepneys* in Manila, The Philippines; *Trotros* in Accra, Ghana; and *minibuses* in Mexico and South African cities. In the United States and Canada, there are very few jitney services, with the best known being jitneys in Atlantic City, New Jersey.

Although jitney use is encouraged by many economists and the World Bank because they require little or no public subsidy, they often contribute to chaotic traffic conditions in already congested streets. When a city wants to upgrade transit services by introducing higher-quality bus or rail systems, it must control jitneys and limit their directly competing services. This has been done in cities where rail or BRT services have been introduced, such as Istanbul, Turkey; Mexico City, Mexico; Cape Town, South Africa; and others.

Flexible Transit Service. Flexible transit services vary vehicle routings and stop locations in response to requests from individual passengers. [Koffman, 2004] These services are called demand-responsive services. Two forces combined to advance the use of these services. First, with the Americans with Disability Act (ADA) of 1990, demand-responsive service for disabled passengers was no longer automatically an acceptable substitute for fully accessible, fixed-route service. Instead, transit agencies were required to determine the most effective way of providing transportation to disabled customers, including mainstreaming—serving them with regular, fixed-route services—where possible. Financial requirements necessary to accommodate the growing demand for disabled passengers motivated transit agencies to seek more cost-effective service. Thus, transit agencies began to coordinate the design and schedule of flexible services in conjunction with their fixed-route services.

Second, regular fixed-route transit systems have difficulties attracting strong ridership in low-density areas. For example, low-density residential areas and dispersed developments with circuitous street networks present challenges to efficient transit operations. With ADA heightening the importance of flexible services, transit operators saw an opportunity to introduce some combination of demand-responsive and fixed-route services to generate increased ridership in such areas or during certain time periods. This flexible service is also known as hybrid-type transit service.

The most common form of flexible transit is route deviation. In this case, the transit operator provides service in an area with a combination of fixed-route service and on-call pick-up and drop-off locations. For example, an operator in a route-deviation zone might be informed by a dispatcher that a customer is waiting two blocks away from the traditional route. In response, the driver will vary his or her route to pick up the passenger at that location and then return to the basic route. Similarly, a passenger may request a specific drop-off location several blocks away from the fixed route.

In a second system, known as point deviation, a transit vehicle departs from the fixed route at a station. The vehicle then operates without a fixed route, picking up and discharging passengers either as requested by passengers on-board or guided by dispatch before returning to the fixed route at a station downstream from the departure point. Operators may also provide demand-responsive connector service. In this case, transit vehicles pick up passengers at user-specified locations and transport them to a fixed-route terminal or transfer station.

The length of the route open to route deviation, as well as the distances away from the fixed route that the operator is permitted to travel, vary among systems. They are usually prescribed or determined by the dispatcher, who must control these deviations within certain time limits, so that a reasonable basic transit schedule is still retained. Route deviation practices may also vary by time of day. A detailed discussion of deviation practices is given by Koffman [2004].

Another common type of flexible service is dial-a-ride (DAR), where people in a defined area can call a control center and ask for service between specified locations and at a desired time. The dispatcher then plans trips of individual vehicles, usually minibuses, to serve several trips using a route that collects and distributes passengers in the most efficient way. There are two types of DAR service. Many-to-many services serve trips between any two points in the service area. This type of service provides rider convenience, but is provided at very high cost because average minibus occupancies are usually very low. Many-to-one and one-to-many DAR services are often used for travel to traffic generators such as train stations, shopping centers, elderly centers, or hospitals. A variation is zone service or checkpoint service where DAR is provided only within a relatively small area. Those wishing to travel outside this area connect to other services at a timed-transfer point.

Demand-responsive operations require special coordination with passengers and within agencies. Because of the complexity of operation, marketing, and information dissemination are key components to successful demand-responsive systems. Passengers must be aware of the boundaries of demand-responsive zones, the hours of operations, and the requirements for accessing service. For example, many operators require 24-hour advance notice to schedule a customized pick-up or drop-off location, although the trend is toward shorter advance notice being required. In some cases, passengers may schedule trips as near as 10 to 15 minutes prior to a desired departure time. Variable fares are also common with demand-responsive systems.

The coordination of full-access and disabled-only demand-responsive transit remains a challenge for many agencies. Many transit agencies contract demand-responsive service to private operators. Increasing the efficiency of demand-responsive transit through improved communications technologies or vehicle-routing algorithms is a very active research area. It is important to note that the expansion of bus and rail services often requires more paratransit feeder services.

E. Terrain-Specialized Systems

While the majority of transit services in the world are provided by bus or rail vehicles, many terrain conditions, such as climbing hills or crossing ravines or bodies of water, preclude their use. Numerous terrain-specialized transit systems are used for these situations.

1. Cable Cars

Invented and built in San Francisco, the cable car was actually the first mechanized mode of urban transportation not using animal or human traction. Cable cars were used in a number of cities until more efficient and faster electric streetcars replaced them everywhere except in San Francisco, where terrain and tradition supported this mode.

A cable car is an unpowered rail vehicle that an operator (gripman) drives by pulling or releasing a special lever that grips the cable that is continuously moving in an underground conduit in the center of the track at a constant speed of 9.3 mph (15 km/hr). Braking to a stop is achieved by releasing the grip and using friction brakes on the wheels and rails. Three stationary motors provide power to the continuous cables of the three lines in San Francisco. The total network in the city is 5.1 miles (8.3 km) with longest line length being 2.1 miles (3.4 km). There are lines operating on gradients of up to 21.3 percent. The service carried 7.4 million trips in 2014. [APTA, 2014a] While cable cars use considerable energy on cable friction, their principle of using the same cable for pulling as well as for braking cars in their steady downhill travel results in lower energy consumption than conventional vehicles, which waste energy during downgrade braking.

2. Cog Railways

The practical limit of track gradients for standard rail technology is about 10 percent. To provide rail service on alignments with higher grades, cog railways are often used. These systems utilize conventional steel rails and steel wheels to provide guidance for the vehicle. The traction for the system is provided through a powered, geared wheel in the center of the axle that is aligned with a linear vertical gear laid in the center of the track. Initially, cog railways employed steam engines (still used on the tourist Mount Washington Railway in New Hampshire); now cog rail systems are electrified.

There are no cog railroads used for urban transit in North America, but such lines do exist in several cities overseas, such as Stuttgart, Germany; Lyon, France, and on a number of urban and rural lines in Switzerland.

3. Funicular Railways

Also known as *inclined plane* or *incline*, funicular is the most commonly used technology for very steep transit lines. This technology involves two rail cars (or short trains) with body floors tilted in relation to the rails to be approximately horizontal on the steeply tilted track. They are attached to the two ends of a single cable, which runs along rollers placed in the centers of each track. Thus, both cars move and stop simultaneously. The motor, located in the upper terminal building, provides power to overcome rolling resistance of the cars and cable, as well as the difference in gravity force between the two cars, which depends on their passenger loadings.

Funiculars can be used to traverse grades from 10 percent to 100 percent (45°angle) or even greater, becoming similar to a balanced elevator. While vertical curves in the line alignments for funiculars can be sharp, concave curves are limited to very large radii to avoid lifting of the traction cable under tension causing slippage from the rollers.

Funicular vehicle capacities usually range from 20 to 50 persons. Five funiculars are in operation in the United States: two in Pittsburgh (which at one time had 17); one each in the cities of Johnstown, Pennsylvania; Dubuque, Iowa; and Chattanooga, Tennessee. Pittsburgh's Monongahela line is the oldest in North America, dating back to 1870. The 636-ft (194-m) line traverses a 58-percent grade. In 2014, the system averaged 3,000 daily boardings, making it the most heavily used funicular in North America. [APTA, 2014a]

Outside of the United States, funiculars are operated in many cities, including Hong Kong; Istanbul (one opened in 1870, another in 2006); Haifa, Israel (rubber-tired short trains); Santiago, Chile; Wellington, New Zealand; and Switzerland (more than 50). Naples, Italy, has four funiculars between large sections of its center city located at different elevations. The largest of them, the 4,167-ft (1,270-m) Centrale Line negotiating a 558-ft (170-m) elevation difference, has three-car trains with a total capacity of 450 persons and provides a maximum capacity of 5,400 persons/hr.

A review of the basic components and operating characteristics of the three rail modes for steep alignments—cable cars, cog railways, and funiculars—is shown in Table 12-9.

4. Aerial Tramways

Aerial tramways consist of unpowered vehicles suspended from a cable powered, similarly to funiculars, by a single electric motor at one terminal. They are most often used to traverse steep grades or to provide transport over deep ravines or bodies of water. Three systems are used in the United States. The first, in New York City, connects Manhattan to Roosevelt Island, located in the East River. The vehicle carries 125 persons traveling at an average speed of 15.5 mph (25 km/hr). The line is about 3,084 ft (940 m) long and rises 131 ft (40 m) above the water level. In 2013, this line carried 2,637,000 passengers. The second system is in Mountain Village, Colorado, and the third system is in Portland, Oregon. While the Roosevelt Island tramway serves as a transit line, many applications of this technology are used exclusively for tourist purposes, as is the case with the lines to Sugarloaf Mountain in Rio de Janeiro, Brazil; Avila in Caracas, Venezuela; and Table Mountain in Cape Town, South Africa.

Table 12-9. Basic Components and Operating Characteristics of Rail Terrain-Specific Modes

Technology	Typical (maximum) Grades (%)	Speeds (mph)/(kph)	Example Cities
Cable car	20 (20)	9.3/15	San Francisco
Cog railway	20 (50)	15.5/25	Stuttgart, Lyon
Funicular	50-60 (122)	22.4/36	Pittsburgh, Dubuque, (IA), Swiss cities

Source: Vuchic, 2007

Another modern innovation complementing the steep topographical niche once served by funicular railways and aerial trams is the use of outdoor escalators. Medellin, Columbia is perhaps the most famous example of this technology where a network of covered escalators and landings provides transportation access for a hilly and economically disadvantaged area of the city.

F. Waterborne Transit

Ferryboats are used to provide urban public transportation services across water bodies. They can be classified in three ways:

- *Type of vessels:* Mono-hulls, catamarans (dual-hull), and hydrofoils.
- *Type of service:* Crossing water bodies, such as rivers, bays, or lakes, and transit lines connecting two or more points along a river or shore. The latter are usually much longer than the former.
- *Type of market:* Water taxis, passenger ferries, and auto ferries.

Nearly all ferryboats are powered by diesel motors, including direct diesel propulsion, diesel electric, and diesel-waterjet. Vessel sizes vary from 49-ft (15-m) long water taxis with a capacity of 50 passengers to the 459-ft (140-m) long ferryboats in Seattle, which carry up to 2,500 passengers and 280 automobiles. New York's Staten Island Ferry has a capacity of 6,000 passengers (no vehicles).

Ferries may be uni- or bidirectional with the vast majority being unidirectional boats. Bidirectional boats are usually designed for shuttle services across the water, where short turnaround times are important for high line capacity. The best example of such service and specialized design of the boats, terminals and operations is the Burrard Inlet Ferry, called SeaBus, in Vancouver, British Columbia. These boats are bidirectional and have six double doors on each side, allowing simultaneous alighting and boarding of passengers separately on the two sides so that terminal times amount to only a few minutes. At both ends, the terminals are major intermodal transit hubs. The terminal on the north has many terminating bus lines. On the south side, SeaBus has transfers to SkyTrain, regional rail, and many bus and trolleybus lines. At the other extreme are large ferry boats that carry passengers and automobiles, requiring much longer maneuvering in docking and terminal times for unloading and loading passengers and vehicles.

Ferries are relatively fuel inefficient due to their size and offer relatively slow service. In the United States, the average speed of ferryboat services is only 8.7 mph (14 km/hr). However, new ferries use water pressure to achieve much higher speeds. These so-called fast ferries can attain speeds of 56 mph (90 km/hr). Ferries are operated in 43 metropolitan areas in North America, with the majority of services offered in New York City (Staten Island Ferry carried 22 million riders in 2014) and in Seattle (23 million riders in 2014). In 2014, ferry service in these two cities handled 57 percent of the U.S. ferry ridership. Major ferry services also operate in Boston, New Orleans, and San Francisco.

A hydrofoil is a surface-effect boat with two supporting floats under the hull. As it accelerates, the hydrofoil rises on the floats, greatly decreasing resistance, so that it can reach speeds as high as 40 to 55 knots (70 to 100 km/hr). Its operating cost is higher than that of conventional boats, but the high speed makes it very attractive on long lines. Hydrofoils are used, for example, in Belgrade, Serbia; Helsinki, Finland; Moscow and St. Petersburg, Russia; and other cities for long transit-type services as well as for their connections with neighboring towns on islands along rivers or seacoasts.

V. TRANSIT COST STRUCTURES

Costs associated with transit systems are divided into two broad categories. *Capital costs* include investments in the durable system components, such as infrastructure, vehicles, and heavy equipment. *Operating costs* are the recurring costs associated with the provision of service, such as labor, fuel, and vehicle maintenance. The magnitude of expenditures on transit systems, the sources of these funds, and the modes and components to which the funds are allocated are reviewed here.

As with other modes of urban passenger transportation, transit usually relies on government funding for capital and a large portion of operating funds. The amount spent annually on capital investments in the United States has more

Table 12-10. Allocation of Capital Funds by Mode and Category for U.S. Systems in 2012 ($ Millions)									
Category	Bus	Commuter Rail	Demand Response	Heavy Rail	Light Rail and Streetcar	Trolley Bus	Other	Total for Each Category	% Total for Each Category
Guideway	$286	$1,510	$0	$1,903	$2,532	$14	$4	$6,248	34%
Stations	396	304	4	2,103	408	1	136	3,353	18%
Admin. Bldgs.	166	8	50	25	2	0	1	252	1%
Maint. Facilities	676	214	34	355	75	0	14	1,368	8%
Passenger Vehicles	2,689	632	393	248	232	4	186	4,384	24%
Service Vehicles	61	19	3	28	3	0	0	114	0.6%
Fare Equipment	72	9	2	23	15	1	2	123	0.7%
Communication Systems	411	186	63	800	138	2	5	1,631	9%
Other	200	73	29	391	23	0	4	721	4%
Total for each mode	4,957	2,955	578	5,877	3,428	22	351	18,168	100%
% of total for each mode	27%	16%	3%	32%	19%	0.1%	2%	100.0%	

Source: APTA, 2014b, Reproduced with permission of the American Public Transportation Association.

than doubled in the last two decades, growing from $5.36 billion in 1992 to more than $23 billion in 2012. This funding has come from many sources. Directly generated funds for capital investments, such as fare revenue, grew by more than 262 percent during that decade, local funding increased by 257 percent, federal funding by 201 percent, and state funding increased by about 103 percent. [APTA, 2014b]

Table 12-10 shows transit capital expenditures (in millions of dollars) for 2012 broken down by category of expenditure and by mode. The two largest categories of expenditure were 34 percent for guideways (acquisition and construction of rights-of-way for exclusive use by rail or bus transit), and 24 percent for rolling stock (revenue transit vehicles—buses or trains). Just over $3.3 billion was spent on stations in 2012. Facilities, which include maintenance, storage and administration buildings and equipment, required $1.37 billion, or 8 percent of total expenditures.

Heavy-rail systems received the greatest amount of funding, just over $5.8 billion. More than $4.9 billion was invested in bus systems, $3.0 billion in commuter rail and $3.4 billion in light-rail systems. Demand-responsive systems, due to their limited infrastructure, and trolleybuses received only 3 percent and 0.1 percent of total capital expenditures, respectively.

Table 12-11 shows the operating costs from 2012 for major transit modes. More than $10.5 billion was spent on the operation of bus systems throughout the United States. Forty-five percent of the total expenditures for transit agencies was for vehicle operations. Of that total, nearly 64 percent went to salaries, wages, and benefits of employees, which underscores the relationship between transit service and local economies. [APTA, 2014b]

Transit agencies monitor operations and maintenance costs very closely given the importance of these costs to agency financial stability. These costs also provide agency planners with a tool that can be used to estimate the costs of expected changes in service. For example, a common practice in the industry is to develop cost models based on allocating all variable costs to key cost drivers, most often revenue hours, revenue miles and number of peak vehicles. The following equation is a typical representation of a model for transit service costs.

$$\text{O\&M Costs} = \$42.67\,(\text{revenue hours}) + \$2.64\,(\text{revenue miles}) + \$108,266\,(\text{peak bus}) \qquad (12.1)$$

The unit cost factors would have been developed by taking all of the variable costs associated with transit service in the agency, allocating them fully or partially to one of the three variables, and then dividing by the total number of revenue hours, revenue miles or peak hour buses provided by the agency. So, for example, assume that the cost allocation process ended up with a total of $43,306,400 of variable costs assigned to the “peak-hour bus” category.

Table 12-11. Operating Expenditures by Mode for U.S. Systems in 2012 ($Millions)						
Mode	**Vehicle Operations**	**Vehicle Maintenance**	**Non-Vehicle Maintenance**	**General Admin.**	**Purchased Trans.**	**Total Expenses**
Bus	$10,386	$3,484	$804	$2,828	$1,903	$19,405
BRT	28	3	3	3	0	36
Commuter Bus	163	55	14	58	136	426
Commuter Rail	1,792	1,064	762	777	650	5,044
Demand Response	304	304	58	628	2,474	4,923
Ferry Boat	349	90	39	78	52	609
Heavy Rail	2,984	2,984	1,766	974	56	6,982
Light Rail	566	316	276	265	67	1,491
Other Fixed Guideway	52	38	28	44	27	188
Streetcar	49	30	11	26	18	134
Transit Vanpool	38	14	2	62	67	183
Trolleybus	123	50	19	42	0	234
Percent of Total Operating Expenses	45%	16%	10%	15%	14%	100%

Source: APTA, 2014b, Reproduced with permission of the American Public Transportation Association.

Assume that the agency provides 400 buses during the peak hour. The unit cost factor would thus be $43,306,400 divided by 400 or $108,266 per peak hour bus, as shown in equation 12.1.

The cost model shown in equation 12.1 can be used to estimate the costs of providing new services, simply by estimating how many new revenue hours, revenue miles, and peak buses will be utilized in the new service.

Chapter 5 on transportation finance and funding further describes cost estimation.

VI. SYSTEM PERFORMANCE AND QUALITY OF SERVICE

The performance/cost characteristics of the modes are important considerations when planning new transit lines. [Bruun, 2007; CUTR, 2009] The first category of characteristics includes quality of service measures, which influence the system's ability to attract potential transit passengers. The second category contains measures of interest to the transit operator, including transit supply and efficiency of operation. Finally, a third set of measures aims to assess transit's positive contributions to the community or city in which it is operated. Table 12-12 presents a list of main

Table 12-12. Transit System Performance Characteristics Grouped by Three Interested Parties		
Passengers: Quality of Service	**Transit Operator: Passenger Attraction/Efficiency in Operation**	**Community/City: Attractive and Efficient Transit**
Service availability (spatially and temporally)	Area coverage/hours of service	Passenger attraction/service quality
Service headway/waiting time	Frequency/headway	Economic/social/environmental impacts
In-vehicle travel time/travel speed	Cycle speed	Impacts on city
Transfer time	Average fleet age	
Reliability	Reliability of operations	
Security and safety	Safety and security	
Comfort and convenience	Line capacity and load factors	
User cost/fare	Investment and operating costs	

Source: As adapted from Kittelson & Assocs. et al., 2013 and Kittelson & Assocs. et al., 2003. Reproduced with permission of the Transportation Research Board.

transit system characteristics classified in the three categories. Some of these characteristics are quantitative, while others are qualitative. Their relative weights in evaluation vary with the type of transit line and local conditions.

A. Quality of Service for Passengers

Passenger attraction to transit is largely determined by the total travel time for a given trip, including: (1) access and egress time to the line or route, (2) wait time at a station or stop, and (3) in-vehicle travel time from origin station/stop to destination station/stop. These travel components are a function of transit network design and system operations. Each is discussed below in terms of the quality of service characteristics presented in Table 12-12.

1. Service Availability (Access Trip Time)

Service availability is the basic precondition for using transit, and directly influences passenger mode choice. It is measured by the proximity of a transit stop or station to a transit user's origin and destination. The willingness of persons to use transit depends not only on distance from the service, but also on the mode of access, type of service offered, and local conditions. Long trips on higher performance modes, such as metro and regional rail, attract people from greater distances than short trips by bus. The total access area from which a transit stop or station attracts passengers is known as the area coverage.

In central cities, access to transit stations is mostly by walking. Considering an acceptable access time of 10 minutes (or 2,400 ft [731 ms] at 4 ft per second [1.2 meters per second]), street transit (bus, trolleybus, or streetcar) systems can usually provide full central area coverage. In medium and large cities with extensive rail transit networks, such as Boston, Munich, Prague, and New York City, the central city also has good coverage by LRT, metro, or regional rail lines, each having acceptable walking access distances (1/2 mile to 3/4 mile (800–1,200 m)). For detailed analyses of transit access times, the lengths of access paths from various points, including indirect walking path routings, may be necessary to compute. While walking access remains the standard for calculating population along transit lines, it should also be recognized that an increasing number of passengers are accessing transit by bicycle as cycling becomes more popular.

Access to stations with park-and-ride facilities on a regional rail line is often by feeder bus or automobiles. Determining area coverage requires a consideration of the direction and speed of travel, natural limits of surrounding areas, and the availability of competing modes, particularly the existence of major highways serving the same market.

The cumulative measure of spatial service availability for a network is computed as the ratio of the sum of all stations' area coverage and the total transit-supportive area of the served region. To be considered transit-supportive, an area must exceed minimum thresholds in employment or residential densities. Typical values are three households per acre or four jobs per acre (7.5 to 10 per hectare).

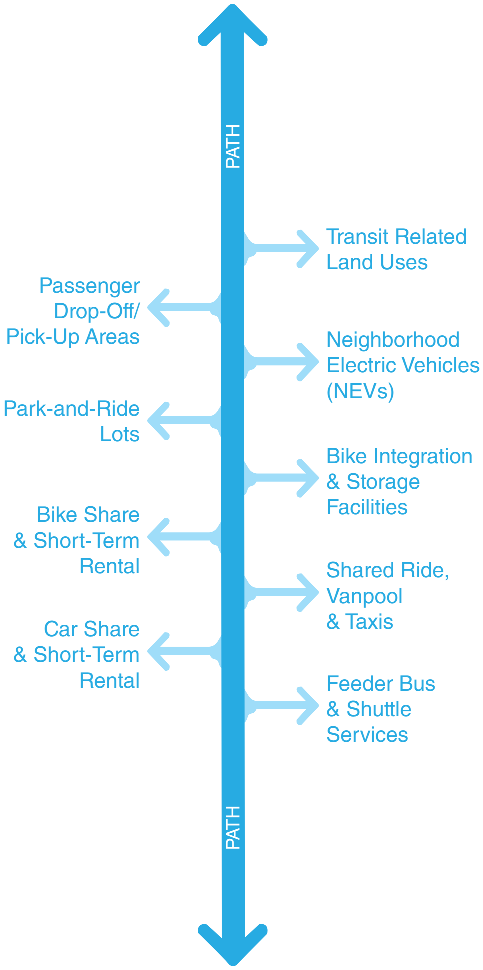
2. Service Availability (Access Environment or the First and Last Mile)

By the very nature of the trip, those who ride a transit system must get to a transit station or bus stop and then arrive at their ultimate destination after leaving the system at the other end of the trip. This is often considered one of the most challenging aspects of transit service. If the perception is that the access and egress portion of the trip is unsafe or inconvenient, potential riders might avoid taking transit. Providing a safe and effective so-called "first or last mile" portion of a total trip, which is often not the responsibility of the transit agency itself (for example, walking to or from a station, or driving to a park-and-ride lot), can be an important factor in attracting and keeping transit riders.

Perhaps one of the best transit guides for this part of the trip experience comes from the Los Angeles Metropolitan Transportation Authority (MTA) and the Southern California Association of Governments (SCAG). In 2013, both agencies published *First Last Mile Strategic Plan, Path Planning Guidelines*. [Los Angeles Metro and SCAG, 2013] As noted in the plan, "though the streets and infrastructure that comprise the first-last mile fall outside the boundaries of Metro's jurisdiction and control, they remain critical components of an effective public transportation system. Simply put, all Metro riders must contend with the first-last mile challenge, and the easier it is to access the system, the more likely people are to use it." Figure 12-17 shows the concept of developing a system of paths and interconnections to the mainline transit service that the transit agency can improve to provide better service to its customers. Determining the paths (and their condition) that transit users follow in getting to and from transit service is a data-intensive effort. Figure 12-18, for example, shows the typical types of data that Los Angeles Metro collects in planning for the first and last mile.

Providing for a safe and effective environment for this portion of a trip will often require close coordination and collaboration with many different agencies and private partners. In some cases, path requirements could be incorporated into the zoning code for developments locating near transit stops, and/or amenities, and safe passage could be the focus of public/private partnerships.

Figure 12-17. Los Angeles Metro's First and Last-Mile Focus



Source: Los Angeles Metro and Southern California Association of Governments, 2013

3. Temporal Availability

The attractiveness of transit also depends on the availability (or span) of the service through the day. System performance can be measured by the hours of operation. Most transit services operate 16 to 20 hours per day. Large cities commonly have a skeleton network of lines that operate night or owl services between midnight and 5 a.m., thus offering 24-hour service.

4. Waiting Time

The waiting time at a station is a function of service frequency or headway. For short headways, usually below 10 minutes, passenger arrivals tend to be random, so that waiting time is considered to be half of the headway. For headways of 10 minutes or longer, passengers are more likely to plan their arrivals based on the published schedule. If service is reliable, passengers time their arrivals so that their average wait times are nearly as short as for services with short headways. Long headways, however, require the use of schedules and are considerably less convenient. When the trip involves a transfer, the passenger experiences a second wait time, which is often perceived as more onerous than the first wait time.

Recent passenger information systems provide riders with advanced notice from apps on when vehicles are to arrive at designated stops. This new technology application will go a long way to minimize wait time at transit stops.

5. In-Vehicle Travel Time

The amount of time spent in-vehicle is determined by the travel speed of the vehicles and the distances traveled. Buses and other street transit usually have average operating speeds of 7.5 to 12.5 mph (12 to 20 km/hr) in the central city and 9.3 to 15.5 mph (15 to 25 km/hr) in the suburbs. LRT and other semi-rapid transit modes operate at average speeds of 12.4 to 18.6 mph (20 to 30 km/hr). Older metro and long LRT lines (such as in Denver and Baltimore) typically operate at average speeds of 15.5 to 21.8 mph (25 to 35 km/hr), while newer regional metro, such as BART, and regional rail systems are in the average speed range of 18.6 to 37.3 mph (30 to 60 km/hr).

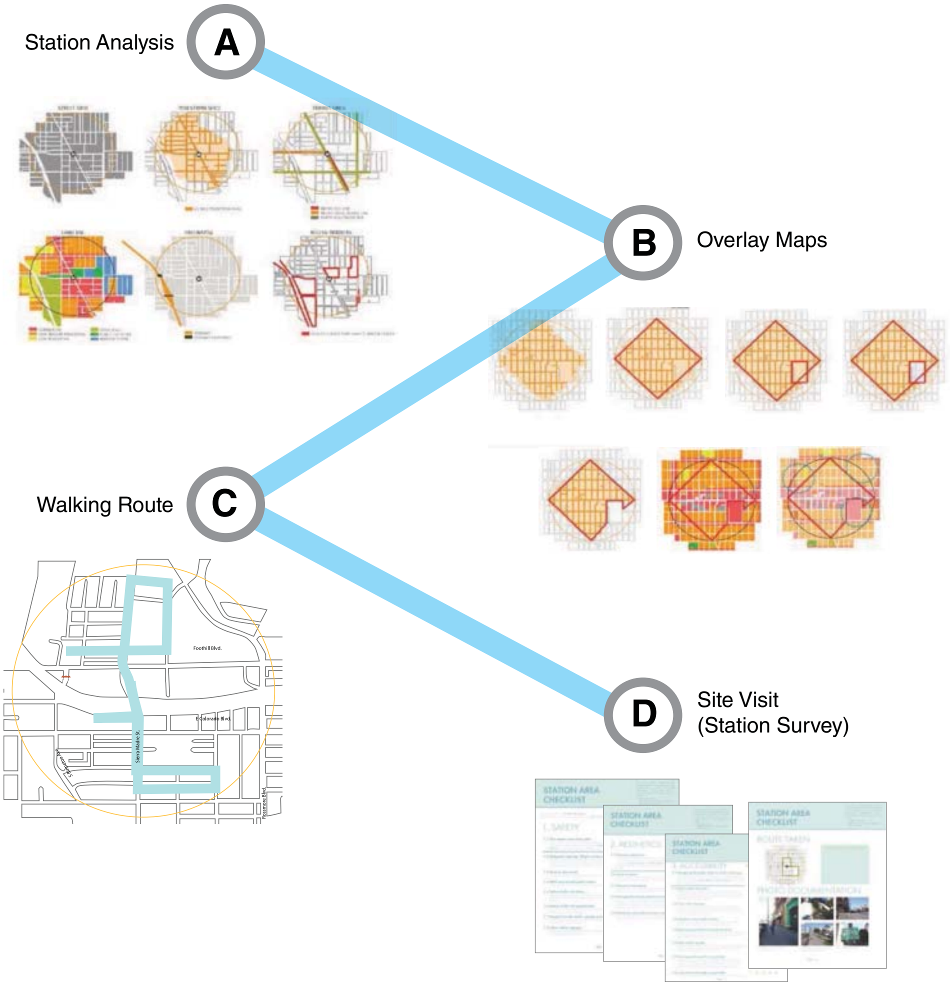
Modal split estimates and comparisons of transit service quality with other modes for individual passenger trips are usually made through computations of the difference or ratio of travel times, depending on the length of the trip being evaluated. Typically, differences are better measures of effectiveness for shorter trips, while ratios are more appropriate when comparing longer trips.

6. Reliability

On-time performance is one of the most important transit service characteristics to riders because unpredictable or frequent delays prevent people with strict schedules from using transit, or when they use it, they must assume considerable flexibility in their travel time. Thus, low service reliability usually results in much longer travel times for passengers, making transit less competitive. Moreover, unreliable service negatively influences a passenger's perception of the system.

Reliability is usually measured by schedule adherence, defined as the percentage of vehicles on a line that arrive within a predetermined limit of their scheduled time, typically 3 to 5 minutes for low-frequency services. Alternatively, system reliability may be measured by the uniformity (or variance) of headways for high frequency services. The coefficient of variation (the ratio of headway standard deviation to mean headway) is also an appropriate measure.

Figure 12-18. Required Data for Los Angeles Metro's First and Last-Mile Planning



Source: Los Angeles Metro and Southern California Association of Governments, 2013

Systems commonly place a heavier penalty on running early than running late when it comes to measuring on-time performance since running early or "hot" means a passenger may miss the trip entirely.

Equation 12.2 shows the relationship between mean wait time and mean headway $\bar{h}$ and the coefficient of variation defined as ($\sigma/\bar{h}$). As indicated, the mean waiting time will decrease with the increase of bus service reliability, that is, with a decrease in the standard deviation of headways.

$$E(w) = \frac{\bar{h}}{2}\left[1 + \left(\frac{\sigma}{\bar{h}}\right)^2\right] \tag{12.2}$$

The main factor influencing reliability of transit service is its right-of-way category. Street transit, being subject to traffic conditions, has the lowest reliability, while rapid transit with fully controlled right-of-way has the highest arrival reliability, often in the range of 95 to 99 percent of vehicle arrivals.

7. Security and Safety

Successful transit system plans and designs instill in passengers a sense of well-being while traveling in the system. System safety and security are defined by the frequency of incidents or accidents per million passenger trips or vehicle-km traveled. An important goal of every transit system is to minimize or prevent these events. Following Crime Prevention through Environmental Design (CPTED) principles and integrating exchanges, stations and stops into "people places" that are located adjacent to other uses are important considerations, as is ensuring high quality and safe pedestrian and cycling connections.

8. Passenger Comfort and Convenience

Comfort is influenced by three primary factors: vehicle loading (availability of seats or degree of crowding), vehicle conditions (temperature, cleanliness, and such) and the movement of the vehicle. The most readily quantifiable and most pertinent to systems planning are vehicle loading (that is, the availability of seats), load factor, and the standard used for the maximum number of standing passengers. A measure of vehicle loading is calculated as the number of passengers per spaces offered on the vehicle. Spaces are computed by summing the number of seats and the number of potential standees, which is calculated as the product of the available floor area in the vehicle or car and the number of passengers per area. The area per passenger requirement varies depending on the length of trip and the socially accepted standards in the area where service is offered. Typical design values for major metropolitan areas are in the range of 0.37 to 0.46 persons/ft^2 (4 to 5 persons/m^2).

Vehicle design, riding comfort, cleanliness, and image are also elements of passenger comfort and attraction. Ease of boarding/alighting, transferring between lines, information systems, and the ability to handle luggage are elements of both comfort and convenience. Accessibility for the disabled and for persons with luggage and baby strollers is required for all new transit systems and vehicles by law in the United States and in many other countries. Integration for bicycles either by exterior racks (common on conventional buses) or inside specially designated rapid transit vehicles is also becoming common.

9. User Cost/Fares

The out-of-pocket expenses incurred for a trip by transit compared to the cost of making the trip by other modes are an important measure of passenger service quality. The transit fare, therefore, represents an element of the transit system affecting passenger satisfaction and decision to use the system. The relative ease of using the fare system, that is, the purchase and utilization of a fare medium during a trip, is also an important consideration for those traveling on transit. For this reason, many transit agencies have instituted open-fare pass systems, that is, an honor system that one has paid a fare, or are using "smart" cards to make the fare transaction as easy as possible. New fare payment options are also being developed (such as with a mobile phone) that will make the fare exchange much easier than in the past.

B. Measures of Transit System Effectiveness from the Operator's Perspective

A transit operator evaluates system effectiveness from a different perspective than passengers. However, some elements are common, but measured in a different way. The measures of system effectiveness from the operator's perspective usually include:

- *Area Coverage*—The amount of service available to potential customers relating to the access to transit stations and stops.
- *Boardings (Rides) per Vehicle (Platform) Hour*—Total ridership divided by the total hours a bus travels from the time it leaves its base until it returns. This is an indicator of all ridership, including time when a bus is traveling and does not pick up passengers. This measure accounts for the full cost of service and values services that connect many people to many places with many ons and offs all along the route.
- *Cycle Speed*—The average speed to complete a round trip, including running time along the trip and any layover used as a scheduling buffer. Maximizing this speed is a goal for both passengers and the operator, but the operator measures it through cycle speed because this speed directly influences the cost of operations, and thus system efficiency.
- *Farebox Recovery*—The amount of revenue collected from passengers compared to operating cost.
- *Frequency of Service/Headway and Service Span*—The number of departures per time period (frequency) and the time between departures (headway), as well as the overall length of the service day (span). Frequency and headways determine fleet size and the number of vehicles in operation and, therefore—in tandem with service span on each operating day--the number of operators.
- *Investment and Operating Costs*—A system's efficiency as measured by the ratio of performance to costs with respect to items such as various units of work (vehicle-miles operated, speed, and frequency of service, reliability, and such).
- *Line Capacity*—A measure of a transit system's ability to meet the demand for travel with a given quality of service (reliability, comfort, safety, and other factors). Computing capacity is very important in planning

transit lines and, particularly, in comparing and selecting transit modes. To avoid errors caused by different methods of computing capacities for individual lines or modes, several concepts relating to transit line capacity are defined here:

  - *Offered capacity* is computed in spaces (seats plus standing spaces) carried past a point along the line, while *utilized capacity* refers to the number of passengers carried. The ratio of utilized to offered capacity is a load factor $\alpha < 1.00$.
  - *Practical capacity* is based on actual observations and measurements; it represents passenger volume that is actually carried on a line under real-world conditions. Practical capacity is, therefore, lower than theoretical capacity (see below).
  - *Station capacity* is the maximum number of transit vehicles or consists that can pass through a station in a given period of time, typically one hour. The line capacity for a given route is determined by the longest minimum headway at a station (sometimes headways at junctions or street intersections may be more critical than at stations).
  - *Theoretical capacity* is the capacity computed based on the minimum headway that can be achieved on a line**.** This calculation assumes ideal operating conditions without any variations in station dwell times (the time a vehicle waits at a stop or station to board or alight passengers), driving regime, and such.
  - *Way capacity* is the maximum number of transit vehicles or consists that can pass a point along the line in a period of time. Way capacity measures the transit vehicle throughput that can be achieved on a transit line without stopping at stations. Because the way capacity applies in extremely rare situations (for example, on a highway or rail section where many lines merge and then diverge without stopping), the station capacity usually dictates the line capacity.

- *Passenger Miles per Vehicle (Platform) Mile*—Total miles traveled by all passengers divided by the total miles the bus operates from its base until it returns. This is an indicator of the average distance traveled by all passengers, including the miles when the bus is traveling and the seats are empty. This measure accounts for the full cost of service and efficiency of route design and values services that have riders who travel long distances along the whole route.
- *Platform Service*—The time when a vehicle is in operation away from the base; this includes revenue service, layover/recovery time, and deadhead time.
- *Reliability of Operations*—Usually measured as on-time performance. The system on-time performance is to various extents (depending on rights-of-way) under the control of the operator. Vehicle design, control of operations, and other system elements contribute to a system's reliability, as do a number of scheduling techniques and vehicle maintenance protocols.
- *Revenue Service*—The time when a vehicle is available to the general public and there is an expectation of carrying passengers, including layover/recovery time.
- *Safety and Security*—Monitored primarily by the number or rate of incidents. As with reliability, transit operators can directly influence the systemwide safety and security of systems through appropriate infrastructure (vehicle, guideway, stations, etc.) design, operational practices, and enforcement.
- *Subsidy per Passenger*—Amount of subsidy required to operate service per passenger served.

Loading standards for computation of vehicle capacities vary greatly among cities and transit modes. In most industrialized countries, loading conditions for standees are based on 2.7 ft^2/person (4 persons/m^2), while in some developing countries a much greater crowding, from 2.2 to 1.8 ft^2/person (5 to 6 persons/m^2), is used for computations, although the high values in this range cannot be physically achieved in real world conditions.

Offered line capacity is one of the more important measures. Line capacity is computed as the product of the maximum frequency (or minimum headway) and transit consist capacity, which is the product of vehicle capacity and number of cars per consist. The shortest headway is the one that can be operated at the critical point along the line, usually at the station with maximum exchange of passengers. Thus, for example, if the frequency of operations is 6 consists per hour, and a consist includes 3 cars with a car capacity of 100 riders per car, the offered line capacity is $6 \times 3 \times 100$ or 1,800 spaces per hour.

Table 12-13. Typical Vehicle and Line Capacities of Different Modes					
Mode	Consist Size (veh/consist)	Vehicle Capacity, C_v, (sps/veh)	Min. Headway $h_{\min}$ (secs)	Max. Frequency f_{max} (buses or consists/hr)	Max Offered Line Capacity C (sps/hour)
Std bus, single stops	1	75	50–70	51–72	3,800–5,400
Articulated bus, single stops	1	120	60–80	45–60	5,400–7,200
50% standard, 50% articulated bus, 4 lanes and multiple berthing	1	75–120	20–40	90–180	8,800–17,500
Streetcar, ROW C, double stops	2	180	150 (2 signal cycles)	24	8,640
Bus rapid transit, North America	1	120	60	60	7,200
Bus rapid transit, developing countries	1	180	30	120	21,600
Light rail transit, ROW B, single track, double stops	2–3	180	240 (3 signal cycles)	15	5,400–8,100
AGT, rubber-tired, Siemens, Bombardier	2	100	60–90	40–60	8,000–12,000
AGT – rail	6	100	75–100	36–48	21,600–28,800
Rapid transit with 8 cars	8	180	90–100	36–40	51,800–57,600
Rapid transit with 10 cars	10	240	120–150	24–30	67,200–72,000
Regional rail – diesel	10	200	180–240	15–20	30,000–40,000
Regional rail – electric	10	200	120–180	20–30	40,000–60,000

The minimum headway depends on the length of the consist, the speed of the consist, and the minimum spacing between successive consists, determined by the operating regime. For buses, streetcars, and LRVs that operate on streets under driver control, capacity depends upon the green time per traffic signal cycle available and the dwell times at busy stops (or intersections). Frequencies up to 60 buses per hour can be achieved on a line with exclusive lane and single vehicle stops. When there are multiple berths or where buses can pass each other, 90 to 120 buses per hour have been reported. When a line has two lanes per direction at every stop and buses/trolleybuses can overtake each other, frequencies of up to 180 vehicles/hr can be achieved (Portland, Oregon, and Madison Avenue in New York City).

Rail transit modes running on segregated or exclusive right-of-way, such as LRT and metros, are controlled by signals that usually require headways of at least 90 seconds, so their maximum frequency is 40 consists/hr (in New York City, current operating practices limit headways to at least 2 minutes). Consist capacity on rail systems, particularly metros and regional rail, is much greater than that of buses (1,000 to 3,000 spaces vs. 80 to 160 spaces), so that line capacities of rail systems are typically greater than those of AGT and street transit (buses, BRT, and LRT).

Table 12-13 shows practical or operational capacities in vehicles or passengers per hour under conditions typical for North America and other industrialized countries. The reader is referred to Kittelson et al. [2013] for an extensive presentation on how one can estimate transit capacity.

C. Transit Impacts on Development

Most North American cities have experienced a decentralization of land-use activities that pose challenges for the efficient provision of transit services and attraction of passengers. [Los Angeles Metro, 2012] In response, many metropolitan areas have planned and constructed rail transit systems in relatively low-density areas with the goal of attracting concentrated development in their service areas.

One such example in the United States is New Jersey's River LINE, a $1-billion, 34.5-mile (55.5-km) LRT line, which opened in 2004. The line connects the cities of Trenton and Camden, New Jersey, along an existing rail corridor running parallel to the Delaware River. The system uses a hybrid diesel-electric vehicle, thus avoiding the cost of electrification. The River LINE was designed to provide commuter service between the two cities, connect the corridor with the city transit systems in Philadelphia, Camden, and Trenton, and to be well integrated with intercity (Amtrak and New Jersey Transit) services in Trenton. More importantly, the system was planned with 20 stations, each of which was intended to act as a location to accommodate residential and commercial growth in southern New Jersey. Development investments have occurred, and ridership has grown steadily now exceeding initial projections.

A similar system is being planned in the Region of Waterloo, Ontario. The region is expected to grow from its current population of approximately 500,000 to 720,000 by 2031. As part of a comprehensive growth management strategy, the region is planning the construction of a transit system operating on right-of-way B along the central corridor. The intention is to intensify urban land uses along the transit line such that the provincial target of accommodating 40 percent of new growth in developed areas can be met.

One of the ways of linking transit investment to development is called transit-oriented development. [Dittmar, 2004] Transit-oriented development (TOD) is the planning and design of medium- or high-density, mixed land uses around a transit node that acts as the center of the development and provides attractive transportation access to the area. The land-use and urban-design practices around the transit node facilitate pedestrian movements between and within the TOD. The goals are to increase choices of travel modes, to decrease the total number and length of automobile trips, enhance nonmotorized access to activities and increase transit ridership. In addition to providing high-quality, high-capacity transit service, successful TODs (and more generally transit supportive land uses) require comprehensive land-use controls and policies. See chapter 3 on land use and urban design for additional discussion on TODs and other policies that can be used to encourage development near transit stations and along transit corridors.

VII. TRANSIT PLANNING PROCEDURES

Transit planners participate in a variety of different planning studies. This section describes four major types of transit planning: strategic planning, comprehensive operations or service planning, long-range transit planning, and planning for major transit investments.

A. Strategic Planning

The objective in creating strategic plans is to develop a clear vision of the desired future state of the transit system and its operating agency. [Lawrie, 2005] The analysis involves assessing the agency's internal organization, services offered, and its role in a coordinated transportation network. The strategic process provides an opportunity to engage stakeholders—agency employees, government or political decision makers, local businesses, and the public—in defining and embracing the transit agency's future directions.

The product of the strategic planning process is usually a document that presents the agency's mission or core values along with foreseen challenges (both internal and external) requiring future action by the agency. Perhaps most important, strategic plans establish desired system performance levels for the transit network using measures of effectiveness such as those discussed earlier. Any proposed change to infrastructure, operations, or agency finance is evaluated against its ability to achieve one or more of the stated system goals.

Successfully implementing the strategic plan requires two major actions. First, the strategic plan should be linked to both the operating and the capital budgeting process in the agency to ensure that financial investments are being made that are consistent with the objectives of the plan. Second, a formal tracking mechanism should be in place to determine if the agency is achieving its goals. There should also be a renewal process and timeline to update the plan, such as every five years.

B. Comprehensive Operations (or Operational) Analysis

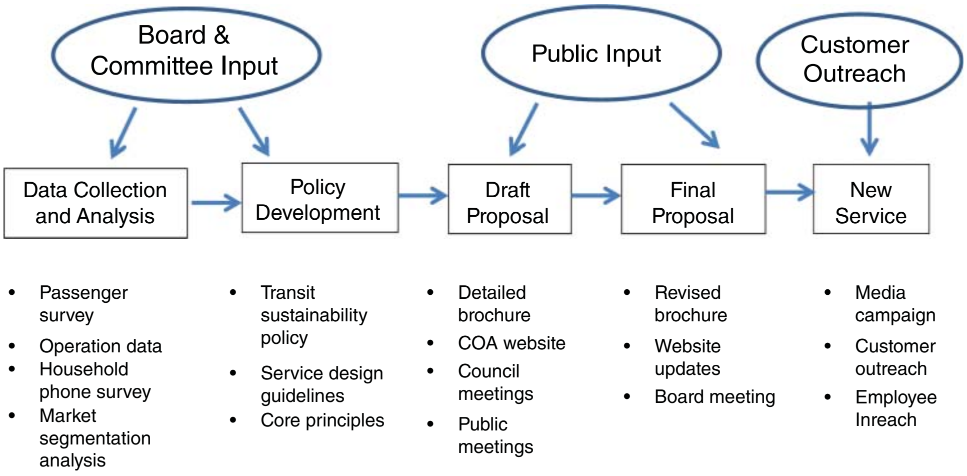
When a transit agency decides to examine all of its routes and services at one time in order to determine where best to change the network and individual services to better reflect today's and future transit markets, it conducts what is called a comprehensive operations (or operational) analysis (COA). For example, the COA for Lynx, the transit system in Orlando, Florida, stated that "the COA will include an analysis of the route network and recommend short-term and long-term modifications including:

- Adjustments to running times, departure times/locations, transfer times, and stop spacing to improve schedule adherence and customer satisfaction.
- Removal of minimally used bus stops and/or consolidation of bus stops.
- Appropriate vehicle type and service characteristics, including fixed- and flex-route, local, limited, and express service.
- Updated service standards based on industry norms as well as LYNX's productivity requirements, as stipulate by the Florida Transit Commission.
- Capital needs, including improvements to passenger facilities.
- Staffing recommendations.
- Implementation phasing." [Central Florida Transportation Authority, 2014]

Figure 12-19 shows a typical COA process that was used for the Santa Clara County Valley Transportation Authority in California. The figure indicates the type of data collected, the roles of both the public and transit agency board members and staff, and the type of outreach that is typically part of a COA effort. Figure 12-20 shows the type of data analysis that typically occurs in a COA, in this case looking at the different market segments and their relationship to the types of services that the transit agency should offer. Key to conducting a successful COA is relating different transit service types to different markets. Table 12-14, for example, shows what was called the tiers of service in the Broward County Transit (Florida) system, defined by the location within the service area and the key markets they serve. In this case, the different tiers were defined as:

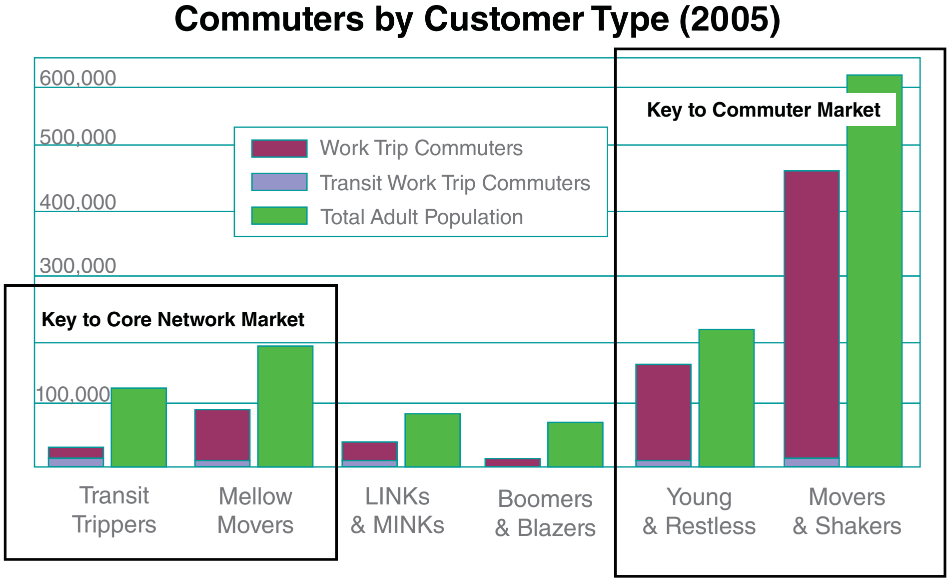
- *Network-Based Service:* Network-based, local, fixed-route service that serve as the backbone of the system. Successful network-based service provides convenient connections to rapid and community service. To meet their role in the future network, Broward County Transit's local services examined service frequency increases and the possible introduction of automatic vehicle location (AVL) technologies, increased onsite supervision, and transit signal priority improvements.
- *Rapid Bus Service:* Major transit corridor service with high service frequencies, limited stop spacing, transit signal priority, enhanced passenger stations, and unique branding.

Figure 12-19. Typical COA Process for a Transit Agency



Source: Burns, M. 2009. Santa Clara Valley Comprehensive Operations Analysis, Accessed March 2, 2016, from http://www.mtc.ca.gov/planning/tsp/Comprehensive_Operations_Analysis.pdf.

Figure 12-20. Typical Data Analysis for a COA Process



Source: Burns, M. 2009. Santa Clara Valley Comprehensive Operations Analysis, Accessed March 2, 2016, from http://www.mtc.ca.gov/planning/tsp/Comprehensive_Operations_Analysis.pdf

Table 12-14. Service Tiers and Market Groups, Broward County, Florida

Service Tier Criteria	Demand Intensity	Corridor Type	Network Role	Key Markets
Network-based Services	Medium to high ridership per route mile	Major and secondary arterial roads	Provide core network	All-day, multipurpose
Rapid bus service	High ridership per route mile	Major arterials and dedicated rights-of-way	Fastest, highest capacity services	High volume, all-day, multipurpose; major destinations
Community-based service	Medium to low ridership per route mile	Local and neighborhood	Community-based network connector or local circulation	Market-specific services tailored to individual community needs
Commuter Service	High point-to-point demand	Freeways and major arterial roads	Fast, efficient, peak-hour service	Peak-hour commuters

Source: Broward County Transit. 2010. *Comprehensive Operations Analysis, 6. Service Framework*. Accessed March 2, 2016, from http://www.broward.org/BCT/COA/Documents/COAServiceFramework.pdf

- *Community-Based Service:* Local circulation catering to specific market needs and connections to network-based services. In some cases, areas now served by BCT's fixed routes may be more suited to flexible options.
- *Commuter Service:* Point-to-point, longer-distance express services that do not make local stops. Geared toward commuters, they provide service to major employment districts in peak hours from hubs such as park and ride lots.

Clearly, service markets will differ by size of service area and type of metropolitan area. [Ceder, 2001] Much of the early analysis in a typical COA will identify what types of service types or tiers make sense for the types of markets that are part of the service district today and those that are evolving to become more important in the future.

Some of the strategies that transit agencies have used to improve the productivity of transit service and, in particular, increase the average speed of service are found in Table 12-15. This table comes from a Transit Cooperative Research Program project that surveyed transit agencies in North America. [Boyle, 2013]

Table 12-15. Strategies to Increase Average Speed of Buses		
Strategy	**Number of Agencies Responding**	**Percent of Agencies Responding**
Route-related Actions		
Streamline routes	39	91%
Introduce limited stop service	18	42%
Introduce BRT service	10	23%
Other	10	23%
Total	43	100%
Stop-related Actions		
Change in stop spacing	30	79%
Change bus stop location	18	47%
Change bus stop design or length	13	34%
Level boarding at transit centers	8	21%
Other	5	13%
Total	38	100%
Vehicle-related Actions		
Introduce/increase use of low-floor buses	33	89%
Switch from lifts to ramps for wheelchair access	29	78%
Introduce/increase use of different size vehicles	22	60%
Introduce vehicles with better performance	17	46%
Change seating configuration	8	22%
Allow bicycle storage inside the bus	7	19%
Change door configuration	4	11%
Other	3	8%
Total	37	100%
External Policy Changes		
Signal priority or queue jump lanes	22	69%
Signal timing	14	44%
Bus-only lanes on arterial streets	13	41%
Yield-to-bus laws	13	41%
Turn restrictions	9	28%
Parking restrictions	8	25%
Other	6	19%
Total	32	100%
Internal Policy Changes		
Pricing to encourage use of prepaid fare media	22	76%
Off-board fare collection	8	28%
All door boarding	7	24%
Changes in hold policies at transit centers	7	24%
Free fares or introduction/discontinuation of fare free zones	6	21%
Changes in bus door practices	3	10%
Other	3	10%
Total	29	100%

Source: Boyle, 2013, Reproduced with permission of the Transportation Research Board.

It is beyond the scope of this chapter to go into great detail on COA analyses. Interested readers are directed to the following COA documents that provide good examples of what a COA consists of:

- Indianapolis, Indiana: http://www.indygo.net/pages/transit-planning.
- Rhode Island Public Transit Authority: http://www.ripta.com/coa-project-documents.
- San Joaquin (California) Regional Transit District: http://sanjoaquinrtd.com/coa.

C. Long-Range Transit Planning

A long-range transit planning study can focus solely on transit investments (and thus likely undertaken by a transit agency), or it can be part of the broader metropolitan transportation planning process (and thus likely undertaken by a metropolitan planning agency). [Sound Transit, 2012; Miami-Dade County, 2013; Central Florida Regional Transportation Authority, 2013] The long-range transit planning process is shown in Figure 12-21. The first steps compare existing and future operating conditions using quantitative/qualitative measures of effectiveness relating to the system's goals and objectives (based on the agency's strategic plan). Here, the goals of transportation and land-use plans are further expanded, examining such things as accessibility, mobility, positive environmental characteristics, and the character of the area served. The necessary data to perform project evaluation include population (often evaluated at the household level to include a disaggregate estimate of age), employment (number of jobs of different classifications), and other social characteristics like income levels and auto ownership. Current land-use patterns are documented, usually by measuring densities and classification of land-use types (agricultural, commercial, retail, and such). Finally, data related to the current travel demand are compiled. These data include travel volumes between origin-destination pairs throughout the study region, observations of link (streets or freeway sections) volumes measured in average annual daily traffic (AADT) or design hour volumes (DHV), and finally ridership on the existing transit system at the route or line level.

To assess future transit services, models are used based on the relationships between system components and system performance (see chapter 6 on travel demand models). The most commonly used transportation planning model is the four-step model, which quantifies system performance by sequentially predicting trip generation, trip distribution, mode split and trip assignment. However, some have argued that this sequential process is inherently weak in its treatment of transit. For example, the mode split decision is made in Step 3, prior to quantifying the performance of the highway network. Essentially, in the first iteration, the mode choice is made based on a comparison of transit costs and uncongested highway travel. To overcome this weakness, a feedback method is used, which iteratively considers

Figure 12-21. Long-Range Transit Planning Process

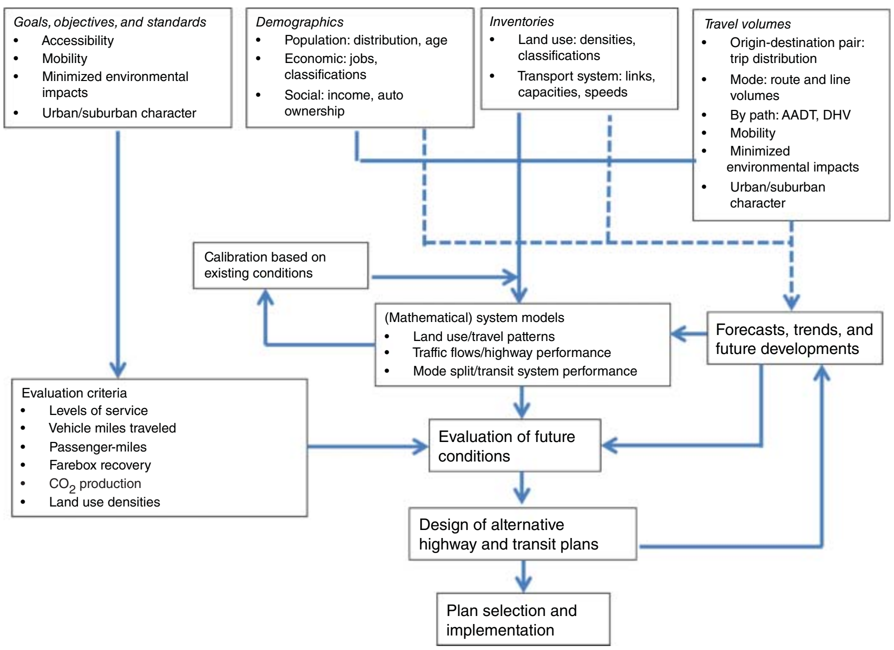
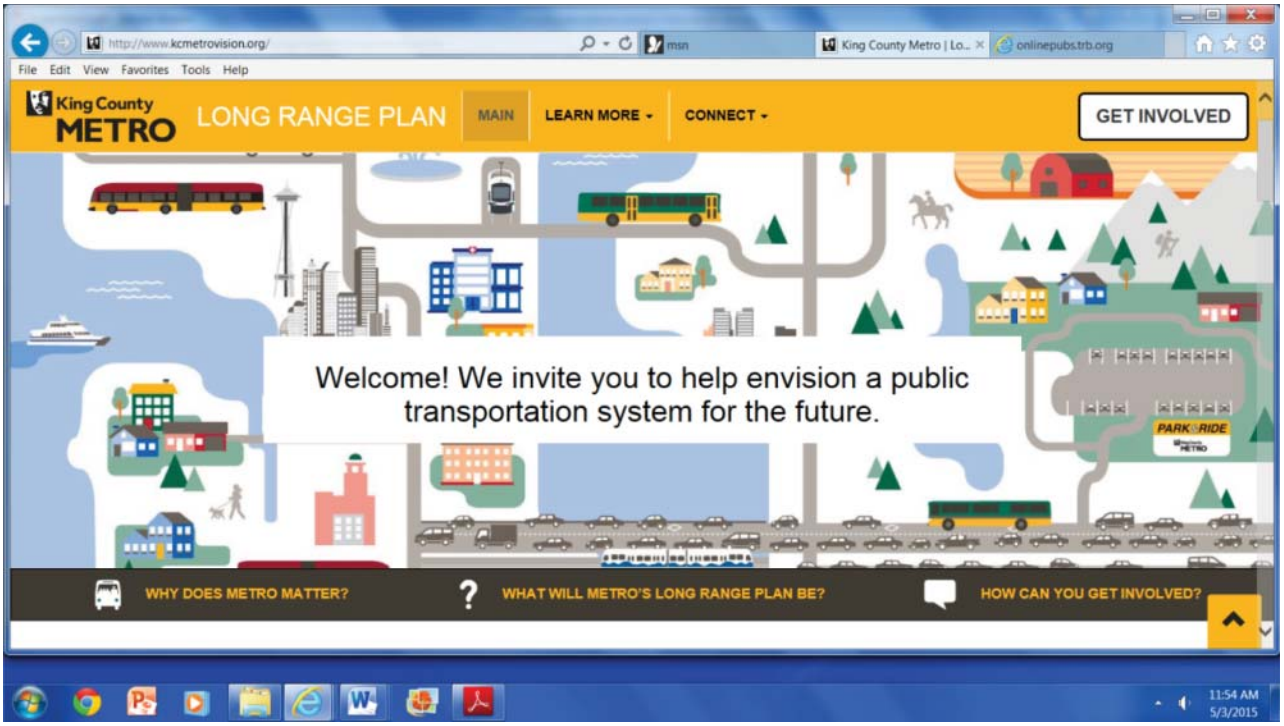


Figure 12-22. Website from King County Transit, Washington Seeking Public Input on Long-range Transit Plan



Source: King County Metro, Website, Accessed Feb. 2, 2016, from http://www.kcmetrovision.org.

network conditions in the mode choice step. The problem is iteratively solved until equilibrium is reached among modal flows. As noted in chapter 6, activity-based models are now being developed to overcome some of the model deficiencies with respect to transit planning.

Although not represented in Figure 12-21, public engagement occurs throughout the process. When federal funds are considered for construction of the project, such public participation is a requirement of the planning process. Figure 12-22 shows an image from the King County Metro, Washington, website for its long-range transit planning process. Through such efforts, those who ride the system and those who pay for it through taxes can provide input into the planning process.

1. Planning for Major Transit Investments

In the United States, the FTA has established a structured process that must be followed to receive federal funding for major transit investments. Once referred to as the alternatives analysis (AA) process, the current procedures have been simplified through federal legislation. Transit planners should always check with the FTA to determine the latest requirements for this type of planning. Although no longer called the alternatives analysis process, the FTA definition of alternatives analysis is still a useful explanation of this type of planning. Alternatives analysis can be viewed as a planning process that:

- Includes an assessment of a wide range of public transportation or multimodal alternatives, which will address transportation problems within a corridor or subarea.
- Provides ample information to enable the Secretary to make the findings of project justification and local financial commitment.
- Supports the selection of a locally preferred alternative.
- Enables the local metropolitan planning organization to adopt the locally preferred alternative as part of the long-range transportation plan. [FTA, 2011]

The 2012 federal transportation law, Moving Ahead for Progress in the 21st (MAP-21), eliminated the alternatives analysis requirement and required instead a review of alternatives during the metropolitan planning and environmental review processes. A new project development phase was defined where the environmental review process is

Table 12-16. Federal Transit Administration Evaluation Criteria for New Starts Transit Projects		
Category	**Stage of Decision Making**	**Evaluation Measure**
Mobility	All	Estimated Annual Trips (Trips by Non-Transit- Dependent Persons plus Trips by Transit Dependent Persons multiplied by 2).
Economic Development	Engineering and Federal Grant Decision	Degree to which growth management and land conservation policies have been implemented.
	Engineering and Federal Grant Decision	Degree to which conceptual plans for the corridor and station areas have been developed.
	Federal Grant Decision	Degree to which local jurisdictions have adopted zoning changes that strongly support a major transit investment in most or all transit station areas.
	Engineering	Degree to which a conceptual planning process is underway to recommend zoning changes for station areas.
	Engineering and Federal Grant Decision	Degree to which transit agencies and/or regional agencies are working proactively with local jurisdictions, developers, and the public to promote transit-supportive planning and station area development.
	Federal Grant Decision	Degree to which a significant number of development proposals are being received for transit-supportive housing and employment in station areas.
	Engineering	Degree to which transit-supportive housing and employment development is occurring in the corridor.
	Engineering and Federal Grant Decision	Degree to which a significant amount of land in station areas is available for new development or redevelopment at transit-supportive densities.
	Federal Grant Decision	Degree to which comprehensive affordable housing plans have been developed and are being implemented that identify and address the current and prospective housing affordability needs along the corridor.
	Engineering	Degree to which plans and policies are in place in most of the jurisdictions covered by the project corridor that identify and address the current and prospective housing affordability needs along the corridor.
Environmental Benefits	Engineering and Federal Grant Decision	Change in total air quality criteria pollutants—carbon monoxide (CO), mono-nitrogen oxides (NO_x), particulate matter (PM2.5), and volatile organic compounds (VOC).
		Change in energy use.
		Change in greenhouse gas emissions.
		Change in safety.
Cost Effectiveness	Engineering and Federal Grant Decision	Annualized capital and operating cost per trip.
Land Use	Engineering and Federal Grant Decision	Employment served by system in station areas.
		Average population density (persons/square mile) in station areas.
		Central business district (CBD) typical parking cost per day.
		CBD parking spaces per employee.
		Proportion of legally binding affordability restricted housing in the project corridor compared to the proportion in the counties through which the project travels.
Congestion Relief	Engineering and Federal Grant Decision	Not yet published as of the date of this handbook.
Finances	Engineering and Federal Grant Decision	Current capital and operating condition (25% of local financial commitment rating).
		Commitment of capital and operating funds (25% of local financial commitment rating).
		Reasonableness of capital and operating cost estimates and planning assumptions/capital funding capacity (50% of local financial commitment rating).

Source: FTA, 2013

to be completed, and what was preliminary engineering and final design was consolidated into an engineering step. [FTA, 2015] In addition, MAP-21 amended the criteria that FTA would use to rate individual transit investment projects. The new criteria, shown in Table 12-16, are part of the information that needs to be produced by the transit project development process. As can be seen, in many cases the criteria are different depending on which stage of the project development process one is at. The approach adopted by FTA is to use threshold values of achievement to assign a "high," "medium-high," "medium," "low-medium," or "low" rating to a particular criterion. Readers are referred to [FTA, 2013] for more detailed information on these criteria.

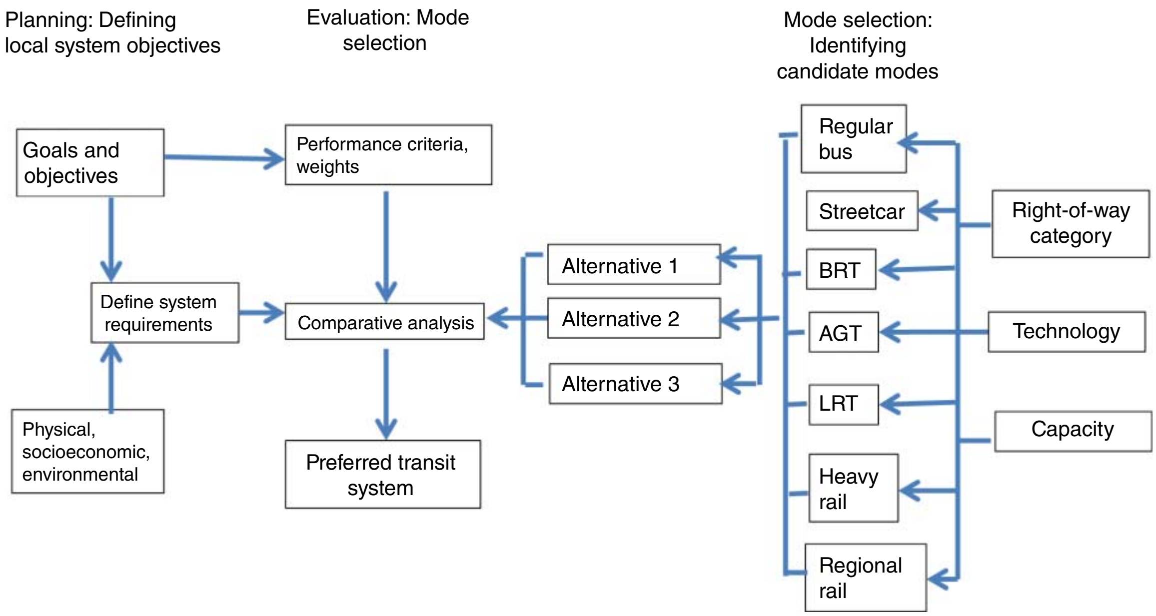
As noted in the definition of the project development process, the evaluation of transit alternatives is strongly linked to the metropolitan transportation planning process and the environmental review process. Readers are referred to chapter 16 on metropolitan transportation planning and chapter 4 on environment and the community for additional information on both processes. In addition, the FTA website http://www.fta.dot.gov/12304.html provides the latest information on analysis and evaluation guidance for major investment planning.

D. Mode and Technology Selection

The characteristics of the alternative modes being considered will have an important influence on expected ridership demand. System performance includes travel speeds, reliability, comfort, and safety, but in most cases ridership forecasting models use travel speed (and thus travel time) as the primary modal characteristic for modeling purposes. As described earlier, transit modes are defined by the right-of-way (ROW) on which they operate, the technology, and the type of operation. Through the mode selection procedure, the optimal combination of ROW and technology is selected to provide the desired service levels (based on the broader system goals) while considering the investment and operating costs. It is logical when selecting technology characteristics to choose a system with a performance package that is consistent with the ROW on which the transit line operates. Greater investments, resulting in higher performance, can be made in three basic technological characteristics—vehicle guidance, propulsion system, and consist control—as the ROW is upgraded from street running to partial and full right-of-way control.

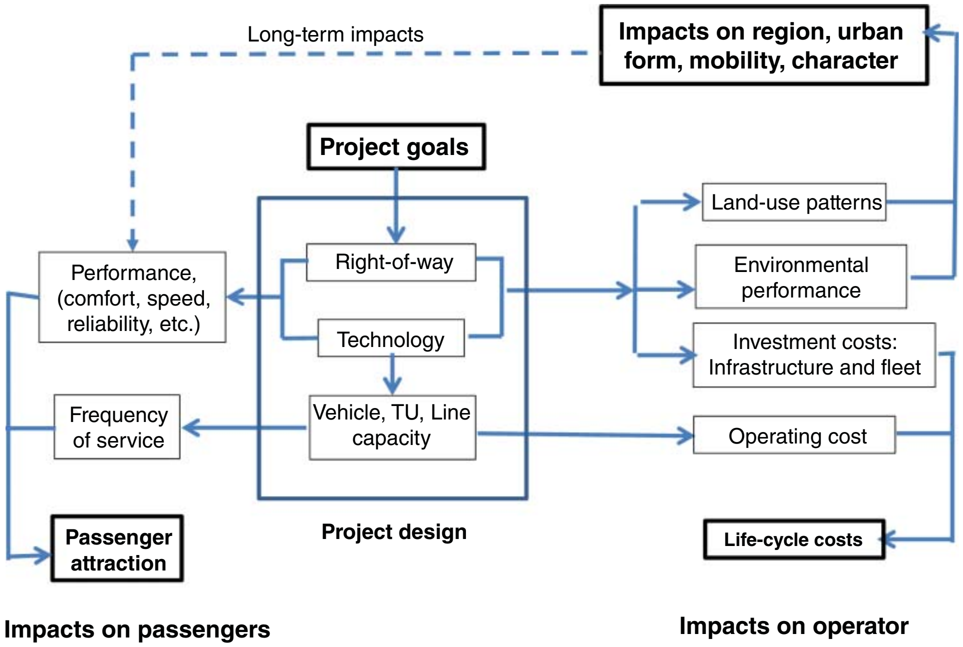
The framework for comparing and selecting a transit mode is shown in Figure 12-23. The first step is to define the goals and objectives of the system subject to the local physical, socioeconomic, and environmental conditions. These goals are translated to specific system requirements, which act as inputs to the comparative analysis. At the same time, candidate modes are selected from the family of modes for the range of defined system requirements based on combinations of ROW, technology, system capacities, and costs.

Figure 12-23. Transit Mode Selection Procedure



Source: Based on Vuchic, 2005

Figure 12-24. Recommended Mode Selection Considerations, Including Regional Impacts



The performance characteristics of candidate modes are then compared to the system requirements. A suggested approach for this comparison is shown in Figure 12-24. As the ability of modes to attract passengers depends on the ROW category, frequency of service offered, and other features of candidate modes, these must be checked against the estimated ridership demand. A feedback loop into the earlier steps of the modeling process is used to ensure an equilibrium state.

Finally, the mode comparison must evaluate the environmental and land-use impacts of the chosen ROW and technology. In some cases, these impacts may carry considerable weight because, in the long term, greater investments in transit infrastructure can change both the character and the development patterns of a city, which ultimately results in overall greater transit ridership and urban livability.

VIII. PLANNING FOR PASSENGER STATIONS[2]

The locations where users access transit services, transfer among routes, or interchange with another mode are among the most important components of the system. Examples include: (1) a corner bus stop where a passenger walks from home and boards a local bus, (2) an exchange where passengers can transfer between transit modes, such as between buses or from bus to rail, (3) an express stop on a rail rapid transit line where passengers can transfer between local and express trains, (4) a major international airport where passengers can transfer from domestic and international flights to express and local bus or rail service, and (5) a terminus point at the end of the line where layover space for vehicles and washroom facilities for drivers may be required. These exchanges, stations, or stops can be key bottlenecks in a typical trip, and are often perceived by the user as a negative characteristic of the system.

For more complex facilities, certain features become necessary because of financial or institutional requirements, the number of alternatives to select from, or the sheer amount of travel to accommodate. Because the cost of building and operating a station must be covered somehow, the methods of collecting fares, parking fees, rental fees, or tariffs are an important design and operations consideration. The expected passenger flow through a station is a key study item when estimating its market potential (forecasted traffic).

[2]The sections on transit stations draws from the Terminals chapter in the previous edition of the handbook written by Leon Goodman, P.E., PTOE, Traffic and Transportation Consultant, New York, and Jerome M. Lutin, P.E., New Jersey Transit Corporation. Changes made are the responsibility of the editor.

A. Vision for a Passenger Station

The first step in the planning process for larger stations is establishing a vision for the station, that is, what role is it intended to play in the transportation system and in the community? A good example of a vision comes from the California High Speed Rail Authority, which developed such a vision as part of the planning process for high-speed trains in California. [California High-Speed Rail Authority, 2011] The planning process linked the development of high-speed rail stations with urban design considerations for the surrounding communities. The following observations were made:

- *The Role of the Station*: Consider the role the station will play in the community and how the physical size of the station will affect that role. Is the station a dominant feature of the landscape? Architecturally, should it blend in with surrounding building aesthetics? Will the station serve as a new "front door" to the community? What does that imply for the organization of land use, the design of streets, and public spaces?
- *New Transportation Hub:* Like a small airport without runways, the California High-Speed Train (CAHST) stations will need to accommodate large numbers of intermodal connections to buses, shuttles, taxis, cars, bicycles, and pedestrians. Development-oriented transit and TOD, (as discussed in chapter 3), can help address the issue of how the station is connected to the community.
- *Multimodal Nature of the Station:* Consider how people will be moving in and out of the station, and how the station will be integrated with other modes of transportation. How will people access cars, transit, bikes, and the street network? How will wayfinding work?
- *The Location of Parking*: It will be important to locate and configure station parking so that it does not create a barrier between the community and the station. For the high-speed rail service, all parking identified as necessary for the project at market rates. This should provide sufficient financial incentive to build needed parking facilities for high-speed train users, including structured parking.
- *Community Growth*: With supportive planning, the accessibility provided by a high-speed rail station can be transformative for some communities. Each community needs to carefully consider how to leverage the coming of high-speed rail and how it fits into their vision for the future. Preparation of new downtown plans or specific plans for the district surrounding the station will be important next steps for most communities. [California High-Speed Rail Authority, 2011]

The Authority also identified the following key lessons from intermodal transit stations in other countries. [California High-Speed Rail Authority. 2011]

- *Have a Vision*: High-speed rail must relate to the activity patterns and developments in the communities it serves and complement the community's vision. Planning for high-speed rail cannot be done in a vacuum. Local planning must consider how the location of the line fits into the vision for the city as a whole. In some cases, the design of the infrastructure and services is modified to better fit with the community, enhancing the economic vitality and quality of life for those living near the station.
- *Focus on Business and Service-Oriented Travel (in Other Words, Know Your Market)*: Business professionals constitute a large percentage of the high-speed rail travel market. In addition, experience has shown that other major markets include leisure and tourist travelers, family travel and governmental services. Station design and functions should provide the ancillary services that will support these types of travel markets.
- *Connect the Station*: The station environment should be pedestrian-oriented with connections, both visual and physical, to and from the station. Local transit should be well-connected with the station, balanced by accommodations for the car. Streets closest to the station should promote pedestrian use.
- *One Size Station Does Not Fit All*: Stations can serve multiple functions in cities. They can be focal points for neighborhood activity, or they can blend into the background. By paying attention to detail, stations can provide an opportunity for "rebranding" a community.
- *Stations Can Be Destinations*: The area immediately around a station, or the station itself, can serve as destinations of considerable note. They can provide new services or be an architectural landmark. The new World Trade Center Transportation Hub in lower Manhattan, New York is an iconic station that along with the nearby 9/11 Memorial is a major tourist attraction. Integration into the city's community vision and other land uses is important so that the station complements, not competes, with other destinations in the city.

- *It Can Change Your City*: High-speed rail represents an opportunity for some of the smaller cities in the corridor to become more important satellite cities to the major hub. High-speed rail provides the opportunity to tap into new economic development strategies, but they will only succeed if careful planning occurs and thought is given to what the market can support.
- *Back to the Future*: Rail stations that are being praised around the world are those that have unique architectural attributes. They return to the "romance of rail's past" with grand entrances and a sense of celebration. Because of the locations in the city center, high-speed rail stations essentially serve as gateways to the city.
- *Political Leadership Required*: Strong political leadership will help move the local vision forward. A vision needs a political champion who will help move the vision forward and work to overcome hurdles that get in the way. [California High-Speed Rail Authority, 2011]

B. Market Research (Demand Estimation)

Many analysis techniques can be used to estimate the demand for transit stations, in particular the number of riders transferring at the station. Demand estimation can be based on surveys of existing usage, mathematical forecasting models (and the associated computer software), trend analysis, future market analysis, and planning judgment. The analyses will vary considerably on whether the planner is dealing with modifying or expanding an existing facility or developing an entirely new terminal or station.

Typically, forecasting demand for terminals follows three steps:

1) Estimate the overall travel magnitude and growth for the market of interest.
2) Determine the market share that can be expected to be attracted to the facility as a fraction of total demand.
3) Estimate the peak period demand, typically expressed as a rate of flow for passengers and vehicles per unit of time.

Demand modeling is described in greater detail in other chapters and in the technical literature (see chapter 6 on travel demand modeling, chapter 11 on parking, and chapter 16 on metropolitan transportation planning). In each case, the following demand variables must be projected for both short- and the long-term forecast periods:

- Overall loading (such as total passengers, consists, and vehicles).
- Type of loadings (such as cars, trucks, buses, commuters, shoppers, and frequent vs. occasional users).
- Time-period volumes (such as annual, daily, peak period, and peak hour).
- Reliability and predictability of flows.

Such estimates should be based on current-use data usually obtained from up-to-date surveys or from data collected from automated passenger count systems. The planner needs to not only assess present patterns, but also market trends including future industry and economic developments, land-use changes, transportation technology, fuel prices, socioeconomic characteristics of the population, and so on.

Note that the FTA has developed a simplified travel demand model that can be used to estimate fixed guideway transit trips (it does not estimate local bus ridership). Called Simplified Trips-on-Project Software (STOPS), the software package applies a set of travel models to predict detailed transit travel patterns for the No-build and Build scenarios. [FTA, 2013a]

Finally, needs estimates should be updated periodically. This should not only include updated ridership counts, but also a new examination of the market forces that are likely to change future transit markets (for example, the impact of the millennial generation on transit ridership). This can be done as part of a comprehensive operations analysis as described earlier, or as part of a region's long-range transportation planning process. In today's fast-changing world, transit agencies need to keep abreast of the changes in society that will affect their business model.

C. Performance Analysis Techniques

After the overall demand for a facility has been established it is important next to understand how that demand will distribute itself in the facility, and the performance characteristics of this experience. To do this, planners use a variety of tools.

1. Process Analysis

The *process flowchart* is an important tool for understanding the performance of stations and other interface areas. It shows the activities that a passenger experiences as he/she proceeds through a facility. It also shows the order of the activities and potential alternative paths or sequences, and thus be used to develop process time requirements. A simple flowchart shows the terminal as a single "black-box" processor with simple inputs and outputs of vehicles, passengers, and freight, as applicable. A more complete representation useful for cost determination might also include supporting inputs and outputs—land, employees, and supplies as inputs and environmental effects, employees, and waste materials as outputs. Figure 12-25 shows a process flowchart for an intercity passenger terminal. It traces the flow of passengers from arrival to departure and includes subprocesses such as passenger transfers to intra-city distribution modes.

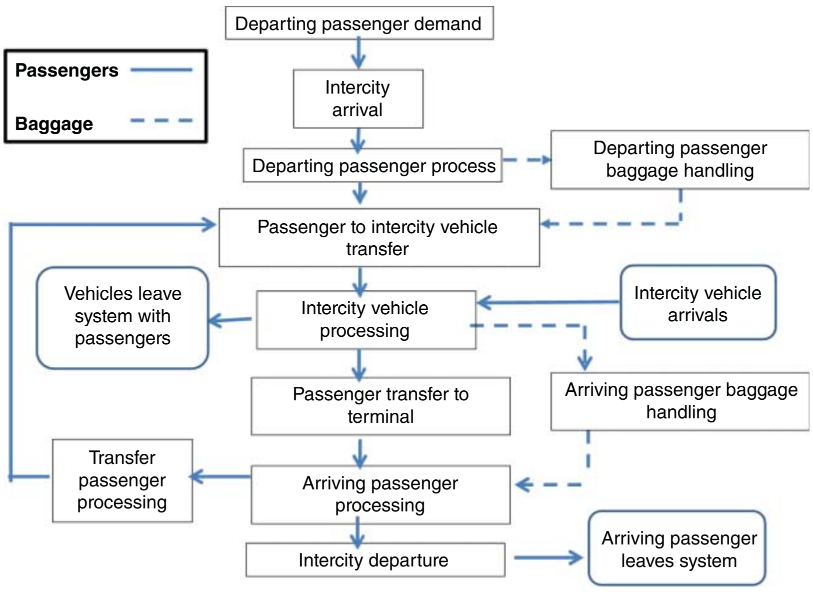
Processing times are a major factor in evaluating the level of service of a terminal. Theoretically, total processing time can be estimated by summing the times for each step shown on a process flowchart. Each of these individual times, however, is subject to considerable variation due to system or user characteristics. Waiting for a vehicle arrival is one of the process steps that has variability associated with it. For rail service on its own right-of-way, variability will primarily relate to high passenger loads and the time it takes to board and alight the train. These dependent-on-flow waits can also be a consequence of vehicles that are behind schedule because of accidents, system overload, passenger health issues, or other incidents.

Some processing time variation is due to individual choice, such as when travelers arrive at different times for a scheduled vehicle departure time. This difference is a result of different personalities (some people like to arrive well in advance, while others will get there just in time) and perceptions of the reliability of the mode of travel. Thus, variations in processing times occur for a number of reasons and are often expressed in numerical distributions, either as a simple range of values or as formal, statistical distributions.

Wait time is one of the most important measures in transit planning. In terminal planning and design, as in any transportation function, the planner's goal is to eliminate or minimize unproductive time, for example, delays and waiting. For stations, however, waiting cannot be avoided, and may be an integral aspect of station design and operation.

Assume a single-unit processing flow (a fare gate) with a constant service time, and assume that passengers arrive at a constant rate (time between arrivals). As long as the time between arrivals (headway) is greater than the service time,

Figure 12-25. Process Flowchart of a General Terminal



all passengers can be served. However, if the headway is less than the service time, a queue will form. In actual systems, times between traffic unit arrivals usually vary. Units sometimes bunch together, as do passengers departing from a vehicle. In addition, there are simply random arrivals, resulting from many people independently deciding when to travel. In the case of varying arrival headways, even if the volume yields an average headway greater than the (constant) service time, some delay is likely. Thus, determining the amount of waiting time and the number of people and vehicles waiting (or to be stored) is the basis of successful terminal design. Adequate storage capacity must be provided.

Capacity, the maximum possible flow of units per unit of time through a terminal or other interface should be estimated for planning the physical dimensions of the station and its facilities for handling passenger flows. Capacity determinations are usually linked to some idea of level of service, which is usually measured by waiting times or waiting delays. Level of service can be thought of as the maximum volume that can be accommodated with acceptable or tolerable patterns of delay. Before defining what are acceptable or tolerable criteria, the planner or engineer must understand the relationship among volumes, service times, queues, and waiting time, as discussed below.

2. Simulation

The irregular occurrence of arrivals is the norm for passenger stations. One of the most useful analytical methods for modeling the performance of systems with irregular traffic flows is *simulation.* Simulation models use a mathematical formulation of the events that occur during a process to assess system performance. Thus, in the context of a transit terminal, the focus is typically on the arrival of passengers and vehicles, the placement in the appropriate serving facility (known as a server), loading and unloading, departure of the vehicle, making the server available to another unit, and other such factors. An important distinction is made between two types of simulation—*deterministic*, meaning that all events are characterized by certainty as to when they will occur, how long each process will take, and so on; and *stochastic*, meaning that there are possible variations in these characteristics of the system as they are represented in the simulation model. In particular, operational characteristics modeled as stochastic (such as the time required to load and unload a vehicle) have probabilities associated with each of the possible outcomes, with the associated probability indicating the relative frequency or likelihood of each outcome occurring.

A probability density function is used to represent the dynamic characteristics of a stochastic system. The most common probability density function used for arrivals at transport stations and other transport operations is the Poisson distribution. The random variable for the arrival problem is the number of units that arrive in a given interval of time where the average arrival rate has been determined from repeated observations.

The simulation process generates numerous randomly generated vehicle arrival times to reflect the fact that there is some uncertainty as to when a vehicle will actually arrive. The number of arrivals generated usually must be large enough so that the simulation results, which are often expressed in averages and perhaps distributions, have settled on reasonably stable values. This can be seen in Table 12-17 where 20 bus arrivals and 19 headways are randomly drawn based on an underlying distribution. As can be seen, the mean headway remains fairly stable in this example after about 10 bus arrivals.

3. Queuing

Although simulation is the most widely used method for modeling stochastic traffic flows in transportation, *queuing theory* and *queuing analysis* are also important methods. Queuing analysis uses formulas to provide information of the type similar to that obtained from simulation, but only for well-specified conditions. Queuing analysis thus has the advantages of simplicity and ease of use over simulation, but it is only possible to derive such formulas given certain underlying assumptions.

Queuing formulas provide useful information for the design and analysis of waiting line systems, as well as the implications of a worst case scenario where there is a service breakdown. For instance, the average number of traffic units in the queue and the average number in the system (queue and servers) are important pieces of information for ascertaining the adequacy of waiting areas in stations. The distribution and average of waiting times are important in assessing the adequacy of the entire system in serving passenger demand. From this distribution, the probability of delays greater than any specified value can be obtained.

Four characteristics of queues must be specified for queuing theory to be applicable:

1) A distribution of the traffic arrival headways must be specified, which may be uniform (that is, constant times between arrivals), distributed as a Poisson or random arrival pattern (that is, a negative exponential probability of headways), or some other pattern.

Table 12-17. Example Simulation of Arrival Times of Buses at a Stop				
Bus Number	**Random Number Drawn**	**Time Headway (seconds)**	**Arrival Time (seconds)**	**Cumulative Mean Headway (seconds)**
1			0	
2	32	49	49	49.0
3	99	1	50	25.0
4	61	21	71	23.6
5	16	80	151	37.8
6	66	18	169	33.8
7	10	100	269	44.8
8	49	31	300	42.9
9	83	8	308	38.5
10	12	92	400	44.4
11	36	44	444	44.4
12	31	51	495	45.0
13	92	4	499	41.6
14	8	110	609	46.8
15	74	13	622	44.4
16	84	8	630	42.0
17	33	48	678	42.4
18	16	80	758	44.6
19	28	55	813	44.6
20	64	19	832	43.8

Note: Random numbers are integers drawn from the range 0 to 100, all with equal probability.

2) The distribution of service times must similarly be defined. Thus, some underlying distribution of how long it takes for a vehicle or person to be served must be specified.

3) The number of serving channels or stations must be given.

4) A so-called queue discipline, which specifies the order in which arriving traffic units will be served, must be defined. In transportation, usually the first to arrive is the first to be served; however, there are situations where exactly the reverse is true. For example, the last person arriving to a crowded subway car will be the first one departing. In queuing theory terminology, the former discipline is usually referred to as *first in, first out (*FIFO) and the second as *last in, first out* (LIFO).

An important class of results (and the easiest mathematically) is the situation of a single-server queue with Poisson distributed arrivals, service times are assumed to follow a negative exponential distribution, and a FIFO discipline. Various measures of how the queue would perform are presented in Table 12-18. Because the Poisson distribution has a single parameter, the mean, the only parameters in the model are the mean arrival rate λ and the mean service rate μ. Both of these would be expressed in traffic units per unit time (as vehicles per hour). The mean headway of arrivals is $1/\lambda$ and the mean service time is $1/\mu$. It should be noted that the mean time between departures from the servicing channel must be greater than $1/\mu$ because the server is not always in use. The mean departure headway must be equal to $1/\lambda$ because there cannot be more units leaving than arrive in the system.

The various equations given in Table 12-18 are self-explanatory. These results are termed *steady-state* results, which means they are the results that would be observed after the system operated for such a long time that the averages or probabilities would not change. In fact, they are actually derived from the situation of an infinite period of operation. It is useful to express many of the formulas in terms of ρ, defined as *traffic intensity,* and equal to λ/μ; ρ must be less than 1.0, otherwise the waiting line would continually build up as time passed and a steady state would not exist.

Another important set of results involves queues with Poisson arrivals, Poisson service times, FIFO queue discipline, and many service channels. Here the FIFO discipline means that an arrival will enter the first available server, implying that there is just one waiting line. Even though this does not represent actual situations where there is a queue for

Table 12-18. Single-Station Queuing Relationships with Poisson Arrivals and Exponential Service Times for Steady State Conditions	
Queuing Model	**Description of Model**
$p(n) = \left(\frac{\lambda}{\mu}\right)\left(1 - \frac{\lambda}{\mu}\right) = (\rho)^n(1 - \rho)$	$p(n)$ = probability of having exactly n units in the system
$\overline{n} = \frac{\lambda}{\mu - \lambda}\ \frac{\rho}{1 - \rho}$	$\overline{n}$ = average number of units in the system
$var\ (n) = \frac{\lambda\mu}{(\mu - \lambda)^2} = \frac{\rho}{(1 - \rho)^2}$	Var (n) = variance of n
$\overline{q} = \frac{\lambda^2}{(\mu)(\mu - \lambda)} = \frac{\rho^2}{(1 - \rho)}$	$\overline{q}$ = average length of queue
$f(d) = (\mu - \lambda)\, e^{(\lambda - \mu)d}$	$f(d)$ = probability of having spent time d in the system
$\overline{d} = \frac{1}{(\mu - \lambda)}$	$\overline{d}$ = average time spend in the system
$\overline{w} = \frac{\lambda}{\mu(\mu - \lambda)} = \overline{d} - \frac{1}{\mu}$	$\overline{w}$ = average waiting time spent in queue
$p(d \leq t) = 1 - e^{-(1-\rho)\mu t}$	$p(d \leq t)$ = probability of having spent time t or less in system
$p(w \leq t) = 1 - \rho e^{-(1-\rho)\mu t}$	$p(w \leq t)$ = probability of having waited time t or less in queue

μ = Average number of arrivals per unit of time

λ = Average servicing rate number of units per unit of time

ρ = Unit intensity or utilization factor

each server, it often approximates the performance of these situations well. If desired, the analyst can use a different (and more complex) set of equations to arrive at the exact result (called the multi-server queuing problem).

4. Pedestrian Flow Analysis

The concepts, processes, and analytical techniques described up to this point have used riders or vehicles as the travel units. Pedestrian movement can also be viewed as a travel flow. There are two conceptual approaches to pedestrian flow analysis: linear situations (walkways, stairways, corridors) and area situations (transit platforms, sidewalk corner areas, terminal areas). Pioneering studies by Fruin and others in the early 1970s initially focused on the linear approach, and these studies led to material such as those contained in the *Highway Capacity Manual* (2010) and the *Transit Capacity and Quality of Service Manual* (2013). The time-space concept, particularly appropriate for area analyses, was described in a 1984 paper by Fruin and Benz [1984] and further developed in a 1986 monograph by Benz [1986]. Both references contain additional information on the analytical approaches toward pedestrian flow analysis. Other useful references include [FHWA, 1998; Jia et al., 2009; TRB, 2010]. Many of the more advanced studies on pedestrian flows use proprietary simulation models.

D. Life-Cycle Planning

Developing plans for new stations or for a major improvement of existing terminals should look beyond the initial construction costs and consider the operating, maintenance, and major capital rehabilitation needs during the projected life of the facility. Maintenance and rehabilitation needs include those relating to the continued economic or transport functioning of the facility (for example, structural integrity and maintenance and cleaning operations, with special consideration given to carrying out maintenance with minimal impact on facility users). Continuing operations considerations include: (1) security, (2) signing and other information systems, (3) safety and maintainability of passenger or freight mechanical-assist systems, (4) sensitivity to long-term, day-to-day functional consequences of initial planning for "low first cost," and (5) ancillary services.

Major assist systems (for example, escalators, elevators, moving sidewalks) need to be designed for minimal life-cycle costs and user impacts. A number of transit systems, for example, incorporate stairways and escalators that are not enclosed from inclement weather conditions. Aside from maintenance considerations, the landing areas in the station concourse level are prime locations for slip-and-fall accidents during rainy weather.

E. Security

Transit systems and stations have long been recognized as targets for terrorism. After the attacks on September 11, 2001, security planning for transit systems became even more important. Such planning has taken on more urgency after attacks on the transit systems in London, Madrid, and Mumbai. Security planning and design requirements are very specialized and change quite often, so the planner will need to consult closely with local agencies and public safety professionals on a case-by-case basis. To provide some general guidance, the references, *Design and Operating Safe and Secure Transit Systems: Assessing Current Practices in the United States and Abroad* [Taylor et al., 2005] and *Security Planning for Public Transit* [APTA, 2013] are offered as good places to start. Federal and state transportation agencies also provide general guidance. Almost all security strategies include visibility and surveillance, communication, and evacuation. These factors also apply to normal requirements for crime and fire prevention that have always been present in the transit industry.

Communication involves providing information to passengers and providing the opportunities for passengers to communicate with security and customer assistance staff. Public address systems have become a requirement for almost all transit systems, along with visual displays to accommodate hearing impaired users. Most transit stations also provide emergency call boxes and/or panic buttons that customers can use to alert staff to incidents and emergencies and to seek customer assistance information. Such devices should be well marked in well-lighted areas and be in view of closed circuit television (CCTV) cameras.

Transit facilities are sized for peak loads and reflect fire and life-safety codes for evacuating crowds in emergencies. In prior terrorist attacks, those seeking to inflict the highest number of casualties often targeted evacuation routes. Evacuation routes also serve as access ways for emergency responders. Designers should, therefore, provide multiple access and egress routes and consider providing more than is required by local fire codes.

Although it is disturbing to contemplate, there are several distinct types of attacks that should be anticipated in station and terminal planning. These include explosive devices, biological, and radiological devices, sabotage, shooting, and hostage-taking. However, new and more deadly means of inflicting damage are likely to appear in the future. Planners and designers must keep up to date on this unfortunate, but necessary, aspect of terminal planning.

Table 12-19 summarizes the security strategies that have been applied to transit systems. Designers and planners are encouraged to incorporate security strategies, both as a way to reduce the risks of terrorism and to deter criminal activity. The nature of transit systems, where large numbers of passengers must be accommodated and quickly processed, will continue to present a challenge of balancing security against costs and convenience to passengers.

Stations need to be well-lighted, inviting, and provide space with lines of sight as direct as possible. Even when supplemented by remote surveillance (for example, television cameras), there should be no hidden corners and other possible real or perceived trouble spots. This concern is not only related to potential criminal activity, but also to the presence of the homeless in stations, regardless of whether any actual problems arise. The perception of a threatening or uncomfortable situation has a real effect on passenger use of modes and their stations.

The complexity of security planning extends beyond the scope of any single design or engineering discipline, and terminal planners should consider assembling a multi-disciplinary team of specialists to provide the safest and most secure environment for passengers.

F. Information Systems

Planning for passenger information systems should not be left as an afterthought but should be addressed early in the design process. Initial signage will need to be periodically reviewed and adjusted in light of operating experience to improve any lack of clarity or to reflect new or modified terminal operations. Signage, including electronic information systems, should be designed with this in mind. Flexibility, rather than first impression, should be a guiding principle. In the BART rail system, for example, a major re-signing of all of the stations occurred only 10 years after the opening of the system because of customer confusion in understanding many of the signs. A similar experience happened on the Washington, DC, WMATA system where station signs on the platform were written sideways (for aesthetic reasons), but which were very difficult for arriving passengers to read. These principles should also hold for wayfinding

Table 12-19. Security Strategies for Transit System Components

Strategy	Platforms	Entrances & Exits	Gates	Elevators	Escalators	Restrooms	Pathways	Parking Lots	Trash Can	Vending Machine	Vehicles
Lighting	X	X	X	X	X	X	X	X			
Visibility (clear lines of sight)	X	X		X	X	X	X	X			
Use of Glass and Natural Light		X		X							
Keep Clear of Obstacles	X						X				
No Hidden Corners/Dead Areas	X	X									
Limit Access Paths/Points	X	X					X	X			
Electronic Access Control		X	X								
Security Cameras	X	X	X	X		X	X	X		X	X
Emergency Telephones				X			X	X			
Emergency Alarms										X	X
Monitoring by Staff/Security			X		X	X		X			
Curved Entrance Wall without Doors						X					
Explosive Resistant									X		
See-Through Containers									X		
Location*			X						X	X	
Minimal/Low Landscaping							X	X			
Fencing								X			
Public Information Signage			X								X
Large Windows											X
Secure Parking											X
Vandal and Graffiti Proof											X

*Configure location of gates to be able to close off sections of station. Locate vending machines in unobstructed locations.

Source: Taylor et al., 2005, Reproduced with permission of the Mineta Transportation Institute.

signs that identify paths and directions to the terminal or station (often discussed as part of the concept of the "last mile" connection to transit services).

Intelligent transportation systems (ITS) technology has led to the implementation of a variety of electronic information systems in stations. Common devices include television monitors displaying arrival and departure information; scrolling or stationary variable message signs using light-emitting diodes (LEDs), fiber optics, liquid crystal displays, and dot displays that use an array of two-colored dots that flip to form characters and graphics; Solari split-flap boards, which use hinged leaf signs that flip through a preprinted list of message options; and flat screen plasma displays, which can display full-motion, full-color images. Other devices are interactive electronic kiosks, which use touch screen menus or audio input to allow users to choose from a library of information. Facilities for personal computer access, including wireless (WiFi) devices, are increasingly being provided in terminals, and innovative smart phone apps are being developed by a host of agencies and individuals to make the travel experience even better.

Terminal planners should consider a variety of factors when deciding on appropriate display devices. Some of these considerations are locating devices to assure visibility; providing standing and queuing space for passengers to read or interact with devices without obstructing pedestrian flows; the need for protective enclosures for many devices; and the ability to easily change out devices as they become obsolete.

IX. STATION DESIGN

Transit station design occurs after the transportation facility plan has been developed and in varying degrees up to the final production of station design plans. Station or terminal design involves developing and evaluating alternative functional and physical configurations. Included within the design stages are the following procedures: (1) establishing design objectives, criteria, standards, and requirements; (2) defining the constraints on station location; (3) developing passenger and vehicle flow data by origin, destination, access mode, line, and headway; (4) preparing alternative station design layouts; (5) evaluating the performance of each design; (6) selecting the design alternative that best meets the standards and criteria; and (7) iterating the process until an optimal design is determined.

A. Design Parameters and Guidelines

In most large projects, design guidance is developed as part of the project development process, and thus design standards and criteria are often oriented specifically to the project context. The material in this section provides an overview of the types of information that would be part of a station planning/design process. For those interested, the following references are good sources and examples of station design guidance for different modes and for different sized communities.

- Coffel, et al. 2012. *Guidelines for Providing Access to Public Transportation Stations.* TCRP Report 153. Transportation Research Board.
- Florida DOT. 2008. *Accessing Transit: Design Handbook for Florida Bus Passenger Facilities.* Florida Planning and Development Lab. Department of Urban and Regional Planning Florida State University.
- Hillsborough Area Regional Transit. 1995. *Transit Friendly Planning and Design Handbook and Technical Manual*. Tampa, FL: Hillsborough Area Regional Transit.
- Kittelson & Assocs., et al. 2013. *Transit Capacity and Quality of Service Manual*—3rd Edition, Part 7, Stop, Station and Terminal Capacity, Transportation Research Board.
- Metropolitan Council. 2012. *Station and Support Facility Design Guidelines User Guide: A Supplement to the Regional Transitway Guidelines,* Minneapolis, MN.
- Riverside Transit Agency, 2004. *Design Guidelines for Bus Transit, How to Make Bus Transit Effective in Your Community, A Guide for Planners, Engineers, Developers and Decision Makers*, Riverside, CA.
- TransLink. 2012. *Transit Passenger Facility Design Guidelines*. Burnaby, BC, Canada.
- University of North Florida, FAMU-FSU College of Engineering, and Hagen Consulting Services. 2010. *Guidelines for Enhancing Intermodal Connections at Florida Transit Stations*. Florida DOT.
- Virginia Department of Rail and Public Transportation. 2008. *Transit Service Design Guidelines* and 2013, *Transit Development Requirements.* Richmond, VA.
- VOTRAN. 2008. *Transit Development Design Guidelines*, Volusia County MPO.

Table 12-20 defines some of the key terms used in transit station planning and design. Design parameters are those factors necessary to create an environment suitable for processing passengers within the terminal. For a transit terminal, this encompasses (as applicable) stairways, ramps and passageways; escalators and elevators; platforms; fare and exit control; moving walkways; bus and rail facilities; and parking facilities. Station designers should be aware of the latest rules and regulations concerning particular design requirements. For example, FRA guidelines require platforms be at least 8 inches above top of rail and that the platforms for new commuter and intercity rail stations must run the length of the passenger boarding area of the station. This permits level boarding to all accessible cars of the trains stopping at the station.

Of particular importance in platform design are the requirements associated with evacuation of both the platform and passengers from a vehicle/consist at the stop. The parameters governing these elements are often included in building codes issued by the jurisdictions in which the facilities are located. In some instances, because of their special

Table 12-20. Key Terms for Transit Planning and Design, TransLink, Vancouver, British Columbia	
Concept	**Example**
Vision: the approach that shapes the overall direction of the guidelines. Transport 2040 is the primary reference point as the vision for the design guidelines.	**Vision:** transit will be the travel mode of choice in Metro Vancouver.
Principles: the overarching concepts that frame application of the goals and strategies.	**Principles:** inclusive design must be an automatic design consideration, which means developing places that are attractive, convenient, and easy to use for all people.
Goals: the desired outcomes that TransLink seeks to realize with the guidelines.	**Goals:** put passengers and pedestrians first.
Strategies: design objectives that should be met for TransLink to achieve its stated goals.	**Strategies:** make transit passenger facilities universally accessible and inclusive.
Guidelines: direction on how designs should be developed to achieve the objectives set by the strategies, without prescribing solutions. This document provides the design guidelines for transit passenger facilities.	**Guidelines:** ensure sufficient spatial capacity is provided to avoid bottlenecks where passenger and pedestrian flows meet.
Standards: measurable design requirements, typically based on technical, safety, or passenger movement requirements. Relevant standards are referred to, but are not included in these guidelines.	**Standards:** the minimum clear width of an accessible route shall be 1830 mm (72 in) for primary, highly frequented routes and 1525 mm (60 in) for secondary routes (1800 mm preferred at all routes).
Specifications: prescriptive design solutions, technical descriptions or requirements, which can include such elements as dimensions, materials, and placement. Specifications are referred to, but are not included within these guidelines.	**Specifications:** where concrete is used as the basic floor and walkway finish, it will be steel-trowelled with aggregate sufficiently exposed at the walking surfaces to provide slip resistance of 0.55 to ASTM C1028-96 for wet or dry conditions.

Source: TransLink, 2012

uses, stations are not specifically addressed by local codes; thus, design parameters may need to be drawn from other categories of facilities. Careful study of local building and planning codes would be necessary.

The need to comply in the United States with the Americans with Disabilities Act (ADA) of 1990 is of particular importance in the design of stations. This law requires all public facilities to be accessible to persons with a variety of impairments, including vision, hearing, and mobility limitations. ADA fundamentally altered the approach to facility design. While ADA requirements are not international standards, there is recognition in most countries that accommodating disabled users is an important design criterion, and that such strategies can improve the usefulness of stations for all users. The FTA and Federal Aviation Administration (FAA) have developed specific ADA policies and guidelines of particular relevance for passenger stations. They are focused on addressing common concerns, such as high curbs or steps, long stairways, inaccessible elevators, steep walks, gratings, difficult doors, narrow aisles, wheelchair accommodations, visual and nonvisual aids, among others.

Evacuation of transportation stations in the event of a fire or other emergency must also be addressed during the design phase. For example, the U.S. National Fire Protection Association (NFPA) has developed the NFPA 130 Standard for Fixed Guideway Transit Systems, which specifies exit capacities, minimum widths for exit passageways, maximum evacuation times, and maximum distances for travel to an exit. Although the NFPA standards are widely accepted, local building codes may take precedence. Consequently, designers of intermodal passenger facilities must have extensive knowledge of applicable codes and standards for the jurisdiction in which each facility is located.

B. Bus Stations/Stops

Planning for bus stops, stations, and terminals depends on the different bus technologies using the facility and should consider new bus developments that might become increasingly important in coming years. Such developments include tube stations, which are used as a key element of the surface bus transit system in Curitiba, Brazil; guided and/or dual-powered buses operating in urban transit systems in several countries; the introduction of low-floor buses, which facilitate step-less boarding; and alternate fuel propulsion systems.

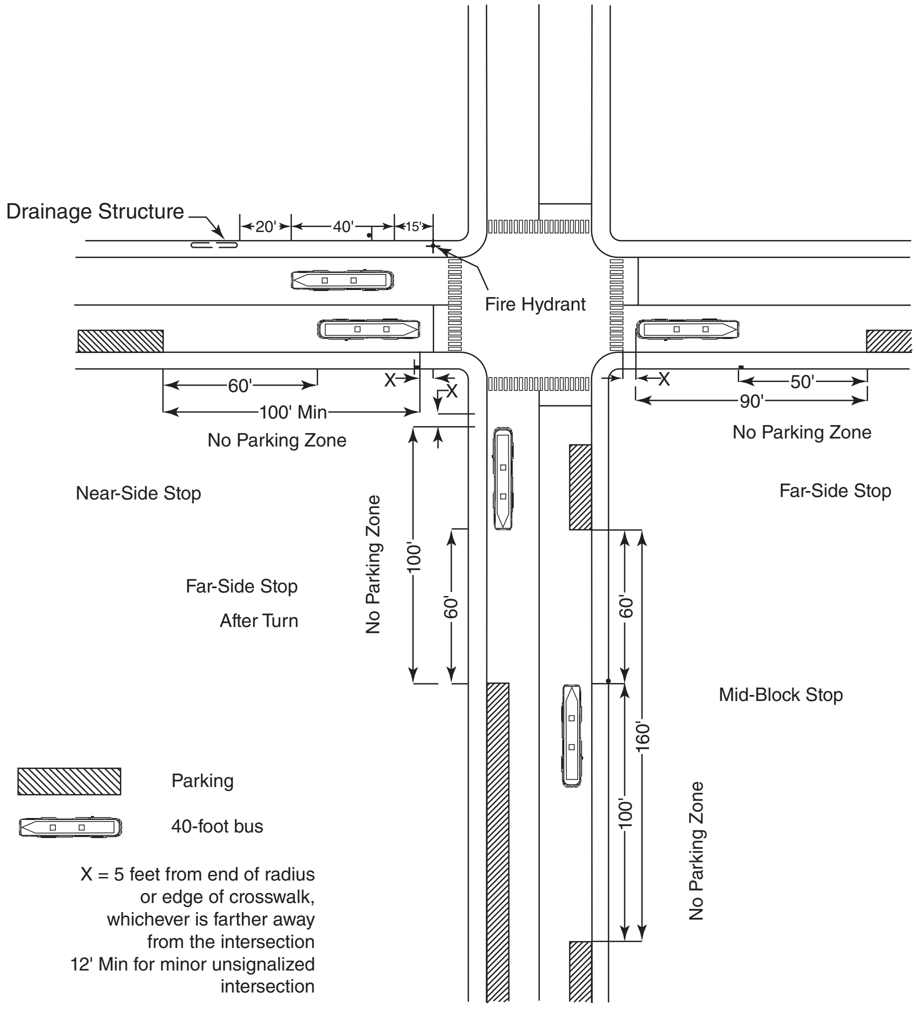
1. Bus Stops on Streets

The planning for bus stops primarily involves decisions on bus stop spacing and location. In particular, the compromise decision is between shorter access times (thus stops close together) and higher operating speeds (thus stops farther apart). Bus stop spacing should reflect the location of expected passenger origins and destinations. Stop spacing should be such that, on average, buses might stop at distances of 1,320 to 1,968 ft (400 to 600 m) and in exceptional cases, somewhat closer. In a number of U.S. cities, shorter spacing, as little as approximately 500 ft (150 m), is used in downtowns and other densely developed areas. This short spacing is not efficient and can degrade service quality, including speed and comfort. The choice of stop spacing in many cases represents a blending of economic and technical factors, local policies, and experiences.

Three types of locations for bus stops occur along streets: the nearside of an intersection before crossing the cross street, the far-side of an intersection after crossing the cross street, and midblock, away from intersections. Because several different factors influence the choice of locations, variations among stop locations along a street, particularly nearside and far side, can often bring considerable advantages in terms of higher bus speeds and passenger comfort. Major factors influencing the choice of stop locations are traffic signal coordination, passenger access including transfers from other routes, vehicular and pedestrian traffic conditions at intersections, and the geometry of bus turning and stopping.

Each of the three bus stop location types has associated desired dimensions. Figure 12-26 shows each type of location and the associated dimensions. [Florida Planning and Development Lab. 2008] Where bus signal priority is deployed,

Figure 12-26. Bus Stop Locations and Dimensions



Source: Florida Planning and Development Lab. 2008 nearside bus stops may reduce or even cancel the benefit of this priority. Far-side stops are preferable in this situation. In general, transit planners and traffic engineers prefer far-side stops for safety and efficiency reasons.

In some locations, it may be appropriate to configure bus stops so they extend out from or are indented into the existing curb lines. Bus stops that are indented from the curb line are called *turn-outs*. Bus stops that are extended out from the curb are called *bulb-outs.*

The *Transit Capacity and Quality of Service Manual* is a good source of information on bus stops. [Kittelson & Assocs. et al., 2013]

2. Bus Stops/Stations on Freeways

Express buses often require intermediate stops on freeways to serve the demand in the corridor. Although these stops may reduce bus operating speeds, they are essential to provide desired service levels and increase bus patronage. Stops within interchange areas can be provided more easily and at lower cost if they are included in the original freeway design.

The location of freeway bus stops will be influenced by: (1) the density of population in the adjacent tributary area; (2) pedestrian, car, and bus access for potential transit users; (3) potential development growth and future demand possibilities; (4) nearby generators such as hospitals and universities; (5) major intersecting transfer routes; and (6) major outlying parking areas. The stops can be located at either the street or freeway level. Street-level stops are generally more convenient for bus passengers because they do not have to change levels to access the bus. Freeway-level stops are generally preferred by bus operators because there is minimal time lost for exiting and reentering the freeway. Street-level stops are usually preferable in urban areas because they provide the most convenient access for passengers and require no special geometric designs at the freeway level.

3. Off-Street Bus Stations

Bus terminal and park-and-ride facilities serve at least two important functions. They provide off-street downtown distribution for radial express bus operations, and they help intercept motorists and local buses in outlying areas and facilitate passenger transfer to express transit lines. Stations and park-and-ride facilities can also be used to facilitate an interchange between suburban-oriented bus and rail services and to encourage the use of ridesharing modes (for example, carpools, and vanpools).

Off-street terminal planning, location, and design embody basic traffic circulation, transit operations, and site planning principles. Relevant factors include line-haul transit routes (for example, rail, and bus); passenger interchange needs; passenger arrival and departure patterns; bus distribution opportunities and constraints within the city center; and land requirements, availability, impacts, and costs. Stations in medium-sized communities will usually be part of transportation centers in which intercity bus services and parking facilities are principal components. They could also be strategically located at outlying parking lots serving express bus lines. Central area stations consolidate bus operations at a single location, facilitate passenger interchange among bus lines, reduce bus journey times, and improve general traffic flow.

Stations are essential to express bus operations where other bus priority measures are not feasible. They make it possible to achieve high bus volumes on expressways, across bridges, and in tunnels by providing off-street loading for large concentrations of buses. In conjunction with special bus ramps and bus roadways, they attain grade-separated bus operations in congested centers, and they provide an option to downtown busway development. One-point delivery in the downtown area usually requires secondary distribution by local bus or rapid transit.

Stations range from single-level facilities serving intercity buses and offering minimum passenger amenities, to large multilevel transportation centers serving several modes and containing supporting land uses. Downtown off-street bus stations should be considered wherever the complementary services and development potential exceed the costs involved. They are appropriate where downtown curb loading capacity is limited, where large volumes of express buses are expected, and where on-street bus routing is slow, unattractive, unreliable, and cannot be improved through bus priority measures.

Central business district (CBD) bus stations should provide direct connections to expressways, be located between the expressways and the CBD core, be removed from points of peak land value, and be within a few blocks of major employment centers. These stations may incorporate air rights developments, depending on the commercial potential of the location. Bus terminal type, size, and design should reflect specific passenger, bus service and traffic access requirements. Relevant factors include passenger traffic volumes, arrival modes and peaking patterns; bus volumes and operating practices including fare collection, service frequency, loading patterns, layover times, and driver rest requirements; and access linkages to surrounding roads and streets. Desirable functional objectives include:

- Grade-separated bus entry and exit.
- Direct pedestrian connections to other modes.
- Separate commuter and intercity bus levels.
- Separate commuter bus loading and unloading areas.
- Parallel unloading areas with passing lanes for commuter buses.
- Commuter bus loading areas in shallow sawtooth platforms.
- Sawtooth loading-unloading platforms with passing lanes for intercity service.
- Platform size adequate for accommodating the projected number of waiting passengers.
- Air-rights development of commercial uses (including accessory parking), if commercially feasible.
- Accessibility and universal design features.

Bus dimensions and maneuverability influence several design aspects, including:

- *Bus Lane Widths*: Buses require additional clearance for mirrors, which can typically add 1.5 ft (0.46 m) to the total width required for the vehicle. Consequently, an 8.5-ft (2.6-m)-wide bus can require a minimum 10.0 ft (3.1 m) of horizontal space (note: many transit agencies will not operate vehicles on lanes that are 10 ft or less). Eleven-foot lanes are preferable where ample terminal space is available and therefore are the minimum width for 8.5-ft-wide buses.
- *Roadway Width:* Double-width or two-lane roadways should be provided wherever possible. They allow passing and overtaking of buses and provide temporary storage. Unloading bus roadways should be two lanes wide to enable empty or lightly loaded buses to proceed past a loaded bus. This is essential where the unloading roadway is also the only terminal entrance road. Double-lane roadways should be at least 22 ft (6.7 m) wide for overtaking buses parked close to the curb; a 24-ft (7.3-m) width is preferable, especially where bus maneuvering distances are limited.
- *Additional Clearances and Widths:* The width and radii of driveway entrances and exits to roadways should permit equipment to operate without sharp turns.
- *Ramping*: Ramp grades to and from street roadways (or busway connections) should be set to avoid rough treatment of equipment and passengers, particularly when buses are heavily loaded.
- *Headroom and Side Clearance:* Adequate headroom and side clearance must be provided where buses enter terminal buildings and other structures. Minimum side clearance to all structures along the roadway should be at least 1 ft (0.31 m). Vertical clearance should be at least 12 ft for typical equipment. Special allowance should be made for use of stations by deck-and-a-half or double-deck buses.

The design and arrangement of bus loading platforms should be scaled to specific capacity and operational requirements for different types of services using the platforms. The following are suggested guidelines for the types of services noted.

Separate Intercity and Commuter Services. These two types of bus operations have different service characteristics and platform design requirements. Intercity buses have long layover times to allow for passenger loading, unloading, and the handling of baggage and parcels. Closely stacked sawtooth platforms should be provided. They allow greater passenger amenity because they can be readily enclosed and climate controlled. Commuter buses need higher peak-hour capacities. Passenger unloading and loading areas should be clearly separated to minimize passenger conflicts and reduce dwell times. Accordingly, stations should use linear or shallow sawtooth loading platforms that allow several buses to queue at the same platform and also allow pull-through bus movements. Some of the design requirements include:

- *Berth Requirements:* Queuing theory or simulation analysis, taking into account projected passenger volumes and loading times, should be used to determine the berth requirements.
- *Loading Platforms:* Loading platform space and arrangement is generally the most critical feature in terminal operation. Separate loading spaces for different main routes or destinations should be provided. Where several bus routes are involved, the number of routes or different-type services assigned to one platform should be held to the lowest possible minimum—preferably not more than two or three. Loading platform widths for simple operations may be as narrow as 8 ft (2.4 m); however, platforms requiring substantial queuing of accumulated passengers and involving considerable circulation should be at least 12 ft (3.7 m) wide. For sawtooth positions, loading platforms parallel to the bus door should be at least 5 ft (1.5 m) wide. In layouts where passengers for different routes must circulate past each other, the platform space may need to be increased.
- *Loading Queues:* Queuing is necessary for most rush-hour conditions to avoid crowding and minimize the use of available space.
- *Passenger Platforms:* Loading and unloading spaces and bus lanes may form one continuous flat surface for low-cost or temporary terminal layouts. For permanent installations, passenger-loading platforms should be raised. Passengers should be protected from buses in multi-lane stations with a guardrail along the back edge adjacent to the next vehicle lane.
- *Platform Shelters:* Canopy-type shelters over loading areas on open lots are important for patron convenience and protection. Canopies should extend over the roof of buses for increased weather protection.
- *Unloading Platforms:* Unloading platform length should reflect the number of berths required to accommodate peak unloading passenger volume, and bus pull-in, pull-out, and tail-out characteristics. Where a considerable number of empty buses enter a terminal with need to stop at the unloading platform, a separate lane protected from the unloading runway by a physical divider should be provided. Another important factor is whether buses are allowed to stand or layover empty at the unloading platform as a holding area in lieu of proceeding to the loading platform, a separate holding area, or out of the terminal. Such layovers generally should not be permitted except for small-scale operations.
- *Vertical Access:* Access should be provided by stairways, ramps, and escalators in multilevel stations. Elevator access should also be provided to accommodate wheel chair users. Location at one end of a platform usually minimizes obstruction, particularly if the platform is relatively narrow. Expanded circulation areas are needed at such access points to maintain passenger throughput.
- *Other Facilities:* Intercity bus stations and large commuter terminals should provide ancillary passenger and bus service facilities. Passenger concourses should be enclosed, well-lit and climate-controlled. Restaurants, newsstands, stores, dispatchers' offices, and restrooms should be provided. Revenue from consumer services can be quite significant in helping to cover the capital and operating costs of the terminal.

Outlying mode transfer stations form the interface between line-haul transit and local transit serving neighborhoods. They are usually found along outlying rapid transit stations, at the ends of rapid transit lines, at interchange points between major highway and rail lines and along express bus lines. They recognize the need for auto and local bus connection to express transit from areas where population densities are too low to rely on walk-in patronage. Parking at outlying express transit stations allows automobiles to serve areas in which it is not economical to operate local bus service. The proportions of park-and-ride and kiss-and-ride passengers usually increase with distance from the city center.

Outlying transfer facilities are developed at a smaller scale than downtown stations. Designs should be simple, ancillary facilities should be kept to a minimum, and relatively few bus bays should serve heavy peak-hour loads. Direct pedestrian access should be provided to major nearby generators such as office buildings, shops and apartments. The application of appropriate transportation planning and engineering principles will produce the designs most suitable for a particular situation. The three designs described below illustrate the application of these principles in several *outlying* transfer combinations.

Arterial Street Bus-Rail Interchange. The most common type of modal interchange involves bus turn-outs on arterial streets that cross express transit lines. Turn-outs are located adjacent to station entrance and exit points. A median island with a fence may be desirable to preclude midblock pedestrian crossings.

Busway-Local Bus Interchange. Local buses circulate in a clockwise pattern crossing the busway at a signalized intersection. Direct platform access is provided to and from the major travel direction. The at-grade bus intersection provides opportunity for entry into the busway and direct expressway service to downtown.

Typical Bus Terminal within Freeway Interchange. A single bus bridge in conjunction with a pair of new bus runways adjacent to frontage roads alongside a depressed freeway provide direct access for arterial and freeway buses. Buses circulate clockwise around a central express transit station. Special bus-actuated traffic signals allow bus entry and exit from adjacent arterial streets. Where a secondary street bridge across the freeway is located within 500 ft (152 m) of the arterial overcrossing, it may be used in lieu of the special bus bridge.

4. *Park-and-Ride Facilities*

Park-and-ride facilities are designed to intercept automobiles at outlying locations along express transit lines and are also used as key elements of programs to encourage ridesharing. They permit principal portions of downtown trips to be made by public transport without reducing passenger convenience or increasing walking distances. Outlying parking facilities are provided in major cities with rail transit and along express bus routes. Individual facilities can range upward to 3,000 spaces, with lots in the 100- to 300-space range common. The optimum distance of intercept parking points from the city center depends on locations of major topographic barriers as they relate to the center city, street convergence patterns, line-haul express transit system configuration, land development intensities, land availability and costs, and parking costs. Common locations for park-and-ride lots are at the stations near the end of the line haul lines. Other factors to be considered include:

- *Bus Service*—Express bus travel from the park-and-ride station to the CBD or activity center should be quick and reliable, either in mixed traffic, in an exclusive lane, or on an exclusive bus roadway. The last stop of an express bus route inbound toward the CBD or activity center is usually a desirable location for a park-and-ride station. Efficiency in bus operations is obtained by filling buses at the parking facility and running them nonstop to the terminal. At the same time, commuter travel times are minimized by eliminating intermediate stops.
- *Intermodal Integration*—While the focus of park-and-rides is on the car, sites should also include bicycle parking and good pedestrian and cycling connections.
- *Land Availability and Use*—Sites should be compatible with adjacent land uses, should not adversely affect nearby environments, and should achieve a reasonable level of use relative to development costs. Development costs and environmental effects can sometimes be minimized by shared use, that is, by leasing existing parking facilities in shopping or recreation centers. This shared use also has advantages in terms of passenger access to other amenities and the perception of safety. Peak parking use at these centers normally does not coincide with commuter peaks.
- *Road Access*—Park-and-ride facilities should have good highway access, intercepting motorists prior to points of major route convergence and congestion. Facilities should be located as far from downtown as practical to reduce VMT as much as possible during the peak traffic period. It may be necessary, however, to locate the lots closer in where there can be more frequent transit service.

Outlying park-and-ride potential should clearly recognize growth patterns in the metropolitan area, constraints to increasing CBD or activity center parking supply, and proposed extensions of express transit services into auto-oriented areas. Important factors include:

- *Demand Estimates*—Multimodal choice models can be used to estimate parking demands as one of the access modes to express transit service (see chapter 6 on travel demand modeling). Importantly, the parking prices will have a strong effect on likely demand for parking spaces.
- *Facility Size*—Parking capacity should be scaled to forecasted parking demand and bus service potentials.
- *Parking Availability*—The design load factor at each park-and-ride facility (that is, the number of autos simultaneously parked divided by the number of spaces) should not exceed 90 to 95 percent, if supported with

real time occupancy signage. This will assure commuters a reasonable chance of finding a parking space. If there is no available community-acceptable backup space on nearby local streets, the design load factor should not exceed 70 to 80 percent. However, for lots or spaces designated for monthly or yearly permit holders, parking authorities often sell permits for more than 100 percent of the spaces, under the assumption that not all permit holders will try to use the lot at the same time.

5. On-Street Bus Stations

Bus streets represent a major commitment to downtown transit operations. They fully separate bus and car traffic, increase bus service reliability, enhance bus identity, and provide downtown distribution for regional express routes. For certain ranges of passenger volume, they can be an alternative to off-street stations, and in some cases as noted below, they can be combined with off-street stations. They enhance pedestrian access and, through the use of supporting amenities, can improve the downtown environment.

Bus streets as part of auto-free zones incorporate bus flow requirements with urban design considerations. Examples in the United States include the Nicollet Mall in downtown Minneapolis, Minnesota; the 16th Street Mall in Denver, Colorado; and the Fulton Street Mall in Brooklyn, New York. Short sections of bus streets are also found in several European cities. Bus streets provide an early-action, cost-effective downtown option for eventual development of busways, BRT services, and transportation centers. Some design characteristics include:

- *Auto-Free Zone*—The elimination of automobiles from major portions of downtown areas is common in European cities with narrow, discontinuous, and highly convergent street patterns. Buses are allowed to traverse the auto-free precincts to maintain route continuity and serve major activities.
- *Bus Loop*—A series of bus-only streets forming a loop may be appropriate where streets terminate and extended bus layovers are required.
- *Bus-Pedestrian Mall*—Downtown bus streets (or bus malls)—as incorporated in urban redevelopment projects—provide direct bus access to major generators. They are designed to simultaneously improve pedestrian amenity and bus access. Bus malls could operate throughout the day or be limited to peak hours. Taxis and service vehicles (during off-peak periods) can use bus streets.
- *Short Connector Links*—Short sections of bus-only roadways may be desirable to achieve direct service where street continuity is limited and bus service over arterial streets is circuitous and slow.
- *Terminal Approach*—Exclusive bus access can be provided adjacent to a downtown bus terminal and on links connecting the terminal to express highways or busways.

Additional considerations include:

- The nature, extent, and operating periods of bus streets should be adjusted to allow for essential services. One variant might be to allow local car access in bus lanes but prohibit through-traffic. Alternatively, mid-block access bays could be provided for off-peak goods delivery.
- Traffic capacities of parallel streets should also be increased to accommodate displaced traffic. This may entail additional one-way routings as well as further restriction of curb parking.
- Turns off the bus street by buses, taxis, and service vehicles should be prohibited in the core area. This will permit conflict-free pedestrian crossings at intersections and two-phase signal operations.
- Kiosks, bus shelters, and waiting areas should be located along the bus street. Consideration should be given to eliminating surface parking lots, especially where they can be served from other streets.

Providing convenient transfer facilities at the destination is one of the major challenges for BRT or other express bus services. There is no one right solution, even when anticipated passenger and vehicular volumes are relatively high. There are usually several potentially feasible on- or off-street schemes or combinations (see [APTA, 2010]). Such a planning process is well illustrated by studies for a major express bus terminal in Phoenix. [Grote et al., 1987] The Phoenix study involved the planning of an interface between express buses on a proposed depressed I-10 freeway and shuttle buses on an intersecting major arterial road. The two routes were to cross within a proposed 30-acre freeway deck park. This park would allow uninterrupted pedestrian movement from one side of the freeway to the other.

This would place the shuttle buses on the bridge two levels above the express buses on the freeway, with an urban park in between. Several alternatives were considered.

- *Bus Mall on the Freeway Deck*—The first alternative was to build a busway across the top of the deck. However, bus operations through the park were deemed inconsistent with the purpose of the park. This alternative was rejected.
- *A Bus Street North or South of the Park*—A second option was to build a bus street north or south of the park. However, no feasible location was found for a bus street.
- *Bus on Existing Streets*—A bus loop could be established with buses exiting the freeway on HOV ramps and traveling along local streets. Flexibility in operating buses would be attained, but buses would lose the time advantage gained from high occupancy vehicle (HOV) lanes on the freeway by operating on congested surface streets.
- *Median Bus Station*—A bus station could be placed in the median of I-10 under the park as shown in Figure 12-27. Riders could walk to nearby offices, or transfer to local buses. Buses would enter and leave the station from separate bus-only ramps to the I-10 HOV lanes. However, the narrowness of the area posed a significant design challenge. Ventilation, noise and security concerns would have to be overcome. On the other hand, the median bus transfer had a greater bus capacity than the other alternatives, avoided significant express bus operations on congested local streets, and avoided negative impact on the park. Consequently, this alternative was advanced into more detailed project planning.

The Phoenix planning process resulted in the development of an innovative, unique design (see Figure 12-28) adapted to the technical, social, environmental, and community characteristics of that particular situation.

Figure 12-27. I-10 at Central Avenue: Cross Section, BRT, Phoenix, Arizona

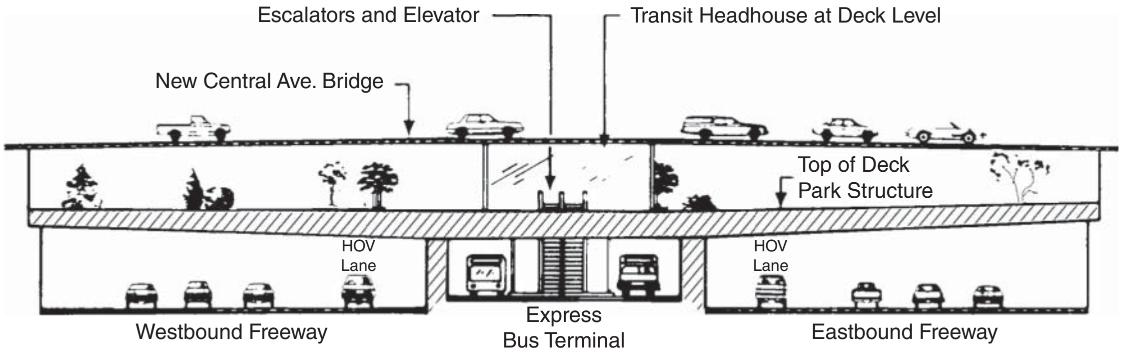
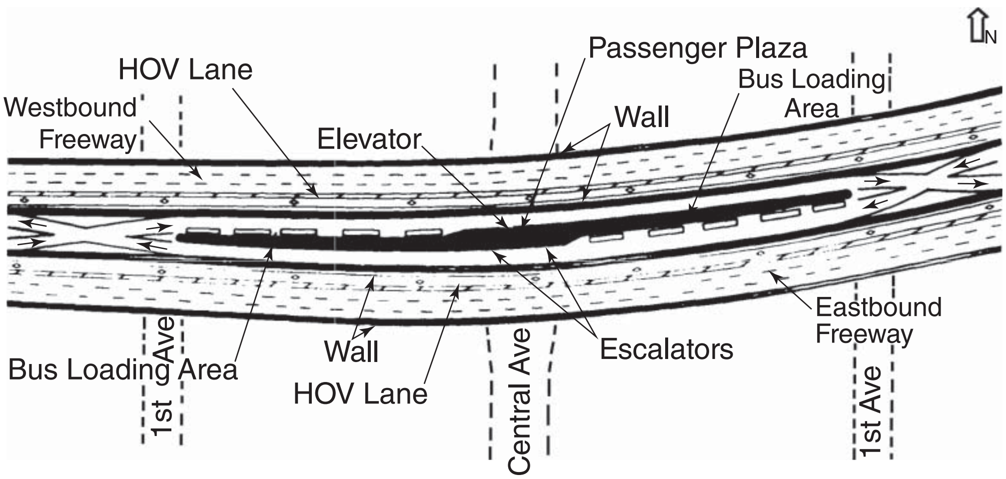


Figure 12-28. I-10/Central Avenue Express Bus Terminal, BRT, Phoenix, Arizona



C. Rail Stations/Stops

Stops, stations, and terminals are important components of rail systems because they represent the major contact points between rail service and the surrounding areas, and with other modes, such as walking, auto, or other transit services. Terminal operations strongly affect passenger convenience, comfort, and safety on one hand, and service reliability, operating speed, and line capacity on the other. Large stations often require considerable investment. Careful design and planning of station operations are, therefore, very important for optimal use of investment and efficient system operation. Stations are discussed in the following sections first for light rail, then for rail rapid transit, commuter rail, and multimodal and ferry stations.

1. Light Rail Stations

Operational Considerations. LRT operations provide some unique challenges with respect to station location and design. Because light rail stations often have few obstacles to pedestrian circulation and most often have low-level platforms, vehicle operators must have a clear view of pedestrians and waiting passengers as they approach stations. Sharp curves with limited visibility, steep grades, and sharp vertical curve crests should thus be avoided for station locations.

Station platforms should be as close to level as possible, preferably with track vertical grades limited to 1 or 2 percent. For new stations constructed in accordance with guidelines established pursuant to the ADA, the gap between the rail vehicle floor and the platform can be no more than 3 inches (76 mm) horizontally and five-eighths of 1 inch (16 mm) vertically. Essentially, ADA requirements dictate that platform edges be tangent and parallel to the vehicle and have no vertical curvature.

Platform Access. Light rail platforms can be either center platforms with a track on each side or side platforms with a track along one side only (see Figure 12-29). Pedestrian access to light rail platforms is often provided at-grade. For side platforms with few obstructions, access may be provided at any appropriate location along the side of the platform opposite the track. For center platforms, at-grade access is typically limited to the ends of the platform. Such end-loaded platforms require all passengers to walk to the end of the platform when exiting, and exit flow capacity is limited by the width of the platform. Consequently, exit flow capacity must be calculated to permit platforms to be cleared of passenger crowding within the interval between arriving trains.

Figure 12-29. Suburban Office Park Light Rail Station, Side Platform

Photo courtesy of Michael Meyer

Waiting and Boarding Areas. Most stations have canopies covering a portion of the platform, and most have some vertical surfaces that are usually transparent to maintain visibility and to provide limited protection from wind and wind-driven precipitation. On exposed platforms, especially in colder climates, more extensive passenger shelters are often used, with enclosures on all sides and in some instances heating provided. Limited seating and leaning areas are usually provided on platforms.

Fare Vending and Collection. Almost all North American LRT systems use a self-service, proof-of-payment (POP) fare system. To facilitate POP fare inspection, some LRT stations have free areas and paid areas. All persons entering a paid area must possess and display upon request a valid ticket. This permits fare inspectors to check tickets in stations prior to passengers boarding vehicles. Ticket vending machines (TVMs) must be located in free areas. Free areas must have adequate space for TVMs and queuing, and good signage is needed to ensure passengers are aware of the limits and access requirements of paid areas. Most POP systems require the use of validators. These are devices into which passengers insert their tickets to have the time and date stamped prior to use. Validators should be located at the entrances to paid areas. For POP systems in which peak-hour vehicle design loads exceed 0.25 passengers per square ft (2 passengers per square meter), onboard fare inspection becomes less effective, because fare inspectors will have difficulty moving through the cars. For these systems, off-vehicle fare inspection becomes a more important consideration, if the agencies place a priority on reducing fare evasion.

Platform and Vehicle Access. LRT stations must be designed to accommodate the needs of individuals with disabilities. TVMs and validators must be usable by individuals with vision and mobility impairments. Accessible paths of travel must be provided that are comparable with paths of travel provided for unimpaired riders. A 24-in.

(61 cm) wide ADA-compliant detectable (tactile) warning surface is required along platform edges or other drop-offs not protected with railings or other barriers. Vertical level changes will require ramps or elevators.

To accommodate the needs of mobility-impaired passengers, all light-rail systems include boarding and alighting provisions that accommodate wheelchairs. These accommodations depend on the height difference between the vehicle floor and the platform. Conventional light rail vehicles have floors approximately 40 in. (1 m) above the top of the rail. Most of these vehicles require passengers to climb three to four steps to enter the vehicle. Mobility-impaired passengers are accommodated by on-vehicle or wayside lifts or by short platform sections constructed at the level of the vehicle floor. Such short high-level or mini-high level platforms are generally reached via ramps from the low-level sections of the platforms, and they require deployment of portable or vehicle-mounted bridge plates to span the gap between the vehicle and the platform. Some LRT systems have stations with all high-level platforms, allowing all vehicle doors to be used by wheelchair users.

New low-floor light rail vehicles are now found in many systems. Low-floor light rail vehicles have all or portions of the vehicle's floor at a level approximately 14 in. (350 mm) above the top of the rail. Doors in the low-floor portions of the vehicles may be boarded directly from platforms at floor height, or from platforms at a nominal 6- to 7-in. (150- to 140-mm) curb height using short bridge plates deployed automatically from the vehicle.

Platform Dimensions. Platform lengths should be designed to accommodate the longest train normally used. Typically, LRT trains are from one to four cars long. Platform lengths will be dimensioned to accommodate a fixed number of car lengths, plus additional length at the ends of platforms to accommodate queuing at end doors, fare collection areas, and variations in stopping distances for vehicles. In many instances, LRT systems are constructed in stages. In such instances it is possible to reduce initial construction costs by constructing station platforms to accommodate train lengths required to support initial operations while designing a station footprint that will allow future platform extensions to accommodate projected ridership.

Platform widths must be dimensioned to accommodate dynamic loads of waiting passengers and passengers exiting the trains, and in particular emergency evacuations. Such loads are usually determined by simulations of peak period conditions. End-loaded center platforms, because of the obvious design constraints, require careful attention to peak-loading conditions. Minimum platform widths must accommodate the detectable warning strip and unobstructed passage for wheelchairs and pedestrians of 6 ft (1.8 m) adjacent to the warning strip. Consequently, side platforms must be no less than 8 ft (2.44 m) between platform edge and any obstruction, including structural members and platform furniture. However, the actual minimum platform width should be determined individually for each station according to local codes and standards for queuing and evacuation of passengers.

Station Types. At-grade LRT stations generally include four types: in-street right-of-way, in reserved street median, side of street, and exclusive right-of-way. With the introduction of pedestrian areas with transit services in many cities in recent years, numerous LRT stops have been placed in areas such as pedestrian malls, shopping streets, large pedestrian squares, and so on. In most cases, crossing the tracks is allowed everywhere because LRT vehicles operate only at moderate speeds. The track consists of rails embedded in pavement with the tops of the rails either flush or slightly depressed and separated by low curbs. In addition to warning pedestrians, the curbs assist vehicle boarding at stops. An effective way of designating stop areas is the use of textured pavement, usually squares of two different colors.

At-Grade Transfer Stations. Major transfer stations for surface transit should be located in large pedestrian areas, separated from automobile traffic. Short walking distances between vehicles of different routes should be provided. Crossing tracks and roadways are usually unrestricted; controlled pedestrian crossings and overpasses or underpasses should be used only if vehicle speeds are high or pedestrian volumes are very heavy.

2. Rail Rapid Transit (Controlled-Access) Stations

All rapid rail transit, some commuter rail, some LRT and most major intercity rail systems use stations that are grade-separated from other facilities and have full control of passenger access. Typically, fares are collected or checked at the entrances to the boarding areas so that this process does not delay the vehicle boarding. This permits simultaneous loading on all doors along the train. In addition, fully controlled stations allow use of high-level platforms that make getting into and out of vehicles extremely easy and fast. Consequently, controlled-access stations represent by far the highest transit terminal capacity.

With long trains and many doors, it is possible to achieve boarding and alighting rates of 40 to 80 persons per second. LRT vehicles with simultaneous loading of two, six-axle cars can achieve rates of 6 to 20 persons per second, while LRT trains of three, eight-axle cars, and high-level platforms can reach rates of 15 to 30 persons per second. These rates are one to two orders of magnitude greater than rates of passenger boarding of surface transit vehicles that involve fare collection at the entrance, require riders to step up into the vehicle, and have only one or two doors.

Controlled-access stations have a durable effect on both the operation of the transit system and its interaction with the surrounding environment. Their design must be based on a very careful analysis of the requirements of the three major affected parties: passengers, the operating agency, and the community.

Passengers using the stations require:

- Comfort, including aesthetically pleasing design, weather protection, small vertical climbs, and the like.
- Linkages to the community, such as wayfinding signage, surrounding area maps, and good pedestrian connections.
- Minimum time and distance to the platform or between platforms for transferring between lines.
- Safety and security, maximum protection from accidents through safe surfaces and good visibility and illumination, which deter vandalism and prevent crime.

The operating agency requires:

- Minimum operating costs.
- Adequate capacity of the transit system and pedestrian areas.
- Flexibility of operation, such as adaptability to different peaking conditions and changes in fare-collection methods.
- Good visibility of platforms, fare collection and other areas to enable supervision of operations and ensure efficiency, safety, and prevention of vandalism.
- Good integration with surrounding areas and utilization of station space for various shops, displays, information booths, and so on.

The *community* is interested in having a well-used and efficiently operated transit system. It is therefore also concerned that the requirements of passengers and the operator be satisfied. The community considers these requirements, together with investment costs that are in many cases its obligation. In addition, however, the community is also interested in both the immediate and the long-range effects of the station on its surroundings. The immediate effects include environmental impact, visual aspects, noise, and possible traffic congestion. Long-range effects include the type of development in the vicinity, which may be stimulated or discouraged by the station's presence.

Station Platforms. Rapid rail stations can have either lateral platforms or a center platform (see Figure 12-30). Because cars have doors on both sides, either of the two types can be used at a station along the line. Several older rapid rail systems used mostly center platforms to reduce right-of-way width and operating personnel needs. However, with increasing and sometimes total automation and centralized supervision of stations, this difference has disappeared on some systems. The choice between the two types thus depends on many factors, such as fare collection, train departure procedure, entrance locations, and available right-of-way width.

Figure 12-30. Side and Center Platforms for Atlanta's MARTA System

Photo courtesy of Phillip Cherry

Stations with multiple tracks and multiple platforms are provided in three different cases. First, when passenger interchange is heavy and the line operates at capacity, three platforms can be provided so that each track has platforms on both sides. This design permits simultaneous boarding and alighting of passengers on the opposite sides of the trains, considerably reducing passenger standing times. This type of station exists in Barcelona, Spain, and on the Munich S-Bahn system. The second case is on lines with local and express service, common in the New York subway system.

A third type of platform arrangement is used for stations where lines intersect and transfers are permitted. This type of station is seen in several locations on the Washington, DC, Metro, on the Atlanta, Georgia, MARTA system and in Montreal, Canada. This type of station has rail lines crossing at different levels. Levels are connected by stairs, elevators, and escalators. Where possible, one level has side platforms and the other has a center platform. This configuration permits stairs and escalators to be parallel to the track on the center platform and perpendicular to the track on the side platforms. Where side platforms are not feasible, escalators and stairs from both track levels must connect with a third-level mezzanine.

Platform length is usually determined as the length of the longest train plus a distance of 16 to 32 ft (5 to 10 m). Although it requires additional construction cost, this extra distance actually reduces travel time because it requires a lower precision of braking. Platform width can also be an issue, especially for older systems that were built to different standards. The most important factor in platform width is the safe handling of passengers, both those waiting to enter the train and those exiting. In some older systems like London and Mexico City, the demand at some stations is so great during peak periods that the transit agency has to prohibit passengers from entering the platform after a threshold has been reached. Once the platform has emptied into a train, the next group of passengers is allowed to enter. Platform heights have a major influence on station construction costs and space requirements, as well as on their operations. There are two categories of platform heights:

- *Low-level platforms* are at a ground level or one curb height above it. Used by all streetcars, most light rail, some commuter rail, and some intercity rail, these platforms require simple, low-cost arrangements, but they may involve slower boarding and alighting if passengers must use steps inside the vehicles.
- *High-level platforms* are even with or slightly lower than the car's floor, 2.8 to 3.3 ft (0.85 to 1.00 m) above the top of the rails. Used on all rapid rail, most commuter rail, some light rail, and most major intercity rail systems, these platforms involve considerably higher construction costs and take more space, but they provide faster, safer, and easier boarding and alighting. Most controlled stations (with access through fare-collection areas only) and some open stations have high-level platforms.

Station Levels. Controlled-access stations usually consist of three levels. Entrances and stairways are at the street level. The intermediate, mezzanine levels contain the fare-collection system, which divides it into a free area (part of a public street) and a paid area (the transit station proper). The third level has platforms and tracks where train boarding takes place.

A variety of designs of the three station levels is possible, but the most typical ones can be classified by their three basic characteristics: subway versus aerial stations, two versus three levels, and center versus side platforms. The differences between these designs can be seen from their schematic cross sections in Figure 12-31.

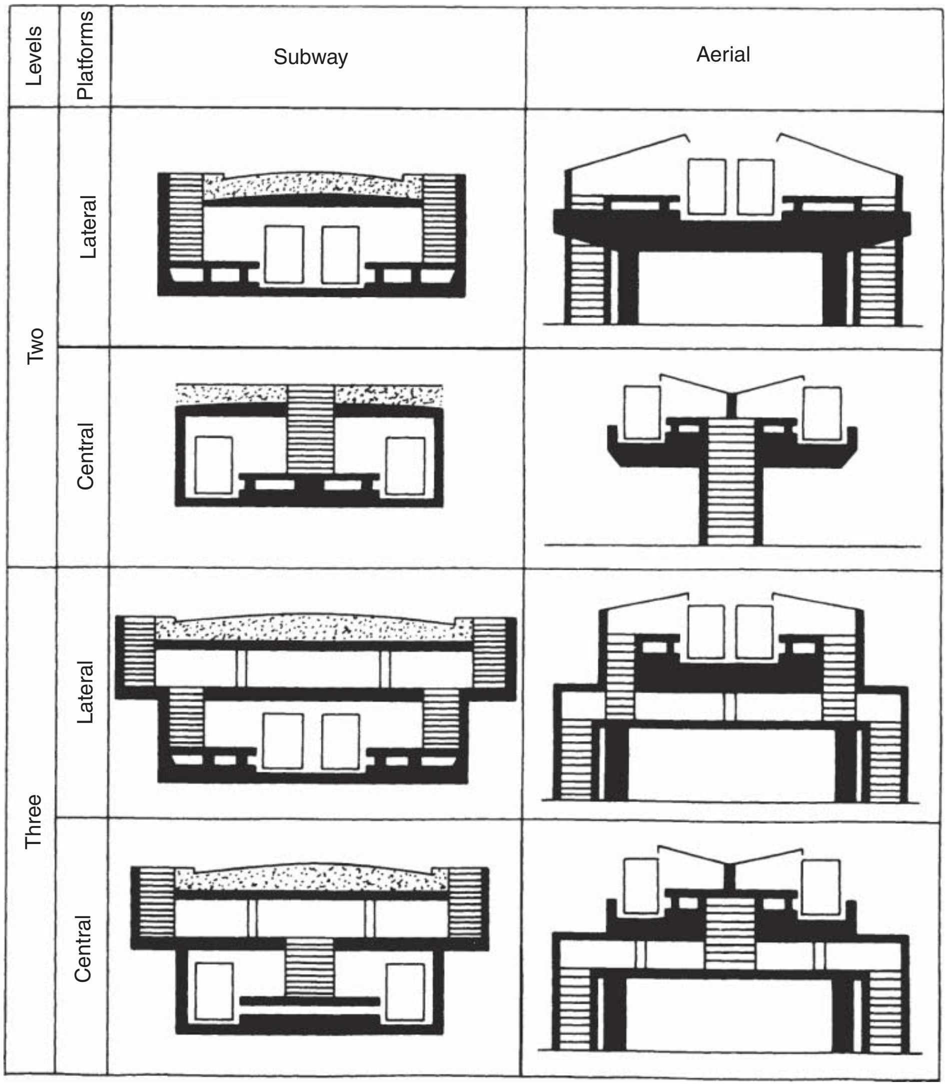
Fare Collection. Virtually all rapid rail systems require passengers to pass through a barrier or turnstile where fares are collected. Gates or turnstiles are usually provided in a bank or several banks of parallel devices to accommodate anticipated peak passenger volumes and provide adequate queuing space. Older transit systems use magnetic stripe tickets (with stored value) have become typical fare media for new systems and some older systems. To accommodate wheelchair-bound passengers, some gates have wider openings or are equipped with special release devices. On some systems, magnetic stripe cards must be inserted in turnstiles on both entry and exit, allowing the use of specific distance-based, station-to-station fares. Common technology is using contactless or proximity cards for fare payment. These smart cards are not inserted in readers, but they can be placed on or near a designated area on the barrier and activate the gate using wireless communications. Emerging technologies include payment directly with contactless credit/debit cards and using Near Field Communications (NFC) technology on smartphones.

In most systems, ticket vending machines are located in free areas near station entrances to permit passengers to purchase fare media. Some systems with distance-based fares also locate add-fare machines in the paid areas near exits. For some rail rapid transit systems that use a proof-of-payment (POP) fare system, validators may need to be placed at the entrance to paid areas as in many light-rail systems.

Entrances and Integration with Surroundings. The number and location of station entrances directly influences passenger convenience and transit system integration with adjacent areas and buildings. Because passengers feel that they have reached the transit system when they come to the station entrance, station layout should provide stairways at both ends of the platform. Such a layout effectively results in an increased area coverage compared with single-entrance layout. For transit stations that are located in the middle of a freeway, often extensive overhead pedestrian bridges will be necessary to connect to the surrounding community (see Figure 12-32).

Direct connections between the station mezzanines and the basements of major stores or other buildings are also common. Well-designed and extensively used large underground plazas and malls with stores, restaurants, and connections

Figure 12-31. Rapid Transit Station Types



Source: Vuchic, 2005

with hotels, office buildings, rapid rail and railroad stations exist in Frankfurt and Hamburg, Germany; London; Montreal (Place de la Marie complex); São Paolo, Brazil; and many other cities.

Highway and Rail Transit Interface (Bus Service and Parking). To achieve an interface between automobile travel in suburban areas and the transit network, stations must accommodate automobile access in two forms—kiss-and-ride (the drop-off and pick-up of passengers) and park-and-ride (transit passengers park their cars at the station). These access modes usually create high peak-hour volumes, such that the station design must extensively utilize traffic engineering techniques. Because of traffic volumes and parking facilities, these stations require a very large area per passenger.

The basic principles governing the design are:

- Priority in convenience of access should be given to modes that are identified as part of the station planning process. For example, some agencies might choose a sequence of: pedestrians, feeder transit, bicyclists, taxis, kiss-and-ride, and park-and-ride. Others, for example, might place bicyclists higher in the priority.
- Maximum possible separation of all access modes is desirable.
- The pedestrian walk between access modes and the station platform should be safe, convenient, and as short as possible.
- Adequate capacity, easy orientation, and smooth traffic flow should be provided for each mode.

Figure 12-32. Pedestrian Access to Center Freeway Rapid Transit Station, Atlanta

Photo courtesy of Metropolitan Atlanta Rapid Transit Authority

Typically, the station building is located in the middle of the station area. Feeder routes (usually buses) have stops close to station doors along curbs that may be straight or have a sawtooth pattern. Where conditions allow, bus ramps are built to provide direct, across-the-platform transfer to trains, eliminating the need for passengers to climb stairs. Pedestrian access from all streets and parking areas requires walkways that should be at least 4.9 ft (1.50 m) or two pedestrian lanes wide. Lowered curbs, mild gradients, and convenient doors should allow access to stations by people in wheelchairs. Bicycle racks and, if bicycle volume is heavy (for example, near schools and campuses), bicycle lanes should be provided.

The kiss-and-ride area should be easily reachable from all access streets. It should have a sheltered drop-off area and a parking area for waiting with good visibility of the station entrance. The remaining station area is used for parking. Circulation roads should be remote from the station building to minimize auto and pedestrian conflicts. Aisles directed toward the building and right-angle parking usually provide the best circulation and space utilization.

Commuter parking facilities can use a variety of payment systems. Because of the regularity with which they are used, some facilities can use prepaid permits that eliminate daily payment transactions and reduce operating costs. Such permit-payment lots can be designed with many access points and no barriers.

Alternatively, as transportation systems become more seamless, there is often a desire to use a single fare instrument for all modes of transportation, such as an electronic smart card. Access to such lots may require channeling all cars past a reading device linked to a moveable gate or barrier to accept the smart card or electronic transponders (tags mounted on the vehicles).

Commuter parking facilities may require special treatment from designers. Facilities that are served by rail transit systems may have surge loads of afternoon peak commuters alighting from trains at frequent intervals. Such loads may place large numbers of pedestrians in the lot coincident with large exiting volumes of vehicles. In addition, parking facility flows may conflict with kiss-and-ride pick-up, queues, and flows. Coupled with the fact that in many locations, for most of the year, either one or both peak periods occur in darkness, surge loads of commuters rushing to and from trains require the designer to consider carefully the safe movement of pedestrians through the facility. The horizontal and vertical distances between parking facilities and the station platform experienced by riders are also an important consideration in facility design. Requiring park and ride patrons to walk long distances or to use stairs to access platforms can serve as an obstacle to many in their decision to use a park-and-ride facility.

3. Regional Rail Stations

Commuter rail is an attractive alternative in areas where existing freight rail lines parallel congested freeways. Most commuter rail stations have major termini in downtown business districts, often areas that were initially developed as commercial districts because of the presence of passenger railroads and terminals. Consequently, access to most of these termini will be on foot or by local transit service. Most commuter rail stations in suburban areas are accessed primarily by auto and have correspondingly sized park-and-ride lots.

Where new stations are developed along existing freight railroads, additional passing tracks may be required to permit simultaneous operation of freight and passenger service. Because freight railroads may need to accommodate tall and wide loads, it is not desirable to operate freight on tracks adjacent to high-level passenger platforms. Freight clearance dimensions might create a wide gap between the platform edge and typical commuter rail cars, which is undesirable. Some commuter rail stations are equipped with movable platform edge strips that can be retracted to allow wider clearances for freight cars and extended to provide smaller gaps for passenger boarding. Retractable platform edge strips require integration with the train control and signal system to ensure safe operation. An option for providing additional clearance for freight cars at passenger stations is use of a gauntlet track, which adds a second set of rails that are parallel to the passenger track, but are offset from the platform by an additional distance.

If freight and passenger trains are permitted to operate simultaneously, grade-separated pedestrian access must be provided to commuter rail platforms. Similarly, grade-separated access is required for stations on lines that feature frequent, high-speed operations, have express trains bypassing stations, or have an electrified third rail. In areas where commuter trains are relatively short and operate at relatively low speeds, it is usually possible to permit pedestrians to cross commuter rail tracks at designated and suitably protected at-grade crossings, similar to light rail operations.

Most commuter rail stations have platforms at car-floor level, which is approximately 4 ft (1.2 m) above the top of the rail. Standard railroad passenger cars are 85 ft (26 m) long and are seldom operated in trains less than two cars long. Typical trains include four to eight cars (10 to 12 cars in major metropolitan areas) and a locomotive. Some new passenger cars, particularly with multiple levels, are low-floor, permitting level boarding from platforms only 25 in. (64 cm) above the top of rail.

Commuter rail systems generally feature on-board fare collection in which conductors walk through the vehicle and validate tickets. High-volume stations may have ticket offices and automated TVMs. Some commuter rail systems use POP fare systems similar to light rail.

4. Intercity Rail Stations

Intercity passenger rail travel in the United States, after a long period of declining traffic, is showing some growth. This is particularly true in the Northeast Corridor between Washington, DC, and Boston, Massachusetts, which is the highest density intercity rail corridor in the United States. During the 1990s, electrified operation on the Northeast Corridor was extended from New Haven, Connecticut, to Boston and new high-speed train sets were acquired. In several states, including California, Illinois, and Texas, corridors have been considered as candidates for high-speed rail operations. Some general principles for intercity rail stations are presented here along with examples of some major existing rail stations of this type.

A rail station complex will include platforms and platform tracks, concourse and other access ways, ticket sales, baggage and checkroom facilities, waiting rooms, restrooms and other amenities, such as restaurants and sales booths, parking areas and access through covered walks or tunnels to streets and to local modes of transport. Stations for rail transport are of two general types—stub and through. The through-station is, in effect, a way station with arriving trains continuing through to the stations beyond. The stub station is found primarily where the trains terminate their runs. Some stations have both stub and through-tracks. At the stub end, the train is stopped, loaded or unloaded and backed out; with electrified and diesel push-pull multipower unit equipment, the engineer shifts operations to the opposite end of the train. Stub-end terminal operations usually consume more time for this changeover and, therefore, usually require more tracks to accommodate the same hourly number of trains processed at the line stations.

At stations with light traffic, the platforms are usually adjacent to the main tracks. Where traffic is heavy, especially where many commuter trains operate, the main line tracks will be augmented by platform tracks diverging from main tracks or terminal lead tracks. The tracks that connect the platform tracks to the principal leads or to the mains are termed *throat tracks*. A general rule is to have a 2.5:1 to 3:1 ratio between a throat track and the number of platform tracks it serves. There must be enough platform tracks to serve all trains scheduled to arrive or depart at a particular time, plus a few additional to take care of off-schedule and extra trains. A track may also be reserved to park special equipment.

Minimum length of platform is based on the longest train anticipated (car length times the number of cars plus locomotive), plus two or three additional car lengths for emergency situations and to provide a factor of safety in stopping the train. Additional length may be added to anticipate longer trains of the future. Platform widths vary from 20 ft (6.1 m) if baggage trucks also use the platform to 13 ft (3.96 m) for passengers only. Wider platforms than these minimums are found in practice, especially if pedestrian flow studies indicate they are needed. Access to the platform gates is through a concourse from the street or through walkways from the station service area. When the waiting and service areas are on different levels, then ramps, stairways, escalators, and elevators are needed adjuncts. Pedestrian flow studies should also be done to size these facilities.

The usual intercity traveler moves slowly through the station area. The passenger may not be familiar with the routine, have baggage to handle and check or retrieve, have a long wait for connections or delayed trains, and may require information, food, and a comfortable place to sit. Commuters, on the other hand, are familiar with the route through the station, have little or no luggage, and are usually in a hurry. They want direct access to or from local streets and transport. These two types of traffic should be kept separate to avoid conflict and confusion. In some large stations such as Grand Central Terminal in New York City, commuter and intercity trains arrive and depart on different levels. In smaller stations, separate platforms should be used and traffic routed so that the two lines of movement do not cross. In some instances, separate stations are in use. Clear and concise direction and routing signs and other means of channelization are desirable.

D. Waterborne Stations

Rivers, lakes, bays, and other bodies of water are often major obstacles to transportation. However, in some cases, they can also be used as transportation routes, offering more convenient and even faster travel than land-based systems. The boat types used for different across-the-water connections can be classified in three basic technologies: ferryboats or ferries, jetfoils or hydrofoils, and hovercraft. This section deals with ferries, the most widely applied mode, particularly for high-volume movement of passengers on-foot or in vehicles.

1. Ferry Stations (Passengers Only)

Ferries are by far the most common vessel for passenger transportation on water. Although they are rather slow, ferries offer low-cost, reliable, comfortable, and sometimes even faster service than any competing mode can offer among the locations served. Ferry systems can be planned for passengers only, passengers and vehicles (for example, autos, buses, and trucks), and special train-carrying ferries (lighterage).

Passenger-carrying ferries are in wide application around the world using conventional ferry vessels of various sizes and configurations. Notable examples include the Staten Island Ferry, Hudson River, and New York Waterway ferries in New York City; the Water Emergency Transportation Authority (WETA) and Golden Gate Ferry services in the San Francisco area; Washington State Ferries in the bays around Seattle; and the Star Ferry service in Hong Kong.

The Vancouver, British Columbia Sea-bus is one of the more innovative examples of ferry service in North America. Ferry stations at both terminals are served by several bus routes. The south (Vancouver) terminal is also connected by direct pedestrian passageway to an automated LRT system and to commuter rail serving downtown Vancouver and some of the easterly suburbs. Bus schedules and fares are integrated with those of the ferries. Each terminal has a floating structure with two docks to provide easy docking regardless of the tides, which fluctuate as much as 20 ft (6 m). The ferries fit precisely in each dock and open six double doors on each side. Passengers embark from the center portion of the terminal, while those leaving the ferry disembark into its outer corridors. This one-way passenger flow allows a complete exchange of 400 passengers (seating capacity of the boat) in 90 seconds.

2. Ferry Stations (Passengers and Vehicles)

Ferries that serve both passengers and vehicles are found in geographic situations where highway transportation via fixed roadways and bridges is not feasible. Examples include Delaware Bay, Puget Sound, and the Great Lakes in the United States; coastal British Columbia; and Scandinavia. The design of these types of ferry stations consider several functional elements: marshaling yards and approach lanes, passenger facilities, and ferry berths and ramps. The baseline for the design is the forecasted traffic and pedestrian volume, with vehicle capacity also being a key factor. Both the total traffic volume and its distribution over time are important parameters, as well as the mode share. Establishing such parameters is challenging in that once a new terminal is established it will itself influence the traffic pattern in ways that are difficult to predict. Fortunately, ferry routes are usually flexible systems, which within a year or two may be modified relatively quickly to cope with changes in traffic volumes and patterns.

Given annual passenger and cargo vehicle peak traffic forecasts, traffic volumes can be projected as direct design parameters for the functional elements of the ferry terminal. The forecasted traffic is often expressed in equivalent passenger car units (PCUs). One PCU may be considered to occupy 32.8 ft (10 m) of deck. Trucks are equivalent to 4 to 7 PCUs, depending on their size, and buses about 4 PCUs. This is used to estimate transfer capacity in terms of car deck area, as well as for marshaling yard requirements.

The turnaround time at the terminal depends mainly on the distance between the ferry landings, the cruising speed, and the loading and unloading time. Analysis of ferry operations will establish whether a few large ferries or more, smaller ferries should be preferred, what cruising speed is desired, and the number of ferry berths.

To speed up operations, reduce bottlenecks, and avoid accidents, it is essential to prepare the layout of marshaling areas to avoid conflicts in vehicle and passenger flows. The departing traffic should not interfere with the arriving traffic. The latter should be separated into passenger cars, trucks and trailers, buses, and other vehicles, with special waiting areas provided for pedestrians, bicycles, and motorcycles. Further, lanes for waiting vehicles with and without reservation should be separated. Reservation possibilities will increase the required number of lanes for waiting vehicles, but they will reduce the required total length of the lanes because vehicles with reservations spend a shorter time waiting. A rough idea of the size of the marshaling area can be obtained under the assumption that waiting time during peak traffic of more than two to three hours would not be accepted. With trip frequencies of about one hour, this would indicate a marshaling area corresponding to two or three ferry departures.

Ramps are designed to sustain the traffic load and to be able to transfer vehicles safely during extreme water levels. The length of the ramp may be determined on the basis of information on high- and low-water statistics and the maximum allowable steepness of the ramp (normally a 10-percent grade), together with specifications of the vehicles to be transported. The ramps must be able to allow small roll movements of the ferry at berth.

E. Multimodal Stations

Stations and interfaces often serve more than one mode. The stations described below are designed to incorporate more than one mode (for example, a major rail station that incorporates a bus terminal within the facility, or vice versa).

Current thinking on the effectiveness of multimodal passenger transportation stations revolves around the concept of seamless transportation. Truly seamless transportation is a one-seat, one-fare ride from origin to destination, with minimal delay and discomfort associated with transfers. However, virtually all journeys include an access trip to the boarding terminal, a line-haul trip on the major mode of travel, possible transfers to other line-haul modes and an egress trip from the terminal to the final destination. To accommodate seamless travel, the terminal designer should maximize passenger convenience for transfers between modes by reducing distances between boarding and alighting points, providing clearly marked routes for transfers, minimizing level changes, and providing real-time information on boarding locations, schedules, and delays.

Terminal planners should examine market forecasts for travel demands and identify the demand for transfers. By studying the relative volumes of passengers transferring between modes, the planner can prioritize the importance of transfers between each mode and develop plans accordingly.

The most recent example of a multimodal terminal is Denver's new Union Station (see Figure 12-33). This station serves light rail, a new 22-gate bus concourse, Amtrak, and commuter rail services in one location. The station was

Figure 12-33. Denver's Union Station

Source: Courtesy of the Denver Regional Transportation District

initiated in 2001 when the Denver transit agency, Denver RTD, purchased the site in accordance with a jointly funded Intergovernmental Agreement among RTD, the City and County of Denver, the Colorado Department of Transportation (CDOT) and the Denver Regional Council of Governments (DRCOG). A master plan for the area was developed and rezoning for transit-oriented development was approved by the city council. Besides serving at a major intermodal hub in downtown Denver, the station has become the focal point for major developments in the downtown as well.

Although not specifically developed for multimodal stations as in the Denver Union Station example, the following guidelines from San Diego on the design of intermodal transit stations and/or stops provide a good framework of the principles that should be followed. [SANDAG, 2009]

Station Location. Transit stations are likely to draw more riders if they are located in areas that attract many visitors and workers, and if they provide nearby amenities that benefit commuters. Locate transit stations at or near major trip generators such as sports venues, concert halls, schools, offices, and shopping areas. Provide frequently used services near transit stations, such as dry cleaners, coffee shops, restaurants, and childcare facilities. To encourage patronage of these businesses, place them between vehicle parking areas and the transit stop.

Intermodal Connections. Many transit trips require people to transfer between buses, trains, and shuttles. Transit stations should be designed to make these transfers as simple and convenient as possible.

- Minimize walking distances between different modes of transportation.
- Allow pedestrians to transfer between modes without crossing major thoroughfares or walking through large parking lots.
- Group bus stops together into one part of the transit station.
- Where passengers often transfer between two bus routes, locate the stops for each route close to one another.
- At transit stations that are near large employers, provide space for commuter shuttles.
- Incorporate space for taxi queueing where demand warrants.
- Post clear, easy-to-read signs that provide direction for how to transfer between different transportation modes and transit operators.
- Provide fare information and timetables at points of transfer, along with maps showing transit routes and connections to other transit services.

Pedestrian and Bicycle Access. Many people arrive at transit stations by walking and biking, and most transit riders will have a short walk to their destination at the end of their trip.

- Design stations to provide for pedestrian and bicycle access, and plan for improved facilities where needed to support pedestrians and bicyclists.
- Provide direct, logical paths from the street to passenger waiting areas.
- Include pedestrian and bicycle connections that link the station to nearby homes, businesses, offices, and civic buildings.
- Post "bike parking" directional signs at entrances to the transit station.

Vehicle and Bicycle Parking. Adequate bicycle parking must be available as well as vehicle parking, with appropriate policies that encourage people to use transit, walk, or bike to reach the station.

- Locate bicycle parking in places with high foot traffic, so that it receives natural surveillance from passersby.
- Provide secure bicycle parking in the form of bike lockers or "bike stations" with valet parking. Use bike lockers that clearly indicate when they are occupied, so station patrons can see they are being used.
- Design transit stations to provide for increased bicycle parking in the future as mode share increases.
- Incorporate an appropriate amount of vehicle parking, using parking structures wherever possible. Manage demand by charging a fee for parking where appropriate.
- Place surface parking lots in clusters that are large enough to be developed in the future with mixed-use buildings, offices, townhouses, multifamily dwellings, or parking structures.

Passenger Waiting Areas. Thoughtfully designed waiting areas create a more welcoming environment for passengers.

- Provide aesthetically pleasing bus shelters that offer protection from sun, wind, and rain.
- Post transit schedules and route maps at all waiting areas.
- Display real-time arrival information for buses and trains if available, and ensure that it can easily be viewed from all waiting areas.
- Provide adequate, well-lit seating at all waiting areas. For safety, design the waiting area so that passengers can see what is around them at all times.

Universal Design. The Americans with Disabilities Act requires transit stations to be designed so that anyone can access and use them, regardless of physical abilities. This requirement ensures that public transit is available to all.

- Provide wide, level, and smooth paved surfaces in boarding areas. Avoid changes in grade or obstacles that could pose a tripping hazard or interfere with the movement of baby strollers and bicycles.
- Connect different parts of the station to one another and to the adjacent street with low-slope ramps and wide, flat paths.
- Where escalators must be used to provide access to part of the transit station, provide an elevator as close to the escalators as possible.
- Ensure that all seating areas also provide adequate space for people in wheelchairs.

Signage. All passengers must be able to find information about how to use the transit station and connect to surrounding areas. Signage must meet the needs of frequent transit riders who need to find schedule or route information quickly, as well as new riders who may not be familiar with the station or its surroundings. Some guidelines include:

- Design signs with typefaces that are easy to read even in dim lighting.
- Display maps that show the transit system as a whole, as well as local maps of the station that indicate connections between different routes and modes of travel.

- At bus stops, display schedules that use a clear symbol to indicate when the bus connects to another mode of travel, such as a commuter train.
- Integrate accessibility features such as Braille signs and audible announcements of upcoming train or bus arrivals.
- Place signage where it is highly visible and easy to locate for people entering the station, as well as new riders who may not be familiar with the station or its surroundings (wayfinding signage).
- Provide schedule information and route maps for all routes that use the transit station.

X. LINES AND NETWORKS

Designing a transit network that promotes efficient and cost effective trips is one of the ways of providing transit service that meets customer and owner expectations. [Chatman et al., 2014] Line alignments and station locations comprise the basic infrastructure of transit systems. Together, the layout and design of lines and stations create transit networks, the nature of which has profound influence on the quality of transit service offered and the function of the system. Investments in lines and stations vary greatly among modes, from minimal facilities for bus lines operating on streets, to very complex, permanent structures of rail systems that are fully grade separated. Although the ranges and scopes of planning vary greatly among modes, the objectives in transit network planning and design are common for all modes. Networks should be designed to achieve the following three basic goals:

- *Maximize transit ridership, as measured in either unlinked trips or passenger-miles served*. This objective requires providing attractive service to passengers, including good area coverage, short access to stations, high-frequency services, and high-speed and reliable services between major trip generators.
- *Achieve maximum operating and economic efficiency.* This objective focuses on operating efficiently, that is, achieve high output per unit costs, labor, and other resources. It should also ensure integration and convenient transfers with other modes of transport, as well as balance the system's investment and operating costs.
- *Achieve maximum positive impacts on the city and region.* These impacts might include short-term increases in transit's modal split and, in the long term, support for desirable urban form and livability, while reducing traffic congestion and ensuring low air pollution and noise.

These service planning principles apply to all types of transit lines. They vary by two basic types of network design and vehicle type. Street transit, generally buses, involves many lines with a dense network that can be established and modified easily, without major investment or construction efforts. Semi-rapid transit, consisting mainly of rail lines, requires longer range planning, and utilizes a separate network of high-performance services. Finally, rapid transit systems, having reserved rights-of-way (category A) only, require large investment and long-range planning, which includes an analysis of the relationship and impact of these systems on ridership and urban form. For example, well-designed, dense transit networks can support and enhance the pedestrian-orientation of urban areas.

Small and many medium-sized cities usually rely on bus services. Large- and some medium-sized cities have rail transit networks, which must be carefully planned and coordinated with bus and other area-wide, lower-performance modes operating supplementary and feeder services.

The following discussion of lines and networks covers mainly rail systems, with some attention given to bus services and various feeders, such as private cars (kiss-and-ride and park-and-ride), taxis, and pedestrians.

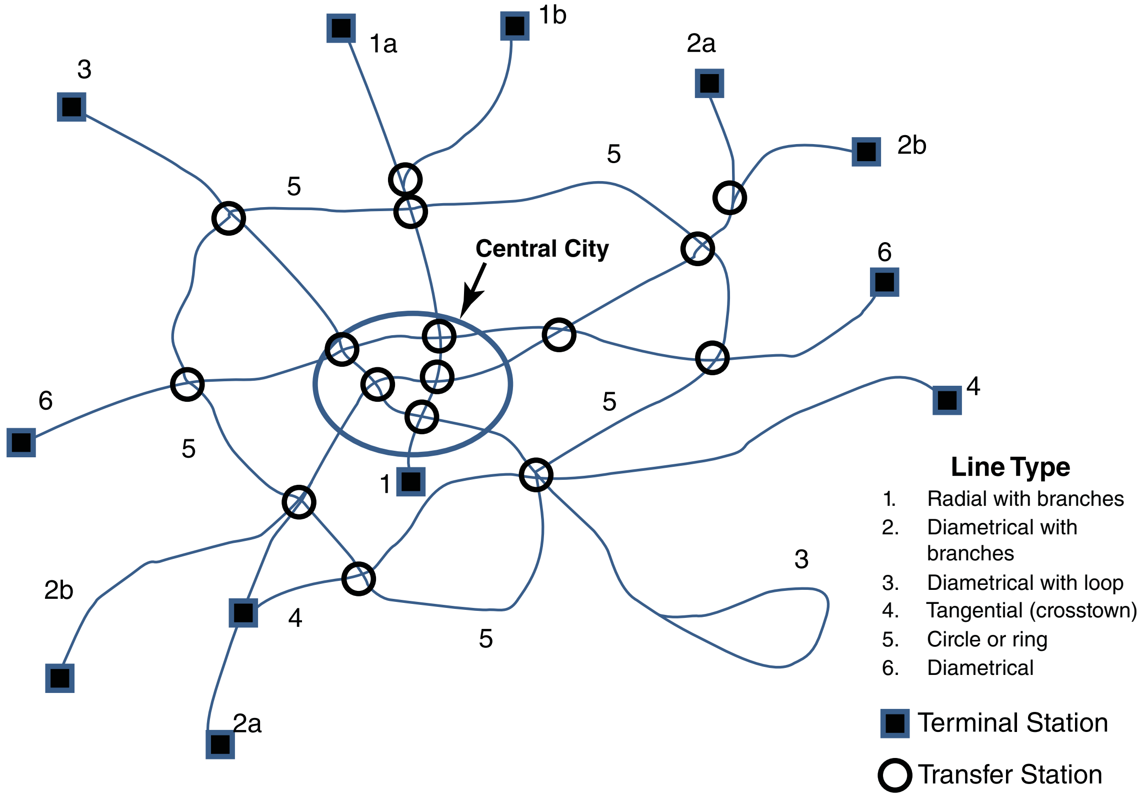
A. Types and Characteristics of Lines

Transit lines are defined and categorized by their alignments and stations, and further identified by scheduling and the efficiency of operation. The basic types of lines are shown in Figure 12-34, with their characteristics described below.

1. Line Alignment Types

Radial lines (also often known as a "hub-and-spoke" network) are the oldest and most common form of transit lines. They originate in a region's CBD and serve radial alignment corridors toward outer suburban areas. These lines are

Figure 12-34. Types of Lines in a Transit Network



typically used by residents commuting inbound to urban employment, commercial, and entertainment locations. Their cumulative loading steadily decreases line utilization in the outbound direction.

Diametrical lines have both route end stations in suburban areas with alignments that pass through the city center. Like radial lines, diametrical lines provide radial access to the CBD from the suburban areas, but also serve suburb-to-suburb connections. Diametrical lines may have generally straight alignment through the downtown or may follow an L-shaped form, common for several subway lines in Manhattan, New York. Such lines generally have more transfer points with other lines than straight lines. One major concern in the design of diametrical lines is the balancing of passenger volumes on the two radial sections. Uneven passenger volumes usually result in low utilization on one side of the diametrical line.

Diametrical lines have several advantages over radial lines: better coverage of the central area, more transfer points in the network, and direct service for many suburb-to-suburb trips. U-shaped lines, such as the Red Line of the Washington, DC, Metro, experience well-balanced ridership, but they may not attract as many trips through the CBD because of their circuitous nature.

Tangential lines serve major corridors perpendicular to radial lines in close suburbs, and do not enter the CBD. Circumferential lines serve portions of circles in close-in suburbs, similar to tangential lines.

Circle or ring lines follow an alignment forming a full circle around the city center, but with a limited number of stations. These lines provide connecting services between radial lines originating in the city center. They also allow for suburb-to-suburb travel without having to pass through the downtown. Operationally, circle lines are more complex because no terminal time can be scheduled to recover delays, and they often need large interchange stations with the radial lines.

2. Line Relationships in a Network
Generally, lines may be operated independently or be integrated with other lines.

Independent lines operate by themselves on their alignment; no other line operations occur on the track. This type of operation is the simplest and most reliable so that minimum headways and maximum line capacity can be achieved. Such lines require passengers traveling to other routes to transfer at stations. These lines usually offer the same capacity along their entire lengths, so that they are used in areas with similar population densities. Examples of this type of lines are found on many metro systems with large, high-density central cities, such as Moscow, Paris, Toronto, Boston, Philadelphia, and Tokyo.

Integrated lines have sections where lines merge, diverge, and overlap, providing line connectivity with fewer transfers. This type of operation results in longer headways in the branch lines than with independent lines, and provides more single-seat trips where shared line operations occur. Scheduling of integrated lines is more complicated and irregular headways may be unavoidable on some joint or separate sections of integrated networks. On the other hand, the combined operations may result in more precise scheduling according to demands on individual sections, resulting in higher load factors and operating efficiency. Examples include Atlanta, Chicago, and New York City.

Figure 12-35 shows the Washington, DC, Metro system, which uses a combination of independent and integrated lines. The Red Line (the U-shaped line) is operated independently between its terminals. The Blue, Orange, and Silver Lines operate on common track and share stations between Rosslyn station and Stadium Armory. The Yellow Line is integrated with both the Blue Line (between National Airport and Pentagon) and the Green Line (between L'Enfant Plaza and Fort Totten).

The most common types of integrated lines are trunks with branches, typically used on radial and diametrical lines (examples include Chicago and San Francisco). As a major common corridor, referred to as the trunk line, goes from center city toward the suburbs, its ridership decreases, while the service area increases. The most used service strategy is to operate a trunk line by a high-capacity mode, usually metro or LRT, which then splits into two or more branches to increase area coverage. This may be done by allocating subsequent trains to different branches beyond the trunk. In the case where, for example, three branches are served, capacity on each branch is one-third the capacity of the trunk.

An alternative approach is to terminate the high-capacity trunk mode at approximately the limit of the city and the suburb. The trunk is then fed by several independent feeders, typically lower-capacity modes operating at higher frequency (the Skokie Swift in Chicago). Passengers are required to transfer from the feeder mode to the trunk mode.

Branches, compared to feeders, have the following advantages:

- They provide direct service without transfers between the trunk and branches.
- Being longer than feeders, branch lines have shorter terminal times, reducing operating costs.
- No transfer stations are required.

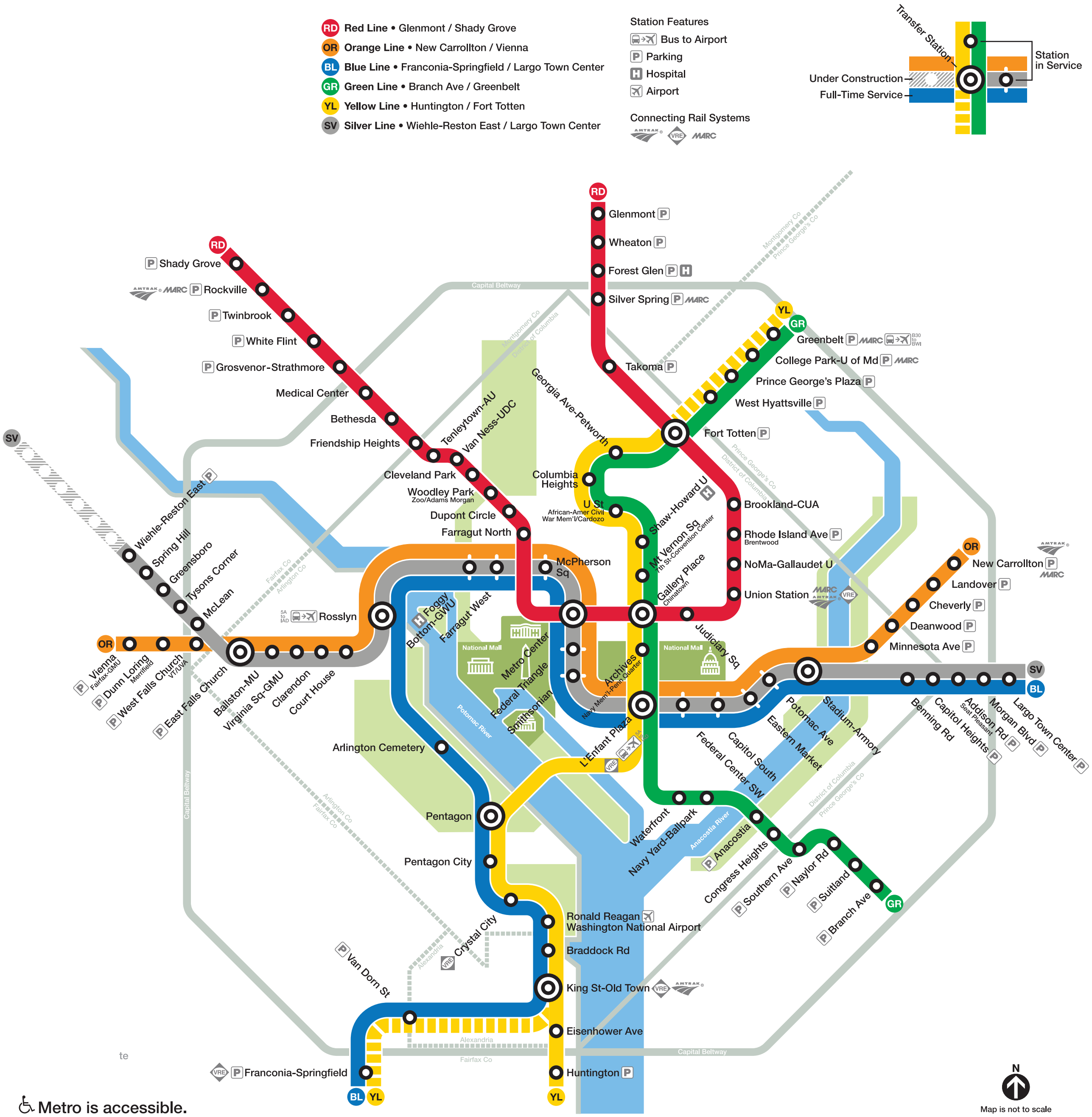
Feeders have the following advantages over branches:

- Each feeder can be optimized with respect to mode, type of vehicle, and schedule. Regular headways can be operated on the trunk and on each feeder.
- Delays are not transferred between the trunk and feeders.

As this description shows, branches and feeders each have certain advantages. In most cases, rail lines with higher performance operating on a major radial corridor have several branches serving major directions, and a greater number of feeder lines served by different types of buses and different headways, depending on their volumes. Branch line operations entering the trunk section must be carefully controlled for reliability.

The choice between trunk line with branches and trunk line with feeders depends heavily on the passenger demand for the trunk line relative to demand in outlying areas. Passenger demand on the trunk determines the cost and reliability of providing service with different modes and rights-of-way. Where demand suggests that high-capacity modes and exclusive rights-of-way may be necessary,, outlying areas may be served with feeder services consisting of lower-capacity modes or smaller vehicles. If demand is more balanced and the trunk headways can be consistent over peak periods

Figure 12-35. Washington Metro with Independent and Integrated Lines



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(for example, consistently 10 minutes during the peak), then branches are more appropriate (in this case operating at 20-minute headways).

The appropriateness of independent versus integrated lines also depends on the mode operated on the line. Regional rail systems usually operate with large numbers of branches. The issue of uneven demand on branch lines resulting in irregular headways on the trunk section is less problematic in regional rail systems because they typically have very short trunk sections. The merging of lines with different headways is, therefore, operationally acceptable. Irregular headways remain a problem when the trunk approaches capacity, such as in Tokyo, Paris RER (which has two branches), and New York City, where Pennsylvania Station serves two trunks of regional rail systems as well as Amtrak.

For metro systems, where system reliability is paramount, some transit operators prefer to have independent lines due to their simplicity. However, integrated networks have significant advantages in reducing the need for passengers to transfer and exhibiting higher load factors on lines. Most metro systems, therefore, have either two to three (exceptionally up to five) branch lines on major corridors, as well as other types of integrated line topologies. San Francisco's BART has four branches in the East Bay, as well as a line connecting two of the branches. This network results in very high frequency on the trunk line.

The New York subway has a highly integrated network, which despite its complexity has a significant advantage in its ability to adjust services under special conditions or emergencies and even to reorganize lines as the travel demand in the city changes. Such changes cannot be done on networks with independent lines, such as in Moscow, Mexico City, or Boston.

LRT systems are operationally more conducive to integrated networks than metro lines, because they usually operate with visual control, which permits short and irregular headways. Therefore, most LRT networks have overlapping lines offering direct services among different parts of the city. Even on trunk-branch lines, LRT trains can merge from four or five branches with satisfactory performance, as is the case in Boston (four lines), Philadelphia, and San Francisco (five lines).

Buses have few restrictions on line integration because they usually operate without any control of headways. On integrated lines, given sufficient lanes and road width, buses can be allowed to overtake each other at stops, achieving headways of less than one minute. In Portland, Oregon, the bus trunk line operates on an exclusive bus street using four sets of stops with leapfrogging of buses. This complex operation achieves an average headway of about 20 seconds or a frequency of 180 buses per hr. Madison Avenue in New York City has similar throughput along its dual bus lanes.

The ability of buses to operate on complex networks is, however, often incorrectly used by transit network designers. Many bus systems have been designed with the goal of providing no-transfer travel throughout city centers. This design can result in many overlapping lines with long headways, unreliable service, and a very poor service image. In some cities, there are even several bus routes designated by the same number using different terminal points. The weak attraction of excessively extensive networks has led to the reorganization of bus networks in many cities into fewer lines with higher service frequencies and capacity. This has been the experience in Los Angeles where this design has been the key to BRT success.

B. Network Design

Designing the alignments for transit lines requires two major considerations. First, transit lines should follow major directions of travel demand in the city. Second, the relationship of each line to other lines must be evaluated. This should include each line's contribution to the system's area coverage, the lines' geometric relationships (merging, diverging, or crossing), and the locations of their transfer and terminal stations.

Rail systems may consist of a few lines serving major corridors or the network may be designed to provide service to a larger central area as is common in several very large cities. While there is a trade-off between network extensiveness and frequency of services on individual lines, in central areas of large cities such as Berlin, Mexico City, and Washington, DC, the metro network should be designed to provide large or total area coverage.

Street transit—bus, trolleybus, and tramway—generally forms a network that provides nearly ubiquitous coverage in the central city area, even when its coverage is defined as one-quarter mile (400-m) circles around stations and stops. Street transit serves short- to medium-length trips dispersed throughout the street network. Rapid transit and LRT networks provide services for large volumes of medium to long trips along major corridors or throughout dense areas of large cities where surface transit serves as feeders to this line-haul service.

Although no metro network is geometrically regular, many can be classified into several geometric forms, which give them certain operating and service characteristics. They can be grouped into several types.

Radial networks consist mainly of radial and diametrical lines, sometimes supplemented by circumferential, circular, or tangential lines. Examples are the Moscow Metro, Philadelphia, and San Francisco rapid transit and LRT networks, and regional rail networks in New York and Chicago. These networks provide excellent access to the center city from many sections of the city and region, but may be limited in the coverage of central city sections.

Grid networks consist of rectangular lines, which provide good area coverage throughout a large city area, but for diagonal trips, numerous transfers are necessary. Such networks are often a result of rectangular street networks, which are common in many North American cities. Good examples are Toronto's rapid transit, streetcar, and bus lines, and the Mexico City Metro.

Ubiquitous coverage networks represent full coverage of an entire city within its boundaries (as well as some radial lines outside of it) using diametrical, tangential, circumferential, and other types of lines. The Paris Metro provides excellent service in a network consisting of 14 lines. The more recently designed Munich U-Bahn network employs diametrical lines intersecting at different points in the central city, each having two branches at one or both ends. For passengers, the Munich system provides excellent area coverage, multiple points of connectivity among U-Bahn lines as well as intermodal transfers with regional rail (S-Bahn). Operationally, passenger loads are well balanced on the lines; both tramway and bus feeders are efficiently achieved. The third example is the Tokyo Rapid Transit network, consisting mostly of L-shaped diametrical lines, which provide a greater number of direct transfers among lines than more traditional diametrical lines would have.

Polycentric networks have been developed in many North American cities in recent decades as a result of the emergence of suburban downtowns or major activity centers (MACs). This urban form poses challenges for transit providers. Multi-centered, radial networks with localized feeder services may be most effective in providing competitive transportation in this type of urban form. [Casello, 2007] This type of transit network is most effective when organized as timed transfer systems (TTS), such as numerous rail/bus TTS centers in Portland, Oregon; Sacramento, California; and Vancouver, British Columbia. The same polycentric form of rapid and regional rail transit networks is also found in large older metropolitan areas, such as New York City and the San Francisco Bay Area, where some diametrical lines connecting suburban towns and MACs have lengths of up to 62 miles (100 kms) (all three regional rail networks in New York and the line from Bay Point to San Francisco Airport in the Bay Area).

C. The Role of Transfers in Transit Networks

Transferring is an important element in network design (see Table 12-21). Well-designed and convenient transfers with coordinated schedules can involve very little physical inconvenience, financial costs, or time delays while providing passengers faster and more attractive trip paths. They can help minimize the adverse effects of changing modes or vehicles between the main trunk line and feeder services. Many large systems such as Toronto, Chicago, and New York City provide extensive intramodal and intermodal transfers.

Transfers should be as direct and physically convenient as possible. The most desirable transfer is directly across a platform where two lines (or a local and express service on a single line) share the station. This design requires the meeting of two track alignments at shallow angles to allow parallel routing of tracks for some time. Hong Kong's metro uses two stations and differing grades to accommodate four transfer movements directly across platforms. Singapore, New York City, Chicago, and Philadelphia also provide transfers across platforms.

Financially, transfers can require that passengers pay a second, full fare, a reduced transfer fare, or no additional fare. Free transfers, the most desirable for both the passenger and the operator, can be accomplished by planning and designing interline (and intra-modal) connections that remain within a station's paid area or through the use of automated fare collection systems.

The duration of transfer times depends on the length and level of coordination of the headways of the arriving and departing lines. In the case where the departing line operates with high frequency (less than 10-minute headways), transfer times will always be short, regardless of the arriving line's headway. If the departing line's headway is long,

Table 12-21. Relationship of Headways and Schedule Coordination to Transfer Times

Headway Arriving Line	Headway Departing Line	Level of Coordination	Transfer Time
Short	Short	Any	Short
Long	Short	Any	Short
Short	Long	None	Variable
Long	Long	None	Variable–Long
Long	Long	Full (TTS)	Short

then, in the absence of schedule coordination, the transfer times are variable, but are likely to be less with short arriving headways (because passengers can choose an arriving service that precedes the departing service). In the case where both lines have long headways, full coordination, or a timed-transfer system (TTS) can be used to ensure short transfer times.

The simplest form of a TTS is a unifocal network (also known as a *pulse system*), a transit network with one transit center at which vehicles from several transit lines meet at regular headways. These are called *clock face headways,* that is, headways that are divisible in 60, so that they repeat themselves every hour. There are two possible sets of clock headways: one with the basic headway of 15 minutes, which also accommodates lines operating at 7.5, 30, and 60 minutes. The other is a set based on 20-minute headway, which can also accommodate lines with 10, 40, and 60-minutes headways. Thus, the lines meeting at the center can have different lengths if their operating speeds are different, so that the cycle times are equal. Differences between operating times can be adjusted by using terminal times at outer terminals to compensate for variations in travel time. Scheduling timed transfers at multiple locations, however, is a challenge.

The cycle time for a TTS center is actually the basic module for the schedule of the lines that radiate from the center, and it can be used not only for the design of radial lines, but also for diametrical lines going through the center with the cycle time $2T$. Some lines can also have cycle times that are multiples of T, with a correspondingly greater number of trains or vehicles in service. Thus, a line that has cycle time $2T$ operated with two consists, (N, the number of cars in the consist is thus $N = 2$), will have the same headway at the transit center as the lines operating with T and $N = 1$. Finally, if some lines do not justify the same headway, they can operate at twice the longer headway, so that its vehicle meets every other pulse at the center. For instance, if a series of routes pulse from the center every half hour (with one bus allocated to each route and a round trip time on those routes of a half-hour) then an additional diametrical route that passes through the center will need to take an hour in each direction and will require two buses.

TTS can be superior in service and performance to conventional transit services in low-density areas. Independent scheduling of individual lines in such areas creates services that require long and inconvenient transfers, so they are avoided by all except captive riders. When a TTS is organized, transit offers a coordinated network that provides short and easy transfers among lines and captures a much greater number of passengers. Thus, the quality and role of transit services can be drastically changed and elevated by the introduction of TTS.

A number of cities, such as Edmonton, Alberta; Vancouver, British Columbia; Portland, Oregon; and Denver, Colorado have introduced TTS for large portions of their service areas and have achieved significant increases in transit ridership. Use of TTS has been particularly successful in increasing ridership when a new LRT system was introduced (Portland, Sacramento, and Dallas). For a more detailed explanation of the scheduling procedure for TTS, see [Vuchic, 2005, Sec. 4.5]. For general references on transit scheduling see [Pine et al., 1998; Boyle et al., 2012].

XI. TRANSIT ROUTE PLANNING

The transit planning process evaluates the impacts of new or modified transit facilities, services, or policies. The evaluation procedure includes an assessment of a plan's effects on passenger attraction (as a function of quality of service offered), the operating agency (in terms of operational efficiency) and on the region served. Proposals may be assessed both quantitatively and qualitatively, and may be evaluated over various timeframes—short-term, medium-term, or long-term—depending on the magnitude of the planned system or service expansions. This section discusses the planning at the individual route level.

Transit service planning occurs all the time in transit agencies. In most cases, transit agencies make changes to their schedules and often route structure on a periodic basis to reflect the ongoing changes in the transit market, for example, every quarter for route schedules and perhaps every three to five years for a comprehensive examination of route structure. Most importantly, planning must consider transit vehicle movements, line schedule, route cycle time, and necessary transport capacity in relation to the market area served. An understanding of these elements is important for comparing and selecting transit rights-of-way and modes, evaluating their level of service (speed, service, frequency), and assessing system operating costs and efficiencies. The following sections provide an overview of key principles of vehicle motion and travel times as they apply to transit route planning and scheduling, factors that influence the locations of transit stops and stations, as well as vehicle design. It is not the intent of this section to delve deeply into the physics of vehicle motion that dictate the guidelines and standards used by planners for transit planning. Those interested are referred to [Vuchic, 2007].

A. Vehicle Motion and Travel Times

The performance of transit vehicles depends very much on the right-of-way on which a line operates. In mixed traffic, transit vehicles travel at speeds that are largely dependent upon the general traffic flow. Transit vehicle speeds are further reduced by stop dwell times. To achieve speed increases for transit vehicles, several strategies are available. Transit signal priority (TSP) allows a traffic signal controller to detect the presence of a transit vehicle and adjust the cycle times such that the transit vehicle is less likely to encounter a red signal. Intersections may be designed to include queue-jumpers, or dedicated lanes that allow transit vehicles to bypass waiting private autos.

On transit lines with separated right-of-way, particularly for electrically powered guided systems on fully controlled right-of-way, travel times can be predicted and programmed much more precisely because they depend on known elements: alignment geometry and vehicle dynamic performance characteristics (acceleration, maximum speed, braking rate, and passenger dwell times at stops). Travel along a line consists of a series of station-to-station travel modules. Analysis of this travel between two stations, that is, analysis of interstation spacing, includes four motion variables as functions of time as shown in Table 12-22.

A typical station-to-station travel module consists of five travel regime intervals: accelerating, operating at maximum (or constant) speed, coasting, braking, and standing. Figure 12-36 simplifies this movement in showing only the operating speed and standing times between two stations. The distance and speed variables are commonly used in computations of travel times and distances; the acceleration/deceleration are mainly used to evaluate vehicle dynamic capabilities and performance; and the jerk is analyzed for measuring passenger comfort.

A fundamental relationship between service frequency and headway serves as the basis for much of the analysis underlying route service planning. Equation 12.3 shows this fundamental relationship.

$$N = \frac{60}{h_{min}} = \frac{3600}{h_{sec}} \tag{12.3}$$

Where:

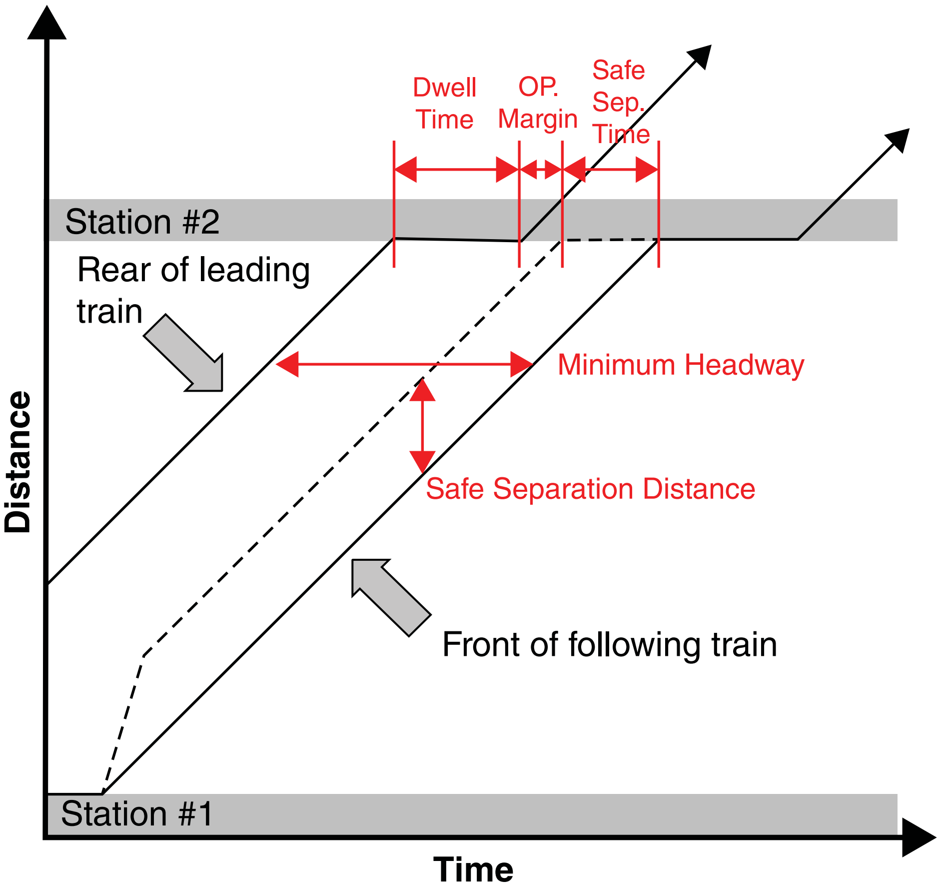
N = Number of transit units per hour (frequency)
h_{min} = Time in minutes between departures (headway)
h_{sec} = Time in seconds in seconds between departures (headway)

Thus, if an agency has established 10 minute headways for a particular bus route, the service frequency is 60/10 or 6 departures per hour. From this fundamental relationship one can determine the capacity of a line by the physics of vehicle motion (acceleration, deceleration, cruise speed, and so forth) and the amount of time it takes for passengers to get on and off the vehicle or rail car. Using Figure 12-36 as an illustration and assuming a consist can enter a station as soon as it safely can do so, the headway variable, h, in equation 12.3 can be replaced with the mathematical relationships dictating how much time it takes for a consist to pass through a particular movement. For example, if an agency has established a minimum distance between trains due to the ability of the control center to safely dispatch

Table 12-22. Motion Variables Necessary in Computing Interstation Travel Times

Motion Variable	Symbol	Relationship to Time
Distance	s	$s = v \times t$; $s = \frac{1}{2}\, a \times t^2$
Speed	v	$v = dx/dt$
Acceleration	a	$a = d^2s/dt^2$
Jerk	z	$z = d^3s/dt^3$

Figure 12-36. Distance-Time Diagram of the Movement of a Transit Unit



Note: Acceleration and braking curves omitted for clarity.

Source: Kittelson et al., 2013, Reproduced with permission of the Transportation Research Board.

trains, called minimum control time separation, and as well has established an operating margin time for the time between trains, the maximum number of transit units per hour can be given by equation 12.4.

$$N = \frac{3600}{h_{gs}} = \frac{3600}{t_{cs} + \ t_d + \ t_{om}} \tag{12.4}$$

Where:

N = Number of transit consists per hour
3600 = Conversion of seconds to hour
h_{gs} = Sum of the controlling time requirements
t_{cs} = Minimum train control separation (secs)
t_d = Dwell or stopped time at station (secs)
t_{om} = Time for operating margin (specified by agency) (secs)

The maximum person capacity of the line can be estimated by applying a person per space factor in equation 12.4, as shown in equation 12.5.

$$P = (N)LP_m\ (PHF) = \frac{3600\ L\ P_m\ (PHF)}{t_{cs} + t_d + t_{om}} \tag{12.5}$$

Where the variables are defined as before except with the following:

P = Person capacity (passengers/hour)
L = Train length (feet or meters)
P_m = Linear passenger loading level (passenger/ft length or per m length)
PHF = Peak hour factor relating peak 15 minute period to total hour

One can derive other sorts of relationships that might be useful in defining transit performance. For example, the time it takes to traverse a rail segment between two stations, assuming that the consist will reach maximum cruise speed, is shown in equation 12.6.

$$t_{ij} = \frac{V_{max}}{2}\left[\frac{1}{a} + \frac{1}{d}\right] + \frac{S}{V_{max}} + t_d \qquad (12.6)$$

Where:

t_{ij} = Travel time between station i and j (secs)
V_{max} = Maximum cruise speed (ft/sec)
a, d = Acceleration and deceleration rates (ft/sec^2)
S = Distance between stations (ft)
t_d = Dwell time at the destination station (secs)

The number of consists that are needed to provide service on a route given a headway and route length is estimated by equation 12.7.

$$N = \frac{120 \text{ x } L}{V_c \text{ x } h} \qquad (12.7)$$

Where:

N = Number of transit consists per hour
120 = Conversion of minutes to hour
L = Length of route (miles)
V_c = Average speed on route (mph)
h = Headway (mins)

Equations 12.3 to 12.7 estimate various variables for fixed guideway transit, that is, where there is no external influence that can affect the movement of a consist, such as traffic congestion. For those cases where there is such an influence, Kittelson et al. [2013] provide other mathematical relationships that can be used to estimate important variables as travel time and vehicle or person capacity. Equation 12.8, for example, can be used to estimate the capacity of a transit line (whether bus or light rail) that runs on a road with traffic signals (assuming no signal preferential treatment for the vehicle or consist). In this case, the capacity is defined at a boarding location, usually the one that takes the longest for riders to get on and off the vehicle or consist.

$$B_l = \frac{3600 \ (g/c)}{t_c + t_d \ (g/c) + Z\ C_v\ t_d} \qquad (12.8)$$

Where:

B_i = Loading area capacity (consist or vehicles per hour)
g/c = Ratio of signal green time to total signal cycle length
t_d = Station dwell time (secs)
Z = Standard normal variable relating to a desired failure rate of vehicle arrivals
C_v = Coefficient of variation of dwell times

Note in equation 12.8 that not only is the influence of traffic signals considered in the capacity analysis, but that the uncertainty associated with dwell times is incorporated through the Z variable and the coefficient of variation. Equation 12.8 can be used as well for light rail and streetcar operations in mixed traffic.

It is beyond the scope of this chapter to provide the reader with all of the analysis approaches and tools that can be used to conduct route-level service planning. The reader is referred to [Kittelson et al., 2013 and Vuchic, 2007] for excellent material on all aspects of transit route analysis.

B. Planning Considerations Influencing Scheduling and Operations

A number of decisions are made in the planning of new lines that directly affect travel time, which in turn influences operations, particularly fleet and driver requirements. First, selecting the line's alignment and degree of right-of-way separation influences operating speed. A second critical component is the selection of station spacing, which requires an analysis of the trade-off between shortened passenger access time and longer in-vehicle time. Vehicle dynamics, such as acceleration rates, braking rates, and maximum speeds, are specified in the planning stages as part of vehicle procurement and also help determine operating speeds.

A critical but often overlooked operational component is standing (or dwell) time, represented as t_d in the travel time equations. Reducing standing time at stations shortens travel times, which may result in higher frequency of service or decreased driver and fleet requirements. Dwell time at a station is a function of the number of passengers boarding and alighting, as well as the number, width, location, access height of a transit vehicle's doors, and method of fare collection. Dwell times increase substantially for crush load conditions. Many of these characteristics are specified during the planning process.

The width and number of doors on a transit vehicle are specified by transit agencies during the vehicle procurement process. The two attributes are often combined and expressed as the number of channels or entry and exit paths. A transit vehicle with three sets of doors, each of which is sufficiently wide to accommodate two passengers simultaneously, is said to have six channels. As the number of channels increases, dwell times decrease. The location of a transit vehicle's doors influences the access time for passengers from within the vehicle. Doors located at the end of vehicles require passengers, on average, to walk a distance equal to one-half of the vehicle's length. By specifying so-called quarter point doors, doors located at one-quarter and three-quarters the length of vehicles, the average passenger walks only three- sixteenths of the vehicle's length to access the doorway. This helps speed the alighting process and reduces total dwell time.

Transit vehicles that require steps to enter and exit have slower boarding and alighting rates, and thus, longer dwell times. High-platform and low-floor vehicles eliminate or reduce the vertical difference in accessing transit vehicles and, therefore, speed boarding and alighting rates and decrease dwell times. High-platform vehicles are most often used when the line is operating on an exclusive right-of-way. Standing times are also greatly influenced by the way passengers' fares are collected.

XII. FUTURE TRANSIT ISSUES

In both developed and developing countries, the primary growth in population is in cities, and in some cases combinations of cities called megaregions. Mobility in urban areas will become increasingly more difficult as population growth spurs new demands for transportation. Public transportation will play an increasingly important role in the function of cities. Several issues in particular will likely present challenges to transit agencies as they attempt to meet this demand.

A. Transit Financing

Obtaining the level of funding that will be necessary to provide transit infrastructure and services will be the most important challenge facing the transit industry in coming years. This is especially the case where megaprojects costing in the billions of dollars will be needed to provide transit with successful performance characteristics. Historically, in the United States, much of this funding has come from the federal government, but this level of contribution has been steadily declining over time. Increasingly, communities have been relying on their own sources of funding through a variety of financing strategies (see chapter 5 on transportation finance and funding). In many cases, the sources of funds for these strategies have been local referenda where voters have approved the imposition of some form of tax (usually sales tax) over some period of time to fund transit. Many of these referenda have been successful and have resulted in important improvements to the local transit system (for example, Denver). Others, however, have been defeated, leaving the transit agency with little opportunity to provide the services that are needed today, no less in the future.

B. Service Branding

Transit agencies need to aggressively market their services if they hope to compete with today's motor vehicle-oriented transportation system, and even more so if connected vehicle technologies make automobile travel more convenient and safer. Part of this marketing effort will be branding their services. Such branding can be done through advertising campaigns, outreach efforts, and vehicle/infrastructure design (see Figure 12-37). In essence, transit service needs to be viewed as a product that needs to be "sold" in the public marketplace.

C. Role of the Private Sector

Given the scarcity of public resources, transit agencies have been looking at innovative financing methods for network construction (or expansion) and greater efficiencies in their operations. These two goals may be achieved by greater involvement of various tiers of government and private sector enterprises. These arrangements are broadly known as public-private partnerships (PPP) (see chapter 5 on transportation finance and funding). The primary goals of engaging the private sector in infrastructure projects are to reduce costs and shift the risk of cost overruns from taxpayers.

Private sector involvement in infrastructure investments ranges from designing and building facilities to the financing, owning and operating of systems. An example of planned and constructed systems with private sector involvement includes Los Angeles's LRT Gold Line, a so-called design build project where the project team simultaneously designed and oversaw the construction of a transit system. This design-build concept helped expedite system construction and reduce the need for communication between designers and contractors.

Figure 12-37. Bus Branded for Downtown Circulator Service, Denver Regional Transportation District

Photo courtesy of Russ Chisholm, Transportation Management & Design, Inc.

In design-build-operate-maintain contracts, like that used on New Jersey's Hudson Bergen LRT Line, the same consortium that designs and constructs the system operates and maintains the system for some prescribed period of time. This method gives the contract team incentive to produce a high-quality, low-operating cost system. In Vancouver, the Richmond-Airport-Vancouver line (the Canada Line) was advanced as a design-build-finance-operate project. A private contractor (InTransitBC) teamed with Translink, the Province of British Columbia, and the Vancouver International Airport Authority to partially finance, construct and operate the $1.9-billion (CDN), 11.4-mile (19 km) automated rail transit line. In other cases, public/private partnerships and value capture techniques are being used to fund rail stations.

It seems likely that in large metropolitan areas in particular the future of transit system expansion will be tied to innovative finance strategies.

D. Taxation and Pricing Changes

In addition to land use management, North American government agencies often implement other policies that can affect transit system performance. One example is the policy dealing with the tax implications of employer-sponsored parking. Briefly, employers receive a tax benefit for providing employee parking, but until 1987 no commensurate benefit was available to promote transit use. Since the mid-1980s, employees and employers may derive taxation benefits for costs associated with transit commuting. In Ontario, the provincial government has made the cost of transit passes fully exempt from provincial tax. Similar tax exemptions are available in U.S. cities for employees of companies who participate in such federally sponsored programs.

A reallocation of gas taxes to fund public transportation can provide a secure revenue source for transit agencies and an overall improvement in the quality of services offered. In Canada, municipalities in provinces have reached gas tax agreements by which the federal and provincial governments transfer a substantial portion of gas tax revenues to municipalities for the promotion of sustainable initiatives. Modern road pricing is a technique that sets and automatically collects tolls on roadway sections. Often, prices vary as a function of the time of day or real-time monitoring of traffic conditions. Road pricing can also act as an auto disincentive. In addition, the revenues generated from highway tolls may be used to finance public transportation systems construction and operation.

This practice has become common in Europe with such programs in place in London, Rome, and other cities. In the United States, the concept has been adopted in California, where San Diego's I-15 is priced with revenues dedicated to supporting the Inland Breeze bus service in the corridor. In New York City, revenues generated from bridge tolls help support public transportation. Litman [2004] identified many other fiscal methods that heighten drivers' awareness of auto costs and present opportunities to generate revenue for public transportation.

E. Advancements in Technology

The rapid development of communications technology has had positive impacts on passenger attraction and operating efficiency. Control centers are now able to monitor and broadcast (by smart phone or Internet) the location of all transit vehicles. This allows users to access real-time information on system performance from home or work using mobile applications (or "apps") or at stations on LED/LCD displays. Real-time passenger information helps reduce uncertainty in waiting times and can increase transit ridership. [Brakewood et al., 2015] For the operator, real-time vehicle location information helps maintain schedule adherence and dispatching of vehicles in response to disruptions in service.

In stations, many transit agencies are installing closed-circuit video surveillance. These systems can be monitored in a control center to expedite responses in emergency situations. Alternatively, the systems may only be recorded and viewed only as necessary in response to a security issue. Closed-circuit TV systems have acted as a deterrent to crime in transit stations and have improved passengers' sense of security. In addition, as noted earlier, automated transit systems have become more common. Improvements in computer control technologies allow automation to play a larger role in the planning and design of medium- and high-capacity transit systems.

Transit agencies will be applying technology to both passenger information and system operations much more in the future. Not only will such technologies make the system more efficient, but they will also provide incentives for people to ride transit.

The other aspect of transportation technology, and one not controlled by transit agencies, is the technological advancements that are occurring in automobiles. New technologies relating to autonomous and connected vehicles are likely going to make automobile travel more convenient, safer, and efficient. One of the first applications of such technologies as the automobile fleet takes time to turn over will likely be dedicated lanes on major freeways where similarly outfitted vehicles can be mixed together. Of course, such freeway corridors are usually prime markets for transit services. Thus, transit agencies need to plan ahead in envisioning their role in transportation system that is more technologically advanced (see discussion above on branding).

XIII. SUMMARY

Public transportation is a key component of comprehensive and coordinated regional transportation system. This chapter has examined this role from the perspective of the magnitude of trip-making and the impacts that transit has on a community's economic and quality of life. Because of the interconnected nature of transit service, that is, the need for riders to access the network and often transfer from one mode or line to another, transit planners must carefully plan the type of service and the service characteristics to appeal to transit riders. This includes attention to route structure, operational characteristics such as headway, station and stop placement and design, trip costs, and the relationship to surrounding land uses. The most successful transit systems are those that provide trips to where people want to go, and that do so in manner that is comfortable, reliable, and efficient.

Transit planners also have access to many planning guides and manuals that serve as excellent sources of information on planning methodology and tools. Some of the more important references include:

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Chapter 13

Planning for Pedestrians and Bicyclists[1]

I. INTRODUCTION

The transportation system provides travel opportunities for many different types of travelers. From the end of World War II to the 1980s, statewide and metropolitan transportation planning—and even planning at the municipal level—focused almost exclusively on motor vehicles, with only limited attention given to transit and even less to bicycle and pedestrian transportation. However, almost every trip taken either by car or by some form of transit begins with a traveler walking to a vehicle. And in many cities, bicycling is no longer just for recreational trips, but has become an important mode of transportation for other trip purposes as well.

Although transportation engineers and planners are gaining a better understanding of the role and characteristics of bicycle and pedestrian movements, there is still much to learn about pedestrian and bicyclist behavior. One issue, in particular, the safety of pedestrians and bicyclists as they use the transportation system, merits much more attention. Efforts such as the Institute of Transportation Engineers' (ITE) pedestrian and bicycle count database (http://bikepeddocumentation.org/) represent important steps in assembling information about the number of nonmotorized travelers, their characteristics, and the trip purposes/land uses most frequently served by such travel. The transportation planning field has a long way to go, however, to develop tools and methods for analyzing walking and bicycling that are as sophisticated as those associated with motor vehicle network modeling. Some of the exciting developments in pedestrian and bicyclist planning include:

- New technologies, such as remote detection and speed control, as well as new design options, such as split pedestrian crossovers and curb extensions for shorter crossings, are enhancing the visibility and safety of pedestrians.
- In some instances, increased emphasis on land-use interrelationships with nonauto trips is resulting in community designs that are more conducive to pedestrian and bicycle use.
- New transportation design practices such as context-sensitive solutions and Complete Streets can produce roadway designs that incorporate walking and bicycling opportunities in more meaningful ways (see chapter 9 on road and highway planning).
- A rising concern about the relationship between public health and transportation has led to greater emphasis on active transportation, whereby walking and bicycling not only serve a transportation purpose, but also lead to health and safety benefits.

The next section describes typical policy goals that have often served as the foundation for pedestrian and bicycle planning. The following section presents a historical perspective on the evolution of pedestrian and bicycle planning in the United States. This is followed with a description of the planning process used to identify strategies and actions to enhance the walking and bicycling experience. The next section examines design issues specific to both pedestrian and bicycle transportation often discussed during the planning process; the final section presents information on the pedestrian and bicycle experience in Europe and Asia.

[1]The original chapter in Volume 3 of this handbook was written by Matthew Ridgway, AICP, PTP, Principal, Fehr & Peers, and Jeremy Klop, AICP, Senior Associate, Fehr & Peers. Changes made to this updated chapter are solely the responsibility of the editor.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

II. GOALS AND BENCHMARKS FOR PEDESTRIAN AND BICYCLE PLANNING

Walking and bicycling are poised to play a greater role in the transportation system. There are many reasons for this. From concerns about increasing levels of motor vehicle congestion to improving public health through increased physical activity to including a more "humanist" perspective in local community design, walking, and bicycling are now commonly part of many transportation plans. Typical goals for pedestrian and bicycle programs usually include: (1) increase the number of bicycling and walking trips as an alternative to motorized transportation, (2) promote bicycling and walking as part of a healthy lifestyle as well as improving the safety of all users of the right-of-way, (3) promote bicycling and walking as a less costly travel mode, and (4) reduce environmental impacts by replacing motor vehicle trips with bicycling or walking trips.

A. Pedestrian and Bicycle Trips as Alternative Modes of Transportation

Table 13-1 summarizes U.S. walking and bicycling trips as a percentage of all trips for 1990, 1995, 2001, and 2009. To put these numbers in context, a National Bicycling and Walking Study (NBWS) authorized by Congress in 1990 established a goal of doubling the percentage of walking and bicycling trips from 7.9 percent to 15.8 percent. [FHWA, 1994] As shown in the table, walking trips as a percentage of total trips decreased between 1990 and 1995 and increased between 1995 and 2009. These changes are likely attributable to both changes in data collection methods and an actual increase in the percentage of walking trips. The 2001 survey specifically asked respondents to report walking trips, whereas previous surveys did not. In addition, the National Household Travel Survey (NHTS) did not record bicycle trips independently, but included them in an "other" category. Table 13-1 indicates that more people walk or use bicycles than use public transit in the U.S. In fact, these numbers might be underestimated, as many advocates of pedestrian and bicycle transportation argue that these modes are underrepresented in national surveys.

A benchmark report from the Alliance for Biking and Walking, sponsored by the Centers for Disease Control and Prevention's Healthy Community Design Initiative, provides another indication of the changing use of walking and bicycling. [Alliance for Biking and Walking, 2014] The report made the following observations about changes in walking and bicycling from 2005 to 2012:

- There was a small but steady increase in the number of people biking and walking to work.
- There are lower bicyclist and pedestrian fatality rates where there are more people biking and walking.
- More people tend to bike or walk to work when a city has strong biking and walking advocacy.
- People are healthier in states where more people bike and walk.
- Biking and walking fatality rates have been decreasing for decades—but are seeing a recent uptick.
- Few federal dollars go toward bicycling and walking, when considering the total number of trips taken and fatality rates.
- More and more cities are setting goals to increase biking and walking and improve safety. [Alliance for Biking and Walking, 2014]

Table 13-1. Walking and Bicycle Trips, National Household Travel Survey Results, 1990, 1995, 2001, and 2009

	Walking Trips (billion)	Walking Trips %	Bicycling Trips (billion)	Bicycling Trips %	Combined Trips (billion)	Combined Trips %
1990 NPTS	21.9	7.2%	1.7	0.7%	19.7	7.9%
1995 NPTS	20.3	5.4	3.3	0.9	23.6	6.2
2001 NHTS	33.1	8.6	3.3	0.8	36.4	9.5
2009 NHTS	41.0	10.4	4.1	1.5	42.5	11.9

NPTS = National Personal Travel Survey

NHTS = National Household Travel Survey

Source: http://nhts.ornl.gov/2009/pub/stt.pdf

B. Walking and Bicycling for Healthy Lifestyles

From 1900 to 2010, average life expectancy in the United States increased by 30 years, mainly reflecting improvements in public health services. [Arias, 2014] However, in the past several decades, the average weight of the U.S. population has steadily increased. By the mid-2000s, as much as 60 percent of the U.S. adult population was overweight or obese. [Glendening et al., 2005; Sallis, et al., 2004] This increase in weight and obesity has been attributed by many studies to a lack of physical activity, which has a pronounced aggravating effect on several chronic diseases. See, for example, [Department of Health and Human Services (DHHS), 1996; Frank et al., 2006; Bodea et al., 2008].

According to the U.S. Surgeon General's report on physical activity and health, 70 percent of adults in the United States today do not get the daily recommended amount of physical activity, and approximately 25 percent report being completely inactive when not at work. [DHSS, 1996] Not surprisingly, using motor vehicles for all types of trips reduces the amount of walking and physical movement associated with accomplishing many tasks. Couple the availability of motor vehicles with suburban land-use patterns that have tended to spread activities far apart, and the result is more reliance on motor vehicle travel. [Marshall and Garrick, 2010] For instance, a U.S. Environmental Protection Agency (EPA) study, *Travel and Environmental Implications of School Siting Policies*, showed that between 1969 and 1998, the number of children walking to school dropped by 33 percent. [EPA, 2003] Lifestyle choices, heavily influenced by transportation and urban development patterns, have removed physical activity for nonexercise purposes from many American's lives. [Ewing et al., 2006; Humphrey, 2005]

Physical inactivity also contributes to other health risks. An estimated 32 to 35 percent of all deaths in the United States are attributed to coronary heart disease, colon cancer, and diabetes. These deaths could be reduced if the population were more physically active. Physical inactivity is estimated to account for about 2.4 percent of U.S. health-care costs, or approximately $24 billion per year. [Task Force on Community Preventive Services, 2002] Chronic diseases exacerbated by inactivity account for seven out of every 10 deaths in the United States and more than 60 percent of all medical expenditures. Active transportation—that is, transportation requiring some form of human physical power—is a simple way that physical activity can be included in people's daily lives. [Safe Routes to School, 2012] Approximately 25 percent of all trips in the United States are less than 1 mile (1.6 km) in distance, but almost 75 percent of these trips are made by automobile. [Transportation Research Board (TRB), 2005] In many cases, these short auto trips could be replaced by an active mode such as walking or biking.

C. Less Costly Travel

Not only has the private automobile been a fixture of American culture for most of the last century, but the cost of owning and operating motor vehicles has also been a major part of an average household's budget. According to the 2009 National Highway Travel Survey, the average U.S. household with a median per-household income of $51,939 per year spends 16.4 percent of its household's expenditures on vehicle ownership (including car payments, fuel, maintenance, insurance, and registration). [U.S. Census, 2012; Oak Ridge National Laboratories (ORNL), 2012] In contrast, the cost of bicycle use is minimal, and the cost of walking is even less. In addition, the cost of providing infrastructure for cycling and walking is significantly less than that for motorized transportation.

D. Environmentally-Friendly Travel Modes

Bicycling and walking offer an environmentally-friendly alternative to motor vehicle use. Motor vehicle use impacts air quality, water quality, noise, and other community functions (see chapter 4 on environmental consequences in transportation planning). For example, approximately 2,300 pounds of equivalent carbon per person are released into the atmosphere each year from motor vehicle use. Vehicle fluid leakage and tire decomposition contribute to water pollution. See the Federal Highway Administration website [FHWA, 2014c] on the health and environmental benefits of walking, and for an overview of the environmental benefits associated with active transportation. See also Litman et al. [2002].

III. PEDESTRIAN AND BICYCLIST SAFETY

Given the difference in mass and speed (fatality risk increases sharply at vehicle speeds of 25 mph or greater) between a motor vehicle and a pedestrian or bicyclist, a crash between the two will likely be more deadly to the nonmotorist. National crash records support this. However, crash records that report bicyclist and pedestrian involvement in a motor vehicle crash represent only a portion of the injuries to bicyclists and pedestrians. In many cases, only collisions that result in an injury or fatality are formally reported and documented in a state's crash database. Many injuries can occur to walkers or bicyclists without a motor vehicle being involved. For example, an analysis of hospital emergency admissions data in 1998 showed that 70 percent of reported bicycle injury events and 64 percent of reported pedestrian injury events did not involve a motor vehicle. [Stutts and Hunter, 1999]

As reported in 2013, 66,000 pedestrians were injured and 4,735 pedestrians killed in traffic crashes. [National Highway Traffic Safety Administration (NHTSA), 2015a] This averages to one crash-related pedestrian death every 2 hours, and a pedestrian injury every 8 minutes. Although a staggering statistic, this actually represents an 18 percent decrease from the number of pedestrian fatalities reported in 1991, consistent with a decreasing trend in all road-related fatalities during the last 15 years. This also exceeds the goal of a 10 percent reduction set in the National Bicycling and Walking Study. [FHWA, 1994]

As shown in crash statistics, pedestrian crashes represent a greater risk for young children and seniors. Nearly one-fifth of children 14 years and younger killed in 2013 traffic crashes were pedestrians, and pedestrians from ages 5 to 15 and 65 and older accounted for 23 percent of all 2013 pedestrian fatalities in traffic crashes. [NHTSA, 2014] Of the estimated 66,000 injured pedestrians in traffic crashes in 2013, 10,000 (15%) were children.

Time-of-day statistics suggest that for young pedestrians (under 16), the afternoon and early evening hours between 3:00 p.m. and 9:00 p.m. are high-risk times, with 61 percent of all fatal young pedestrian crashes occurring during these hours. Nearly half of all pedestrian fatalities involved alcohol, for either the driver or the pedestrian. The number of pedestrian fatalities from distracted drivers rose from 344 in 2005 to 500 in 2010. [Stimpson et al., 2013]

Reported bicycle fatalities have historically represented a smaller percentage of traffic fatalities than pedestrians. Some sobering facts:

- Traffic crashes killed 743 pedalcyclists (bicycles and tricycles) in 2013, and 48,000 were injured, of which 7 percent were children. [NHTSA, 2015b]
- Hospital emergency rooms recorded 515,000 bicycle-related visits in 2012. [DHHS, 2013]
- Over a 10-year period (2004 to 2013), the average age of pedalcyclists killed in motor vehicle crashes has steadily increased from 39 to 44.
- Bicyclists aged 45 to 54 represented 22 percent of those killed and 15 percent of those injured in 2013.
- Alcohol involvement for either the driver or bicyclist was reported in 34 percent of the fatal pedalcycle crashes. [NHTSA, 2015b]
- The number of pedalcyclist fatalities from distracted drivers rose from 56 in 2005 to 73 in 2010. [Stimpson et al., 2013]

See Table 13-2 for the top reasons associated with pedestrian and pedalcyclist fatal crashes in 2013.

Analysis of 2013 crash types and locations indicates that 20 percent of pedestrian fatal crashes (45 percent of those injured) and 33 percent of pedalcyclist fatal crashes (56 percent of those injured) occurred in or near an intersection. [NHTSA, 2014] Of these, almost one-third involved a turning vehicle, and approximately one in five involved a pedestrian running across the intersection or darting out in front of a driver whose view was blocked prior to the event. Sixteen percent of the crashes were related to a driver violation. Midblock locations account for another 26.5 percent of all crashes, with the "dart-out" crash type being the most common.

Several reports illustrate the types of strategies that can reduce pedestrian and bicycle-related crashes, for example:

- *Reducing Collisions Involving Bicycles*, http://safety.transportation.org/htmlguides/bicycles/description_of_strat.htm.
- *Improve Pedestrian and Bicycle Facilities to Reduce Conflicts between Motorists and Non-motorists*, http://safety.transportation.org/htmlguides/UnsigInter/description_of_strat.htm#S17.1_B18.

Table 13-2. Top Reasons for Pedestrian and Pedalcyclist Fatalities, Representing over 1 Percent of Fatalities, U.S., 2013		
Contributing Crash Factor		
Pedestrian	**Number**	**Percent of Fatalities**
Failure to yield right of way	1,181	24.9
In roadway improperly (standing, lying, working, playing)	744	15.7
Not visible (dark clothing, no lighting, etc.)	733	15.5
Improper crossing of roadway or intersection	686	14.5
Under the influence of alcohol, drugs, or medication	658	13.9
Darting or running into road	618	13.1
Failure to obey traffic signs, signals, or officer	175	3.7
Physical impairment	103	2.2
Inattentive (talking, eating, etc.)	99	2.1
Wrong-way walking	81	1.7
Pedalcyclist	**Number**	**Percent of Fatalities**
Failure to yield right of way	233	31.4
Failure to obey traffic signs, signals, or officer	79	10.6
Not visible (dark clothing, no lighting, etc.)	78	10.5
Under the influence of alcohol, drugs, or medication	55	7.4
Darting or running into road	40	5.4
Making improper turn	38	5.1
Wrong-way riding	34	4.6
Improper crossing of roadway or intersection	32	4.3
Operating without required equipment	28	3.8
Inattentive (talking, eating, etc.)	16	2.2
Riding on wrong side of the road	14	1.9
Failing to have lights on when required	19	1.5
Improper or erratic lane changing	9	1.2
In roadway improperly (standing, lying, working, playing)	9	1.2

Source: NHTSA, 2014

- *Separated Bike Lane Planning and Design Guide*, http://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/separated_bikelane_pdg/page00.cfm.
- *Florida Pedestrian and Bicycle Strategic Safety Plan*, http://www.dot.state.fl.us/safety/6-Resources/FloridaPedestrianandBicycleStrategicSafetyPlan.pdf.
- *Minnesota's Best Practices for Pedestrian/Bicycle Safety*, http://www.lrrb.org/media/reports/201322.pdf.

See chapter 23 on integrating safety into the transportation planning process, for further discussion on pedestrian and pedalcyclist safety. (Note: The term *pedacyclist* was used in this section because of the way safety statistics are reported. The following sections will use the more common term *bicyclist.*)

IV. EVOLUTION OF PEDESTRIAN AND BICYCLE PLANNING IN THE UNITED STATES

A. Early History

Walking is the oldest and most basic form of transportation, whereas the use of bicycles is more recent, dating from the mid- to late 1800s. The ability to walk from place to place directly contributed to the size and shape of cities before the Industrial Revolution. Only the very largest cites could not be crossed on foot in less than 1 hour. Accordingly, planning for pedestrians prior to the last 50 years typically consisted of providing the ability to walk safely from one part of the community to another (for example, sidewalks). This was particularly true in downtowns and city centers. In most cases, in the late 1800s and early 1900s, sidewalks were paved before roadway surfaces.

Bicycling became immensely popular in the late 1800s. The League of American Wheelmen was formed during this period to lobby for better roads for bicycles, which led directly to the paving of some roadways even in advance of the automobile. The first officially designated bicycle path in the United States was built in 1894 along Ocean Parkway in Brooklyn, New York, and other roads were designated as bicycle routes. Dedicated bicycle facilities, such as bicycle lanes and multi-use paths, did not become widespread until the latter half of the twentieth century, when more formal planning efforts for bicyclists and pedestrians were initiated.

B. Beginning of Formal Planning Efforts

The bicycling boom of the late 1800s was followed by a period of declining bicycle use in the early 1900s as the motor vehicle became the most popular means of transportation. As the demand for paved roads increased due to rising auto ownership, many urban road designs relegated bicycle use to a secondary or even a nonexistent concern. Outside of downtown areas, pedestrian accommodations such as sidewalks were hardly ever part of the road design. When the U.S. federal-aid highway program was established in the late 1950s, federal aid was targeted toward highway projects, with transit investments becoming eligible in the mid-1960s. Sidewalks and bike paths were considered a local responsibility.

By the 1970s, several states and cities had initiated studies on pedestrian and bicycle transportation. In 1971, for example, Oregon passed legislation requiring the Oregon DOT as well as cities and counties to spend at least 1 percent of their highway funds on bicycle and pedestrian facilities. This resulted in new planning efforts to identify the highest-priority projects for these funds. States such as California, Florida, and New Jersey also began active bicycle programs in the 1970s and 1980s.

At the national level, several initiatives reflected the increasing interest in pedestrian and bicycle transportation. The U.S. DOT *Policy on Major Urban Mass Transportation Investments*, published in August 1975, included a provision for pedestrians and bicycles. The Surface Transportation Assistance Act of 1978 included federal funding support for bicycle projects at about $20 million annually. The Transportation Research Board's *Highway Capacity Manual* first included chapters on pedestrians and bicycles in its 1985 edition, presenting methods to analyze the operations of pedestrian and bicycle facilities.

C. Recent Interest

Additional support for formal bicycle and pedestrian planning efforts came from the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. ISTEA represented a significant shift in U.S. transportation policy because it allowed states and local agencies to develop programs and plans to meet their unique needs. Under ISTEA, all states and metropolitan planning organizations (MPOs) were required to consider facilities for bicyclists and pedestrians as part of their transportation plans. Federal annual spending on bicyclist and pedestrian improvements increased from $4 million to an average of $160 million. And in 2010, the U.S. DOT issued a policy statement on bicycles and pedestrians that stated, "every transportation agency, including DOT, has the responsibility to improve conditions and opportunities for walking and bicycling and to integrate walking and bicycling into their transportation systems. Because of the numerous individual and community benefits that walking and bicycling provide—including health, safety, environmental, transportation, and quality of life—transportation agencies are encouraged to go beyond minimum standards to provide safe and convenient facilities for these modes." [U.S. DOT, 2010]

With the passage of ISTEA, many states and local agencies prepared bicycle master plans, whereas some combined both bicycling and walking in a bicycle and pedestrian master plan. Some states, such as California, required local agencies to have an approved bicycle master plan to qualify for certain state funds. Elements of such plans typically included designating routes and design guidance for new facilities. More sophisticated planning techniques occurred in the 1990s with the advent of geographic information systems (GIS) and aerial imaging to designate bicycle routes and close network gaps.

Through much of the 1990s, pedestrian planning efforts were typically combined with bicycle plans and often were not treated as a distinct mode of travel (and in some cases were grouped with transit in the form of "alternative transportation"). Even today, many state and local agencies combine bicyclist and pedestrian planning under the umbrella of *nonmotorized planning*. However, pedestrian needs are different from those of other travelers. Pedestrian plans typically include policies for pedestrian planning and a discussion of the relationships between transportation and land use. Improvements are typically prioritized and, as with bicycle plans, design guidance for new facilities is frequently suggested. In this text, pedestrians and bicyclists are treated similarly in each section, and differences noted where appropriate. The reason for this is that much of the research and literature on pedestrian and bicyclist transportation can be found together in most reports.

Providing mobility for those with disabilities is a major concern in pedestrian planning. The U.S. Americans with Disabilities Act (ADA) of 1990 is the primary law directing such consideration. Under Title II of the act, all state and local governments "must ensure that individuals with disabilities are not excluded from services, programs (pedestrian facilities such as sidewalks and curb ramps fall under the definition of government programs), and activities because facilities are inaccessible." A U.S. Access Board is responsible for developing minimum standards for accessible design. The ADA Access Guidelines (ADAAG) provide guidance for the design of accessible bicyclist and pedestrian facilities. [U.S. Access Board, 2007] The Board has also adopted Public Rights-of-Way Accessibility Guidelines (PROWAG) that include accessibility provisions for pedestrian access routes (including width, grade, and cross slope) and alternate routes; curb ramps and blended transitions; street crossings; transit stops and shelters; street furniture; and on-street parking.

To assist with designing accessible facilities and ensuring access for all users, FHWA produced *Designing Sidewalks and Trails for Access*, a two-part design guide for designing bicyclist and pedestrian projects. [FHWA, 2001] In addition, the FHWA provides a reference library on bicyclist and pedestrian planning and design at the following website: http://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/.

D. State, Regional, and Local Programs

Much of the bicyclist and pedestrian planning efforts in the United States occur at the state and local levels. The federally required statewide bicyclist and pedestrian programs were intended to establish goals and policies for state agencies and to summarize design guidance for local jurisdictions. Some state DOTs have created policies supporting or requiring the integration of bicyclist and pedestrian considerations into the transportation planning and design process [Biton et al., 2014] as well as manuals and guides for design, construction, maintenance, and operation of such facilities. [FHWA, 2014a] Importantly, in some states, dollars have been set aside to support investment programs. For example, statewide programs in Michigan and Oregon allocate 1 percent of gas tax revenues to bicycle and active transportation programs.

Education and safety issues can also be coordinated at the state level. For example, from 2005 to 2012, a federal program called Safe Routes to School provided more than $1 billion to states to support walking and bicycle school access improvements (later legislation combined this with other programs to create a Transportation Alternatives program). Many states have programs to provide off-street trails for bicyclists and pedestrians. National organizations such as the Rails to Trails Conservancy also actively campaign for increased trail facilities.

At the regional level, metropolitan planning organizations (MPOs) are required to develop long-range (20 to 25 years) transportation plans (LRTPs) and multiyear transportation improvement programs (TIPs) to qualify for federal transportation funds (see chapter 16 on metropolitan transportation planning). These plans are required to consider such factors as safety for pedestrian and bicyclist travel, accessibility, environmental quality, and community quality of life impacts, each of which relates to pedestrian and bicyclist transportation.

Given that much of the physical environment for walking and bicycling is the result of local government decisions, local policies and actions are an important context for bicyclist and pedestrian planning. [Meyer and Dumbaugh, 2005] Policies establish long-term directions for jurisdictions and guide staff in the everyday decisions that affect bicyclists and pedestrians, with a goal of creating safe environments for all roadway users. The mechanisms for implementing local policies typically include general or comprehensive plans, modal plans, redevelopment plans, bicyclist and pedestrian plans, ordinances, codes, and standards (see chapter 3 on land use and urban design). Zoning ordinances and development review procedures, for example, can ensure the inclusion of bicycle or pedestrian facilities in new development and redevelopment projects.

Standards describe the types, dimensions, and other design specifications of transportation improvements. In addition to typical roadway cross sections, standards can also include guidelines for traffic control and the requirements for all road users, especially for accommodating pedestrians and bicyclists. Street design that safely accommodates bicyclists and pedestrians and that is sensitive to the surrounding context is one of the most important factors in creating safe travel ways for bicyclist and pedestrian trip-making. For an excellent example of how street designs can do this, see the National Association of City Transportation Officials (NACTO), *Urban Street Design Guide*. [NACTO, 2013]

E. Important Considerations in Today's Planning Environment

Given the large number of topics and issues considered in the transportation planning process, it is not surprising to find walking and bicycling a consideration in many of them. Some of the more important concepts relating to walking and bicycling include:

1. Balance among Transportation Modes and Complete Streets

The underlying principle of bicyclist and pedestrian planning is that a *balanced* transportation system recognizes the important role that walking and bicycling can play in giving travelers a choice for certain types of trips. For this to happen, bicycling and walking must become more attractive as modal options. In many cases, creating a reasonable balance means more than simply installing sidewalks or designating bicycle facilities. For the pedestrian, it means increased attention to factors that have in the past been beyond the domain of engineers. For example, it could mean making streetscape improvements, which requires collaborative efforts among transportation engineers, planners, landscape architects, and urban designers.

The concept of Complete Streets has become an important framework for considering pedestrians and bicyclists (and other modes) in roadway design. The National Complete Streets Coalition defines a complete street policy as "routinely designing and operating the entire right of way to enable safe access for all users, regardless of age, ability, or mode of transportation." [National Complete Streets Coalition, 2014] Many states and cities have developed planning and design manuals that emphasize design flexibility and balance in developing road space. Some notable examples include:

- Boston—*Boston Complete Streets*, http://bostoncompletestreets.org/.
- Chicago—*Complete Streets Chicago: Design Guidelines*, http://www.cityofchicago.org/content/dam/city/depts/cdot/Complete%20Streets/CompleteStreetsGuidelines.pdf.
- New York City—*Street Design Manual*, http://www.nyc.gov/html/dot/downloads/pdf/nycdot-streetdesign manual-interior-lores.pdf.
- Institute of Transportation Engineers—*Designing Walkable Urban Thoroughfares: A Context Sensitive Approach*.
- National Association of City Transportation Officials (NACTO)—http://nacto.org/usdg/.
- Seattle—Complete Streets Checklist, http://www.seattle.gov/transportation/docs/UPDATED_Complete %20Streets%20Checklist_%2011%2021%2014.pdf.
- Washington State Department of Transportation—*Washington's Complete Streets and Main Street Highways Program*, http://www.wsdot.wa.gov/research/reports/fullreports/780.1.pdf.

See also chapter 9 on road and highway planning.

2. Context-Sensitive Design/Solutions

The quality and character of bicycle and pedestrian facilities have a strong relationship to the *livability* of surrounding communities. Context-sensitive solutions (CSS) is a collaborative, interdisciplinary approach to roadway design that encourages stakeholders to consider the many different aspects of how a roadway "fits" into its environment (see chapter 3 on land use and urban design). The CSS approach seeks designs and solutions that fit the physical setting and that preserve scenic, aesthetic, historic, and environmental resources while at the same time improving safety, access, and mobility. CSS calls on transportation professionals to consider the needs of all roadway users and the special design features and elements for each group. For bicyclists and pedestrians, these efforts can result in more flexible designs responding to a broader range of community interests. See also chapter 9 on road and highway planning.

3. *Land Use*

Bicyclist and pedestrian trips are typically characterized by short trip distances, approximately up to one-quarter to 1 mile (1.6 km) for pedestrian trips and up to one-quarter to 3 miles (4.8 km) for bicycle trips. Land-use patterns, therefore, have a critical influence on bicyclist and pedestrian trips. Suburban sprawl and decentralization do not provide effective linkages between residential areas and shopping/employment centers; they instead create a distance barrier for bicycling and walking. Opportunities to provide accessible, safe, convenient, and inviting environments for walking and bicycling need effective land-use planning and design standards. As discussed in chapter 3 on land use and urban design, there is a clear link between urban form and travel characteristics. Some have estimated that land-use strategies involving the 4 Ds—diversity (mixed-use development), density, destinations, and design—have the potential to reduce auto trips by more than 20 percent when compared to sprawling development patterns. [McCormack et al., 2001]

4. *Education, Encouragement, and Enforcement*

Training and educating bicyclists, pedestrians, and motorists, as well as enforcing laws and regulations, are critical elements of a successful program to enhance walking and bicycling. Children, older adults, recreational bicyclists, walkers, and commuters all have different skill levels, experience, and perceptions of risks when it comes to active transportation. It is important to understand these varying types of users and their needs, to provide both the infrastructure and services that best meet active transportation demand. Every state has a Governor's Highway Safety Representative (with an accompanying office) who is responsible for coordinating the federally supported safety programs in the state. This office is an important participant in planning efforts to enhance the safety environment for those who walk or ride bicycles.

An example of an education and encouragement campaign comes from Pasadena, California, where the city has targeted commuter bicyclists. As of 2015, the city has installed 450 bicycle headlights and tail lights and has distributed bicycle helmets to bicyclists throughout the city. The police department has also focused enforcement efforts on motorist violations that are most dangerous to bicyclists in areas of the city having the most bicycling. [City of Pasadena, 2015]

Perhaps one of the most comprehensive education programs in the country is found in New York City, where the city's transportation and police departments have been working together to provide a safer environment for walking and bicycling. Some of the strategies as targeted on particular groups include:

School Programs

- Continue to provide Safety City and in-school presentations for children ages 5–14 focused on navigating streets safely with an increased emphasis on arterial streets and high-risk corridors.
- Develop intensive traffic safety workshop, theater, and art programs (after-school and summer) for students aged 11–17 that reside near the highest-risk corridors in each borough.
- Expand sign and mural artist-in-residence programs for students to engage local communities in traffic safety issues through the creative arts.
- Expand the use of web-based social media resources such as YouTube, Facebook, and Twitter for teens to share their involvement in traffic safety programs with peers.
- Provide Train-the-Trainer programs to Substance Abuse Prevention and Intervention Specialists (SAPIS) at the City's Department of Education to help incorporate traffic safety education into classroom curricula.

Parents

- Host parent workshops and "Safety from the Start" program for new parents, targeting low educational attainment populations.

- Focus new effort on pedestrian, passenger, and bicycle safety through Safe Kids Coalition injury prevention outreach to new immigrant groups.
- Expand non-English outreach programs and education efforts, targeting neighborhoods that face a higher risk for pedestrian fatalities.

Older Adults

- Provide Safe Streets for Seniors presentations at senior centers located near high-risk corridors and major arterial streets.
- Expand multilanguage pedestrian safety programs, particularly to Asian residents ages 65+ who face higher risk for pedestrian fatalities.
- Develop comprehensive active transportation programs for older adults including information on pedestrian safety, biking, fall prevention, nutrition, medicine, and fitness.

Materials

- Update and create new printed educational materials highlighting dangerous behaviors, including failure to yield, speeding, aggressive driving, and inattention.
- Translate additional materials for high-risk, non–English speaking populations. [City of New York, 2010]

5. Design Flexibility to Enhance Safety

The 2010 U.S. DOT *Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations* "encourages transportation agencies to go beyond the minimum requirements, and proactively provide convenient, safe, and context-sensitive facilities that foster increased use by bicyclists and pedestrians of all ages and abilities, and utilize universal design characteristics when appropriate." [USDOT, 2010] All of the design manuals referenced in this chapter provide such flexibility in their guidance and recommended design concepts.

The City of New York has considered a range of design strategies to enhance the walking and bicycling environment, including turning downtown streets into pedestrian zones. Other actions have included:

- Improvements near schools such as signs, high visibility school crosswalks, speed reducers, traffic signal improvements, and bike lanes.
- Removal of curbside parking spaces at the approach to an intersection, to increase pedestrian visibility and reduce turning-vehicle pedestrian crashes.
- Reduction in speed limits in selected neighborhoods and near schools.
- Installation of around 75 speed reducers per year. Before/after studies found an average of 19 percent reduction in speeds where speed reducers are in place, and a city DOT study has found that speed reducers reduce injury crashes by approximately 40 percent.
- Installation of pedestrian countdown signals at the majority of intersections in the city, with priority given to intersections with high pedestrian crashes.
- Added pedestrian crossing time at over 400 traffic signals, installation of 25 pedestrian refuge islands and numerous curb extensions, median extensions, and pedestrian ramps at locations with higher-than-normal elderly populations. [City of New York, 2010]

As will be discussed in the next section, one of the recent perspectives on the design of bicycle networks is the desire to create comfortable and low-stress conditions for use of the lanes and paths. The intent is to provide a design (for example, separated and/or buffered lanes) such that users will perceive the use of the lane as being comfortable and safe.

The best approach for dealing with these considerations is to develop a comprehensive strategy for the community. Pedestrian and bicyclist crashes and injuries, hazardous traffic conditions, lack of enforcement of traffic laws, poor maintenance of walkways and bicycle routes, inadequate lighting and security, and inadequate bicyclist and pedestrian training programs contribute to a challenging environment for walking and bicycling.

V. PEDESTRIAN AND BICYCLIST PLANNING

Enhancing the pedestrian and bicyclist experience can occur through urban design, facility design, traffic calming, traffic engineering, landscaping, and bicyclist and pedestrian behavior strategies. Notwithstanding the distinct nature of several aspects of both bicycling and walking, this chapter follows the same basic structure described in chapter 1 for transportation planning and shown in Figure 1-1. Each step will be presented from the perspective of how both bicycling and walking transportation planning can be considered. Where specific characteristics of each warrant separate discussion, it is presented in that section.

A. Understanding the Context and Problem

Most planning studies begin with a preliminary analysis of the problem(s) or challenges being faced. In the case of pedestrian and bicyclist planning, this might reflect such questions as, What are the safety challenges facing pedestrians and bicyclists? Where are the demands for such travel now and in the future? How do demographic characteristics influence walking and bicycling, and thus the characteristics of the facilities and services to meet this demand? What are the characteristics of current walkways and bike lanes, and how do they provide safe and low-stress travel experiences? Is the "network" truly connected to the community, to the transportation system, and to other pedestrian and bicycle facilities?

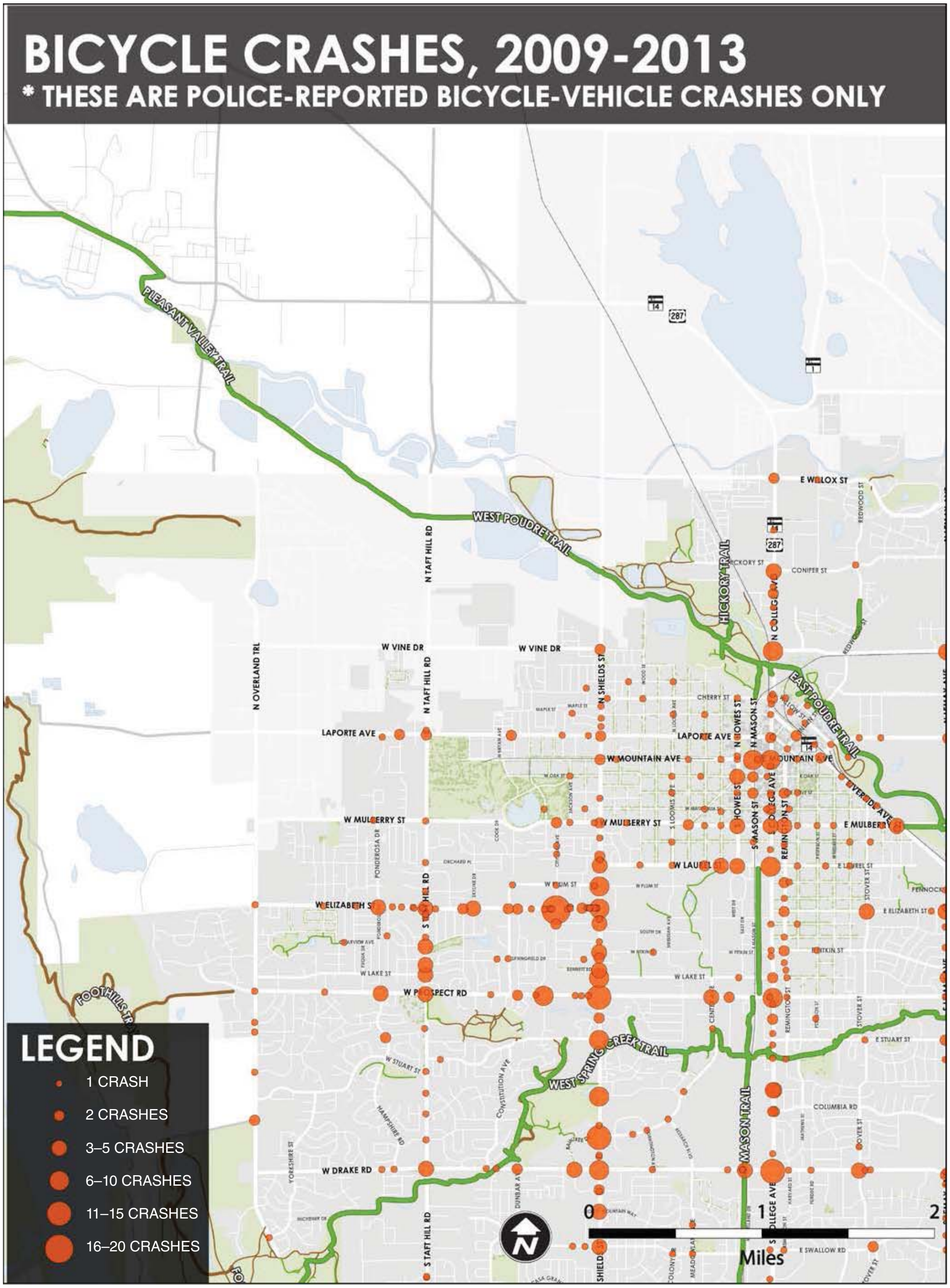
This early analysis is intended to present a comprehensive picture of the existing pedestrian and bicycle system, and the way that addressing its challenges can help guide policy making and the selection and prioritization of future improvements. According to the FHWA, an assessment of current conditions and needs should include the consideration of:

- Current levels of use for walking and bicycling trips, and current numbers of injuries and fatalities involving pedestrians and bicyclists.
- Existing transportation infrastructure (including on- and off-road facilities) to determine current conditions and capacities, and to identify gaps or deficiencies in accommodating potential and existing pedestrian and bicyclist travel.
- Capacities and the type and security level of bicycle parking offered at intermodal connections such as transit facilities and major destination points.
- Desired travel corridors for pedestrian and bicyclist trips.
- Existing land use and zoning, and the patterns of land use in the community.
- Planning, design standards, and agency policies, and the extent to which they affect the accessibility of the transportation system for pedestrians and bicyclists; for example, do they meet policies and design guidance issued by national organizations such as the American Association of State Highway and Transportation Officials (AASHTO) for bicycle and pedestrian facilities?
- State and local laws and regulations affecting a community's vision and goals, for example, growth management and trip reduction laws, or constitutional restraints on expending highway funds on walking and bicycle facilities.
- Availability of bike-on-bus or bike-on-rail access, including hours of service, routes where available, and incentives and barriers to using the service (that is, training, permit, or additional charges). [FHWA, 2014b]

Existing condition data can come from surveys of existing street conditions, journey-to-work data from the most recent U.S. Census, pedestrian and bicycle collision data, and community input. As an example, Figure 13-1 shows the location of bicycle crashes in Ft. Collins, Colorado. By using such information, planners and engineers can better understand the types of issues facing a community, and as illustrated by Figure 13-1, show where serious problems exist.

Gaps in the current network are another common problem/need. In many cases, the pedestrian and bicyclist "network" has developed incrementally over time and often in different geographic locations. Thus, some neighborhoods might have an excellent sidewalk network, while adjacent neighborhoods suffer from a very limited one. Conducting

Figure 13-1. GIS Depiction of Bicycle Crashes, Ft. Collins, Colorado

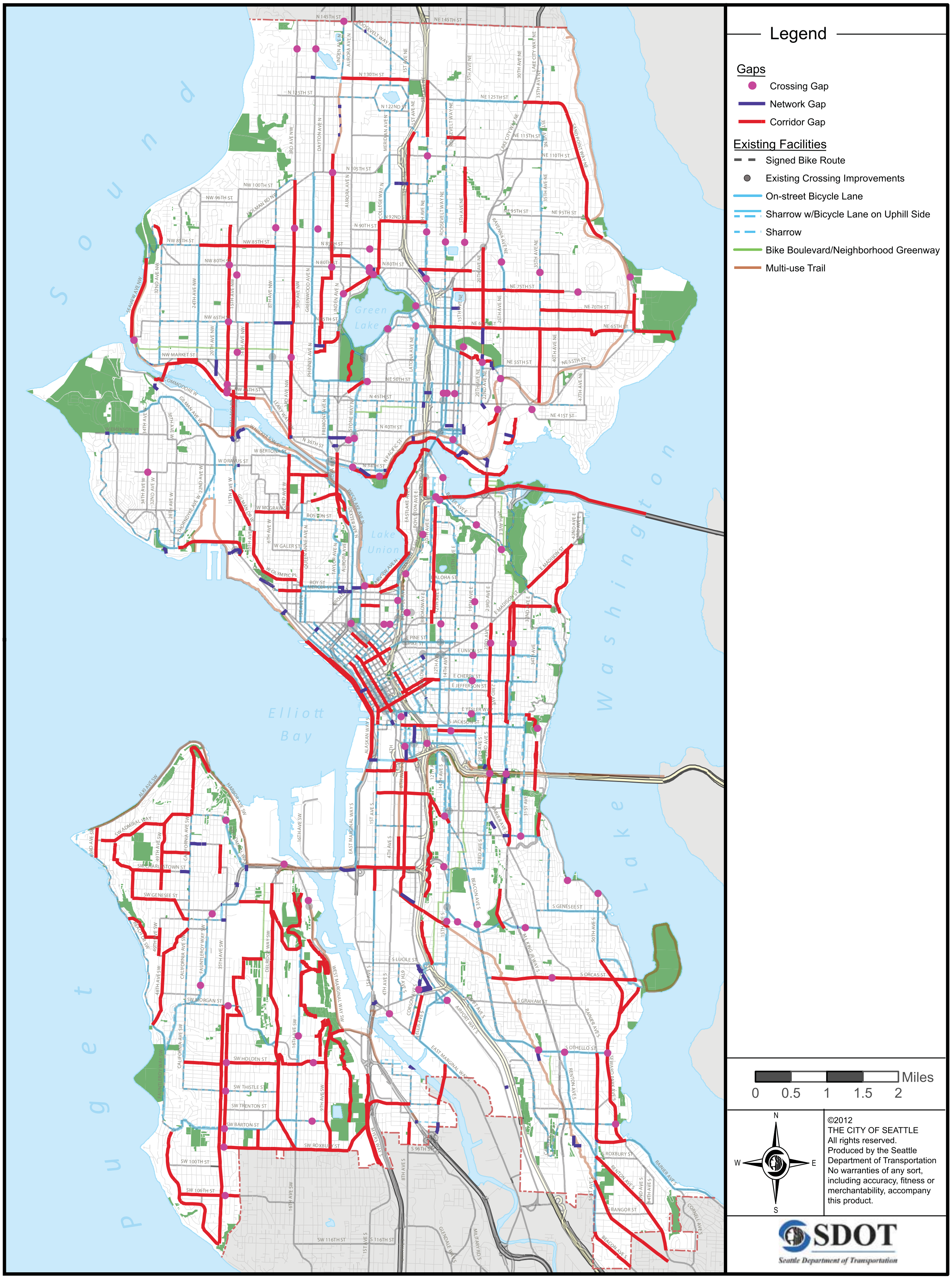


Source: http://www.fcgov.com/bicycling/pdf/appendix_b_state_of_bicycling_in_fort_collins.pdf

a network gaps analysis is one of the first steps in understanding the challenges facing pedestrians and bicyclists. Figure 13-2 shows a typical gaps analysis from Seattle, Washington. Three types of gaps were defined as:

- Crossing gaps are bicycle-related intersection improvements recommended in the 2007 Bicycle Master Plan (BMP), which have not been implemented.

Figure 13-2. Bicycle Network Gaps Analysis, Seattle, Washington



Source: City of Seattle, 2012

- Network gaps are "missing links" in the network recommended in the 2007 BMP that are less than 1/4 mile (0.4 km) in length and were recommended as either bike lanes, climbing lanes, bicycle boulevards, or multi-use trails, which have not been implemented.

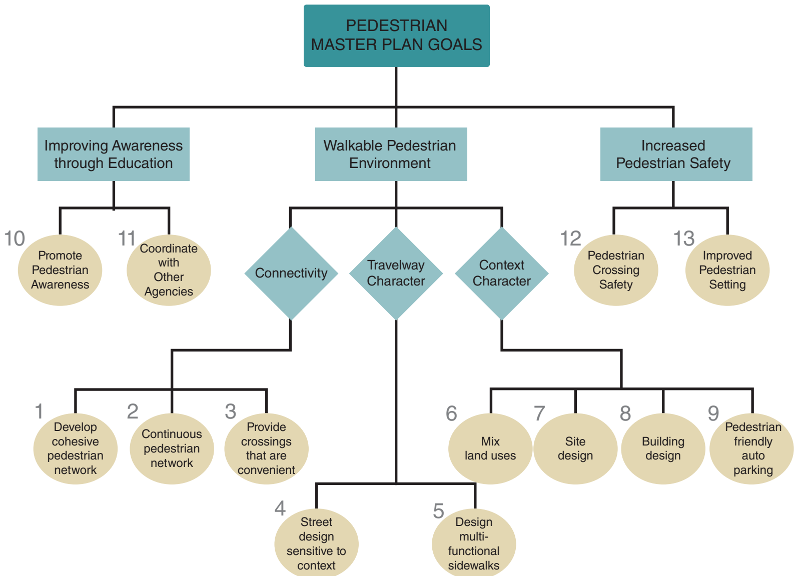
- Corridor gaps are larger voids in the network (greater than 1/4 mile in length). These gaps are most often corridors needed to connect neighborhoods to destinations, giving bicycle riders a variety of travel route options. [City of Seattle, 2012]

B. Developing Vision/Goals/Objectives/Performance Measures

Planning for pedestrians and bicyclists should be based on a vision of what a community desires with respect to pedestrian and bicycle movement, and a clear statement of a study effort's goals and objectives. As with any planning document, it is important to delineate existing and proposed policies and objectives. These help guide subsequent planning and other future planning activities. The vision/goals/objectives also clearly communicate to citizens, government agencies, and developers the desired role of pedestrian and bicyclist transportation in the state, region, or city. Good plans also evaluate broader jurisdictional goals, such as those contained in general or comprehensive plans, to determine their influence on bicycling and walking. Land use, level of service, and level of stress or comfort policies are particularly relevant.

The vision should inform the development of the goals, which are subsequently used to determine program objectives and policies. Objectives, in turn, determine the evaluation criteria for assessing actions, programs, projects and tasks. Figure 13-3 shows the concept of a hierarchy as seen in the Sacramento Pedestrian Plan, and Table 13-3 shows a similar hierarchy with performance measures from the 2015 Chicago Bike Plan. Note in Table 13-3 that examples of strategies and performance measures are provided for only one objective, to illustrate the concept. The remainder of the table presents the objectives and corresponding strategies. For a more complete presentation of the Chicago material, see [City of Chicago, 2015].

Figure 13-3. Goals and Objectives for Sacramento Pedestrian Plan



Source: City of Sacramento, 2006

The City of Pasadena's Bike Plan provides another example of a goals statement. [City of Pasadena, 2015] Six goals were identified to guide the process of bike planning:

1) Create an environment where people can circulate without a car.

2) Increase the number of bicyclists in Pasadena by encouraging people to use their bicycles instead of driving.

3) Increase the safety of bicycling in Pasadena.

4) Increase opportunities for traffic safety education for all travel modes and age groups in Pasadena.

5) Promote the health of Pasadena residents by providing opportunities to bicycle for commuting, recreating, shopping, and visiting.

6) Facilitate the economic viability of Pasadena by making Pasadena an attractive place to live, shop, and operate a business.

Table 13-3. Vision, Objectives, Strategies, and Performance Measures, City of Chicago Bike Plan
Vision: Establish a 500-mile bikeway network in Chicago that is the equal of the best in the world
Objective 1: Add new bike lanes and signed bike routes
Strategy 1: Establish the bike lanes recommended in the *Streets for Cycling Plan*.
Performance Measure: Establish 10 miles (16.1 km) of bike lanes by 2007; an additional 10 miles by 2010.
Strategy 2: Establish bike lanes at locations that are not identified in the *Streets for Cycling Plan*.
Performance Measure: Determine locations by 2007. Establish 26 miles (41.8 km) of bike lanes by 2015.
Strategy 3: Establish shared bus/bike lanes.
Performance Measure: Establish 2–3 bus/bike lanes by 2008.
Strategy 4: Continue signing the bike routes identified in the *Streets for Cycling Plan*.
Performance Measure: Sign an additional 85 miles (136.8 km) of bike routes by 2009.
Objective 2: Establish new trails, improve existing trails, and improve access to trails
Strategies • Construct grade-separated connections at appropriate locations to connect trails and provide safe crossings of busy roadways. • Regularly update trail planning, design, and construction standards. • Ensure that trails built as a condition of development approval are designed and built to appropriate standards. • Establish a trail circuit to permit a long recreational or fitness bike ride in Chicago. • Establish the trails recommended in the *Chicago Trails Plan*. • Establish the new trails, trail improvements, and new trail access points recommended in the South Lakefront Access Study and Chicago Park District Framework Plans. • Upgrade and extend existing trails.
Objective 3: Use innovative designs to expand and enhance the bikeway network.
Strategies • Color the pavement at selected bikeway locations to alert motorists and bicyclists of conflict areas and assign the right-of-way to bicyclists. • Install special pavement markings on streets too narrow for bike lanes. • Install signs advising motorists and bicyclists that bicycle traffic may move to the center of the travel lane. • Consider establishing bikeways on streets with rush hour parking controls. • Establish dedicated right and left turn lanes for bicycles. • Determine the appropriateness of advanced stop bars at intersections with high volumes of bicycle traffic. • Install raised bike lanes at appropriate locations. • Establish bike boulevards to prioritize bicycling on streets with low traffic volumes and slow speeds. • Implement measures on selected streets with bikeways to reduce speeding and encourage bicycling.
Objective 4: Establish bikeways to priority destinations.
Strategies • Establish bikeways to elementary schools, high schools, colleges, and universities. • Connect bikeways to adjoining municipalities. • Establish or enhance existing bikeways to transit stations.

(*continued*)

Table 13-3. (*Continued*)
Vision: Establish a 500-mile bikeway network in Chicago that is the equal of the best in the world
• Identify the locations for new crossings over the Chicago River, Calumet River, North Shore Channel, and Sanitary and Ship Canal. • Establish bikeways to and within the loop. • Improve access to the Lakefront Trail and other popular trails.
Objective 5: Help current and potential bicyclists choose safe, convenient routes.
Strategies • Develop and widely distribute a new Lakefront Trail map. • Collect data to identify popular bikeways and the impact of Bike 2015 Plan strategies. • Provide detour routes and signage. • Provide interactive online mapping to enable bicyclists to develop personalized maps. • Install bicycle information boards at critical junctures in the bikeway network to provide bicyclists detailed route information.
Objective 6: Prioritize ongoing maintenance and repair of the bikeway network.
Strategies • Maintain bike lanes in excellent condition. • Ensure prompt repair of pavement cuts on streets with bikeways. • Upgrade the on-street bikeway network on a regular basis. • Identify and immediately replace grates that trap bicycle wheels. • Retrofit metal grate bridges to make them safer for bicycling.

Source: City of Chicago, 2015

Each of these goals had related objectives, and each objective had recommended actions to achieve the objective. For example, one of the objectives and associated actions for the first goal above included:

Objective: Increase the proportion of bicycle commute trips in Pasadena by 5 percent.

Actions

1. Implement planned citywide network of bikeways.
2. Recognize that bicyclists ride on all streets and that all streets need to accommodate bicycles.
3. Improve technology to ensure that bicyclists can activate traffic signals at vehicle-actuated intersections.
4. Maintain bikeway and roadway system.
5. Conduct periodic bicycle counts at various locations and upgrade the bikeway network.
6. Assist employers with promotional campaigns to encourage bicycle commuting.
7. Coordinate with the Pasadena Trip Reduction Ordinance enforcement and monitoring to ensure that employers and land owners of commercial property carry out bicycle commuter incentive programs.

Performance measures monitor the performance of the transportation system with respect to identified goals. This is a relatively recent concept in transportation planning and is intended to provide accountability for the investments made to improve system performance. Examples of performance measures for pedestrian and bicyclist planning might be the number and rate of pedestrian- and bicycle-related crashes, the number of established pedestrian and bicycle routes to schools and transit stops, the level of investment in pedestrian and bicyclist amenities, the number of outreach meetings or website hits, and the number of projects that incorporate pedestrian and bicyclist considerations into their design.

The bicycle plan for the City of Ft. Collins, Colorado, [City of Ft. Collins, 2014] provided some sense of what a bicycle future in the city might look like:

- A target 20 percent of people will commute by bicycle.
- A balance of genders will bicycle.
- There will be zero bicycle fatalities.
- The number and severity of bicycle-related crashes will be lower than today.
- There will be a 162-mile (260.7 km) low-stress bicycle network.
- A target 80 percent of residents will live within one-quarter mile (0.4 km) of a low-stress bicycle route.
- All neighborhoods will have access to a low-stress bicycle route.
- The City will have implemented a protected bike lane demonstration program.
- A target 8,000 K–12 students will receive bicycle education annually.
- Participation in the City's bicycle education and outreach programs will reflect the demographic and socioeconomic breakdown of the Fort Collins population.
- The number of residents participating in the City's education and outreach programs will have doubled.
- A target 55 percent of residents will find it very easy to travel by bicycle.
- Childhood and adult obesity rates will be lower.
- Greenhouse gas emissions will be 20 percent lower than 2005 levels.

An effective pedestrian and bicyclist planning process should involve the public and various stakeholders, especially in helping define the community vision and related goals/objectives. This participation may include staff from related agencies, potential users of the system, citizen's advisory committees, and other groups that the plan may affect. Bicyclists, in particular, have formed advocacy groups that are very active in the transportation planning process. Partnerships, including intra-agency partnerships, public-private partnerships, and community involvement strategies, can be useful for implementing local bicyclist and pedestrian policies and helping secure necessary funding. Because an entire chapter is dedicated to public engagement techniques and strategies, the reader is referred to chapter 24 on public participation and engagement for further information.

C. Analyzing Walking and Bicycling Alternatives

Several techniques and tools can be used to analyze the conditions faced by pedestrians and bicyclists, and to identify improvement strategies. The first section focuses on the types of data that these techniques and tools rely on.

1. Data

As with data collected for motor vehicle and transit trips, planners will want to collect data on the characteristics of walking and bicycle trips. This includes such things as the overall number of trips, trips by time of day, distance traveled, number of repeat trips, and characteristics of the travelers themselves. However, walking and bicycle trips exhibit very different characteristics than trip-making by car or transit. According to Ryus et al. [2014], the main differences include:

> *Pedestrian and bicycle volumes are more variable than motor vehicle volumes. While both motorized and nonmotorized volumes vary over time (e.g., by time of day, by season of year), nonmotorized volumes on a given day are much more sensitive to the weather that day than are motorized volumes. In addition, hourly pedestrian and bicycle volumes at*

most locations tend to be relatively low compared to the volumes observed at typical motorized vehicle count sites; these lower volumes also contribute to higher day-to-day variability.

Pedestrian and bicycle trips tend to be shorter than automobile trips and are often made for different purposes. As a result, pedestrian and bicycle volumes tend to be more sensitive to adjacent land uses (automobiles may be just passing through an area, rather than beginning or ending a trip there), and peak periods for pedestrian and bicycle trips may not necessarily coincide with the peak periods for automobile traffic.

Motor vehicles tend to be easier to detect than pedestrians and bicycles. Pedestrians and bicyclists are smaller than motor vehicles, often travel together in close groups, and may travel outside designated walkways and bikeways. In contrast, motor vehicles are large, metal objects that move in lanes and travel with relatively sizable gaps between each vehicle.

Experience with pedestrian and bicycle counting technology is more limited than for motor vehicles. The technologies commonly used to count motor vehicles are well established, counting errors associated with particular technologies are understood, and methods for addressing errors are fairly well developed [FHWA 2013]. In contrast, some of the counting technologies used for nonmotorized counting are different than those commonly used for motorized vehicle counting, and new technologies are emerging.

The type of data collected will depend on the type of study being undertaken, and the evaluation criteria that will be used later to assess the relative effectiveness of different strategies and alternatives. For example, if the data are intended for an area-wide pedestrian and bicycle study, then it is likely that data collected would relate to existing conditions, trip-making characteristics, factors affecting future demand, and socioeconomic characteristics of those walking or bicycling. However, if the study is a before-and-after study of the implementation of a particular strategy or action, then the data collection would be much more targeted on the specific changes that were expected once the project was in place.

An example of the influence of evaluation criteria on data collection comes from the City of Pasadena Bike Plan. The major evaluation criterion in determining need and network gaps was the level of stress associated with traveling the current bicycle network. Table 13-4 shows how four levels of stress were defined in the study.

It was noted in the study that vehicle speed was the most important factor in defining the level of traffic stress, and that lower levels of stress could be achieved only on streets with a speed limit of 30 mph or lower. Figure 13-4 shows how the collected data on traffic stress were portrayed on a network map. Those segments with bolder colors are identified as routes with extremely low comfort levels for many bicyclists.

It is beyond the scope of this chapter to present all of the information and data that would likely be collected as part of a study on pedestrians and bicyclists. However, Tables 13-5 to 13-8 illustrate the types of data that are often collected. These tables come from NCHRP Report 803, *Pedestrian and Bicycle Transportation Along Existing Roads—ActiveTrans Priority Tool Guidebook*. [Lagerwey et al., 2015] This report is discussed in more detail in the section on prioritization.

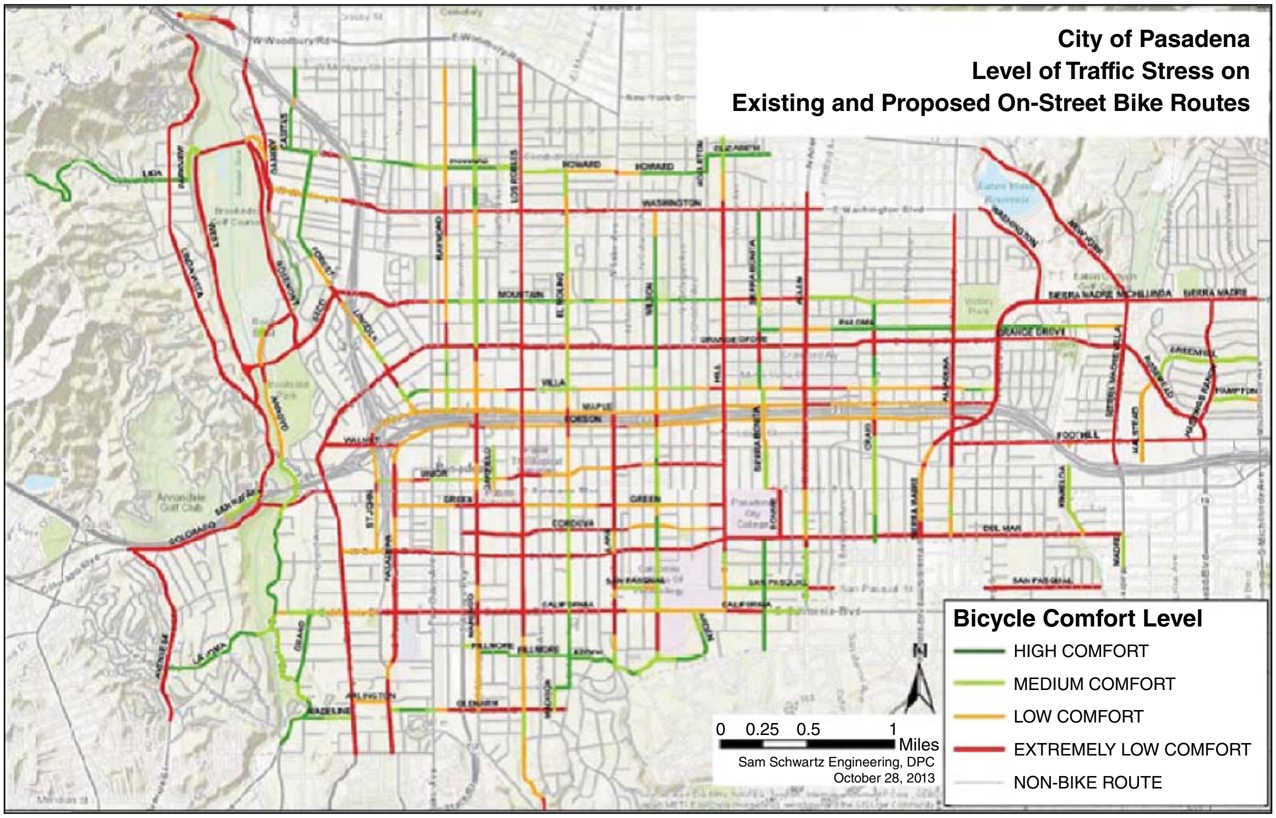
In addition, cell phone–based probe data can be used to obtain bicycle and pedestrian speeds. Detailed information on the data collection process and typical data collection technologies is found in [Ryus et al., 2014].

Table 13-4. Level of Traffic Stress Criteria, Pasadena, California

Level of Traffic Stress (LTS)	Level of Comfort	Description
LTS 1	High	Comfortable for most children
LTS 2	Medium	Comfortable for mainstream adult population—generally considered to be 60% of the U.S. population who are interested in bicycling, but only comfortable, generally, on off-street bikeways or quiet residential streets
LTS 3	Low	Comfortable for “enthusiastic and confident” adult bicyclists generally considered to be +/− 6 percent of the population and who prefer dedicated bicycling space
LTS 4	Extremely low	Comfortable for only “strong and fearless” adult bicyclists generally considered to be ≤ 1 percent of the population and who will generally bicycle regardless of the facility type

Source: City of Pasadena, 2015

Figure 13-4. Application Traffic Stress Level Data in Defining Bicyclist Comfort Level, Pasadena, California



Source: City of Pasadena, 2015

2. Surveys

One of the most common approaches for identifying current problems and defining the characteristics of walking and bicycling demand is to survey likely travelers. For survey results to be representative, they should be statistically valid (that is, sample sizes and population distributions should reflect the community's population), although many informal surveys are done simply to assess people's attitudes about walking and bicycling (see chapter 2 on travel characteristics and data). For example, a telephone survey conducted by The Gallop Organization for the National Highway Traffic and Safety Administration (NHTSA) in 2008 included a nationally representative sample of 9,616 respondents 16 or older. [Royal and Miller-Steiger, 2008] The results were then weighted to reflect the national population of 208 million aged 16 or older at that time in the United States. These survey results were not only useful in understanding some of the key factors that influenced pedestrian and bicyclist trip-making, but they could readily be related to the types of variables used in travel demand models. Some of the interesting results from this survey included:

- Nearly half of people 16 or older (46 percent) had bicycles available for their use on a regular basis. Those under 21 were the most likely to have access (62 percent), while less than one-quarter (23 percent) of those 65 or older reported access.
- While males are only somewhat more likely to have access to a bicycle than females (51 percent versus 42 percent), they are nearly twice as likely as females (24 percent versus 13 percent) to say they ride their bicycle at least once a week in the summer months.
- Reasons for not bicycling include lack of access to a bicycle (28 percent) and lack of need or desire to ride a bicycle (25 percent). Physical difficulty (11 percent) or weather conditions (10 percent) were mentioned by 1 in 10. Bicyclists 65 and older were most likely to cite physical difficulty (21 percent) as their primary reason for not bicycling recently.
- Nearly 9 in 10 (89 percent) trips began at a residence either belonging to the bicyclist or someone else. An additional 7 percent of trips began at a leisure or recreational site such as a park. Just 1 percent began at work, and 3 percent began in some other location.

Table 13-5. Data Sources/Tools for Inventorying Data and Related Existing Conditions Variables for Nonmotorized Transportation	
Inventory Data Source/Tool	**Can Be Used to Inventory Data for These Variables**
Aerial imagery	• Sidewalk and buffer presence and width • Marked crosswalk presence and type • Median island presence and width • Bicycle facility presence and width • Lane width/shoulder width • Pedestrian crossing distance
Street-level imagery (e.g., video log, street view)	• Curb ramp presence • Tactile warning strips • Pedestrian/bicycle-related signage • Major sidewalk obstructions • Pedestrian signal heads • Pedestrian push buttons
Direct field observation (using technological data collection tools or manual observations)	• Precise lane width/shoulder width • Traffic volume • Traffic speed • Sidewalk condition • Crosswalk condition • Pavement condition • Curb ramp slope • On-street parking presence and occupancy

Source: Lagerwey et al., 2015, Reproduced with permission of the Transportation Research Board.

- The most common purposes of trips were for recreation or leisure (29 percent) and for exercise or health reasons (24 percent). Fewer trips were made to run personal errands (14 percent), to go home (14 percent), or to visit a friend or relative (10 percent). Just 5 percent said they used their bicycles for commuting to work or school.
- Nearly 3 in 4 (72 percent) people 16 or older reported that they walked on average at least once a week during the summer months.
- While about one half (51 percent) of all pedestrians reported no change in their walking behavior compared to a year ago, 3 in 10 (30 percent) reported walking more often, while 19 percent reported walking less often. Females (32 percent) were slightly more likely to report an increase in walking behavior from a year ago than were males (28 percent).
- The top reasons given for not walking included lack of desire or need (27 percent), disabilities and other health impairments (25 percent), and weather conditions (23 percent). Females were more likely to cite disability (31 percent) and weather conditions (28 percent) as a reason for not walking than were males (18 percent and 19 percent, respectively). Males were more likely to report a lack of desire or need (32 percent) than females (23 percent). One-half (50 percent) of those 65 and older who did not walk reported the main reason was because of a disability.

Table 13-6. Data Considerations/Sources for Demand Proxy Variable for Nonmotorized Transportation	
Example Demand Proxy	**Data Considerations/Sources**
Population density	• Population of given geography divided by its area
Employment density	• Employment is often compiled at the regional level and made available to local agencies by request from the Census for traffic analysis zones. Density is calculated by dividing the number of employees by a measure of area.
Commercial retail property density/proximity/accessibility	• Parcel data
Transit station or stop density/proximity/accessibility	• Point data typically maintained by the transit agency
Density/accessibility/proximity of key attractors (schools, parks, community centers)	• Parcel data, point data layers for specific land use attractor types
Proximity to college/university campus	• Parcel data
Bicycle facility density/accessibility	• Facility inventory
Presence of sidewalk	• Sidewalk inventory
Roadway density/connectivity	• Street centerline data
Roadway slope	• May be calculated using topographical data and length of segment, may also be part of street centerline data
Number of boardings at transit stop	• Daily, monthly, or annual boardings may be available from the transit agency, or may be an attribute of stop location point data or transit route data; may include patrons with bicycles.
Socioeconomic characteristics	• U.S. Census data
Proximity to or number of bike share docking stations	• Point data layer (GIS) of bike share stations

Source: Lagerwey et al., 2015, Reproduced with permission of the Transportation Research Board.

Table 13-7. Data Considerations/Sources for Safety Variable for Nonmotorized Transportation	
Example Safety Variable	**Data Sources**
Total number of pedestrian/bicycle crashes	Police crash database, often available at the state or local level
Fatal and severe injury pedestrian/bicycle crashes	Police crash database, often available at the state or local level
Pedestrian/bicycle crash rate	Police crash database combined with measure of exposure (e.g., pedestrian/bicycle counts, pedestrian/bicycle demand proxy variables)
Proportion of pedestrians walking in the roadway	Pedestrian counts (generally manual counts in the field, with instruction to note pedestrians in roadway)
Proportion of pedestrians complying with "Don't Walk" signals	Pedestrian counts (generally manual counts in the field, with instruction to note "Don't Walk" compliance)
Proportion of bicyclists complying with red lights	Bicycle counts (generally manual counts in the field, with instruction to note red light compliance)
Proportion of motorists complying with right turn on red restrictions	Vehicle counts (generally manual counts in the field, with instruction to note right turn on red movements)
Proportion of motorists yielding to pedestrians in crosswalks	Vehicle counts (generally manual counts in the field, with instruction to note yielding rates)
Number of "near misses" involving pedestrians/bicyclists	Multimodal counts (generally manual counts in the field, or based on video footage of a location)

Source: Lagerwey et al., 2015, Reproduced with permission of the Transportation Research Board.

Table 13-8. Data Considerations/Sources for Equity Variable for Nonmotorized Transportation	
Example Equity Variable	**Data Sources**
Household automobile ownership	• U.S. Census, American Community Survey (ACS)
Household income	• U.S. Census, ACS
Proportion of population < 18	• U.S. Census, ACS
Proportion of population > 64	• U.S. Census, ACS
Proportion of population with physical disabilities	• U.S. Census, ACS
Proportion of children receiving subsidized lunches	• School district enrollment data
Proportion of population with asthma or diabetes	• Public health agency community surveys or health profiles
Proportion of population that is overweight or obese	• Public health agency community surveys or health profiles

Source: Lagerwey et al., 2015, Reproduced with permission of the Transportation Research Board.

Because this was a representative sample of the U.S. population, the results can be understood to explain bicyclist and pedestrian behavior in the United States during the mid-2000s.

An example of a nonrepresentative survey comes from Baltimore, Maryland, where planners distributed surveys over a multiyear period at public meetings, libraries, universities, and on the Internet to find out more about bicyclist behavior and desires. [City of Baltimore, 2006] Just over 300 surveys were completed and, although from a statistical sense the results cannot be considered representative of the entire community, they did provide useful information concerning bicycle use and bicyclists' desires. Some results included:

Preferred facilities for bicycling:

- 43 percent—bike lanes
- 31 percent—street with no facilities
- 19 percent—bike paths
- 7 percent—sidewalks

Factors for choosing to bike:

- Safety of travel route
- Weather
- Traffic levels
- Need for exercise

Respondent profile: 58 percent men; 42 percent women; average age 36; used a bike on average 3 days per week; and 30 percent had been involved in a crash.

3. Travel Demand Models

Current bicycle and pedestrian volumes are not a complete indication of the potential demand for walking or bicycling. Inadequate facilities for safe travel as well as dispersed land-use patterns that create a perception of long trip distances can dampen the desire to walk or bicycle. While bicyclist and pedestrian travel demand models have not reached the level of sophistication of road network demand modeling, some techniques can provide reasonable estimates of the demand for such travel (see, for example, [Krizek et al., 2006]). Characteristics of the land uses adjacent to bicycle and pedestrian networks and how they can influence the decision to bicycle or walk are an important consideration in these models. NCHRP 770, *Estimating Bicycling and Walking for Planning and Project Development: A Guidebook* [Kuzmyak et al., 2014], is one of the best references for estimating pedestrian and bicycle demand. Some lessons learned from this research included:

- Recognize an obvious but critical difference between biking and walking; although both are nonmotorized modes and often combined as such in regional models, the distance range (0.7 mile [1.1 km] average trip length for walk, 2.3 miles [3.7 km] for bike), network needs, user characteristics, and trip purpose types are substantially different between the two modes.
- The relationship between the built environment (land use) and travel network are extremely important, particularly for walking and biking. Walking and biking demand levels are heavily predicated on the number and variety of opportunities accessible within comfortable travel distance/time envelopes.
- Acceptable trip distances vary by trip purpose: travelers seem more willing to travel longer distances for trips to work (about 1 mile for pedestrians, 4 miles for cyclists) than for personal business, shopping, or socializing (0.5 to 0.7 miles [0.8 km to 1.1 km] for pedestrians, 1.0 to 1.5 miles [1.6 to 2.4 km] for cyclists).
- Persons living in more compact, mixed-use settings tend to make more trips as simple tours (single-purpose, one-stop journeys), while those in automobile-oriented settings make more multi-stop complex tours; the choice of walk, bike, and transit as modes was found to be much more likely with simple tours.
- The natural environment is of much greater consequence to nonmotorized travelers than those traveling by automobile or transit: steep hills and topography that cause circuitous travel paths are barriers. Extremes in temperature, precipitation, and hours of daylight affect proclivity to walk or bike.
- Personal safety is a major concern to nonmotorized travelers, particularly in relation to exposure to motor vehicle traffic. In areas with higher traffic volumes or higher speeds, as in commercial areas, sidewalks and separated paths become more important considerations in the decision to walk or bike.
- Sociodemographic differences are observed between motorized and nonmotorized travelers, and between pedestrians and cyclists. In general, walking and biking rates peak in the youngest years, and then tail off with advancing age, although this is a trend more common in the United States than in other peer (Western) countries. Although women over 25 years of age have a higher percentage of walking than men, male cyclists outnumber females by almost four to one (again a trend highly indigenous to the United States).

The report identifies several analysis methods and tools that can be used to estimate the travel demand for walking and bicycling. The authors divide them into three major categories:

- *Tour-Generation and Mode-Split Models*. Pedestrian and bicyclist models can be used for generating trip tours as well as predict mode choice as part of activity-based models (see chapter 6 on travel demand modeling for a more detailed description of tour-based and activity-based modeling).
- *GIS-Based Walk-Accessibility Model*. Estimates of walk trip generation and mode split can come from geographic information system (GIS) tools and data. Similar types of analyses have been conducted in several U.S. cities. The approach estimates measures of accessibility to or from any point by any mode and by type of attraction. By comparing modal accessibilities, the model can then estimate mode split and create walk trip tables by trip purpose.
- *Enhancements to Trip-Based Models*. The conventional four-step modeling process can be modified by introducing a "pre-mode split" step, which first divides trips into intra- versus interzonal groups, and then performs a mode-split step specific to those groups. This allows the analysis to take into account zone-specific characteristics that could influence pedestrian and bicyclist demand. Some of these variables could include: number of local intersections within one-half mile (0.8 km) of each zone, households within one-half mile of each zone, retail employment within one-half mile of each zone, total employment within one-half mile of each zone, door-to-door travel time, zone-to-zone travel time, and auto ownership. See chapter 6 on travel demand modeling for a discussion of the four-step model.

Table 13-9. Different Tools for Estimating Pedestrian and Bicyclist Demand
Application Category/Approach
Regional Planning
Trip generation: trip generation augmented by special models that estimate nonmotorized productions based on density, land-use mix, accessibility, and/or urban design.
Auto ownership: context-enhanced auto ownership as input to nonmotorized trip production.
Destination choice: separate models to forecast trip generation for inter- and intrazonal trips based on land-use/accessibility context factors.
Mode choice: Special context-sensitive models to estimate nonmotorized mode split for intrazonal trips.
Activity/tour-based models: projected replacement to trip-based models, spatial resolution reduced to parcel level and individual travelers—remove traffic analysis zone (TAZ) aggregation bias in clarifying nonmotorized mode use; travel treated as simple versus complex tours which impact mode choice.
Corridor, Subarea, and Transit Oriented Development Planning
Scenario planning tools: Estimation of nonmotorized travel and vehicle miles traveled reduction in relation to alternative land-use and transportation investment scenarios.
Walk trip models: Models that resemble four-step regional approach, but employ "pedestrian" zones instead of TAZs; create trip tables and assign to facilities.
Facility Planning
Factoring and sketch-planning methods: attempt to predict facility-demand levels based on peer comparisons, application of trip generation rates to sociodemographic data, association with other related data/trends, proximity rules, etc.
Direct demand: Project bicyclist or pedestrian volumes based on counts related to various context and facility factors through regression models.
Aggregate demand: Seek to quantify relationship between overall demand (e.g., annual regional bike trips) and underlying factors, often as a way of gauging importance of infrastructure types and extents.
Route or path choice: Methods that try to account for the characteristics of a transportation network or its users in determining route choice, and for identifying network improvement priorities.

Source: Kuzmyak et al., 2014 Reproduced with permission of the Transportation Research Board.

Table 13-9 summarizes the different types of models that can be used for walking and bicycling analysis. The NCHRP report also described several other tools, such as walk trip generation and flow models, the Portland Pedestrian Model, and facility demand models. The reader is referred to NCHRP 770 for more detailed information on these analysis tools. In addition, Alisar et al. [2015] provide a good overview of how travel demand models can be used in pedestrian and bicycling analysis.

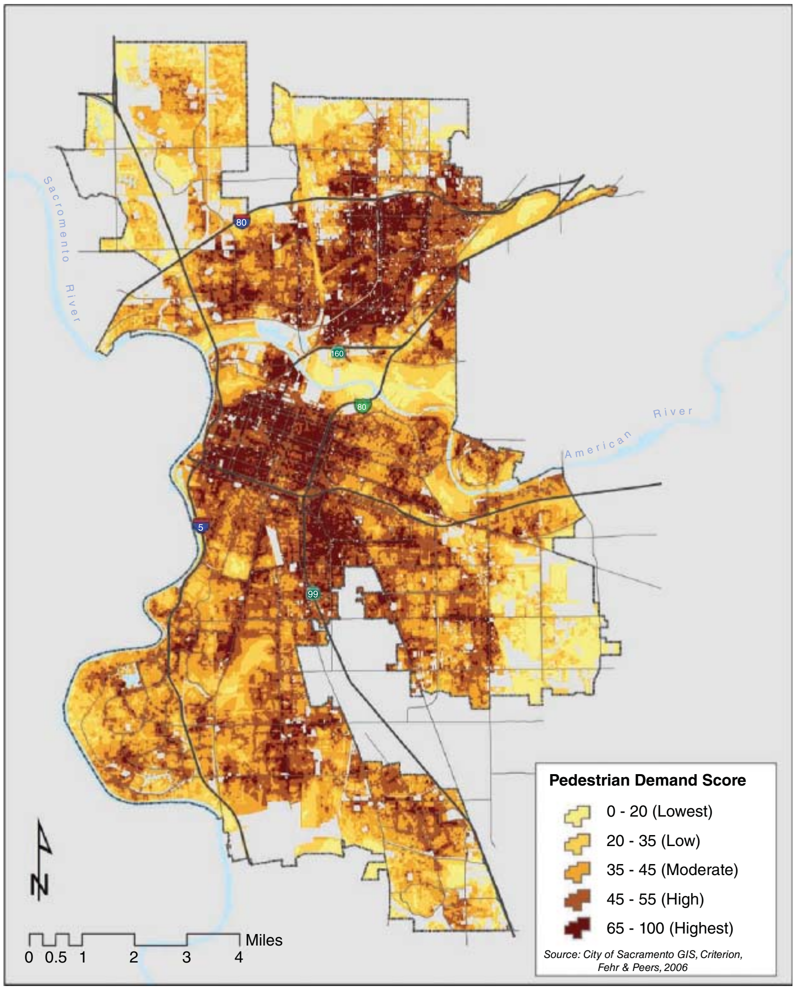
The U.S. Environmental Protection Agency's (EPA's) Smart Growth Index was one of the earliest efforts to analyze a community for walking and bicycling use. [EPA, 2003] This is a GIS-based sketch tool for comparing alternative land-use and transportation scenarios, and evaluating the outcomes using indicators of community and environmental performance. Transportation inputs to the index include such things as sidewalk completeness, pedestrian route directness, street network density, street connectivity, bicycle network, transit stop coverage, regional accessibility, parking demand, parking supply, transit service density, and rail transit boardings. The following factors are among those recommended by the U.S. EPA in developing its Smart Growth Index for identifying locations that have the greatest potential to serve a large number of cyclists or pedestrians: population density, employment density, mix of land uses, zero-vehicle households, proximity to transit, and proximity to a university. Figure 13-5 shows the application of this Index approach to Sacramento.

4. *Pedestrian and Bicyclist Suitability, Level of Service, and Level of Traffic Stress Analysis*

Suitability and level of service (LOS) analysis for bicycling and walking is used by many transportation planning agencies to identify network deficiencies and to determine what type of improvements are needed. [Landis et al., 2005; Sisiopiku et al., 2007] Some analysis methods determine the relative comfort of a bicyclist given the conditions of a particular street segment, such as FHWA's Bicycle Compatibility Index [FHWA, 1998] and the Bicycle Level of Service (BLOS) model. [Baltimore Metropolitan Council, 2004] These methods use variables such as the amount of motor vehicle traffic, traffic speed, degree of separation between the bicyclist and moving traffic, percentage of heavy vehicles, presence of on-street parking, and the condition of the pavement surface to determine bicycle compatibility. Figure 13-6 shows a bicycle level of service analysis for Baltimore.

Pedestrian suitability (or walkability) models are in a more formative stage. Pedestrian suitability refers to the ease, comfort, and safety of walking, and is influenced by network connectivity, accessibility, the sense of safety (real and perceived), and the quality of the pedestrian environment. A suitability analysis can account for physical deficiencies in the pedestrian environment to determine where walkability is low and improvements may be needed. GIS applications are particularly useful for performing suitability analyses. Early research focused primarily on quantifying walkway space, flow characteristics, and pedestrian capacity analysis. Today more advanced simulation models (as discussed in the next section) can be used to conduct this analysis.

Figure 13-5. Application of a Smart Growth Index for Pedestrian Demand, Sacramento, California



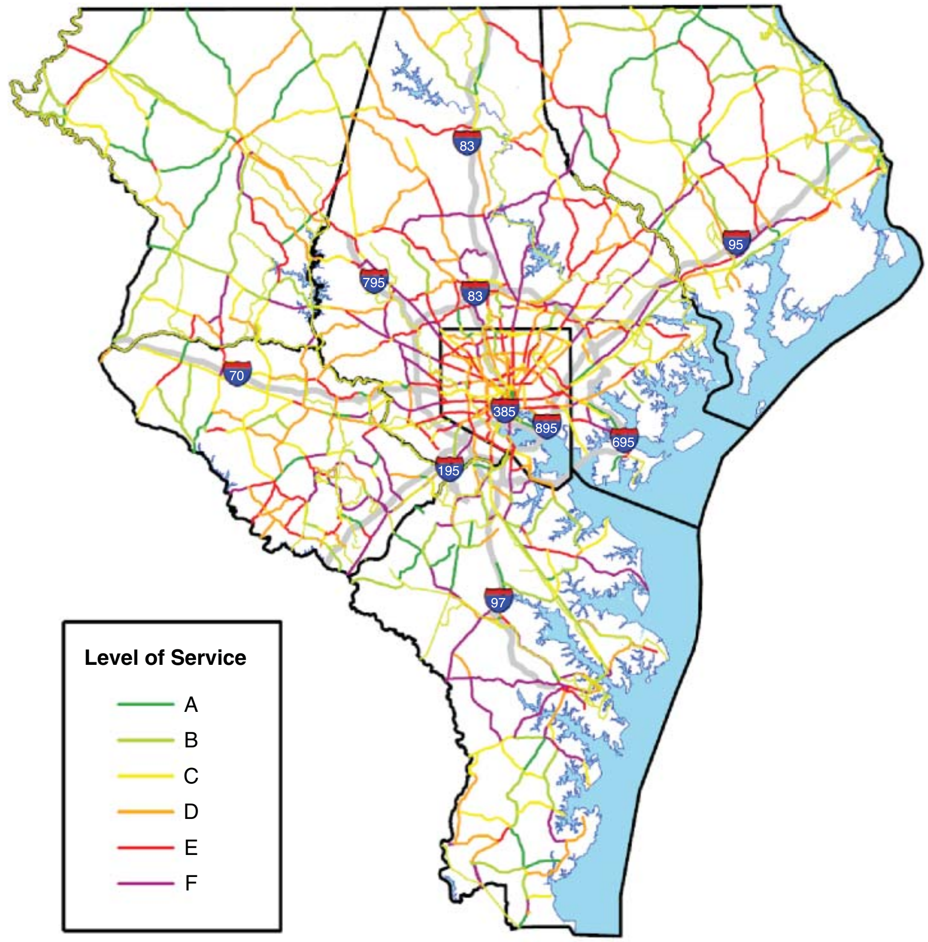
Source: City of Sacramento, 2006

As noted earlier, many bicycle studies are now using the concept of level of traffic stress as a means of understanding bicycle networks from a user perspective. This measure is intended to account for limitations in the BLOS approach, which include the need for traffic volume and lane width data (often not available networkwide), and an unclear correspondence between the BLOS level and user tolerance. The basis for the analysis is the identification of criteria that can be used to classify road segments by level of traffic stress depending on "traffic characteristics (for example, road width, traffic speed, the presence of a parking lane) and whether bikes are in mixed traffic, in bike lanes, or on segregated paths. A low level of stress can be achieved in mixed traffic on local streets with low traffic speeds. As the number of lanes, traffic speed, and traffic volume increase, providing a low level of stress requires progressively more protective measures such as dedicated bike lanes and ultimately physically segregated bikeways." [Mekuria, Furth, and Nixon, 2012] This concept can also be used to evaluate network connectivity for a specified level of traffic stress by using "percent trips connected" (the percentage of trips in the regional trip table that are connected without exceeding the specified level of stress and without undue detour) and the "percent nodes connected" (the percentage of node-to-node pairs in the street network that are connected without exceeding the specified level of stress and without undue detour) as evaluation criteria.

The Transportation Research Board's *Highway Capacity Manual* includes analysis procedures to evaluate both bicyclist and pedestrian delay at signalized intersections. [TRB, 2010] In both cases the measure for quality of service is related to the amount of delay experienced when traveling through the intersection; specific time thresholds have been established to correspond with the familiar LOS A to F scale. Each measure is directly related to the signal timing and green time allocated to the particular crossing movement. More recent pedestrian analyses have also investigated factors affecting a pedestrian's level of comfort in a given road corridor. These models examine quality-related comfort, convenience, and safety factors of the pedestrian environment through a mix of qualitative and quantitative analysis elements.

For example, Fort Collins, Colorado, includes categories of "visual interest and amenity" and "security" in its evaluation of pedestrian LOS. It has also developed its own local multimodal LOS guidelines that address bicyclist and

Figure 13-6. Bicycle Level of Service, Baltimore, Maryland



Source: Baltimore Metropolitan Council, 2004

pedestrian operations. Another approach taken in Charlotte, North Carolina, is to consider the pedestrian and bicyclist impacts of roadway capacity improvements as they occur.

The Pedestrian and Bicycle Information Center is an excellent source for analysis, audit, and data tools that can be used for pedestrian and bicyclist planning (see http://www.pedbikeinfo.org/planning/tools_audits.cfm).

5. Pedestrian and Bicyclist Safety Analysis

Safety is the most important goal in transportation planning and design. Many analysis tools are available for identifying crash "hot spots" and determining the most appropriate countermeasures. Some of the tools include:

- Pedestrian and Bicycle Crash Analysis Tool (PBCAT)
- Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE)
- Bicycle Countermeasure Selection System (BIKESAFE)

These tools are described at the FHWA website for transportation safety (see http://safety.fhwa.dot.gov/tools/data_tools/fhwasa09002/). Chapter 23 on integrating safety into the transportation planning process provides more detail on transportation safety analysis.

6. Simulation and Network Models

Traffic operations modeling and microsimulation tools also provide new methods to quantify and evaluate interactions among motor vehicles, bicyclists, and pedestrians, primarily at intersections. These models specify the behavior and desired paths through a network for each individual, allowing the analyst to quantify delay for each mode due to interactions such as right-turning conflicts. In addition, pedestrian flow models simulate pedestrian interactions and design requirements in settings such as transit platforms, shopping malls, evacuation routes, and sports stadiums. Figure 13-7 shows a simulated intersection crossing for both pedestrians and bicyclists.

Figure 13-7. Multimodal Intersection Simulation Using VISSIM™

Source: Courtesy of WSP | Parsons Brinckerhoff. Vissim 7.00 -15

Space Syntax™ is another suite of modeling tools and simulation techniques for analyzing pedestrian movements and predicting pedestrian volumes. Space Syntax™ uses the layout and connectivity of urban street grids to generate movement potentials, which it then compares to sampled pedestrian counts at key locations and land-use indicators, such as population density. The resulting correlations are used to predict pedestrian volumes on a street-by-street level for an entire city. Space Syntax™ was created at the University College of London in the mid-1980s and is widely used throughout Europe and Asia.

7. Transportation Impact Studies

Although not an analysis tool by themselves, transportation impact studies, whether as stand-alone documents or as chapters in an environmental document, are intended to assist decision makers and the public in the project review process. As such, they serve as an important platform for the analysis of pedestrian and bicyclist transportation needs. The National Environmental Policy Act (NEPA), the federal law governing environmental analysis, as well as many state environmental laws, requires a full disclosure of transportation impacts, including those on pedestrians and bicyclists, not just vehicular traffic impacts (see chapter 19 for more discussion on site-impact analysis).

Transportation impact analyses should evaluate the effects of new developments on vehicle movements, transit ridership, and bicycle and pedestrian trips. This evaluation should examine not transportation access to a site, but on-site circulation as well. The analysis scope might be even broader in jurisdictions that define neighborhood livability, land-use compatibility, transportation demand management, and/or quality of life objectives. The significance criteria that follow represent a minimum standard for assessing a broad set of transportation impacts. They are generally organized around the themes of identifying impacts that disrupt existing operations, interfere with plans for the future, conflict with adopted policies, and/or create new demand beyond that anticipated in existing planning documents.

Pedestrian and bicyclist impacts are considered significant if any of the following apply:

A project disrupts existing pedestrian and bicycle facilities. This can include adding new vehicular, pedestrian, or bicycle traffic to an area experiencing safety concerns (such as on a crosswalk adjacent to a school), particularly if the added traffic reduces the number of opportunities for pedestrians to cross at unsignalized locations or causes queues to spill back through pedestrian crossings. (Note: Particular attention should be paid to on-street bicycle facilities on roadways with proposed driveways.)

A project interferes with planned pedestrian or bicycle facilities. In existing and/or planned urbanized areas, main streets, or pedestrian districts, this can include impacts to the quality of the walking and bicycling environment, such as reduced sidewalk widths. This includes failure to dedicate right-of-way for planned on- and off-street bicycle facilities included in an adopted bicycle master plan, or to contribute to construction of planned bicycle facilities along the project's frontage.

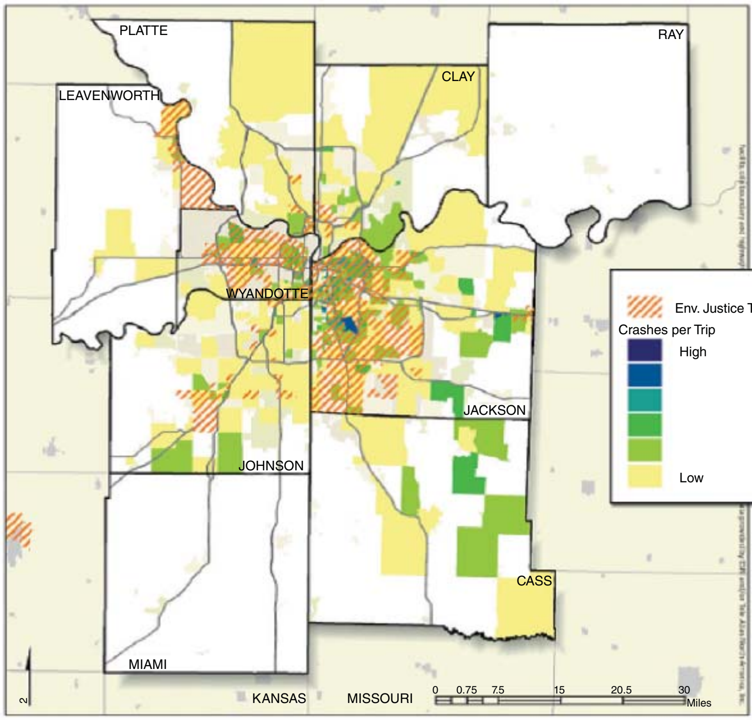
A project conflicts or creates inconsistencies with adopted pedestrian and bicyclist system plans, guidelines, policies, or standards. This can include project designs that are in conflict with policy language, such as pedestrian and bicyclist directness, connectivity, and network completeness.

8. *Environmental Justice Analysis*

Transportation planning should consider the disproportionate impacts of transportation benefits and costs on different population groups. Environmental justice analysis examines such impacts on a study area's low-income and minority populations, defined as: [Mid-America Regional Council (MARC), 2013]

- *Minority Population*—Any identifiable group(s) of minority persons who live in geographic proximity. This includes persons who are Black/African-American, Hispanic or Latino, Asian American, American Indian and Alaskan Native, and native Hawaiian and other Pacific Islander.
- *Low Income*—A person whose median household income is at or below the U.S. Department of Health and Human Services poverty guidelines.

Figure 13-8. Environmental Justice Analysis of Pedestrian Crashes, Kansas City, Kansas



Source: MARC, 2013

A typical environmental justice analysis from the Mid-America Regional Council (MARC) is shown in Figure 13-8. The analysis used GIS to identify the locations of environmental justice census tracts as compared to pedestrian crashes. The accompanying statistical analysis in Table 13-10 shows that a disproportionate number of pedestrian crashes occur in the environmental justice tracts. This would suggest that investment priorities should focus on reducing the number of crashes occurring in low-income and minority neighborhoods. See City of Seattle [2012] for another good example of an environmental justice analysis.

Table 13-10. Environmental Justice Analysis of High-Severity Pedestrian Crashes, Kansas City, Kansas, 2009–2012

	EJ Areas	Non-EJ Areas	Total
Total number of high-severity pedestrian crashes	183	209	392
Total Percentage	46.7%	53.3%	100%
Total Population	620,937	1.347,932	1,968,869
Population Percentage	31.5%	68.5%	100%

Source: MARC, 2013

D. Prioritizing Projects/Strategies

States, metropolitan areas, and municipalities do not have enough funds to meet all of the needs identified by the planning process. Thus, an important step in the planning process is to prioritize the many different projects and strategies that can improve the bicycling and walking experience. [Swords et al., 2004] One of the challenges facing such a process for pedestrian and bicyclist planning (especially if the process is based on benefit/cost analysis) is that, when compared to large-scale road improvements, pedestrian and bicycle projects usually do not have the same aggregate level of time or cost savings as road projects. For metropolitan areas, in particular, pedestrian and bicycle projects could be competing with thousands of projects. In response, many states and MPOs have set aside funds only for pedestrian and bicycle projects. Choosing which projects to fund in these programs requires a process for establishing a priority ranking among the eligible projects.

One of the ways to prioritize projects is by ranking them according to the score each receives in a suitability analysis. Table 13-11 shows how this approach was used in the San Diego region. In this approach for active transportation projects (including pedestrian and bicycle projects), the ratings compared the degree to which each capital project satisfied 16 criteria. [San Diego Association of Governments (SANDAG), 2014] Another set of criteria was used for noncapital projects. Note that the criteria are applied to projects once 25 percent of the funds have been spent on disadvantaged communities, a policy decision of the SANDAG Board of Directors. Geographic equity is thus an important consideration in the prioritization process.

Another key aspect of prioritizing projects is the phasing of implementation. With limited resources, it is often good practice to consider the likelihood that projects will be ready for implementation if funds are assigned to them in the regional program. This is especially true where local governments are expected to provide a match to federal or state funds.

Table 13-11. Capital Project Prioritization Points for Active Transportation Projects, San Diego Region

No.	Category	Criteria	MPO Points Possible	%
Project Readiness				
1	Completion of Major Milestones	Projects are eligible for points following the completion of each phase: • Community active transportation strategy/neighborhood-level plan/corridor study • Environmental clearance • Right-of-way • Final design	Up to 12 2 4 4 10	13%
2	Connection of Regional Bicycle Network	Project directly connects to regional bikeway network or Project is a part of the regional network	Up to 8 6 8	5%
3	Completes Connection/Linkage in Local Bike Network	Closes gap between existing bicycle facilities (guidance will include definition of gap and will include situations where there exists an undesirable change in facility type)	8	5%
4	Completes Connection/Linkage in Existing Pedestrian Network	Closes gap in the existing network	8	5%
5	Connection to Transit	*Bike improvements proximity:* Within 1.5 miles (2.4 km) of regional transit station *Pedestrian improvements proximity:* • Within 1/4 mile (0.4 km) of a local transit stop • Directly connects to a local transit stop • Within 1/2 mile (0.8 km) of a regional transit station • Directly connects to a regional transit station	Up to 12 6 2 4 4 6	8%
6	Safety Improvements and Overcoming Barriers	Completes connection in existing network at location with documented safety hazard or accident history. 1–2 correctable crashes involving non-motorized users within the last 7 years 3–4 correctable crashes involving non-motorized users within the last 7 years 5 or more correctable crashes involving non-motorized users within the last 7 years and/or creates access or overcomes barriers in area where hazardous conditions prohibited safe access for bicyclists and pedestrians	Up to 12 2 4 6 6	8%

(*continued*)

Table 13-11. (*Continued*)

No.	Category	Criteria	MPO Points Possible	%
		Quality of Project		
7	Effectiveness and Comprehensiveness of Proposed Bicycle, Pedestrian, and/or Traffic Calming Measure	How well will the proposed traffic calming address the identified need in the project area? How well will the proposed pedestrian improvements address the identified need in the project area? How well will the proposed bicycle improvements address the identified need in the project area?	Up to 15 Up to 5 Up to 5 Up to 5	9%
8	Relationship to Program Objectives	How well does the project meet the program objectives?	Up to 18	11%
9	Innovation	Is the project an FHWA or state experimentation effort? Does the project propose solutions that are new to the region, and have the potential to serve as a replicable model for other cities in the region? Does the project utilize innovation solutions such as those listed in the NACTO Urban Bikeway Guide?	Up to 8 4 Up to 4	5%
		Supporting Policies and Programs		
10	Complementary Programs	Is the project accompanied by programs that complement the capital improvements, such as an awareness campaign, education efforts, and increased enforcement?	Up to 3	2%
11	Supportive Policies and Plans	Demonstrated policy language in approved plan, or a completed community active transportation strategy/plan	Up to 3	2%
		Formula Scores		
12	Demand (GIS Analysis)	Factors not contributing to score: population and employment, population and employment densities, intersection density, vehicle ownership, and activity centers	Up to 15	9%
13	Matching Funds	Matching funds can be from any of the following sources: Identified and approved capital funding from identified source Approved match grant In-kind services	Up to 10	6%
14	Cost/Benefit	Subtotal score (not counting matching points)/Grant application amount	Up to 10	6%
15	Public Health	Does the project improve public health by targeting populations with high-risk factors for obesity, physical inactivity, asthma, or other health issues?	Up to 10	6%
16	California Conservation Corps	Has the applicant sought California Conservation Corps or qualified Corps participation on the project?	0 to −5	−3%
		Total Points	**160**	
		Total Score After Reaching 25% for Disadvantaged Communities		

Source: SANDAG, 2014

NCHRP Report 803, *Pedestrian and Bicycle Transportation Along Existing Roads—ActiveTrans Priority Tool Guidebook*, is a step-by-step methodology for prioritizing improvements to pedestrian and bicycle facilities, either separately or together as part of a Complete Streets evaluation approach (see chapter 9). The methodology identifies nine factors that are commonly considered in prioritization and that can reflect a range of community/agency values. They include:

- *Stakeholder Input*—The amount of public feedback in support of (or against) a pedestrian or bicycle facility improvement at a particular location.
- *Constraints*—The relative level of difficulty in implementing a pedestrian or bicycle project.

- *Opportunities*—The ability of an agency to take advantage of resources that can support project implementation.
- *Safety*—The risk of a pedestrian or bicyclist being involved in a traffic collision (or crash).
- *Existing Conditions*—Physical conditions that have an impact on pedestrian or bicyclist safety, comfort, or demand, such as whether or not a sidewalk exists, the number of travel lanes, or the presence of a buffer.
- *Demand*—Existing or potential pedestrian and bicyclist activity levels.
- *Connectivity*—The degree to which a project allows pedestrians or bicyclists to travel comfortably and continuously throughout their community.
- *Equity*—The degree to which opportunities for safe and convenient pedestrian and bicyclist travel are distributed evenly to all groups within a community.
- *Compliance*—Whether or not existing infrastructure is compliant with current pedestrian and bicycle standards and guidelines.

Table 13-12 shows how important some of these factors can be given different types of prioritization contexts. Tables 13-13 and 13-14 provide more information on two of the prioritization factors to illustrate the types of data and data sources necessary for this tool, but also the type of information that could be used in any prioritization scheme.

Note in Table 13-14 the use of variables that represent total crashes. Another way of representing such information that accounts for different segment characteristics is to normalize, in this case by unit length, so that all projects compete on the same basis.

E. Producing Planning Products

A planning process can result in many different products, ranging from recommended projects to changes in regulations and policies. For pedestrian and bicyclist transportation, in particular, many different outcomes are possible. Strategies and programs for bicyclists and pedestrians require a comprehensive strategy, encompassing the five E's defined by the League of American Bicyclists and commonly used in safety programs:

- *Engineering*—Physical measures constructed to create safer conditions for cyclists and pedestrians.
- *Education*—Raising awareness and sharing information with drivers, pedestrians, and cyclists on best ways to share the road.
- *Encouragement*—Promotion and advocacy of bicycling and pedestrian amenities.
- *Enforcement*—Targeted police enforcement supports neighborhood and community goals for improving safety.
- *Evaluation and Planning*—Level to which walking and bicycles are used as a transportation mode and ways to increase this usage.

Readers are referred to the Fredericksburg, Virginia, Bicycle and Pedestrian Plan [Fredericksburg Area MPO, 2013] and [Walsh, 2012] for good examples of the types of actions that can be taken in each category.

The following sections describe possible products resulting from a pedestrian and bicyclist planning process.

1. Master Plans

Walking and bicycling master plans typically include the following topics:

- *Introduction*. The introduction usually provides background on the pedestrian and/or bicyclist planning process in the community. A description of the extent of citizen and community involvement in development of the plan, including but not limited to letters of support, could be included in this section.

Table 13-12. Illustrative Prioritization Contexts and Relevance of Criteria

	Stakeholder Input	Constraints	Opportunities	Safety	Existing Conditions	Demand	Connectivity	Equity	Compliance
Corridor									
Given 20 high pedestrian-crash corridors in a region, identify four to receive grant funding for safety enhancements.	Ø	Ø	Ø	•	•	•	o	•	Ø
Given 10 candidate corridors for side path construction, identify the top three for implementation.	•	Ø	•	•	•	•	•	Ø	o
Segment									
Given a planned bicycle network consisting of approximately 500 miles (804.7 km) of recommended facilities (bike lanes, cycle tracks, shared lane markings, etc.), select 50 miles (80.7 km) for implementation in the next five years.	•	•	•	Ø	•	•	•	•	o
Given a neighborhood where sidewalks are absent, select 30 segments to construct sidewalks over the next three years.	•	Ø	Ø	•	•	•	Ø	•	o
Intersection/Crossing									
Given a regional trail with 50 unsignalized roadway crossings, identify 12 to implement safety enhancements.	•	o	Ø	•	•	Ø	o	Ø	•
Given 500 locations where curb ramps are missing in a municipality, identify an initial 50 locations for ramp installation using available grant funding.	•	Ø	Ø	Ø	o	•	Ø	•	o
Given a city with more than 500 signalized intersections, identify the 30 priority traffic signals to be converted to accessible pedestrian signals when they are upgraded or replaced.	•	o	Ø	•	•	•	Ø	•	•
Area									
Given a county with 30 elementary schools, rank the designated school zones to determine which ones should be further evaluated for future pedestrian improvements.	•	o	Ø	•	•	Ø	o	•	•
Given a city that consists of 15 defined neighborhoods, prioritize two for the initial focus of a Complete Streets evaluation.	Ø	o	o	•	•	•	•	•	•
Given a city of 20 neighborhood commercial centers, rank all 20 centers in terms of their need for additional bicycle parking.	•	o	Ø	o	•	•	o	Ø	o

• = Very Relevant   Ø = Less Relevant   o = Not Likely Relevant

Source: Lagerwey et al., 2015, Reproduced with permission of the Transportation Research Board.

Table 13-13. Stakeholder Input Variables				
	Relevance		Potential	
Example Variables	**Ped**	**Bike**	**Location**	**Data Sources**
Number of public comments about specific issue received by phone or online from citizens	•	•	S, CR, Co, A	Requests, complaints compiled on a map or in a database
Identification/inclusion of a particular improvement location in adopted plans	•	•	S, CR, Co, A	Comprehensive plans, master plans, transportation plans, etc.
Number of comments received at public meetings or through a public survey during a master planning process	•	•	S, CR, Co, A	Comments compiled on a map or in a database
Supported by advisory committee or decision-making body	•	•	S, CR, Co, A	Documentation such as meeting minutes or memoranda

• = Very Relevant   Ø = Less Relevant   o = Not Likely Relevant

S = Segment   CR = Crossing   Co = Corridor   A = Area

Source: Lagerwey et al., 2015, Reproduced with permission of the Transportation Research Board.

Table 13-14. Safety Input Variables				
	Relevance		Potential	
Example Variables	**Ped**	**Bike**	**Location**	**Data Sources**
Total number of pedestrian/bicycle crashes	•	•	S, CR, Co, A	Police crash database, often available at the state or local level
Fatal and severe injury pedestrian/bicycle crashes	•	•	S, CR, Co, A	Police crash database, often available at the state or local level
Pedestrian/bicycle crash rate	•	•	S, CR, Co, A	Police database combined with measure of exposure
Proportion of pedestrians walking in the roadway	Ø	o	S	Pedestrian counts (manual or video)
Proportion of pedestrians complying with "don't walk" signals	Ø	o	Cr	Pedestrian counts (manual or video)
Proportion of bicyclists complying with red lights	o	Ø	Cr	Bicycle counts (manual or video)
Proportion of motorists complying with right-turn-on-red restrictions	Ø	Ø	Cr	Vehicle counts (manual or video)
Proportion of motorists yielding to pedestrians in crosswalks	Ø	o	Cr	Vehicle counts (manual or video)
Number of "near misses" involving pedestrians and bicyclists	Ø	Ø	S, CR, Co, A	Multimodal counts (manual or video)

• = Very Relevant   Ø = Less Relevant   o = Not Likely Relevant

S = Segment   CR = Crossing   Co = Corridor   A = Area

Source: Lagerwey et al., 2015, Reproduced with permission of the Transportation Research Board.

- *Vision, Goals and Policies*. This section includes a definition of the community's vision for pedestrian and/or bicyclist transportation and desired outcomes.
- *Existing Conditions*. This section paints a comprehensive picture of existing facilities, including an inventory of the facilities and assets existing in the study area, the condition of these assets (data usually coming from surveys of existing street conditions, collision data, and community outreach), and an assessment of current performance levels. This section also describes current land uses and characteristics that will influence the propensity to use pedestrian or bicycle facilities.
- *Future Problems and Challenges*. This section identifies future locations where, because of development growth or increases in traffic volumes, the pedestrian and bicyclist environment will deteriorate. This usually includes

estimated performance measures and the results of suitability metrics. GIS techniques may be particularly useful for mapping and identifying areas where the need for improvements exists. A description of the methodology used to estimate future performance could be presented here or in an appendix.

- *Recommended Network*. This section defines the desired network based on the policies and objectives established in the beginning of the plan and opportunities for improvement in the network identified in the future problems section. In contrast to a bicyclist plan, a pedestrian plan sometimes does not have recommended pedestrian routes. It should be possible, however, to identify areas where pedestrian activities will be the most concentrated, such as the central business districts, transit stations, civic centers, commercial centers, schools, universities, and the like.
- *Support Facilities and Intermodal Connections*. Support facilities at or near the destination of a trip, including on transit vehicles or at transit stations, can play a large role in making walking and/or bicycling an attractive transportation alternative. Pedestrian master plans can also contain other elements, such as pedestrian-friendly site design guidelines and recommendations for development review.
- *Design Guidelines*. Design guidelines (sometimes created as a separate document or included in the appendix) are intended to identify and communicate the design elements necessary to improve pedestrian and bicyclist comfort levels.
- *Education and Enforcement*. One of the main goals of a plan is to provide facilities that help improve bicyclist safety. Safer facilities alone, however, will not ensure that no crashes will occur. As with motor vehicles, a combination of education and enforcement plays a large role in making pedestrian and/or bicyclist transportation safer.
- *Implementation: Capital Improvement Program*. The capital improvement program is one of the most important elements of a plan, in that it helps guide implementation. The content can include: (1) a consolidated list of all proposed improvement projects, (2) the priority or phasing for the implementation of each improvement, (3) the cost of each project, and (4) the anticipated source(s) of funding for each project.

2. Development Plans

Project site plans and proposed offsite improvements, including mitigation strategies, should be reviewed for consistency with local design standards, parking codes, and other adopted guidelines. Where local policies do not identify significance criteria for project impacts, the impacts should be considered significant if a project fails to provide accessible and safe pedestrian connections between buildings and to adjacent streets and transit facilities. Developers should be encouraged to coordinate with future capital investments by others, such as government agencies or other developers.

3. Trail and Greenway Plans

Trail and greenway plans concentrate on an offroad system of pathways that supplement sidewalks and bikeways. Accessibility for all should be part of the planning process (for example, considering the hard surfacing of trails). The paths or trails included should be planned and designed to meet the needs of various users, including bicyclists and pedestrians. Individual greenway and trail projects are typically addressed through a feasibility study and/or in a pre-engineering phase of a road project. Atlanta's Beltline project is an excellent example of an urban multiuse trail that has had a significant impact on development and neighborhood quality of life (see Figure 13-9).

4. Traffic Calming

Traffic calming programs are often a critical component of pedestrian and bicyclist planning. Many traffic calming measures enhance the pedestrian environment by reducing traffic speeds and volumes. Traffic calming can also be used to create a network of streets that encourages bicycling. Best practice examples can be found in U.S. cities such as Boulder, Colorado; Boston, Seattle; and Portland, Oregon. Good practice is well documented in *Traffic Calming: State of the Practice*, published by FHWA and ITE [Ewing, 1999], as well as the websites http://trafficcalming.org/ and http://www.pps.org/reference/livememtraffic/. See also chapter 9 on road and highway planning.

5. Streetscape Plans

Streetscape plans typically focus more on physical planning issues. Such issues could include traffic calming; streetscape and urban design improvements; improvements to pedestrian, bicycle, and motor vehicle flow; and removing barriers to improve accessibility, among others.

Figure 13-9. Example of an Urban Multiuse Trail, Atlanta's Beltline

Photo courtesy of Adam Rosbury

6. *Safe Routes to School*

Safe Routes to School (SRTS) was a federally funded program designed to increase the number of children walking and biking to school. The program was intended to integrate health, fitness, traffic relief, environmental awareness, and safety under one program. Many local and regional agencies have developed programs in recent years primarily in response to the federal program. Although it is no longer a stand-alone program, many states and local communities have continued with similar types of strategies.

7. *Safe Routes to Transit*

Safe Routes to Transit is similar in concept to the SRTS programs. Studies have shown that easy and safe access to transit services is one of the most important considerations in a traveler's decision to ride transit. Travel- demand models usually consider a distance of one-quarter mile (0.4 km) as the potential walk-to-bus-transit market area (one-half mile [0.8 km] for rail transit). The time to walk this distance is about 6 minutes, given an average walking speed of 3 to 4 feet per second (0.9 to 1.2 meters per second) or 2 to 2.7 miles per hour (3.2 to 4.3 kilometers per hour). Distances and travel times for different trip purposes are shown in Table 13-15.

Safe Routes to Transit programs are designed to promote bicycling and walking to transit stations by making walking and bicycling feeder trips easier, faster, and safer. Safe Routes to Transit projects usually focus on areas adjacent to or surrounding transit stations or stops. They may also address onsite pedestrian and bicycle accommodations.

Table 13-15. Assumed Distances for Modeling Pedestrian Trips by Trip Purpose

Type of Trip	Example Distance	Travel Time
Commute trip to work	3/4 mile (1.2 km)	20 minutes
Errands trip to bank	1/4 mile (0.4 km)	6 minutes
Incidental trip from parking	1/8 mile (0.2 km)	3 minutes

Source: City of Sacramento, 2006

8. Americans with Disabilities Act (ADA) Transition Plans

The ADA and subsequent interpretations by the Department of Justice require municipalities to prepare a plan detailing how they will make their streets and roads accessible to disabled individuals. These so-called *ADA transition plans* identify and prioritize access projects, estimate project costs, note the implementation schedule and funding strategies, and establish grievance and monitoring programs.

The ADA transition plan should be coordinated with pedestrian master plans to provide consistency in all forms of pedestrian planning. Recent litigation has concluded that jurisdictions are responsible not only for curb ramps at intersections—typically included in transition plans—but also for the area between the intersections. In *Barden v. Sacramento*, the U.S. Supreme Court ruled that cities and other public entities must make all public sidewalks accessible, which includes addressing barriers such as missing or unsafe curb cuts on the public sidewalk system, as well as barriers that block access along the length of sidewalks.

F. Monitoring Plan Progress

The final step in the pedestrian and bicyclist planning process is to monitor the progress occurring with respect to goals and objectives. This monitoring is usually tied to the performance measures identified early in the process. An example of such monitoring is shown in Table13-16, which shows the report card prepared periodically in Seattle to monitor the degree to which goals are being achieved.

Key References

The following references provide useful guidance on planning for pedestrian and bicyclist transportation.

- Ewing, R. and K. Bartholomew. 2013. *Pedestrian- and Transit-Oriented Design*. American Planning Association and the Urban Land Institute.
- Federal Highway Administration. 2003. *Bicycle and Pedestrian Transportation Planning Guidance*. Accessed at http://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/inter.cfm
- Institute of Transportation Engineers. 2010. *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach: An ITE Recommended Practice*.
- Transport for New South Wales. 2015. *Active Transport Planner's Toolkit*. Accessed at http://www.transport.nsw.gov.au/about/transport-planner-resources/active-transport-planners-toolkit.
- Victoria Transport Policy Institute. 2016. *Pedestrian and Bicycle Planning, Guide to Best Practices*. Accessed at http://www.vtpi.org/nmtguide.doc.

VI. PEDESTRIAN AND BICYCLIST PLANNING/DESIGN ISSUES

Although transportation planning can recommend actions appropriate for both pedestrians and bicyclists, some issues are specific to each mode. This section discusses some of the mode-specific issues that engineers and planners often face when planning for pedestrian and bicyclist transportation.

A. Bicycle Network/Facility Design

When designing for bicycle facilities, it is important to, (1) know the travel-related characteristics of the bicyclist, (2) follow design guidelines and standards established for different bikeway types, (3) make certain that transition areas (where facilities begin and end) are safe for both bicyclists and motorists, and (4) address not only the need for additional operating space, but also any existing spot hazards as well as ongoing maintenance of the facility.

1. What type of bicyclist is most likely to use a facility?

Bicycles are legally classified as vehicles in most states and are therefore subject to the same rules and responsibilities as all other vehicles. One of the first steps in determining appropriate design for bicycle facilities is to determine the characteristics of the users, because it is the bicyclist who determines how the bike facility will be used. In a 1994 document, *Selecting Roadway Design Treatments to Accommodate Bicyclists*, FHWA stated, "any roadway treatments intended to accommodate bicycle use must address the needs of both experienced and less experienced riders."

Table 13-16. Performance Monitoring of Bicycle Program in Seattle

Goal	Performance Measure	Baseline Measurement	Performance Target	2011 Evaluation
Goal 1: Increase use of bicycling in Seattle for all trip purposes. Triple the amount of bicycling in Seattle between 2007 and 2017.	Number of bicyclists observed at counting locations throughout Seattle	2007 counts	Triple number of bicyclists between 2007 & 2017	2007 downtown counts = 2,273 2011 downtown counts = 3,330
Goal 2: Improve the safety of bicycling throughout Seattle. Reduce the rate of bicycle crashes by one third between 2007 and 2017.	Number of reported bicycle crashes per total number of bicyclists counted and annual traffic volumes	2007 collision rate	Reduce the bicycle crash rate by one third between 2007 & 2017	2007 collision rate = 0.158 2011 collision rate = 0.105
Objective 1: Develop and maintain a safe, connected, and attractive network of bicycle facilities throughout the city.	Percentage of Bicycle Facility Network completed	67.6 miles (108.8 km) of existing facilities (in 2007)	Implement 450 miles (724 km) of recommended facilities by 2017 (includes existing)	67.75 miles (109 km) with 67.6 miles of existing facilities prior to the adoption of the 2007 BMP (52.8% not including the facilities that were existing prior to 2007)
Objective 2: Provide supporting facilities to make bicycle transportation more convenient.	Number of bicycle racks installed through the SDOT Bicycle Parking Program		Provide 6,000 racks by 2017 (includes existing)	806 bicycle racks installed between 2007 & 2011 + 3,000 existing bicycle racks = 3,806
Objective 3: Identify partners to provide bicycle education, enforcement, and encouragement programs.	Number of Seattle Bicycling Guide Maps distributed	23,338 maps distributed in 2005	150,000 bicycle maps to be distributed between 2007 & 2017	Approximately 292,780 maps distributed between 2007 & 2011
Objective 4: Secure funding and implement bicycle improvements.	Percentage of targeted SDOT staff who participate in training on bicycle issues	Counted in 2007	100% of targeted staff participating in training every year	SDOT has not tracked this metric
	Number of bicycle project grant applications applied for and obtained for bicycle programs	Tracked in 2007	At least one grant application for every available funding opportunity	2008 applied for 3 grants & received 2 – 2009 applied for 4 grants & received 3 – 2010 applied for 4 grants & received 4 – 2011 applied for none – 2012 applied for 7, all pending
	Number of Bicycle Spot Improvements completed	Counted in 2007	Depends on needs & priorities set for each year	33 on-street spot improvements

Source: City of Seattle, 2012

[Wilkinson et al., 1994] Whereas in the 1990s and early 2000s this was defined by level of service calculations, as described earlier, many studies have now adopted a "level of traffic stress" estimation that relates directly to the type of bicyclist using a facility.

The concept of providing a user-oriented metric for planning and designing bicycle facilities has taken several forms. AASHTO, in its bicycle design guide, adopted the skill level of bicycle users as an important factor in designing bicycle facilities. [AASHTO, 2012] More experienced cyclists are confident riding on high-speed roads with or without designated bicycle facilities. At the other end of the skill spectrum, children often lack the experience of many older riders. AASHTO defined three types of bicycle users:

Group A — Advanced or experienced riders generally use their bicycles as they would a motor vehicle. Their primary purpose for riding is to reach a destination with minimum delay. They are comfortable riding with motor vehicle traffic.

Group B — Less confident adult riders use their bicycles for transportation but avoid roads with fast traffic unless there is ample room for safe motor vehicle passing. They are comfortable riding on neighborhood streets and shared-use paths.

Group C — Children will not likely ride very fast, but will still need access to such destinations as schools and parks. Streets with low motor vehicle speeds and well-defined separation between vehicles and the child bicyclist are preferred.

The city of Portland, Oregon, one of the leading municipal governments in the United States with regard to bicycle planning, has identified four categories of bicyclists: "The Strong and the Fearless," "The Enthused and the Confident," "The Interested but Concerned," and nonriders, called the "No Way, No How" group. [Geller, 2015] As noted by Geller, "The Strong and the Fearless" are the people who will bicycle regardless of roadway conditions. They are "bicyclists;" riding is a strong part of their identity, and they are generally undeterred by roadway conditions. "The Enthused and Confident" are those who are comfortable sharing the roadway with automobiles, but they prefer to do so operating on their own facilities. "The Interested but Concerned" group are curious about bicycling and like riding a bicycle, but they are afraid of sharing the road with automobiles. The "No Way, No How" group is not interested in bicycling at all.

Separated bike lanes have great potential to fill needs in creating low-stress bicycle networks (generally separated from heavy vehicular traffic or sharing the road with motorists only on very low-volume residential streets). To encourage the "Interested but Concerned" group to use cycling as a transportation option for short- to moderate-length trips, many municipalities are focusing on creating a connected bicycle network that these riders will confidently use.

This enhanced network pays particular attention to higher-quality, lower-stress connections, even if this results in some backtracking or extra distance requirements for cyclists using it. An example of a planning effort in Montgomery County, Maryland focused on low-stress bicycle networks is shown in Table 13-17. The goal of a low-stress network is to create connections within a municipality while emphasizing the *quality* of bicycle facilities over the number of miles available.

2. What guidelines exist for bicycle facilities?

Several national design guidelines and standards apply to bicycle facilities. The AASHTO *Guide for the Development of Bicycle Facilities* is a comprehensive guideline to bicycle facility planning and design. [AASHTO, 2012] The *Manual on Uniform Traffic Control Devices* (MUTCD) addresses bicycle facility signage and striping, both for onroad and offroad bicycle facilities. [FHWA, 2009] The 2010 ADA *Access Guidelines* should be consulted if a particular bicycle facility is also expected to accommodate pedestrians, as is the case with most trails. [U.S Department of Justice, 2012] Other useful guidelines include:

- ChooseHealth Utah [undated]
- CROW (the Netherlands) [2007]
- FHWA [2015b]

Table 13-17. Montgomery County, Maryland Bicycle Stress Map	
Level of Stress	**Bicyclist Response**
Very High	Very few adults will bicycle.
High	Few adults will bicycle.
Moderate High	Some adults will bicycle.
Moderate Low	Many adults will bicycle.
Low	Most adults will bicycle.
Very Low	All adults and some children will bicycle.
None	Everyone will bicycle.

Source: Montgomery County, www.mcatlas.org/bikestress/

- Nabti and Ridgway [2002]
- National Association of City Transportation Officials (NACTO) [2013, 2014]
- Torbic et al. [2014]
- Vermont Agency of Transportation [2002]
- Ryan Snyder and Associates and Transportation Planning for Livable Communities [2011]

Instead of relying on national design guidelines, however, one of the common recommendations of planning studies for both bicyclist and pedestrian transportation is to develop local design guidance. Such guidelines are defined in ways that are more appropriate to the context in which a bicycle facility is being constructed or implemented. As a general guide, most communities choose to design their bicycle network to meet the needs of basic adult riders and youth bicyclists. In this context, the most important question is: What type of improvement would work best to increase the comfort level of bicyclists on each segment? If a bicycle suitability analysis has been performed, it is possible to show different design scenarios and their effect on the bicycle level of service for the given roadway segment.

3. What treatments are appropriate for different facilities?

A variety of facility types or roadway treatments can be used to accommodate bicyclists. They can include signed routes, shared lane markings, onstreet bike lanes, onstreet buffered bike lanes, separated bike lanes, and offstreet paths/side trails. [FHWA, 2015b] The following discussion divides the treatments by whether the road space is shared.

Shared Roadways. All streets where bicyclists are permitted to ride and share the same travel lanes with motor vehicles are technically classified as shared roadways. In most cases, a motorist will usually have to cross into the adjacent travel lane to pass a bicyclist. However, there are several treatments that can enhance shared roadways for cyclists—bike routes, bike lanes, paved shoulders, bike boulevards, and road diets.

Bike routes are shared roadways that meet a set of minimum design and operational criteria for bicycle compatibility and that have been designated with bicycle route signs as connector routes within a bicycle network. Suggested criteria for bike routes include:

- Obstacles and barriers to bicycle travel should be addressed, including hazardous drainage grates, potholes, uneven manhole covers, angled railroad crossings, and narrow bridges. Where certain obstacles cannot be improved but do not pose an undue risk to bicyclists, advance-warning signs (as recommended by the MUTCD) should be used to alert bicyclists of their presence.
- The proposed bike route should be part of an interconnected system of bicycle facilities. Bicycle routes should not abruptly end at barriers.
- Pavement markings should be provided and well maintained that clearly indicate where bicyclists should be riding (see Figure 13-10).
- Future street maintenance and construction activities should consider and plan for safe transport along this route. This normally means more frequent street clearing and paving.

Bike lanes are a portion of the roadway designated for preferential use by bicyclists, typically with a minimum width of 5 ft (1.5 m). Many communities have begun installing bike lanes not only for the additional operating space they provide for bicyclists, but also as a method to encourage more bicycle travel. The needs of cyclists can be accommodated by retrofitting bike lanes onto existing urban streets. In many cases this can be accomplished by re-striping the existing cross section to add bike lanes. Figure 13-11 presents a typical road cross section including a bike lane. Figure 13-12 shows another cross section with a shared use path.

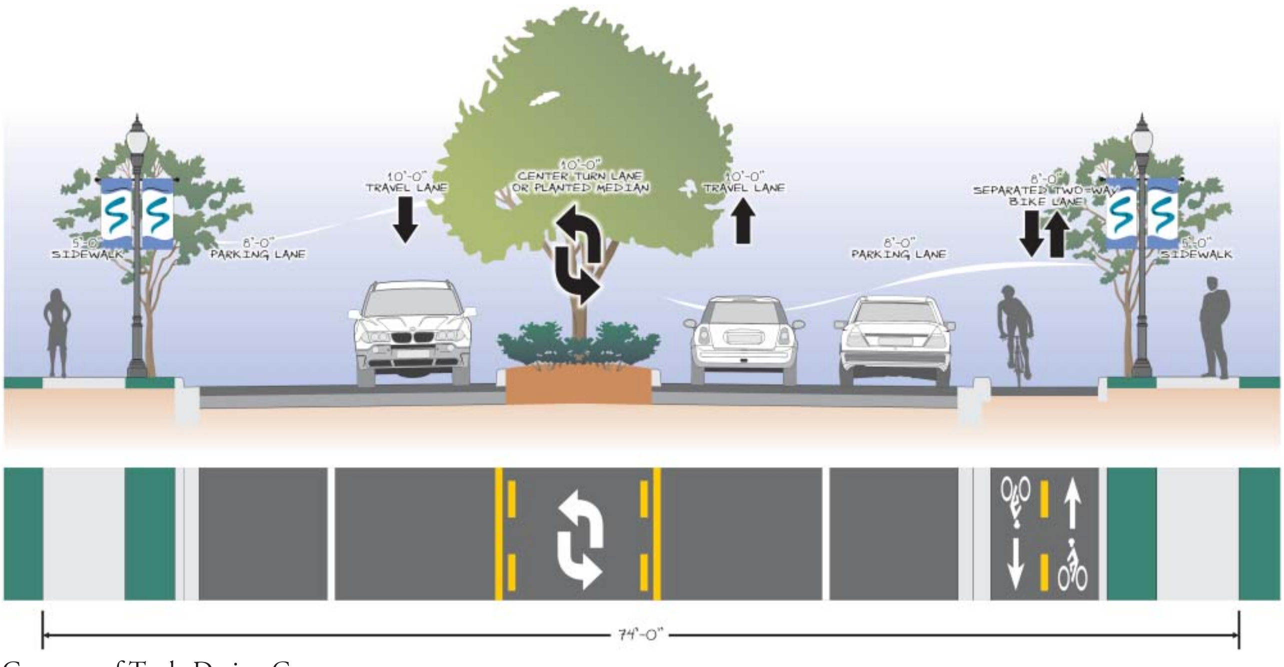
Paved shoulders can also be used in some cases on streets with no curb and gutter, particularly in rural areas. While any additional space is beneficial, a 4- to 6-ft (1.2-m to 1.8-m) shoulder is preferred. Paved shoulders should be included on both sides of the roadway. In addition to the benefits to bicyclists, paved shoulders can also serve the needs of motorists. As with bike lanes, paved shoulders should be constructed to withstand heavy loadings (since trucks and service vehicles will occasionally use them) and should be free of surface irregularities. Regular maintenance is essential if paved shoulders are to be useful to bicyclists. The use of edge-of-road rumble strips could create a dangerous situation for bicyclists; therefore, sufficient warning should be provided via signs.

A *bicycle boulevard* is a roadway that motorists may use, but that gives priority to bicycle traffic through the use of various treatments. Through motor vehicle traffic is discouraged on the street. Local traffic is slowed to approximately the same speed as bicyclists. Stop signs and signals

Figure 13-10. Example Bike Route Pavement Marking

Photo courtesy of Michael Meyer

Figure 13-11. Road Cross Section with Bike Lane



Courtesy of Toole Design Group

Figure 13-12. Road Cross Section with Shared-Use Path

Courtesy of Toole Design Group

on the bicycle boulevard are limited to the greatest extent possible, except where they aid bicyclists in crossing busy streets. The bicycling environment may be further enhanced through the use of directional signage and other amenities. The development of a bicycle boulevard may include changing intersection controls and installing signage, stencils, or other treatments that facilitate bicycling. Bicycle boulevards are most effective when several treatments are used in combination. Cities that have implemented bike boulevards include, not surprisingly, many university communities, including the cities of Palo Alto, Berkeley, and San Luis Obispo, California; Portland, Oregon; Cambridge, Massachusetts; and Denver. Vancouver, British Columbia, has an extensive system of bike boulevards.

Road diets, or a reduction in the number of roadway lanes to improve safety and reduce traffic volumes, may also provide opportunities for new bike lanes. In many cases, road lanes can be converted to a dedicated bike lane along with increased median or pedestrian space for those crossing the road. Figure 13-13 shows the concept of a road diet and the incorporation of a bike lane into a reconfigured cross section.

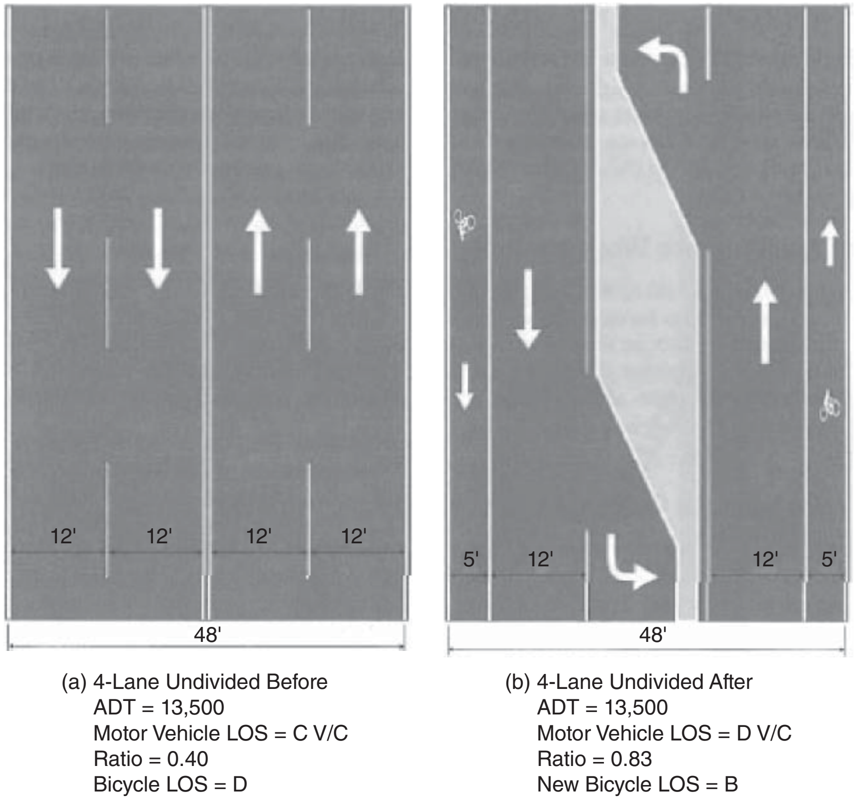
A number of innovative, onroad bicycle treatments not included in the MUTCD are used throughout the United States. Examples of these include left-side bike lanes on one-way streets and contra-flow bike lanes. ITE's *Informational Report on Innovative Bicycle Treatments* describes these innovative applications. [Nabti, 2002]

Separated Bike Lanes. A separated bike lane is an exclusive facility for bicyclists located within or directly adjacent to the roadway and is physically separated from motor vehicle traffic. Research has shown that most Americans are reluctant to ride bicycles in the absence of physical separation from motor vehicles. Those willing to face a higher stress factor in traveling without some physical separation represent a very small minority of those who are willing to bike. As part of a connected bicycle network, separated bike lanes can:

- Provide a more comfortable experience for less-skilled riders.
- Improve access to destinations such as schools, jobs, health-care facilities, and essential services.
- Enhance access to public transportation, for example by helping to solve the first/last mile challenge.
- Improve access to employment opportunities, especially for those without access to a private automobile.
- Provide a linkage between regional trail systems. [FHWA, 2015b]

Cycle tracks are physically separated from motor traffic and distinct from the sidewalk. Common elements include: (1) space intended to be exclusively or primarily used for bicyclists, and (2) separation from motor vehicle travel lanes, parking lanes, and sidewalks. Where on-street parking is allowed, cycle tracks are located to the curb side of the parking (in contrast to bike lanes). [NACTO, 2014]

Figure 13-13. (a) and (b): Road Diet and the Incorporation of a Bike Lane into a Reconfigured Cross Section



Source: Huang and Zegeer, 2002 Reproduced with permission of the Transportation Research Board.

Offroad Multiuse Trail. Offroad and multiuse trails are the highest-order bicycle treatment, involving the complete separation of bicycle and motor vehicle traffic, and are appropriate for all skill levels. Multiuse trails are physically separated from motor vehicle traffic (except at crossings with streets) by an open space or barrier. They are usually built within an independent right-of-way, such as a utility or railroad right-of-way, or along easements across private lands (see Figure 13-14). Trails can accommodate a variety of users for both recreation and transportation purposes, including pedestrians, joggers, skaters, bicyclists, horseback riders, and people in wheelchairs. A shared-use level of service calculation is a great tool for determining the width of the trail. The minimum width for two-directional trails is 10 ft (3 m); however, 12- to 14-ft (3.7- to 4.3-m) widths are preferred where heavy or mixed traffic is expected. Due to the popularity of offroad trails, centerline stripes should be considered for paths that generate substantial amounts of pedestrian traffic.

Multiuse trails can provide connectivity in corridors not well-served by the street system, and they are particularly helpful to bicyclists if they provide a direct, traffic-free route linking origin and destination points. National guidelines for the design of multiuse trails are provided in AASHTO's *Guide for the Development of Bicycle Facilities*. [AASHTO, 2012]

Trail and roadway intersections can become areas of conflict if not carefully designed. In some cases, these intersections could be signalized (in California, such an intersection is one of three instances where a warrant exists for bicycle traffic signals). For high-speed, multilane arterials and freeways, the only viable solution may be a grade-separated crossing. Overpasses can be extremely expensive and marginally successful if users are expected to climb long entrance ramps. Underpasses should be of adequate width and should be well lit with vandal-resistant fixtures. Crime Prevention Through Environmental Design (CPTED) principles should be followed when designing underpasses (see [U.S. Department of Justice, 1996]).

Approach ramps for grade-separated crossings must meet ADA or American National Standards Institute (ANSI) standards.

Figure 13-14. Off-Road Bike Trail, Cape Cod, Massachusetts

Photo Courtesy of Toole Design Group

As the demand for trails increases, planners and user groups are increasingly considering putting trails into corridors alongside active rail lines. Many railroad corridors are more than 100 feet wide and have just one or two active lines still in operation; other corridors are bounded by open space and appear to be good candidates for trail development. Many rail lines have low service levels, with one or two trains per day. Examples of successful rails-with-trails programs and of “user separation” issues such as grade separation, vegetation, ditches, and fencing can be found at http://www.fhwa.dot.gov/environment/recreational_trails/publications/rwt/page08.cfm.

Bicycle Route Signage. Signing should always include directional information, such as an arrow and the name of the destination served, and, if appropriate, the distance to the destination. Signage is also helpful for wayfinding (see Figure 13-15). Signage on state highways will need to meet the standards of the *Manual of Uniform Traffic Control*

Figure 13-15. Example of Wayfinding Signs

Photo courtesy of Toole Design Group

Devices (MUTCD), which should be considered when planning a wayfinding program for a city or community. Some communities have developed unique bike route signs, which is acceptable provided the design is simple so that cyclists do not have to stop to read the sign.

Bicycle Storage and Parking. Bicycle parking is an important part of improving and encouraging bicycle travel in urban areas, especially as it interfaces with transit stations and major attractors. Transit stations and schools are examples of locations typically needing bicycle parking facilities (see Figure 13-16). Parking can be addressed through city ordinances or zoning codes and can refer to the bicycle master plan for policies and guidelines on the type and location of parking.

Appropriate locations for bicycle parking facilities should be considered on a case-by-case basis with an analysis of the specific design constraints at each location. The following general location criteria are recommended:

- Parking facilities should be located immediately adjacent to the building entrance they serve (where bicyclists would naturally transition into pedestrian mode).
- Parking facilities should be installed in a public area within easy viewing distance from a main pedestrian walkway, usually on a wide sidewalk with 5 or more feet of clear sidewalk space remaining. In general, sidewalks that are narrower than 12 ft (3.7 m) cannot accommodate bike racks.

Figure 13-16. Example Bike Parking at Transit Station, Boston. (a) Storage Cage, Alewife Transit Station, and (b) Covered Bike Racks, Maverick Transit Station

(a)

(b)

Photos courtesy of Toole Design Group

- For bike parking facilities placed near walls or buildings, a minimum of 2 ft (0.6 m) clear space is needed between the bicycle rack and a parallel wall, and 2.5 ft (0.8 m) from a perpendicular wall.
- Bike racks should be placed on hard surfaces rather than in grassy medians or unpaved areas.
- Racks should be placed to avoid conflicts with pedestrians. They are often installed near the curb and at a reasonable distance from building entrances. They should not be placed in a manner that interferes with pedestrian traffic exiting crosswalks.
- Bicycle rack placement within the right-of-way should not block access or obstruct movement. In general, bike racks should not be placed in front of doors (including cellar doors in urban downtowns) or in close proximity to fire hydrants, bus stop shelters, telephones, mailboxes, benches, newsstands, or subway exits. On streets with metered parking, racks placed between meter poles should be as close to midway as possible. [Association of Pedestrian and Bicycle Professionals, 2002]

Bike parking has become an even more important issue with the popularity of bike-sharing programs. Bike-sharing programs have been created in over 600 cities worldwide, including many in major U.S. cities. The concept of renting a bicycle, using it, and depositing it when finished, implies that there need to be many locations where bicycles can be stored. Parking is often located at major trip origins and destinations in cities, and in particular at major intermodal transportation terminals. Often in cities catering to tourists, one will find parking for bike sharing programs at parks, major tourist sites and attractions, and at convenient locations where space is available near streets or bike paths.

4. What spot hazards need to be identified and rectified?

Sudden changes in the bicycle facility alignment or pavement conditions can have a very detrimental effect on bicyclists, particularly when they occur with no forewarning. Unless quick evasive actions are taken, such obstacles and irregularities can cause bicycle crashes. It can also be a problem when bicyclists suddenly swerve to avoid a hazardous condition, since unpredictable movement can result in a crash with a motor vehicle. The following are some examples of bicycle hazards and special design considerations (consult AASHTO's *Guide for the Development of Bicycle Facilities* for further detailed solutions).

Maintenance on an urban street network occurs frequently, causing problems for bicyclists who must maneuver across milled pavement, over sudden pavement changes and steel plate covers (which are slippery when wet), and through narrowed lanes. In general, bicycles are far more susceptible to sudden pavement changes in construction areas than motor vehicles are. Warning signs can help give bicyclists advanced notice of upcoming pavement changes. When at all possible, a clear path should be maintained through construction areas for bicycle travel.

Rough railroad crossings set at an acute angle to the roadway are particular obstacles to bicyclists. Streets with inlaid rails (trolley streets) can also be difficult to negotiate if the rail is in the normal operating area for bicyclists, or if pavement adjacent to the rail has deteriorated and left open cracks.

Adequate space for bicyclists and pedestrians should be a standard element for all new bridges where bicycles are permitted to operate. These guidelines should apply regardless of whether bicycle lanes or sidewalks connect to the bridge at the time it is built. Minimum accommodations for bicyclists should include bike lanes and sidewalks on each side. It is also important to provide bike lanes where roadways pass beneath bridges, so that these areas do not present a barrier.

Manholes that are lower or higher than the surrounding pavement create an obstacle to cyclists. This sometimes occurs during roadway resurfacing when a manhole is not raised to the new surface level. Local roadway engineers should develop specific design solutions to address the need for a level pavement surface, including raising manholes to meet the same grade as newly laid pavement. In addition, avoid placing utility covers in bike lanes, where possible.

Some types of drainage grates can trap a bicycle wheel and cause a crash, particularly those with a wide opening between bars or with bars parallel to the direction of travel. Bicycle-safe drainage grate designs have been developed and should be used wherever bicyclists are expected to ride. It is also important that drainage grates be placed on an even grade with the surrounding pavement.

Acceleration and deceleration lanes can create difficult and continuous conflicts between bicyclists and motorists. Conflicts occur when the vehicle is accelerating or decelerating and making a merge or turning maneuver. At intersections and driveways where adequate width is available, the bike lane should be transitioned to the left of the acceleration or deceleration lane. In addition, the mixing zone should be as short as possible and designated with green paint.

At merge locations, the acute angle of approach creates visibility problems, and the speed differential is often high. In this situation the bike lane can be transitioned to cross the merge lane at close to a right angle, improving sight distance and moving the crossing point away from the vehicular merge point.

B. Pedestrian Network/Facility Design

An individual's decision to walk is as much influenced by the perceived quality of the experience as it is by security, safety, and convenience. Thus, whereas traditional pedestrian planning has focused on the physical characteristics of the pedestrian and of pedestrian movement, more recent studies have looked at a much broader context. This perspective not only includes what is needed to physically walk from one location to another, but also how urban design and the interaction between road network structure and land-use patterns can enhance or degrade this experience.

Table 13-18. Pedestrian Crash Survival Versus Speed on Road	
	Pedestrians vs Speed
Speed	**Survival %**
20 mph	95%
30 mph	55%
40 mph	15%
80% of pedestrians struck at 35 mph will be killed	

Source: City of Sacramento, 2003

For example, one study found that streets without sidewalks had 2.6 times more pedestrian and automobile collisions than expected based on exposure, while streets with sidewalks on only one side had 1.2 times more pedestrian crashes. [Knoblauch, 1988] Design and control speeds for adjacent roadways also affect pedestrians; higher travel speeds result in more severe injuries for pedestrians in the event of a collision (see Table 13-18). It is both clearly preferable and good practice to have some type of safe walking facility out of the traveled roadway. A separate walkway is the best option, but a roadway shoulder will also provide a safer pedestrian accommodation than walking in the travel lane.

Direct and convenient pedestrian connections should be provided between residences and activity areas. It is usually not difficult to determine where connections between residential areas and activity centers will be required during the early stages of development. Development density can be used as a surrogate for pedestrian usage in determining the need for sidewalks. Local residential streets, especially cul-de-sacs, can accommodate extensive pedestrian activity on the street because there is little vehicular activity (although cul-de-sacs also discourage connectivity among neighborhoods). Collector streets are normally used by pedestrians to access bus stops and commercial developments on major arterial roads.

Sidewalks are particularly important for those desiring to use transit. Sidewalks should be provided on all streets within one-quarter mile to one-half mile (400 to 800 m) of a transit station, depending on agency policy. Sidewalks should also be provided along developed frontages of arterial streets in commercial areas. Collector and arterial streets near schools should be provided with sidewalks to increase school trip safety.

1. What are the characteristics of pedestrians that need to be considered in the planning process?

Basic definitions and the characteristics of pedestrian movement, their relationship to various land-use contexts, quality of space, proximity to nearby active uses, and common pedestrian crash types should be considered when planning for pedestrian movement. Pedestrian characteristics, described in AASHTO's *A Policy on Geometric Design of Highways and Streets* (known as the "Green Book") and the Transportation Research Board's *Highway Capacity Manual*, include information on, (1) average pedestrian space needs (the average pedestrian occupies a space of 18 in. by 24 in. [45 cm by 60 cm]), (2) walking speeds, and (3) capacities for pedestrian-related facilities. Where pedestrian movement is very dense, such as on pedestrian bridges or tunnels, intermodal connections, outside stadiums, or in the middle of a central business district, pedestrian capacity analysis may be needed. As with road capacity, level of service concepts have been developed for pedestrians that relate flow rate to spacing and walking speed.

An average walking speed of 4 ft/second (sec) (1.2 m/sec) has been used as a standard walking speed for many years. This speed has been shown to be closer to the 50th percentile of pedestrians crossing an intersection; the 15th percentile is roughly 3.5 ft/sec (1.1 m/sec), and the 5th percentile is roughly 3.0 ft/sec (1.0 m/sec), which is appropriate near senior housing, hospitals, and schools. Many pedestrian studies are now using 3.5 ft/sec (0.9 m/sec).

Facility design must also take into account pedestrians with physical, visual, or mental disabilities, for example, providing increases in average pedestrian space requirements for individuals using canes, walkers, wheelchairs, shopping carts, or baby carriages. Pedestrians with ambulatory difficulties are sensitive to walking surfaces. Persons with hearing or visual impairments or learning disabilities may be less able to process typical sensory information, such as colors or signage.

2. What are typical design considerations for pedestrian facilities?

With limited funding and varying demands for pedestrian facilities in most jurisdictions, the type of pedestrian improvements should be compatible with the characteristics of the area. This concept is described in the City of

Sacramento's *Pedestrian Master Plan* [City of Sacramento, 2006]. The most fundamental level of improvement is referred to as "basic." This is the baseline that should apply to all parts of the jurisdiction. The "upgraded" level of improvement includes everything in the basic level plus added features such as wider sidewalks, more intense lighting and landscaping, and higher-quality street crossing treatments. These improvements are targeted for commercial streets with medium to high levels of automobile traffic. "Premium" improvements include all of the basic and upgraded-level improvements plus additional elements that make the pedestrian setting an active urban place. Items such as extra-wide sidewalks, special lighting, signage, and seating are some of the features included. Upgraded improvements are recommended for all pedestrian corridors, and premium improvements are appropriate for pedestrian activity nodes.

Pedestrian facilities should be designed with the following factors in mind:

- *Sufficient Width*. Sidewalks should accommodate anticipated volumes based on adjacent land uses, and they should at a minimum allow for two adults to walk abreast. Greater detail on sidewalk dimensions is provided later in this chapter.
- *Protection from Traffic*. High-volume or high-speed (greater than 25 miles per hour, or 40 kilometers per hour) motor vehicle traffic creates dangerous and uncomfortable conditions for pedestrians. Above 25 mph, the chance of death increases by 50 percent for pedestrian/motor vehicle crashes. Physical (and perceptual) separation can be achieved through a combination of methods: a grassy planting strip with street trees, a raised planter, bicycle lanes, on-street parallel parking, and others.
- *Intersection Design*. Intersection design should facilitate both vehicular and pedestrian movement with geometric dimensions that reduce pedestrian crossing distances and provide median refuge islands.
- *Street Trees*. Street trees are an essential element in a high-quality pedestrian environment. Not only do they provide shade, they also give a sense of enclosure to the sidewalk environment, which enhances the pedestrian's sense of walking in a protected environment. Concerns about trees limiting pedestrian visibility, particularly at intersections, can be mitigated by use of proper street trees with mature trunk diameters of 12 in. (30.5 cm) or less and canopies higher than 8 ft (2.4 m). Such trees should be considered from the perspective of approach sight distance for motor vehicles.
- *Pedestrian-Scale Design*. Large highway-scale signage reinforces the general notion that pedestrians are out of place. Signage should be designed to be seen by the pedestrian. Street lighting should likewise be scaled to the level of the pedestrian rather than provided by light poles that are more appropriate on high-speed freeways. Components such as street furniture, vistas, and landmarks should be incorporated into designs to help make walking routes interesting.
- *Continuity*. Pedestrian facilities are often discontinuous, particularly when private developers are not encouraged to link on-site pedestrian facilities to adjacent developments and nearby sidewalks or street corners. New developments should be designed to encourage pedestrian access from nearby streets. Existing gaps in the system should be placed on a prioritized list for new sidewalk construction.
- *Clearances*. Vertical clearance above sidewalks for landscaping, trees, signs, and similar obstructions should be at least 8 ft (2.4 m). In commercial areas and central business districts, the vertical clearance for awnings should be 9 ft (2.7 m). The vertical clearance for building overhangs that cover the majority of the sidewalk should be 12 ft (3.6 m).
- *Conformance with National Standards*. All pedestrian facilities should be consistent with ADA requirements. Specific guidance is provided by the Architectural and Transportation Barriers Compliance Board's *ADA Access Guidelines*, and "Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG)."

A number of guidelines are available for pedestrian facility design, including:

- AASHTO, *Guide for the Planning, Design, and Operation of Pedestrian Facilities* [2004]
- City of Chicago, *Complete Streets Chicago* [2013]
- City and County of San Francisco, *Designing Complete Streets* [2015]
- City of New York City, *Street Design Manual* [2013]

- Department of Transport, Main Roads Western Australia, *Planning and Designing for Pedestrians: Guidelines* [2012]
- Institute of Transportation Engineers (ITE), *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach* [2010]
- MetroAnalytics, *Utah Bicycle and Pedestrian Master Plan Design Guide* [undated]
- NACTO, *Urban Street Design Guide* [2013]
- New Zealand Transport Agency, *Pedestrian Planning and Design Guide* [2016]

The MUTCD and ADA *Access Guidelines* also address a range of pedestrian facility design standards. Many of these resources, however, deal primarily with roadway design for motor vehicles and contain limited pedestrian-related material. At the local level, when pedestrian planning has occurred, it is often common to find examples of comprehensive design practices that recognize locality-specific pedestrian needs.

3. What design treatments are appropriate for different pedestrian environments?

How planners provide for pedestrian transportation varies from one context to another. The following sections present some of the factors that should be considered when designing facilities in specific contexts.

Sidewalk width and setbacks will vary, depending on the community. The following recommendations provide guidelines for sidewalk width and setbacks. It is important to note that some area contexts warrant wider sidewalks than the minimum width. For example, sidewalks in and around universities and colleges must accommodate a much higher volume of pedestrians and, therefore, warrant additional width. The following recommendations are based on FHWA and ADA guidelines and common practices used by pedestrian-friendly communities in the United States.

Sidewalks in Community Benefit Districts (CBDs). Sidewalk widths in CBDs are, for the most part, already determined by building setback and street widths, although in some cities such as New York City sidewalks are being made wider by taking road space. Should a reconstruction project warrant further study of sidewalk width in a CBD, service standards are found in AASHTO's *Green Book* [2011].

Arterial and Collector Streets in Commercial and Residential Areas. Sidewalks on arterial and collector streets in commercial and residential areas should be a minimum of 5 ft (1.5 m) wide. A minimum of a 2-ft (0.6-m) wide planting strip should be provided. If no planting strip is possible, the minimum width of the sidewalk should be 6 ft (1.8 m).

Sidewalks on Local Streets in Residential Areas. On local streets in residential areas, sidewalk width may be based on the number of dwelling units per acre. For multifamily developments and single-family homes with residential densities that exceed four units per acre, the sidewalk should be a minimum of 5 ft (1.5 m) wide with a minimum setback of 2 ft (0.6 m). For densities up to four dwelling units per acre, the sidewalk should be a minimum of 4 ft (1.2 m) wide with a 2-ft (0.6-m) setback.

Curb Extensions or Bulb-Outs are extensions of the sidewalk into the street on one or both sides of a crosswalk. The primary benefits are shorter crossing distances at intersections for pedestrians, increased visibility for the pedestrian, reduced traffic speeds, and less exposure to vehicle conflicts in the roadway. Curb extensions are normally only used where onstreet parking is present. The design typically extends into the street by the same or lesser dimension as the on-street parking. To avoid bike conflicts, the curb extension should not extend into bike lanes or wide outside lanes for bikes.

Sidewalks on Streets with No Curb and Gutter. The setback requirement is based on roadway cross sections that include curb and gutter. Sidewalks located adjacent to "ribbon pavement" (pavement with no curb and gutter) are not recommended. However, if no other solution is possible, sidewalks adjacent to ribbon pavement should have a much greater setback requirement, depending on roadway conditions. More specific guidelines can be found in the AASHTO *Green Book*.

Sidewalks in Rural Areas. In most rural areas, the low volume of pedestrians does not warrant sidewalk construction. In most cases, 4-ft (1.2-m) wide paved shoulders can provide an adequate area for pedestrians to walk on rural roadways. Exceptions should be made in areas where isolated developments such as schools, ballparks, or housing communities create more pedestrian use. For example, motorists might regularly park along a rural road to access a nearby ballpark. A sidewalk may be warranted in this circumstance so pedestrians can be separated from traffic. Sidewalks in rural areas should be provided at a width based on the anticipated or real volume of pedestrians, with 5 ft (1.5 m) being the minimum width.

Crosswalks serve to channel pedestrian traffic through an intersection, as well as heighten the awareness of motorists to possible pedestrian crossing movements. It is important to note that although crosswalks are an important element in intersection design, a crosswalk alone does not ensure the safety of a pedestrian. Too often, crosswalks are the sole provision for pedestrians at intersections, when other safety measures are also needed.

The recommended width of crosswalks is 10-ft (3-m) wide, with a minimum width (as set by MUTCD) of 6 ft (1.8 m). Wider crosswalks should be installed at locations with higher pedestrian volumes. At signaled intersections with stop bars, a minimum separation of 4 ft (1.2 m) is necessary between the stop bar and edge of the crosswalk. At midblock locations, stop or yield bars should be placed to allow motorists adequate stopping time, particularly on multilane sections.

Curb Ramps should always be placed to lead the pedestrian directly into a striped crosswalk area. Intersection corners should include two curb ramps or at least one broad ramp that serves both crosswalks. Curb ramps should always be provided with a matching ramp on the opposite side of the road, as well as ramps at pedestrian refuge islands. ADA provides federal guidance for curb ramp installation.

Pedestrian safety at intersections depends in part on minimizing the length of time that the pedestrian is exposed in the street. One way of minimizing conflict and exposure at intersections is to improve *traffic signalization* and improved intersection geometric design. Traffic signal improvements for pedestrians may include:

- Improvements to timing options and turn phasing.
- Elimination of right-turn-on-red movements.
- Elimination of free-right turning movements (with yield signs).
- Addition of pedestrian signals (WALK and DON'T WALK).
- Pushbutton signals that can be actuated by pedestrians.
- Reduced corner radii and curb extensions to shorten the distance the pedestrian must cross, therefore also shortening the signal intervals.

Guidelines for traffic signalization to accommodate pedestrian crossings are provided in the MUTCD. Traffic engineering analysis is necessary on a case-by-case basis in order to determine the best signal option. Signaled intersection design and audible signals should be given special consideration in areas with higher numbers of senior citizens, school-age children, and disabled persons, including longer pedestrian clearance intervals.

Characteristics of good pedestrian signaled intersections include:

- Compact intersections with short cycle lengths.
- Short pedestrian crossings.
- Medians for multilane streets.
- Crosswalks with pedestrian indicators on all approaches.
- Signal heads (pedestrian and vehicle indicators) located for optimum visibility.
- Heads on the intersection side of the crosswalk so they are not obstructed by large vehicles stopped at the stop bar, and concurrent pedestrian and vehicle phase heads co-located on one pole (this is especially important where permitted left-turn phasing is concurrent with the crosswalk being crossed by the left-turning vehicle).
- Advanced stop bars to enhance pedestrian visibility and reduce incidence of motorists stopping in the crosswalk.
- Signal controller located outside of walking areas.
- Pedestrian pushbuttons located at or near the top of curb ramps.
- Audible signals for all new installations and significant signal modifications.
- No right turns on red where conflicts with pedestrians are likely.
- Good intersection lighting, including pedestrian-scale lighting.

Curb Extensions or Bulb-Outs, as previously discussed, are extensions of the sidewalk and curb into the street on both sides of a pedestrian crosswalk. Curb extensions have several advantages for the pedestrian. The primary benefit is a shorter crossing distance at an intersection. Shortening this distance decreases the amount of time the pedestrian is exposed to traffic. By narrowing the traffic lane and creating a smaller corner radius, curb extensions also reduce traffic speeds at the intersection. Curb extensions increase visibility for the pedestrian in areas with on-street parking by offering an unimpeded view of oncoming traffic (and allowing oncoming traffic to see approaching pedestrians).

Pedestrian Refuge Areas can be essential for large, multilane, urban, and suburban intersections. These areas serve several purposes. They allow a resting place for slower pedestrians who cannot make it across the intersection within the time allotted. In wider urban intersections, refuge areas allow pedestrians to cross one direction of traffic at a time and provide a place to wait for the next pedestrian cycle. In this case, they also reduce the overall delay to motor vehicles that would otherwise have to stop to allow a pedestrian to cross the entire length of the intersection.

Medians and refuge areas can be particularly important for urban intersections with center turn lanes and left turn signals. Traffic signals that serve these intersections often do not allow adequate time for the pedestrian to traverse the length of the intersection. The center median, therefore, provides a refuge for pedestrians who must wait through several cycles to complete a crossing.

Split Pedestrian Crossings (SPXOs) represent a variation on a median refuge where pedestrians are encouraged to cross one half of the street, enter the refuge, walk toward traffic, and then exit across the second half of the street. The benefit of this design is that pedestrians face on-coming traffic as they maneuver through the crosswalk. This treatment is typically used at midblock locations or near transit connections.

MidBlock Crossings are most appropriate in locations where a high pedestrian traffic attractor is located directly across the street from a significant source of pedestrians. Examples include a commercial area with fast food restaurants across the street from a university, or a shopping center across from a high school. However, due to the increased safety risk of a pedestrian crossing in midstream traffic, midblock crossings should be generally discouraged unless one or more of the following conditions apply:

- The location is already a source of a substantial number of midblock crossings, or it is anticipated to generate midblock crossings (for a new development).
- The land use is such that a pedestrian is highly unlikely to cross the street at an adjacent intersection and midblock crossings are frequent.
- The safety and capacity of adjacent intersections create a situation where it is dangerous to cross the street, except at a designated midblock location.
- Spacing between adjacent signals exceeds 600 ft.
- Other lesser measures to encourage pedestrians to cross at adjacent intersections have been unsuccessful.

Other treatments such as flashing beacons and high-intensity activated crosswalk (HAWK) signals can improve pedestrian safety at midblock crossings. HAWK signals are a combination of beacon flashers and traffic signals (see Figure 13-17). Bulb-out designs might also be appropriate at such locations.

Grade-separated crossings are considered when the volumes of pedestrians and motor vehicles on the crossing road are very high. Pedestrians can rarely be convinced to use a poorly located crossing, and will almost never use an overpass if it takes 50 percent longer to cross than an at-grade crossing. Grade-separated crossings should thus be provided within the normal path of pedestrians wherever possible.

Topography should be a major consideration in determining whether an underpass or overpass is more appropriate. These facilities are regulated by ADA standards; therefore, extensive ramping is usually necessary to meet the ADA grade requirements.

Sidewalk Pavement Design is important not only from a safety perspective but also because it adds to the walking experience of the pedestrian. Sidewalks and roadside pathways should be constructed of a solid, debris-free, and slip-resistant surface. Special paving, stamped concrete, and colored concrete can enhance the pedestrian environment and are popular for more decorative sidewalks. The use of stylized surfaces is encouraged; however, they must be designed with surface uniformity and slip resistance characteristics that meet applicable standards.

Sidewalk Obstacles can create safety and pedestrian flow problems. Street furniture and utility poles create obstacles to pedestrian travel when located directly on the sidewalk. At a minimum, there should be 4 ft (1.2 m) of sidewalk width to allow a wheelchair to pass. Where possible, utilities should be relocated so as not to block the sidewalk.

Figure 13-17. Midblock Crossing with HAWK Signals

Photo courtesy of Adam Rosbury

Benches should not be sited directly on the sidewalk, but set back at least 3 ft (0.9 m). Curb design can also result in obstacles related to on-street parking. Use of vertical curbs is preferred to rolled curbs.

On-Street Parking, especially parked cars near intersections, has been cited as a contributing factor in many pedestrian crashes in urban areas. Parked cars block visual access to oncoming traffic, so that neither pedestrians nor motor vehicles can see each other. Parked cars also provide a buffer between the sidewalk and the travel lane, however, increasing the space between pedestrians and vehicles traveling at high speeds. Consideration should be given to removing parking in the immediate vicinity of crosswalks for adequate sight distance and visibility. Curb extensions at intersections can also mitigate visibility problems with less loss of parking.

Construction Zones can disrupt pedestrian and bicycle circulation and often create barriers for pedestrian movement. Just as traffic is rerouted during roadway construction, pedestrians and bicyclists should be provided a safe alternative through the work zone. Factors to consider include extent of the construction zone, duration of construction, convenience and safety of alternate routes, and cost of accommodation.

Pedestrians and bicyclists should be rerouted well in advance of the construction barriers because most are unlikely to retrace their steps to get around the work zone. Construction sites are particularly difficult to traverse for disabled pedestrians. An alternate accessible route should always be provided when the main route is interrupted by construction activities.

Pedestrian facility maintenance is an important aspect of creating adequate and comfortable facilities for pedestrians. A crumbling sidewalk is not only an eyesore, but also a hazard to the pedestrian and a barrier to the disabled. Most sidewalk maintenance is the responsibility of the fronting property, but in some cases, jurisdictions have assumed this responsibility. A periodic inspection schedule for pedestrian facilities should be adopted by local jurisdictions. Crosswalks will need restriping. A general maintenance budget should be allocated by each local government for use on a yearly basis, perhaps combined with a maintenance budget for bicycle facilities.

Pedestrian safety is often jeopardized in areas where freeway and expressway ramps intersect with arterial, collector, and local streets. For new roadways and roadway-widening projects, a pedestrian circulation plan should be developed for interchange exit and entrance ramp locations, particularly for areas with the following characteristics:

- Areas having substantial pedestrian volume or nearby pedestrian attractors.
- Where existing sidewalks are located in the vicinity of expressway exits and entrances.
- Where new sidewalks are planned for the vicinity of expressway exits and entrances.

Several measures can increase the awareness of motorists and improve conditions for pedestrians at interchanges. Ramp width should be minimized to reduce the crossing distance for pedestrians. Warning signs should be posted on exit ramps to warn motorists of upcoming pedestrian crossings. Motorists should be encouraged to quickly reduce their vehicle speed after exiting the highway, both through signage and traffic calming methods. Extra care should be taken to improve these areas for pedestrians wherever possible.

Modern *roundabouts* reduce traffic speeds at junctions and reduce severe vehicular crashes. Their design also minimizes the number of pedestrian conflicts when compared to traditional intersections. This is accomplished in part by removing some of the conflict points, such as left turns, that cause crashes at traditional intersections. Roundabouts can also reduce delay for vehicles in many cases, replacing stop control with the yield-at-entry rule.

Roundabouts should be designed to accommodate pedestrians and bicyclists safely. [Harkey and Carter, 2007; Rodegerdts et al., 2007] It is important that automobile traffic yield to pedestrians crossing the roundabout. Splitter islands at the approaches slow vehicles and allow pedestrians to cross one direction of travel at a time. Single-lane approaches can be designed to keep speeds down to safe levels and allow pedestrians to cross.

Finally, it is important for all of the facilities described to have good drainage such that walk areas do not flood or experience ice accumulation (such as at corner street ramp locations). Street drains should not be located in crosswalks.

VII. PEDESTRIAN AND BICYCLE TRANSPORTATION IN ASIA AND EUROPE

Notable efforts to enhance bicyclist and pedestrian travel in Asian, Australian, and European cities include bike-share systems, transportation pricing, safety, and traffic calming treatments. The lessons learned from these experiences are presented in a FHWA study on case studies from around the world. [FHWA, 2015a] The report notes that following practices from overseas that might by appropriate for the United States:

- Various types of bicycle priority streets (superhighways, shared bicycle priority streets, wider separated lanes, and “green waves”) for longer cycle trips and improving connections to employment and urban centers. Some communities have planned extensive networks of connected facilities linking important origins (outlying areas and cities) to important destinations. Overpasses, underpasses, and grade separated junctions are frequently used to bypass major roads and other barriers such as rivers and canals.
- Lower-speed, experimental designs for multi-lane, at-grade roundabouts and their approaches to help bicyclists safely travel through.
- Path or lane lighting (energy-efficient) for nighttime use, using technologies to detect users and raise the lighting and then dim the lighting as the user moves away.
- Bicycle signals and various measures for bicycle priority at intersections, including:
    - “Green waves” traffic signal progression.
    - More green time for bicyclists.
    - More split phasing to separate conflicting motor vehicle and bicycle movements.
    - Allowing nonconflicting bicycle through movements (bicycle green) when signal is red for parallel motorized traffic.
    - Leading bicycle interval/head start.
- Path or two-way bicycle facility priority at junctions with low-volume streets.
- Traffic restricted, pedestrian priority zones.

The case studies from Asian and Australian cities, in particular, indicate that nonmotorized transportation use varies primarily on how the safety of bicyclists and pedestrians is perceived by the general public, bicyclists, and pedestrians; and the degree to which the street character is considered inviting for walking or bicycling. These findings suggest that perhaps household income and weather—two factors often pointed to in the United States as reasons for minimal bicycle and pedestrian use—are not always the most appropriate factors in explaining the propensity to walk or bike.

Japanese and European examples show the importance of bike-share systems for the efficient operation of an intermodal transportation system. Guarded bicycle parking, bicycle rental services, and bicycle accommodations on transit vehicles enhance the efficiency and effectiveness of transit. In China and India, bicyclists use transit to travel long distances for work, which reduces congestion on city streets (although in both countries, automobile ownership is rapidly overwhelming the road networks). Comprehensive bicycle networks, effective pedestrian facilities, and traffic calming efforts further reinforce nonmotorized transportation access to transit stations in Asia and Europe (see Figure 13-18).

Figure 13-18. Parking Facility at the Main Train Station in The Hague, The Netherlands

Photo courtesy of Michael Meyer

An FHWA synthesis of international pedestrian safety research included a review of pedestrian amenities such as crossing signs, marked versus unmarked crosswalks, countdown pedestrian signals, illuminated pushbuttons, automatic pedestrian detectors, and traffic calming efforts. The synthesis found that European cities are particularly innovative in the application of pedestrian-only zones to encourage walking, with limited late night and early morning delivery truck access. [FHWA, 2003] Australia was a leader in combining education, promotion of designated routes, and individual pedestrian design treatments. The United Kingdom was the key developer of the midblock Puffin crossing in high pedestrian activity areas (the Puffin crossing controls pedestrian clearance intervals with crosswalk detectors, which minimizes motor vehicle delay and improves pedestrian safety).

An ITE bicycle tour of The Netherlands provided important insights on how and why bicycling has become such a major form of transportation in that country. [Miller et al., 2013] Most importantly, the Dutch have been systematically planning bicycle networks for many decades. National and local policies have been put in place to encourage bicycle transportation, often with a trade-off of less capacity for motor vehicles. Most cities have cycle tracks, bike lanes, bike paths, bike signals, bike-share programs, and indoor/outdoor bike parking. The facilities try to separate bicyclists from motor vehicles as much as possible, but where this is not possible, vehicle speed limits are reduced.

One of the important strategies to complement pedestrian and bicyclist treatments is a reduction in vehicle speeding. In 1988, for example, the United Kingdom implemented a remote speed enforcement policy that allowed automatic speeding citations without the need for a police officer. The results of the 3-year evaluation period (2000–2003) of 24 new camera areas in the United Kingdom showed a 7 percent reduction in average speed and a 30 percent reduction in vehicles over the speed limit. Adjusting for long-term trends, there were 33 percent fewer personal injury collisions and 40 percent fewer persons injured or killed during this same period.

In London, England, the implementation of a downtown congestion pricing program shifted commuters primarily to transit, while others shifted their route, walked, or used a taxi, motorcycle, or bicycle (30 percent increase in cycling following implementation). Japan and Singapore have implemented transportation policies with pricing elements related to parking, vehicle registration, gasoline tax, and tolls, which have contributed to higher use of nonmotorized travel.

Colored bike lanes and advanced stop lines are other innovative bicycle treatments being used in Asia and Europe to enhance the safety and attractiveness of a bicycle network. A cycle track increases the separation between motor vehicles and bicycles and minimizes encroachment of motor vehicles into the bicycle lane. Colored bicycle lanes define the right-of-way at locations with a high conflict potential between motor vehicles and bicycles. Finally, an advanced stop line or bicycle box improves the visibility of bicyclists and allows them to correctly position themselves at intersections with high motor vehicle and bicycle volume. The ITE publication *Innovative Bicycle Treatments: An Informational Report* includes other applications with a discussion of sample sites, a description of each treatment, and the costs, advantages, and disadvantages of each. In addition, readers are referred to the following FHWA website for the latest information on pedestrian and bicyclist transportation, http://www.fhwa.dot.gov/environment/bicycle_pedestrian/resources/.

VIII. SUMMARY

This chapter has presented an overview of planning for pedestrians and bicyclists. In urban areas, in particular, such transportation can be an important component of the transportation system. Enhancing the ability of travelers to walk or bike involves not only providing the infrastructure and safe strategies for using the facilities but also linking urban design and streetscapes to those factors that encourage walking and bicycling. Of great concern, pedestrians represent a disproportionate percentage of road-related fatalities, and thus, special focus should be given to addressing safety issues.

The planning process for pedestrians and bicyclists can range from master plans to recommendations for spot improvements. As zoning codes and infrastructure standards evolve in a community to reflect changing values and desires as to community character, serious attention should be given to how these tools can be used to foster development patterns more conducive to nonmotorized transportation. Most importantly, pedestrian and bicyclist transportation needs to be considered as a serious component of a state, region, or city/town transportation plan.

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Chapter 14

Travel Demand Management[1]

I. INTRODUCTION

Beginning in the 1970s and 1980s, transportation planners became increasingly interested in ways of providing mobility and accessibility without necessarily expanding the physical capacity of the transportation network. There were many reasons for this. The oil embargoes against the United States of the late 1970s caused federal, state, and local governments to encourage more efficient use of the transportation system. Air quality legislation around the same time sought to lower motor vehicle–related emissions, which led to initiatives to encourage auto drivers to seek other means of travel, such as ridesharing. In addition, federal investment in transportation was being strained by numerous requests for federally supported projects, and federal officials soon realized that there would not be enough federal dollars to support all of the requests. Their response was to encourage alternative mobility strategies that did not need massive levels of federal investment.

At the state and local levels, governments and employers became interested in ways of reducing congestion on the highway network, especially at major activity centers. This often led to interest in flexible work hours, rideshare programs, subsidies for transit services, and parking management.

Thus, by the mid-1980s, many transportation professionals were involved with a variety of strategies to influence travel demand, an effort known as travel (or transportation) demand management (TDM) (or mobility management in Europe). The Center for Urban Transportation Research (CUTR), the Federal Highway Administration (FHWA), and Litman [2014] define TDM in the following ways:

> *CUTR: "TDM is helping people change their travel behavior to meet their travel needs by using different modes, travelling at different times, making fewer or shorter trips, or taking different routes."*
>
> *[CUTR, 2005]*

> *FHWA: "Managing demand is about providing travelers, regardless of whether they drive alone, with travel choices, such as work location, route, time of travel and mode. In the broadest sense, demand management is defined as providing travelers with effective choices to improve travel reliability."*
>
> *[Gopalakrishna et al., 2012]*

> *Litman: "Various strategies that change travel behavior (how, when and where people travel) in order to increase transport system efficiency and achieve specific planning objectives."*
>
> *[Litman, 2014]*

As can be seen in these definitions, providing travelers with a trip choice is a key TDM concept. This choice can include: (1) determining whether travel is necessary, given changes in communications technology and lifestyles, (2) shifting demand from single-occupancy vehicles to other modes of transportation such as transit, carpools or vanpools, bicycling, or walking, (3) shifting travel times to reduce peak-period congestion, (4) reducing the distance of required travel through land-use planning and urban design strategies, and (5) helping travelers to choose less congested facilities by providing real-time information. For transportation planners, TDM strategies represent another tool that can be used to enhance mobility and accessibility in support of state, regional, or community goals.

Today, TDM has evolved into a means of achieving multiple community goals. Litman [2014], for example, suggests numerous TDM benefits that reflect a range of goals (see Table 14-1). According to Black and Schreffler, TDM also promotes the following sustainability benefits, which broadens the role of TDM in community planning:

- *TDM reduces the need for new or wider roads.* By persuading people to drive less often, to closer destinations, outside of rush hours or using less busy routes, TDM can reduce the demand for new road infrastructure.

[1]This chapter was written by Michael D. Meyer, WSP/Parsons Brinckerhoff.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

Table 14-1. Benefits of Travel Demand Management Strategies	
Benefit	**Description**
Congestion Reduction	Reduces traffic congestion delays and associated costs.
Road & Parking Savings	Reduces road and parking facility costs.
Consumer Savings	Helps consumers save money by reducing their need to own and operate motor vehicles.
Transport Choice	Improved travel options, particularly for non-drivers.
Road Safety	Reduced crash risk.
Environmental Protection	Reduced air, noise, and water pollution, wildlife crashes, and other types of environmental damages.
Efficient Land Use	Supports strategic land-use planning objectives, such as reduced sprawl, urban redevelopment, and reduced habitat fragmentation.
Community Livability	Improved local environmental quality and community cohesion.
Economic Development	Supports a community's economic objectives, such as increased productivity, employment, wealth, property values, and tax revenues.
Physical Fitness and Health	Improved public fitness and health due to more physical activity, usually through increased daily walking and cycling.

Source: Litman, 2014

- *TDM makes personal travel decisions more efficient.* Many drivers make travel decisions based on poor information and a lack of experience with non-automobile options. TDM improves their awareness and understanding of options, and their willingness to try them.

- *TDM maximizes return on infrastructure spending.* Studies have shown that good information can significantly increase ridership on new transit infrastructure and services. Likewise, reducing overall travel demand on highways adds to the effective lifespan of strategic capacity improvements.

- *TDM makes the most of our current assets.* It saves people money and time by helping them make efficient travel decisions. It improves health by promoting physical activity and less-polluting modes. It benefits employers by increasing productivity, reducing parking costs, and helping to attract and retain workers. It promotes economic development by reducing congestion and enhancing worker mobility.

- *TDM is a versatile and dynamic management tool.* TDM measures can be customized for specific audiences (e.g., business park commuters), destinations (e.g., major hospitals), travel modes (e.g., cyclists), travel corridors (e.g., a busy highway), trip purposes (e.g., school), or specific timeframes (e.g., major events). TDM strategies can be delivered in months, rather than years.

- *TDM initiatives have multimodal benefits.* It recognizes that people see alternatives to driving as a "suite" of options. Nondrivers tend to be public transport users, carpoolers, pedestrians, or cyclists at different times, for different reasons. TDM expands travel choices within this suite of options.

- *TDM works at the scale of individuals, but has huge power across a community.* If every person who drives to work in a community decided to leave his or her car at home just one day a month, the 5 percent reduction in commuter traffic could significantly ease daily congestion.

- *TDM strategies are relatively low cost for meeting mobility solutions.* In general, the budgeted amounts allocated for TDM are considerably less than those for more capital-intensive and operational projects.

- *TDM strategies are comparatively cost-effective in meeting policy objectives.* Similarly, TDM strategies have been shown to be a cost-effective means of meeting key policy objectives. One study of projects funded by the federal Congestion Mitigation and Air Quality (CMAQ) program concluded that TDM measures were among the most cost-effective of those implemented as part of the program.

- *TDM strategies generate good benefit/cost ratios.* Several research projects have developed methodologies to calculate the costs and benefits of TDM in order to allow for objective project selection and evaluation. [Black and Schreffler, 2010]

Although this chapter uses the transportation planning process outlined in chapter 1, and in particular Figure 1-1, to provide a foundation for the discussion of transportation planning, another conceptual planning framework, called least-cost planning, is particularly relevant to TDM. The Oregon DOT defines least-cost planning in the following manner:

> *"Least-cost planning means a process of comparing direct and indirect costs of demand and supply options to meet transportation goals, policies or both, where the intent of the process is to identify the most cost-effective mix of options."*
> *[Oregon DOT, undated]*

Similar in concept to the planning process shown in Figure 1-1, least-cost planning includes the following steps:

1) Identify goals (general things that you want to achieve), objectives (ways to achieve those goals), and targets (measurable outcomes that you want to achieve).
2) Identify various strategies that can help achieve the objectives and targets. These can include both projects that increase capacity and demand management strategies.
3) Evaluate the costs and benefits of each strategy (including indirect impacts, if any), and rank them according to cost-effectiveness or benefit/cost ratios.
4) Implement the most cost-effective strategies as needed to achieve the stated targets.
5) After they are implemented, evaluate the programs and strategies with regard to various performance measures, to insure that they are effective.
6) Evaluate overall results with regard to targets to determine if and when additional strategies should be implemented. [Litman, 2010]

As can be seen, the major steps in least-cost planning include the same steps as found in Figure 1-1. Least-cost planning, however, explicitly recognizes that demand management is equivalent to capacity expansion and considers indirect costs and cobenefits of implementing TDM actions. The justification for encouraging mode shift is that, compared to automobile travel, alternative modes (for example, walking, cycling, ridesharing, public transit, telework, and delivery services) tend to be much more resource-efficient. The assessment of transportation projects and actions in a least-cost evaluation framework includes road and parking space total costs, user financial costs, fuel consumption, pollutant emissions, and other societal costs such as public health impacts. TDM programs tend to broaden the assessment criteria used in the decision-making process.

This chapter focuses primarily on the different types of strategies and actions to influence the demand for transportation. It is important first, however, to place the use of these strategies in the institutional and planning contexts most often found in the United States and Canada. Three major contexts are of most interest to planners: (1) statewide or regional TDM programs, including medium to small urban areas (for example, see Fraser Basin Council [2009]), (2) activity center programs aimed at subareas with multiple employment sites, and (3) site-specific programs primarily created in response to local development ordinances such as trip reduction ordinances. The first two will be addressed together given their similarities in program structure; the site-specific programs, although discussed briefly, are presented in greater detail in chapter 18 on local/municipal and activity center planning.

The next section presents examples of TDM goals, objectives, and performance measures. The following section examines different TDM strategies that can be used by both government-sponsored programs and private companies interested in enhancing mobility for their employees. Typically, a TDM program will consist of a number of complementary strategies, which are described in the following section. The impacts of TDM strategies are presented next, followed by a section on data analysis and models.

TDM programs use many different strategies in their efforts to influence travel behavior. Readers might find the following chapters in this handbook of particular interest: chapter 3 on land use and urban design, chapter 11 on parking, chapter 12 on transit planning, chapter 13 on pedestrian and bicycle planning, chapter 18 on local/municipal and activity center planning, chapter 19 on site planning and impact analysis, and chapter 24 on public participation and engagement.

II. TDM GOALS, OBJECTIVES, AND PERFORMANCE MEASURES

TDM plans or programs focus on enhancing traveler mobility. In some cases, such as in California and the state of Washington, the goals relate to state legislation requiring demand management considerations in the planning process. In others, an areawide TDM plan is viewed as just another part of the transportation planning process, usually found as a chapter in the long-range transportation plan, thus reflecting the normal steps in planning whereby goals and objectives represent an important starting point.

Traditionally, TDM programs focused on employer-based strategies, utilizing such strategies as ridesharing, vanpools, and telework programs. As noted earlier, TDM today has much broader interests and focus. In Atlanta, Georgia, for example, a recent TDM plan "expanded the view of traditional TDM strategies by making the connection between traditional TDM (employer-based rideshare, vanpools, and telework programs) with livability, sustainability, transit, walking and biking, systems operations, transportation planning, economic development, climate change, healthy communities, and active aging." [Atlanta Regional Council (ARC), 2013] The goals and key strategies in this plan were (note: those indicated in bold were identified as having the highest priority):

Improve customer convenience and user experience.

- **Build on Georgia Commute Options rebranding to promote seamless customer experience.**
- **Improve connection of TDM to regional information systems.**
- Develop more targeted messaging for specific modes, locations, audiences, and customers.

Increase transportation connectivity, mode choice, and access.

- **Improve regional coordination of transportation planning, land use, and travel choice.**
- Incorporate TDM into local development policies and review processes.
- Improve and invest in bicycle and pedestrian infrastructure, access, and safety.
- Restructure parking policies to encourage non-single-occupant vehicle (SOV) travel.
- **Strategically link express bus service, local transit, vanpools, managed lanes, and park-and-ride lots.**

Streamline regional coordination of policies, programs, services, and investments.

- Determine a lead agency to oversee management and funding for regional TDM programs.
- Coordinate regional and local marketing and outreach through a marketing manager.
- Create a TDM Advisory Committee aligned with the regional planning committee structure.
- **Enhance integrated operations, branding, and marketing of the regional vanpool program.**
- Align TDM planning and decision making with the regional planning process and programs.

Leverage and diversify funding sources for program sustainability.

- Better educate policymakers, local governments, and the public on TDM benefits and funding.
- Better leverage public and private infrastructure investments.
- Incorporate TDM into strategic funding allocations through the regional planning process.
- **Leverage and diversify existing and potential funding sources to support creative, long-term, and innovative strategies.**

Pursue continuous performance and operations improvements.

- Establish a single portal for collection and reporting of TDM and other transportation data.
- **Develop performance metrics and evaluation criteria for all programs and services.**
- **Use data to improve programs and services.** [ARC, undated]

Another example of TDM goals and objectives comes from Arlington, Virginia, where the following goals were adopted for the countywide TDM program. (Note: Only objectives for the first goals are shown to illustrate how more specific objectives are associated with individual goals. For the complete goals and objectives, see [Arlington County Department of Environmental Services. 2012].

GOAL 1: Influence Growth in the Use of Transportation Options. Offer programs and services to get Arlington residents, employees, businesses, and visitors to use transportation options for travel to, from, and within Arlington County.

Objectives

- Maintain and improve current mode splits for Arlington, contributing to the County's overall objective of one-half percent single occupant vehicle (SOV) reduction per year for all types of trips the next 20 years.
- Encourage efficient, cost-effective modes of transportation that focus on moving people, not vehicles.
- Maximize use of transportation options while minimizing SOV travel.
- Minimize perceived barriers to using transportation options.
- Maximize the use of transportation options for trips generated by new development.

GOAL 2: Provide Quality TDM Service to Arlington Residents, Employees, Businesses, and Visitors.

GOAL 3: Encourage a Culture in Arlington in which there is Increased Awareness and Appreciation of Transportation Options and Their Benefits.

GOAL 4: Increase Transportation System Sustainability through TDM.

GOAL 5: Provide Transparency and Ensure Return on TDM Investment through Program Monitoring and Evaluation.

The goals for TDM programs at development sites are much more targeted on desired mobility outcomes. Such outcomes are often defined in the zoning ordinances that require developers to provide mitigation strategies for expected development-related trip generation. For example, the trip reduction requirements in the City of Pasadena, California, zoning code is intended, "to reduce the demand for vehicle commute trips by ensuring that the design of major residential and nonresidential development projects accommodates facilities for alternative modes of transportation." [City of Pasadena, undated]

Performance measures are used to monitor the outcomes of a TDM program (see chapters 7 on evaluation and 16 on metropolitan planning). Performance measures thus relate to the goals that a program is trying to achieve. The Arizona DOT notes that the most important primary measures for TDM programs are mode split and vehicle trips. [Arizona DOT, 2012] Thus, reductions in vehicle trips and vehicle miles traveled are two measures that could be used to assess the effectiveness of a TDM program or of individual strategies. However, as noted in the DOT report, decision makers often want to know more about the impact of a TDM program, and thus measures such as energy and emissions reductions, cost-effectiveness, number of parking spaces reduced, potential user awareness of the program, and participation levels are sometimes added to the performance report.

The TDM program in Halifax, Nova Scotia, Canada, is very similar in terms of measuring two primary indicators—mode split and individual TDM measure metrics. Mode split (or mode share) is the percentage of person-trips made by one travel mode relative to the total number of person-trips made by all modes. The individual TDM measure assessment was simply the number of users associated with each TDM strategy. [Halifax Regional Municipality, 2010]

Most of these measures are quantitative in that specific numbers or amounts can be attached to the metric. Some planning agencies augment the performance measurement with qualitative performance measures. This is usually done through surveys of those using the TDM program services, as well of the general population to determine why these services are not being used. For example, the San Diego Association of Governments (SANDAG), the metropolitan planning organization (MPO) for the San Diego metropolitan area, measures the number of trips and vehicle miles of travel avoided in the region due to the SANDAG iCommute program (part of its TDM effort), as well as the associated environmental and monetary savings. The data are collected on a monthly basis and reported on quarterly. Qualitative measurement is obtained from yearly customer surveys. [SANDAG, 2012]

Table 14-2, from Arlington County, Virginia, shows the metrics that are used to monitor the progress of the county's TDM program. As shown, each performance measure is linked to a particular goal and includes both quantitative and qualitative measurements. [Arlington County Department of Environmental Services, 2012]

Other good examples of performance measures for TDM programs are found in Loudoun County, Virginia [Loudoun County, 2010] and Hampton Roads, Virginia. [Hampton Roads Transit, 2014]

III. TDM STRATEGIES

TDM programs can lead to many different outcomes. First and foremost, the primary impact will be on travel demand, the major focus of almost all TDM programs. Second, over the long term, TDM measures can influence land use in terms of density and urban design considerations. Third, in combination with other supply-side strategies, TDM programs can affect the performance of the transportation system and services. For example, flex time and variable work hour programs can have a very positive effect on freeway and transit facility performance by "flattening" peak-period demands.

TDM strategies have been classified in many different ways. Table 14-3 shows one way of portraying different types of TDM strategies. In this case, the classification identifies two major focus areas—transportation options and land-use management—along with the incentives that encourage travelers to shift behavior and the implementation programs that institutionalize TDM strategies in existing standard operating procedures.

The classification scheme in Table 14-3 is used in the online *TDM Encyclopedia* as the organizing concept for a large amount of information on TDM strategies and program structure (see http://www.vtpi.org/tdm/tdm12.htm). The same encyclopedia presents TDM strategies from the perspective of how they help achieve equity objectives (see Table 14-4).

A common way of representing TDM strategies is to identify the most appropriate strategies by scale of application. Table 14-5, for example, shows SANDAG's approach to its comprehensive TDM strategy categorized by site, city, and regional/state applications. The table also shows performance measures that can be used to measure the effectiveness of individual TDM actions. Many of these strategies are specific to San Diego, such as the state's Sustainable Communities Strategies (SCS) requirement. However, in general, the strategies shown in the table are illustrative of the many strategies that can be considered by a metropolitan area.

The following sections adopt the classification scheme presented in Table 14-3, primarily because it is the approach used by the *Online TDM Encyclopedia* (http://www.vtpi.org/tdm/tdm12.htm). The encyclopedia provides extensive descriptions of the individual TDM actions in each category, which will thus not be repeated here. However, some of the more important TDM actions in each category are described below.

A. Improve Transportation Options

TDM strategies aimed at improving transportation options (and thus reducing single-occupant vehicle (SOV) use) were some of the first TDM strategies implemented in the 1970s. [Meyer, 1999] They are today considered some of the more traditional TDM strategies, those needed in your program because they provide travelers with important alternatives to SOV use. The effectiveness of strategies aimed at reducing SOV use relates to the reasons that travelers would be willing to use an alternative mode. Figure 14-1 shows the results of a survey from northern Virginia that solicited reasons for commuters to use modes other than single-occupant vehicles. As shown, reducing stress, helping the environment, and reducing costs were the major reasons for reducing SOV use. The "Inner Beltway" and "Outer Beltway" labels reflect the residential address of those responding to the survey, inside and outside of the Washington, DC beltway freeway.

The following types of TDM actions are commonly found in the "Improve Transportation Options" category.

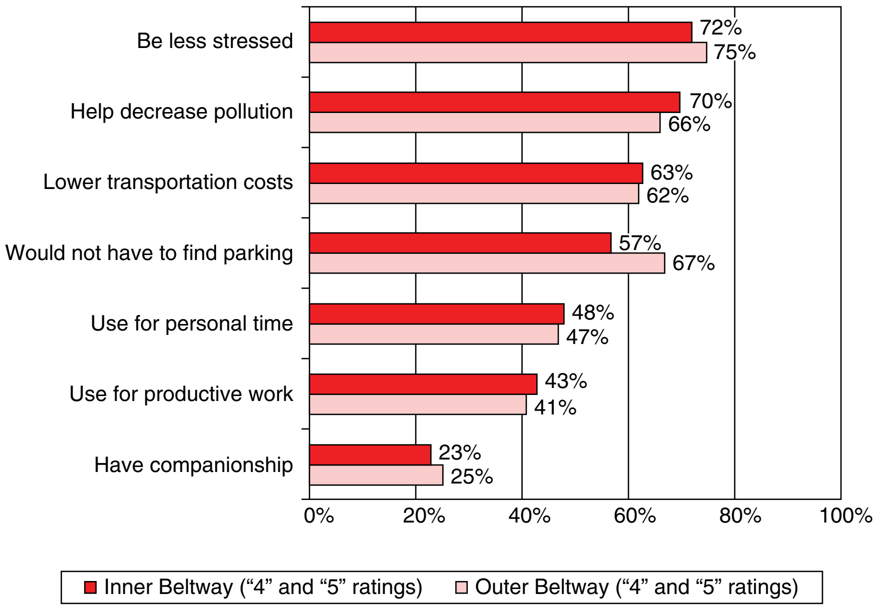
Table 14-2. Performance Measures for a TDM Program, Arlington, Virginia		
Goal	**Performance Measure**	**Metrics Used**
Goal 1: Influence Growth in the Use of Transportation Options	Mode split data from surveys	• SOV usage as compared to previous survey. • Non-SOV usage (i.e., mode splits between alternative modes of transportation) as compared to previous survey. • Mode use at Arlington worksites offering TDM services.
	Growth of TDM conditions in site plans	• Percent of new development/redevelopment with TDM conditions implemented in site plan vs percent of total new development/redevelopment.
	Service enhancements/growth of transit corridors	• Growth in increased transit options. • Removal/decrease in transit corridors/gaps in service.
	Environmental impact measures attributed to TDM plan	• Use Environmental Protection Agency (EPA) approved models to measure vehicle trip reduction changes per year. • Use EPA approved models to measure Green House Gas Emission increases/reductions as a result of annual changes in SOV use.
Goal 2: Provide Quality TDM Service to Arlington Residents, Employees, Businesses, and Visitors	Customer approval and satisfaction ratings for measured programs	• Number of employer clients participating in employee commute programs (i.e., transit subsidies, on-site pass sales, etc.).
	Program use	• Number of commuter store/commuter direct customers. • Fare-media sales by commuter stores and commuter direct. • Website hits/unique visitors.
Goal 3: Encourage a Culture in Arlington in Which there is Increased Awareness and Appreciation of Transportation Options and Their Benefits	Number of new and continuing transportation options awareness events	• Event attendance and participation figures. • Post-event awareness satisfaction ratings (from surveys administered after a county event. • Number of sponsorships of transportation-themed events (i.e., bike to work sponsors, rideshare fairs, sports arena advertisements for transit). • Dollar amounts of non-in-kind sponsorships of transportation-related causes.
	Employer-based TDM program awareness	• Survey employees in regards to whether they were aware if their employer has a commuter program (yes or no).
	Membership-based program growth	• Car share membership.
	Transit-oriented development growth	• Increase in square footage of development surrounding transit stations/hubs (commercial, retail, residential).
	Vehicle ownership	• Number of vehicles registered as a percentage of the population.
Goal 4: Increase Transportation System Sustainability through TDM	Greenhouse gas emission and vehicle miles traveled reductions	• Peak-period VMT on Arlington street network (5% of 2005 levels). • Peak-period vehicle trips on Arlington street network (5% of 2005 levels). • Peak-period to nonpeak trip shift (10% of 2008 peak-period trips to nonpeak trips by 2020).
	Transit sales	• SmartBenefits sales, pass sales.
	Policy growth	• Number of new buildings with compliant TDM site plans. • Number of existing buildings with compliant TDM site plans.
Goal 5: Provide Transparency and Ensure Return on TDM Investment through Program Monitoring and Evaluation	No performance measures other than to conduct monitoring and evaluation.	

Source: Arlington County Department of Environmental Services, 2012

Table 14-3. TDM or Mobility Management Strategies			
Improve Transportation Options	**Incentives**	**Land-Use Management**	**Implementation Programs**
• Car sharing • Flextime • Guaranteed Ride Home • High occupancy vehicle (HOV) priority • Public transit improvements • Rideshare programs • Taxi service improvements • Telework • Walking & cycling improvements • Bike/transit integration	• Road pricing • Distance-based fees • Commuter financial incentives (parking cash out, transit subsidies, etc.) • Parking pricing • Parking regulations • Fuel-tax increases • Pay-as-you-drive insurance	• Smart growth • New Urbanism • Transit-oriented development • Location-efficient development • Parking management • Car-free planning • Traffic calming	• TDM programs • Commute trip reduction • Freight transportation management • TDM marketing • School and campus transportation management • Tourist transportation management • Least-cost planning • Market reforms • Performance evaluation

Source: Litman, 2014

Figure 14-1. Reasons for Using Alternative Transportation Modes, Northern Virginia



Source: Loudoun County, 2010

1. Rideshare Services

Ridesharing occurs when two or more people share a single vehicle. In most metropolitan areas, a public agency or private firm provides ride-matching services, acting in essence as a facilitator for matching potential rideshare users. In Denver, the program is called RideArrangers; in Atlanta, it is called Georgia Commute Options; and in Boston it is called NuRide (although there is a website called Carpool Massachusetts that provides similar matching services). The regional ride matching database in the Washington, DC, metropolitan area is administered through Commuter Connections. Using Commuter Connections' online tool for regional carpool ride matching, residents, and employees can receive ride-matching information almost instantaneously.

Table 14-4. TDM Strategies and Equity Considerations

Treats Everybody Equally	User Pays	Benefits Lower Income Households	Benefits Transportation Disadvantaged	Basic Mobility and Access
• Institutional reforms • Least-cost planning • Location-efficient mortgages • Parking management	• Comprehensive market reforms • Distance-based fees • Fuel tax increases • Parking management • Pay-as-you-drive insurance • Parking pricing • Road pricing • Smart growth	• Alternative work schedules • Car sharing • Commuter financial incentives • Guaranteed ride home • HOV priority • Improved security • Location-efficient mortgages • New urbanism • Pay-as-you-drive insurance • Park & ride • Parking management • Pedestrian & cycling improvements • Ridesharing • School trip management • Shuttle services • Smart growth • TDM marketing • Telework • Transit improvements • Transit-oriented development	• Bike/transit integration • Car-free planning • Commuter financial incentives • Comprehensive market reforms • Guaranteed ride home • HOV preference parking • Parking management • Improved security • Location-efficient development • New urbanism • Pedestrian & cycling improvements • Ridesharing • School trip management • Shuttle services • Smart growth • Street reclaiming • Taxi service improvements • TDM marketing • Telework • Tourist transportation management • Transit improvements • Traffic calming • Transit-oriented development • Universal design • Vehicle use restrictions	• Access management • Bike/transit integration • Freight transportation management • Guaranteed ride home • HOV preference • Improved security • Parking management • Pedestrian & cycling improvements • Ridesharing • School trip management • Shuttle services • Smart growth • Telework • Transit improvements • Traffic calming • Universal design • Vehicle use restrictions

Source: Litman, 2015 Reproduced with permission of Todd Litman.

Table 14-5. Candidate TDM Strategies for San Diego

	TDM Strategies							
	Land Use & Urban Design	**Transit**	**Rideshare**	**Parking Management**	**Pricing**	**Ped/Bike**	**TDM Programs & Support**	**Measures**
Site/Employers	• Site design that promotes and facilitates transit, walking, and biking	• Provide transit facilities (such as shelters) • Subsidize transit fares • Provide transit information (maps, signage, real-time info, etc.) • Provide shuttles from transit to worksite • Support car sharing and other first and last mile measures • Allow employee use of company vehicles for personal appointments/ errands	• Preferred parking for carpools and vanpools • Promote the regional ride match service • Provide or subsidize vans and/or vanpooling • Subsidize ridesharing • Support car sharing • Allow employee use of company vehicles for personal appointments/ errands	• Reduce or eliminate free parking • Include priority parking for carpools or vanpools • Limit parking spaces on site (parking maximums) • Implement Parking Cash Out • Parking reservation system (Smart Parking – pay more for priority spots) • Unbundle the price of parking	• Charge market rate for parking • Parking Cash Out	• Site design that promotes walking and/or biking • Provide showers and lockers at employment sites • Provide secure bike parking • Bicycle-sharing/ loan programs	• Designate an employee transportation coordinator to promote and coordinate transit, ridesharing, walking, and biking. • Implement flex hours, telework, and/or compressed work week options. • Allow employees to relocate jobs to branch office nearest their homes. • Provide pre-tax benefit for employees who use transit, vanpool, or bike to work • Promote/enhance the Guaranteed Ride Home program .	• Parking and vehicle counts • Average Vehicle Ridership (AVR) • Vehicle Employee Ratio • Number of equivalent SOV trips not made/ reduced • VMT reduced • Parking revenue • Transportation Management Association memberships

Table 14-5. (*Continued*)

	TDM Strategies							
	Land Use & Urban Design	**Transit**	**Rideshare**	**Parking Management**	**Pricing**	**Ped/Bike**	**TDM Programs & Support**	**Measures**
City	• Urban design guidelines that promote and facilitate transit, walking, and biking • Street design that accommodates all users (transit, bike, walking, ADA) • Restricted automobile use in pedestrian-oriented areas • Growth Management Boundaries	• Transit priority signaling at intersections • Transit-only lanes or priority routes • Improved accessibility to transit stops (safe bike and pedestrian connections) • First mile and last mile solutions to transit • Outreach and promotion • Support the implementation of transit facilities (shelters, stations)	• Priority or preferred parking for carpools and vanpools • Car sharing • Park & ride lots • HOV lanes • Managed lanes • SchoolPool programs	• Supportive zoning requirements-parking maximums • Shared parking between compatible land uses (office and restaurant/cinema) • Priority public parking for carpool/vanpool • Wayfinding and guidance system to available parking • Demand-based or performance-based pricing • Restrict long-term/commuter parking to peripheral areas • Unbundle the price of parking	• Congestion pricing on roadways or areas • Variable market rate on-street parking pricing	• Plan and implement a bicycle and pedestrian network that is connected to regional and state facilities and that connects to transit • Provide ample and secure bike parking • Public awareness programs for bicyclists/pedestrians • Bike share program	• Promotion and outreach to major employers and the community • Enforcement of TDM policies • Form TMAs to achieve shared goals.	• Level of service (LOS) • Mode split and mode shift • Bicycle and pedestrian counts for commute and other trips • Transit travel time reliability • Public parking demand • VMT • SOV trip reduction

(*continued*)

Table 14-5. (*Continued*)

Region/State	TDM Strategies							
	Land Use & Urban Design	**Transit**	**Rideshare**	**Parking Management**	**Pricing**	**Ped/Bike**	**TDM Programs & Support**	**Measures**
	• Smart Growth Tool Kit • Growth Management Boundaries	• HOV lanes/transit only lanes/ transit-supportive infrastructure and facilities/ managed lanes • Safe Routes to Transit • Traveler information • Transit marketing programs	• Regional vanpool program • Carpool incentive program • Guaranteed ride home • Free ride match service • Multimodal park & ride lots • Support car share programs	• Advanced traveler information systems	• Provision and support of HOT lanes • Dynamic pricing of roadway facilities and managed lanes	• Plan for and implement a regional/ statewide bicycle network • Public awareness programs for bicyclists and pedestrians • Provide secure bike parking at key intermodal transit centers • Bikeshare program	• iCommute services and programs • SANDAG: Regional Intermodal Transportation Management Systems (TMS) Network • Education and awareness campaigns for all modes • 511 phone and 511ad.com	• Transit and roadway LOS • LOS uniformity within a corridor or network • Transit and roadway capacity available • Transit usage • Transit and auto travel times • Mode split and mode shift • Transit travel time reliability • Regional or statewide VMT • SOV trip reduction • Non-motorized trip counts

Source: SANDAG, 2012

With respect to vanpools, many metropolitan areas have companies and/or subsidized programs to provide vans and to recruit vanpool participants. The Commuter Connections online tool can also be used for regional vanpool ride-matching. A VanStart/VanSave program is available that provides financial assistance to pay for vacant seats when starting a new vanpool or to keep an existing vanpool in service until vacant seats can be filled by regular riders.

In Denver, RideArrangers also targets families who need to transport their children to school, either by carpool, walking, biking, or riding transit. The program, which operates through the schools, is the largest school pool program in the United States.

2. *Transit Services and Amenities*

Efforts to reduce SOV use depend on there being desirable and convenient alternatives to SOV travel. Transit services and amenities are often the most common of such potential alternatives. In London, for example, site of one of the world's largest congestion pricing programs, the implementation of a significant increase in the price for automobile travel in central London was preceded by extensive upgrades in transit services in the area, so that those leaving their cars had a reasonable mobility alternative. Depending on the size of the metropolitan area, transit could include bus, light rail, heavy rail, and paratransit services (see chapter 12 on transit planning).

Although transit service is an important alternative to SOV use, research has shown that other incentives and support programs can often make the difference in choosing transit over auto use. For example, discounted transit passes, other transit subsidies, and targeted marketing are important services for informing and encouraging travelers to use transit. [Boyle, 2010] Most transit systems have different transit passes that can be subsidized by employers, local governments, or some other organization. For example, in Denver, many employers offer their employees the EcoPass, which allows unlimited rides on the bus or light rail anywhere within the transit agency's fixed-route system. A program called Flex Pass is designed to offer employers an annual pass program that can be customized to meet the needs of the company and its employees. Similar types of passes are available for college campuses and neighborhoods. The use of transit passes as an encouragement to ride transit has been made easier through the use of "smart cards," which not only expedite the traveler's trip through a station or boarding a transit vehicle, but that also allow easy reloading of cash values.

Other transit-related actions that can make a transit trip easier and more comfortable include: bus shelters, informative and visible signs and maps, car- and/or bike-sharing services at stations, accommodations for bicycles on transit vehicles, and wireless capabilities on vehicles.

3. *Active Transportation: Programs and Infrastructure*

The Denver Regional Council of Governments (DRCOG) estimates that more than 1.5 million car trips each day in the Denver region are less than 5 minutes in length. Many of these trips could be made on foot. Many opportunities to ride bicycles for some types of trips exist as well. Companies can encourage employees to bike to work by offering amenities such as secure bicycle parking and shower and changing facilities. Others sponsor bike-to-work day events. Many cities are increasingly seeing bike-sharing programs whereby members can pick up a bike at any bike station and return it to that same station or any other station when they are done. In Denver, in addition to individual memberships, corporate memberships in such a program are offered through the B-Cycle Program, which allows companies to purchase various levels of membership for employees.

An important component of a TDM program that encourages bicycle and pedestrian transportation is providing the facilities needed to safely accommodate such travel. This could mean the construction of new pedestrian/bicycle facilities, the improvement of existing facilities, enhanced safety features, and better accessibility/linkages to the existing system (see chapter 13 on pedestrian and bicycle planning).

4. *Teleworking*

In a company teleworking program, employees are allowed to work from home for one or more days each week, and in some cases remote telework sites are set up so employees can drive a short distance to their work site. Teleworking only makes sense for those types of jobs where an on-site presence is not necessary. Not only does it reduce the amount of work-related travel, research has shown that for high-tech companies in particular it is becoming an important recruiting advantage. Some examples include:

- Telework Arizona is a telework program operated by the Arizona Department of Administration. An evaluation of the program revealed that more than 75 percent of supervisors approved of the program and appreciated the resulting increases in employee productivity and morale. By 2007, state agencies, boards, and commissions reported that more than 20 percent of state employees in Maricopa County (Phoenix) teleworked.

- U.S. Patent and Trademark Office's Trademark Work-at-Home Program has 46 percent of its more than 9000 nationwide employees teleworking at least weekly.
- Georgia Power's Telework Program (Atlanta, Georgia) has shown that prior to teleworking, 70 percent of the participants drove alone; after teleworking, the drive-alone rate dropped to 44 percent, with 28 percent of the change attributed to teleworking. Eighty percent of teleworkers reported that productivity increased an average of 27 percent while teleworking. Forty percent of managers believed productivity had increased by 5 percent as a direct result of teleworking, while 60 percent of managers thought that productivity had stayed the same. [Arizona DOT, 2012]

Telework can be a strong component of an overall congestion management strategy given that it is an effective method of fully removing commute trips from the roadway system while simultaneously reducing parking demand.

5. Compressed and Flexible Work Schedules

Next to rideshare programs, encouraging employers and employees to adopt more flexible work hours or locations has been one of the mainstays of TDM programs. To a large extent, these programs surfaced in the 1970s in response to oil embargoes and a growing concern for energy conservation. Compressed work schedules include different work hour arrangements.

- *Flexible Work Hours*. Flexible work hours are programs allowing employees a degree of freedom in choosing their starting and quitting times. Employees must be at work during core periods (typically 9:30 to 11:30 a.m. and 1:30 to 3:30 p.m.) and must observe earliest allowed starting time and latest allowed quitting time limitations.
- *Staggered Work Hours*. Staggered work hours are a fixed scheduling of work that normally spreads the employee starting and quitting times over a 1- to 3-hour period, with individual groups of employees designated to report and leave at 15- to 30-minute intervals.
- *Compressed Work Week.* A compressed work week allows employees to work a greater-than-standard number of hours each day so as to reduce the total number of days worked, and hence, the number of times it is necessary to commute to the work site. A popular arrangement is the 9/80 schedule in which employees work 9 hours per day versus the standard 8 hours, and then get the 10th day off. [Kuzmyak et al., 2010]

A major new development in northern Virginia proposed the following steps to implement a flex work week as part of its TDM commitments to the local jurisdiction. A designated transportation coordinator(s) will:

- Coordinate with tenant organization points of contact to educate them on the importance of Flex Work Week (FWW) schedules and encourage making most employees eligible for FWW.
- Advertise FWW in the orientation handbook, and encourage employees who have not taken advantage of FWW to do so as they relocate to the new site.
- Develop new-hire orientation packets to inform employees about their FWW eligibility and encourage employees to travel during the early or later part of the peak period.
- Coordinate with traffic engineers to conduct biannual traffic counts at key intersections and parking garage entrances to determine actual peak-hour congestion levels. The Transportation Coordinator will issue a report to tenant organization points of contact detailing peak hours of congestion. If it is determined that at a certain peak hour, intersections are operating at consistently failing levels of service, the report will encourage supervisors within each tenant organization to inform employees to avoid traveling to work during the peak hour of congestion and encourage being flexible with their arrival time to work, within reason and when possible.
- Develop and/or acquire brochures, pamphlets, web-content, and posters advertising the FWW program. [City of Alexandria, undated]

6. Guaranteed Ride Home (GRH)

Studies in the 1980s that examined the effectiveness of ridesharing programs determined that one of the greatest barriers for many who might be interested in using such services was "getting caught" at work without a means to leave the workplace. This was a particularly big concern for those who felt they needed the ability to leave if necessary to pick up a sick child, handle emergency situations with elderly parents, or deal with similar situations. Starting in the 1980s, several ridesharing programs offered a guaranteed ride home program that did exactly as the name implies—provided rides either through a company car or by taxis to those in ridesharing programs who needed to leave unexpectedly. This program became a mainstay of many ridesharing (and today, bike) programs and has been successful in reducing the level of anxiety in participating in ridesharing programs. For more information on GRH, see University of South Florida, [2010].

B. Incentives

Regional and employer-based TDM programs are more successful when incentives (usually monetary) reinforce the desired change in travel behavior. The most common form of TDM incentive increases the cost of SOV use.

1. Road Pricing

For many years, economists who have studied road congestion have argued that marginal pricing of road use would go a long way toward reducing congestion by encouraging travelers to seek alternative modes of travel or to encourage trip-making outside of the peak period. One of the best ways of influencing travel demand is thus by pricing the use of automobiles. [Saleh and Sammer, 2009] Several strategies have been suggested for doing this. (Note that chapter 5 on transportation finance and funding provides more in-depth discussion of most strategies, viewed primarily as the source of funds for investment purposes. Thus, for example, motor fuel taxes are not discussed in this chapter.)

VMT Fees or Mileage-based User Fees. Charging a per-mile fee for using the road network is a suggestion that has received increasing attention in recent years. This is very close to the economic concept of a "user fee" in that the amount paid is directly related to how much one uses the road network. Although conceptually appealing, proposals to adopt such a fee structure have run into opposition from those who, on average, travel many miles per year. In addition, some of the strategies for collecting vehicle mileage have been viewed by some as infringing upon personal privacy.

Tolling. Toll roads are another variant of road pricing. Tolls have been used for many years to pay for the construction and maintenance of critical road facilities (for example, the New Jersey Turnpike, Pennsylvania Turnpike, and the like). Over the past two decades, with the emergence of public/private financing of new roads, tolls have again become an important part of highway finance. Many metropolitan areas have also implemented managed lanes where a fee is charged that varies by time of day or by the level of congestion in the lane itself (see chapter 10 on transportation system management). Although tolls have been used primarily as a financial strategy, the pricing of road use does influence travel demand on that facility.

Cordon Pricing. Cordon pricing charges road users for entry into a defined cordon area. Singapore was one of the first cities in the world to implement such a program in the 1970s. In 2003, Central London introduced cordon pricing (the "London Congestion Charge"), using license number plate recognition technology. Cordon pricing strategies have been proposed in many European cities and in New York City.

Pay-As-You-Drive (PAYD) Insurance. Pay-as-you-drive (PAYD) insurance links insurance premiums to vehicle miles of travel. The more one travels, the higher the risk of accidents and thus the higher the premium. Alternatively—and thus the influence on travel demand—the lower the mileage, the smaller the premiums.

2. Parking Pricing and Cash Out

Managing the price and availability of parking is widely recognized as one of the most effective TDM strategies. [Shoup, 2005; Marsden, 2006] Strategies include parking regulations; parking space maximums; priority parking for carpools, vanpools, and short-term parkers; remote parking with shuttle service; and parking pricing. According to a City of Seattle report, "the most effective parking strategies are cost-based or pricing measures that link parking rates more directly to demand or provide financial incentives and/or prime parking spaces to preferred markets such as carpools, vanpools, and short-term parkers." [City of Seattle, 2007] Parking cash-out policies are an example of this.

These are used in some cities where the employer subsidy for the cost of parking is assumed as a monthly subsidy to the driver, and that amount is provided to the company's employees to use for parking, transit passes, or for walking and bicycling. [Shoup and A. P. Association, 2005] Using the subsidy for transit, walking, or bicycling (which would cost must less than the subsidy itself) provides extra dollars to each traveler that can be used at his/her discretion.

Unbundling parking costs from the leasing cost of property is another parking strategy identified in the Seattle report. Unbundling the costs means that parking spaces would be leased or sold separately from the property itself. The evidence suggests that this strategy can reduce parking demand and increase nonSOV mode share. As noted in the report, it was estimated that including the price of parking in an overall lease can increase costs by as much as 25 percent—whether or not the tenant has a car—and can be perceived by the customer as an "invisible" cost. [City of Seattle, 2007]

See chapter 11 for further discussion on parking strategies.

3. Commute Benefits

In keeping with the important role that financial incentives can play in influencing traveler behavior, the federal government changed the tax code in 2001, allowing employers to provide tax-free transit, vanpool, or parking benefits to employees (Section 132 (f) of the tax code). Qualified benefits included:

- *Transit Passes* — Transit passes include any vouchers, passes, fare cards, tokens, or related items that employees can use to pay for transportation on mass transit facilities or on transportation provided by a person in the business of transporting persons for compensation or hire, if such transportation has a seating capacity of at least six adults (not including the driver).
- *Transportation in a Commuter Highway Vehicle* — Better known as a vanpool, the tax code defines a "commuter highway vehicle" as a vehicle that has a seating capacity of at least six adults, not including the driver; at least 80 percent of the vehicle's mileage results from trips between work and employees' homes, and during these trips at least one-half of the vehicle's capacity must be filled (not including the driver).
- *Qualified Parking* — Qualified parking is defined as parking near or at the employers' place of business or parking located near or at a place where employees commute to work by mass transit, commuter highway vehicles, or carpools (for example, parking at a transit station, park-and-ride lot, or vanpool staging area). [ICF Consulting et al., 2003]
- *Qualified Bicycling* — Qualified commuting expenses include the purchase of a bicycle and bicycle improvements, repair, and storage.

As of 2015, employers can subsidize parking at $250 per month, offer $130 per month for transit/vanpool, and reimburse up to $20 per month for regular commuting by bicycle. Commuters can receive both the transit and parking benefits (that is, up to $380 per month). Depending on the individual's income tax bracket, the savings could add up to hundreds of dollars annually for employees.

In some cities, nonprofit organizations have been created to motivate employers and employees to use alternative modes of transportation. For example, in Atlanta, Georgia, a group called Georgia Commute Options provides consulting advice to metropolitan Atlanta employers on implementing telework programs, compressed work weeks, and flextime. Staff members speak at events about commute options and the resources available to employees at the worksite, as well as the monetary incentives to motivate commuters to switch from driving alone. Expert consultants are available to start or expand telework, compressed work week, or flexible work hour programs. Surveys are provided to employers to help them better understand the mobility needs of their employees. Consultants provide assistance to employees in finding carpool or vanpool partners who live and work near each other. Up to five free rides home each year are provided via a guaranteed ride home program for registered employees who use commute alternatives. The organization promotes employers in local media, provides annual awards that spotlight an organization's positive impact on commute options, and provides assistance to employees moving into the region by showcasing the best commute options.

Another commute benefit program, also from Georgia, is called "cash for commuters." [Georgia DOT, 2009] This program provided $3 per day to commuters for each day they used a clean commute (defined as an alternative to single-occupant motor vehicle use), up to $100, over an assigned 90-day period. The program also adopted a systematic monitoring program that followed the cash for commuters program participants, primarily to determine the extent to which the program provided lasting changes in travel behavior. Table 14-6 shows the results of the surveys for two waves of participants in 2007 and 2008.

Remarkably, 57 percent of the first program participants were still using alternative modes of transportation 18 to 21 months after the cash subsidy ended. Table 14-7 shows the reasons that participants gave for starting the use of alternative modes (note: 2008 was the start of an economic recession and gas prices rose dramatically).

Alternatively, Table 14-8 shows the primary reasons why participants stopped using an alternative mode. Notice the importance of losing a rideshare partner. This has been shown in other studies to be an important factor in the ending of car pools.

Table 14-6. Short- and Long-Term Impact of Cash for Commuters Program, Atlanta, Georgia

Alternative Mode Status	Cash for Commuters (CFC) Wave 1			CFC Wave 2	2007 CFC Program Year	2008 CFC Program Year
	3–6 Months After Program Completion (n = 302)	9–12 Months After Program Completion (n = 300)	18–21 Months After Program Completion (n = 308)	3–6 Months After Program Completion (n = 300)	18–24 Months After Program Completion (n = 237)	3–6 Months After Program Completion (n = 400)
Continued use of alt. mode	71%	64%	57%	74%	74%	69%
Stopped use of alt. mode	29%	36%	43%	26%	26%	31%

n = sample size

Source: Georgia DOT, 2009

Table 14-7. Factors Influencing Switch to Alternative Mode, Cash for Commuters Program, Atlanta, Georgia

Factors that Led to Using Alternative Modes	2007 Program Year (18–24 Months After Ending Subsidy, n = 237)	2008 Program Year (3–6 Months After Ending Subsidy, n = 400)
Gas prices	17%	46%
Save money	28%	21%
Friend, family member, co-worker wanted to carpool	23%	16%
$3 incentive	20%	20%
Convenience	16%	18%
Less stressful than driving	9%	3%
Reduce congestion/Help environment	8%	6%
Save time	5%	3%

Source: Georgia DOT, 2009

Table 14-8. Primary Reasons for Stopping Use of an Alternative Mode, Cash for Commuters Program, Atlanta, Georgia

Factors that Led to Stopping Use of Alternative Modes	2007 Program Year (18–24 Months After Ending Subsidy, n = 53)	2008 Program Year (3–6 Months After Ending Subsidy, n = 99)
Lost carpool partner	38%	38%
Schedule or work location change	32%	25%
Too inconvenient	25%	19%
Gas prices went down	0%	13%

Source: Georgia DOT, 2009

C. Land-Use Management

Many of the TDM strategies presented in the previous sections are focused on what can be done in the short term to influence travel behavior. Over the long term, this means influencing land-use and development decisions. Some TDM programs thus consider strategies such as transit-oriented development (TOD) as part of their TDM strategy. Others consider TDM site plan review requirements—for example, reviews of developments of regional impacts (DRIs) or trip reduction ordinances—as part of a regional TDM strategy (see chapter 12 on transit planning for further discussion of TOD strategies).

Table 14-9 shows some of the TDM strategies that can be considered in the land development process. As shown, such strategies aim to, (1) influence trip length, choice of mode, and route, (2) link to regulation, and (3) use travel costs, trip frequency, and time of day/week of trip-making as key focal points. Table 14-10 shows different types of TDM strategies recommended in Arizona as they relate to different land uses.

Many examples exist of how TDM strategies are linked to land-use decisions. For example, a British Columbia, Canada, planning district allows developers a reduced parking requirement in exchange for providing new residents with a transit pass for one year, a car-share vehicle with membership for each unit, and secure underground bicycle storage. [SANDAG, 2012] The city of New York has adopted Active Design Guidelines that encourage active transportation (walking and biking to transit or work) and recreation for neighborhoods, streets, and outdoor spaces. Key strategies include:

- Mixed land uses in city neighborhoods.
- Improved access to transit and transit facilities.
- Improved access to recreational facilities such as parks, plazas, and open spaces.
- Improved access to full-service grocery stores.
- Accessible, pedestrian-friendly streets with high connectivity, traffic calming, landscaping, and public amenities.
- Facilitate biking for transportation and recreation through bicycle networks and infrastructure. [SANDAG, 2012]

In Seattle, Washington, Growing Transit Communities (GTC) is an initiative to encourage housing, jobs, and services to locate close enough to transit to make it a viable option for most people. Ultimately, the goal is to "provide all people the choice to live in affordable, vibrant, healthy, and safe communities where they can conveniently walk or take a train or bus to work, and have good access to services, shopping, and other activities." [PSRC, 2013]

In Loudoun County, Virginia, developer proffers are often part of the development negotiations. Proffers are frequently used for the construction of sidewalks, trails, bike paths, bus stops, and other transit and TDM-supportive elements on development sites in addition to the purchase of transit vehicles.

See chapter 3 on land use and urban design for more detail on land-use strategies and smart growth. For a review of TDM programs in Canada and in many other parts of the world, see Halifax Regional Municipality [2010].

D. Implementation Programs

Although the TDM strategies presented in the previous sections were described individually, in reality, many are often packaged into a program. At the metropolitan or subarea levels, this means that governments or TDM providers operate at an areawide level.

1. Government-Sponsored TDM Programs

TDM programs sponsored by government agencies often tie their TDM policy to other planning efforts. Thus, for example, Arlington County, Virginia, has incorporated TDM into its master transportation plan policies, as seen in Table 14-11. As shown, TDM is tied into the comprehensive transportation master plans for all new development sites as well as existing public buildings and facilities.

Table 14-9. Range of TDM Strategies Potentially Addressed in the Land Development Process, Arlington County, Virginia

Means of Influencing Travel Behavior	TDM Strategy (Examples)	Supporting Action (Land Development Process)
	Trip Length	
Reduce Quantity of Vehicle Miles	• Transit-oriented development. • Proximate commuting by allowing employees to relocate job to the branch office nearest their homes.	• Clustering related land uses and providing more direct access (comprehensive plans and land development regulations). • Providing incentives to employers.
	Mode	
Increase Efficiency of System to Carry More People in the Same Number of Vehicles	• Developing land support of alternative modes, such as transit-oriented development. • Limited parking supply. • Offering alternative modes, such as transit, vanpooling, carpooling, bicycling, walking.	• Locating land development to take advantage of existing underutilized transportation services such as transit routes. • Providing on-site amenities, such as lockers, showers, bicycle parking, and preferential carpool parking (land development regulations). • Providing support services such as marketing, ride matching, and guaranteed ride home. • Providing transportation services and physical transportation facilities off-site. • Shared parking.
	Route	
Bypass Congestion	• Transit-oriented development. • Providing route alternatives. • High-occupancy vehicle lanes with queue jumps.	• Providing a grid system, street connectivity, and destinations within easy walking distance (comprehensive plans and land development regulations). • Implementing Advanced Traveler Information Systems.
	Regulation	
Mandate Specific Traffic Management Actions or Outcomes by Local Ordinance	• State growth management provisions. • Concurrency. • Trip reduction ordinances. • Zoning ordinances. • Subdivision ordinances. • Parking ordinances. • High-occupancy vehicle lanes.	• Carried out primarily by land developers, property managers, employers, neighborhood associations.
	Cost	
Establish Incentives and Disincentives	• Parking pricing. • Transit subsidies. • Parking cash-out. • High-occupancy toll lanes. • Commuter tax benefits.	• Tax benefit program assistance.
	Frequency	
Reduce Number of Trips over Given Time Period	• Providing on-site amenities. • Compressed work week. • Telework.	• Providing physical facilities, such as employee cafeteria, fitness center, bank. • Providing technical support to employers.
	Time of Day/Day of Week	
Move Trips to Less Congested Periods or Avoid Vehicle Trip Completely	• Compressed work week. • Staggered work hours. • Telework. • Flex time.	• Unbundling parking from employment site leases. • Providing technical support to employers.

Source: Center for Urban Transportation Research (CUTR), 2005

Table 14-10. Candidate TDM Strategies for Different Types of Land Uses, Arizona						
Level of Transit Service	**Class A**		**Class B**		**Class C**	
	Within 1/2 Mile of Rail and Short Bus Headways		**Connectivity to Rail and/or Short to Moderate Bus Headways**		**No Transit Service**	
Land-Use Assessment Score	High	Low	High	Low	High	Low
TDM Strategy or Program						
Basic Strategies						
Bike racks	XXX	XXX	XXX	XXX	XXX	XXX
Carpool and vanpool preferred parking	XXX	XXX	XXX	XXX	XXX	XXX
General marketing materials	XXX	XXX	XXX	XXX	XXX	XXX
Information kiosks	XXX	XXX	XXX	XXX	XXX	XXX
On-site transportation fairs	XXX	XXX	XXX	XXX	XXX	XXX
Pedestrian facilities	XXX	XXX	XXX	XXX	XXX	XXX
Pre-tax commute benefits	XXX	XXX	XXX	XXX	XXX	XXX
Program manager	XXX	XXX	XXX	XXX	XXX	XXX
Vanpool-accessible parking and drop-off	XXX	XXX	XXX	XXX	XXX	XXX
Bicycle and Pedestrian Programs						
Bike lockers	XXX	XX	XX	XX	XX	XX
Shower facilities	XXX	XX	XX	XX	XX	XX
Bike routes/lanes	XX	XX	XX	XX	XX	XX
Bike paths	XX	XX	XX	XX	XX	XX
Transit Programs						
Bus benches	XXX	XXX	XX	XX	X	X
Bus shelters	XXX	XXX	XX	XX	X	X
Free transit passes	XX	XX	XXX	XXX	X	X
Real-time transit information	XXX	XXX	XX	XX	X	X
Reduced-cost transit passes	XX	XXX	XX	XXX	X	X
Shuttles/circulators	X	XX	XX	XX	XXX	XXX
Marketing Programs						
New employee information	X	XX	XXX	XXX	XX	X
Bricks-and-mortar commuter store	XX	X	XX	X	X	X
Customized travel plans/profiles	X	XX	X	XX	XXX	XXX
Incentive programs for first-time users	XXX	XXX	XXX	XXX	XXX	XXX
Individualized marketing programs	XXX	XXX	XXX	XXX	XXX	XXX
Live-near-work marketing	XX	X	XX	X	XX	X
Shop-near-work marketing	XX	X	XX	X	XXX	X
Parking Programs						
Advanced parking technologies	XXX	XXX	XXX	XXX	XXX	XXX
Occasional parking program	XXX	XXX	XXX	XXX	XXX	XXX
Paid parking	XXX	XXX	XXX	XXX	XX	XX
Parking cash out	XX	XX	XX	XX	XX	XX
Unbundle and share parking	XXX	XXX	XXX	XXX	XXX	XXX
Rideshare Programs						
Vanpool program	XX	XX	XX	XX	XXX	XXX
Site-based carpool matching	X	XX	X	XX	XXX	XXX

Table 14-10. (*Continued*)						
Level of Transit Service	**Class A**		**Class B**		**Class C**	
	Within 1/2 Mile of Rail and Short Bus Headways		**Connectivity to Rail and/or Short to Moderate Bus Headways**		**No Transit Service**	
Alternative Work Programs						
Compressed work weeks	XX	XX	XX	XX	XX	XX
Flexible work schedules	XX	XX	XX	XX	XX	XX
Telework programs	XXX	XXX	XXX	XXX	XXX	XXX
Other Programs						
Car-share program	XXX	XXX	XX	X	XX	X
Concierge service	XX	XX	XX	XX	XX	XX
Guaranteed ride home	XXX	XXX	XXX	XXX	XXX	XXX

XXX: High Applicability XX: Medium Applicability X: Low Applicability

Source: Arizona DOT, 2012

Table 14-11. Incorporating TDM into Transportation Master Plan Policies, Arlington County, Virginia
Incorporate comprehensive TDM plans for all site plans and use-permit developments to minimize vehicular trips and maximize the use of other travel options.
Incorporate TDM measures with respect to all existing public buildings and facilities, irrespective of redevelopment status. Explore strategies and incentives to achieve TDM measures in existing private buildings.
Require regular travel surveys of new development with TDM plans and link to performance measures to enable follow-up actions. Undertake biennial evaluations of the effectiveness of the County's TDM policies and private-sector compliance with TDM commitments, and implement revisions as warranted.
Conduct County-wide resident and worker transportation surveys every 3 years, in conjunction with the Virginia and Metropolitan Washington Council of Governments (MWCOG) State of Commute surveys, to monitor travel behavior and system performance, and guide future efforts.
Apply TDM programs to non-work travel, as well as commuting, for resident, visitor, and employee trips through informational displays, website, promotional campaigns, and mailings of materials.
Coordinate TDM efforts with other jurisdictions and agencies across the region, and actively promote the expansion of the TDM program.

Source: Arlington County Department of Environmental Services. 2012

In Kitchener, Ontario, Canada, the city adopted a parking control strategy to implement a policy of shifting mode share to non-SOV travel, but subsequently realized that the control of parking was not sufficient to achieve the total shift desired. The city therefore relied on the bicycle master plan and a new TDM plan to augment the expected shifts from the parking program. These plans included the following strategies: [City of Kitchener, 2011]

Cycling Master Plan

- Implement the cycling network over time.
- Develop and implement a cycling wayfinding signage strategy.
- Update zoning bylaws to include bicycle parking.
- Develop program to assist property owners in retrofitting for bike parking.
- Develop and communicate design guidelines and review of site plans.
- Integrate cycling infrastructure in every new road and road reconstruction.

- Consider needs of cyclists in transportation projects and services.
- Work with Region to integrate cycling with bus services and rapid transit.
- Provide staff training on cycling needs and infrastructure.
- Partner with Region, School Boards, and Public Health to provide education and cycling programs.
- Develop marketing program to promote cycling.
- Provide support to events that promote cycling.
- Provide support to the Cycling Advisory Committee.

Transportation Demand Management

- Subsidize corporate transit passes.
- Carpool matching.
- Guaranteed ride home program.
- Conduct promotional events.
- Develop and distribute promotional materials.
- Pilot telework program.
- Carbon tracking tools.
- Employer stakeholder support.
- TDM-friendly site design.
- Outreach to large employers citywide.
- Outreach to downtown residents and employers.
- Individualized marketing campaigns.

A more aggressive approach to publicly sponsored TDM programs commonly occurs in community policies and regulations for the review of large development projects. In Cambridge, Massachusetts, for example, a combination of TDM incentives to walk, bike, take transit, and rideshare, along with disincentives to drive alone, are required for larger projects and projects that expand parking. These incentives include, but are not limited to:

- Transit subsidy.
- Free shuttle bus.
- Bus shelter.
- Market-rate parking fee charged directly to employees or patrons.
- Daily parking charge available for occasional drivers instead of monthly parking pass.
- Bicycle parking above minimum zoning requirement.
- Shower/locker.
- Financial incentive for walking or biking.
- Emergency ride home.
- Car/vanpool matching.
- Priority/discounted HOV parking.

Table 14-12. State DOT Participation in TDM Activities		
Activity	**Percent**	**Number**
Bicycling	95%	39
Carpooling	88%	36
Promotion of transit use	83%	34
Walking	80%	33
Vanpooling	80%	33
Ride matching	68%	28
Telecommuting	49%	20
TDM marketing	49%	20
Employer-based	46%	19
Commuter Financial Incentives	44%	18
HOV (high-occupant vehicle) lanes/priority	44%	18
Outreach/programs	41%	17
Transit-oriented development	39%	16
Trip chaining	22%	9
Congestion/road pricing	12%	5
Parking pricing/management	7%	3
Pay-as-you-drive insurance	2%	1

Source: ICF International, 2010

- Transportation information.
- Hiring of Cambridge residents.
- On-site TDM coordinator.
- Transportation Management Association (TMA) membership.

Government-sponsored TDM programs also occur at the state level. Many state DOTs aggressively pursue strategies for reducing travel demand, and in fact were at the forefront of some TDM strategies such as ridesharing and van pools starting in the 1970s. The impetus for this involvement was primarily an increasing concern about energy conservation and mitigation efforts associated with major freeway reconstruction projects. A survey of state DOTs in 2010 showed that many state DOTs are still involved in a range of TDM strategies (see Table 14-12). "Bicycling" at the top of this list is not surprising given the federal requirement to have a state bicycle coordinator; "parking management" near the bottom of the list is also not surprising, given that most responsibility for parking management rests with local municipalities.

One of the important roles for government-sponsored TDM activities is that they can be part of a much larger mobility strategy. For example, sponsoring an area-wide ridesharing or van pooling program can be an important supporting strategy for a managed lane or high-occupancy vehicle lane program. Supporting flextime programs can help dampen the peak demand on publicly supported and operated transportation facilities. Table 14-13 from ITE's *Traffic Engineering Handbook* shows the many different strategies that can be considered for traffic management and TDM. The TDM strategies are shown in the shaded areas. Again, as noted, it is often the combination of many of these strategies that leads to notable changes in travel behavior.

2. Private Company-Sponsored TDM Programs

The types of TDM strategies considered by private companies at large employment sites are very similar to those described above, and thus will not be repeated. In most cases, however, the program is not as expansive as might be found in a government agency–sponsored TDM initiative. In many metropolitan areas, transportation management organizations (TMOs) or associations (TMAs) have taken the lead in TDM implementation. TMOs are usually nonprofit organizations formed by employers and other major stakeholders in an area to provide (primarily) transportation services to the area. They serve as a focal point for TDM implementation for their members, and in some cases, such as in Atlanta, Georgia, they are combined with community investment districts (CIDs) having a dedicated

Table 14-13. Traffic Management and TDM Strategies Influencing Choice

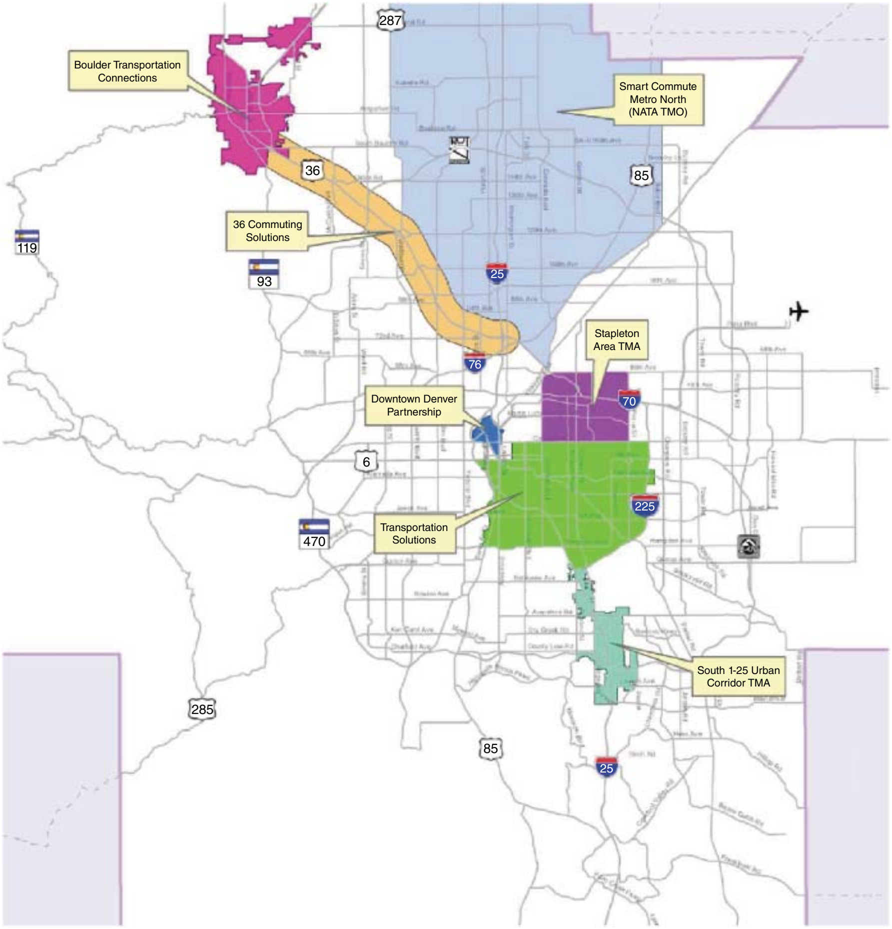
Technique	Traveler Choices Affected
Arterial Management – The management of traffic signals, dynamic and fixed lane management along surface streets including speed management, pedestrian and bicycle interaction with vehicles, vehicle priority coordination, and coordination with other techniques such as traveler information, electronic payment, or incident management.	R, M, L
Freeway Management – The management of lanes along freeway and associated ramps interfacing with the arterials including speed management, and coordination with other techniques such as traveler information, electronic payment, or incident management.	R, M, L
Transit Management – Transit service available to a site, personal security, route and scheduling information, and coordination with traveler information services.	R, M, T, OD
Incident Management – The detection, response, and recovery from events that are non-recurring, providing information to response personnel and the public, minimizing the impacts on traffic flow, and optimizing the safety of the public and responders.	R, L, T, OD
Emergency Management – Hazardous material routing and security management, routing, coordination of emergency response service providers, and information dissemination and coordination.	R, M
Road Pricing and Electronic Payment – Payment services and systems associated with toll facility operations, variable pricing, VMT fees, parking facilities, and transit services.	R, M, L, T, OD
Traveler Information – Pre-trip, near pre-trip, and en-route information provided to the traveler via roadside, in-vehicle or personal communication devices on the current travel conditions, trip planning services, tourism, special events, and parking information.	R, M, L, T, OD
Roadway Operations and Maintenance – The management of work zones and route closures through the use of traveler information, lane and speed management systems, and enforcement and response service providers.	R, L, T, OD
Road Weather Management – Planning for and responding to weather events impacting traffic operations and roadway conditions, information distribution to travelers and response personnel, and operations of facility under inclement conditions.	R, M, L, T, OD
Commercial Vehicle Operations – Clearance and screening of commercial carriers to optimize flow of goods and services while optimizing safety and efficiency through the use of roadside and in-vehicle technology.	R, L, T
Intermodal Freight – Integrated operations of freight transported by multiple modes both internationally and domestically.	R, M, L, T, OD
Parking Management – Parking information, variable pricing, routing to available parking.	M, T, OD
Quality Pedestrian Movement – Availability of pedestrian facilities that are integrated within the overall transportation network and accommodate or even promote non-motorized travel.	R, M, T, OD
Amenities On-Site – Bicycle locks, showers, automated teller machines, vanpool or carpool parking, local shuttle service, infrastructure for teleworking.	M, T, OD
Ridematching Program – Carpools, vanpool programs, preferred parking, transit, or parking subsidies.	R, M, L, T, OD
Alternative Work Schedules – Four 10-hour days per week, staggered hours, flexible hours.	R, M, L, T, OD
Telecommuting Options – Work environment that supports employer-employee relationship from remote sites with consideration of accessibility, accountability, and productivity.	R, M, T, OD
Travel Plans – Worksite, school, or event plans that incorporate travel demand and traffic management strategies to reduce the negative impacts of car use to the site.	M, T, L, OD
On-Site Travel Coordinator – Staff and services focused on travel services and demand management strategies.	R, M, T, OD

Key travel choices: Route (R), Mode (M), Location (L), Time (T), or origin/destination (OD)

Shaded areas indicate TDM strategies.

Source: Kraft, 2009

Figure 14-2. Transportation Management Associations in Denver, Colorado



Source: DRCOG, undated

funding source (for example, receiving a percentage of the commercial property tax millage rate). The TMO/CID combination is particularly useful for TDM strategy implementation because the financial resources are available to implement many different strategies. Figure 14-2 shows the TMAs that have been formed in Denver, Colorado. They tend to focus around major employment sites, such as the Stapleton Area TMA, or along interstate corridors, such as the 36 Commuting Solutions TMA.

For further information on employer-sponsored TDM programs, see Luten et al. [2004], ICF Consulting and Center for Urban Transportation Research [2005], and Kuzmyak et al. [2010].

3. Marketing and Employer Support

Marketing includes both general efforts to promote the use of alternative modes of transportation and efforts that are more targeted on specific marketing objectives, such as promoting transit passes. As noted in the Denver, Colorado, TDM plan, there are several scales of marketing efforts:

- *Regional campaigns* require participation and collaborative efforts among all TDM service providers and the media in order to be successful and cost-effective.
- *Subarea campaigns* are often led by individual employer associations or local governments with specialized messaging for their localized audience.
- *Site-based marketing* efforts are usually led by individual employers or property managers.

In many public agencies, a TDM coordinator has been hired to provide assistance to employers interested in implementing a TDM program. For example, in Loudoun County, Virginia, a full-time staff member provides outreach and assistance to employers to promote transit and high-occupancy commute modes and encourage and assist employers with employee commute benefits and incentives. Other examples might include conducting SOV trip reduction challenges, sponsoring an employer vanpool, or the providing transit passes or discounts. [DRCOG, 2012]

Beginning in the mid-1990s, many marketing scholars proposed the adoption of marketing theory to bring about social change, called social marketing. Social marketing (sometimes called individualized marketing) was defined as:

> *"The application of commercial marketing technologies to the analysis, planning, execution, and evaluation of programs designed to influence the voluntary behavior of target audiences in order to improve their personal welfare and that of their society."*
>
> *[Andreasson, 1995]*

First applied in transportation applications in Germany, the concept was soon transferred to Australia (where it was called TravelSmart), and first used in the United States in Portland, Oregon, in the early 2000s. The concept is to provide marketing materials and other information concerning mobility options to individuals, households, or targeted neighborhoods. [McGovern, 2005; Cooper, 2006; Taylor, 2007; Thogerson, 2013] In Portland, residents in the targeted neighborhoods received personalized information from city officials about different travel options (walking, cycling, transit, and car sharing) and were made aware of guided walks, rides, and other events. [Dill and Mohr, 2010] Most evaluations of the impacts of such marketing are based on before-and-after surveys, usually one year after the start of the marketing campaign. The results have been impressive. Table 14-14, for example, shows such before-and-after evaluations in different cities in the United States. The reduction in drive-alone trips ranges from 4 percent to 12.8 percent.

One of the limiting factors of the trip reduction results shown in Table 14-14 is that most of the before-and-after studies have occurred after a relatively short period of time. Dill and Mohr [2010] examined the longer-term impacts of such marketing in the Portland neighborhoods that had been targeted by the city. The findings of this study varied by neighborhood. In one neighborhood, there was a notable drop in the share of weekday trips made by single drivers, but much of this change could have been attributed to a significant increase in gas prices between surveys. The increase in walking was not statistically significant, and the share of people who had biked in the previous month saw a significant increase.

In another neighborhood, the share of drive-alone walking, and bicycling daily trips were comparable to the results of the short-term surveys; that is, there was a significant decrease in drive-alone trips and a significant increase in walking and bicycling. As noted by the authors, "The findings indicate that the benefits of the programs may extend beyond one year and up to at least two years. However, the findings from the Southwest target area indicate that the programs may not be as effective in all environments. The programs may be more effective in neighborhoods with a physical environment more conducive to walking, bicycling, and transit." Perhaps most importantly, the authors

Table 14-14. Estimated Short-Term Trip Reduction from Individualized Marketing Campaigns, United States

Location	Date	Results
Portland, OR—Hillsdale	2003	9% reduction in drive-alone trips
Portland, OR—Interstate	2004	9% reduction in drive-alone trips
Portland, OR—East	2005	8.6% reduction in drive-alone trips
Portland, OR—Northeast	2006	12.8% reduction in drive-alone trips
Portland, OR—Southeast	2007	9.4% reduction in drive-alone trips
Cleveland, OH	2005	4% reduction in drive-alone trips
Durham, NC	2005	7% reduction in drive-alone trips
Sacramento, CA	2005	2% reduction in drive-alone trips
Bellingham, WA	2004	8% reduction in drive-alone trips

Source: As reported in Dill and Mohr, 2010 noted that "the research also found that attitudes, norms, and perceptions play a large role in travel decisions. To be most effective, individualized marketing programs need to influence these factors." [Dill and Mohr, 2010]

IV. POTENTIAL IMPACTS OF TDM STRATEGIES

The impacts of TDM strategies on the number of trips, trip rates, vehicle emissions, and mode split are often difficult to determine, especially when a comprehensive TDM program is being evaluated. In such cases, given that many different strategies are being utilized, it is challenging to distinguish which strategy is contributing what impact to the overall outcome. Accordingly, many of the studies that have assessed the effectiveness of TDM strategies have resorted to qualitative assessments to indicate the level of impact for different types of policy goals. Tables 14-15 and 14-16 are examples of such an assessment.

However, some studies have been conducted to determine the actual impact of TDM actions on a variety of performance measures. Many of these studies were conducted in the 1990s, such as the Transit Cooperative Research Program (TCRP) Report 95 series on traveler response to transportation system changes. This series of reports was one of the first major efforts to understand systematically the potential consequences of implementing TDM strategies. Gopalakrishna et al. [2012] also present a good overview of the likely impacts as identified in other reports. Tables 14-17 to 14-19 provide some of the latest information on the impacts of different TDM strategies. As shown, the tables reinforce many of the factors described in this chapter that influence the choice to change travel behavior, such as the importance of having alternatives available when providing disincentives to automobile use, or the significant impact of pricing on travel behavior. Other useful information on the impacts of TDM strategies can be found in City of Seattle [2007], ICF Consulting and Center for Urban Transportation Research [2005], and Ison and Rye [2008]. See also the *Transportation Demand Management Encyclopedia*, http://www.vtpi.org/tdm/.

Table 14-15. General Emissions Impact of TDM Strategies

	Category of Primary Effect						General Pollutant Effect						
Strategy	**Reduce VMT**	**Reduce Trips**	**Shift Travel Time**	**Reduce Idling**	**Change Speeds**	**Change in Fuels**	**PM2.5**	**PM10**	**CO**	**NO_x**	**VOCs**	**SO_x**	**NH_3**
Park and ride facilities	●	-					↓	↓	↓	↓	↓	↓	↓
HOV lanes	●	●			●		↓	↓	↓	↓	↓	↓	↓
Ridesharing	●	+					↓	↓	↓	↓	↓	↓	↓
Vanpools	●	+					↓	↓	↓	↓	↓	↓	↓
Bicycle/pedestrian	●	●					↓	↓	↓	↓	↓	↓	↓
Transit service enhancement	●	●					↓*	↓*	↓	↓*	↓	↓*	↓
Transit marketing, information	●	●					↓	↓	↓	↓	↓	↓	↓
Transit pricing	●	●					↓	↓	↓	↓	↓	↓	↓
Parking pricing/management	●	●					↓	↓	↓	↓	↓	↓	↓
Road pricing	●	●	+				↓	↓				↓	↓
VMT pricing	●	●					↓	↓	↓	↓	↓	↓	↓
Fuel pricing	●	●				●	↓	↓	↓	↓	↓	↓	↓
Employer-based TDM programs	●	●	+				↓	↓	↓*	↓*	↓*	↓	↓
Non-employer-based TDM programs	●	●	+				↓	↓	↓*	↓*	↓*	↓	↓
Land-use strategies	●	●			●		↓	↓	↓*	↓*	↓*	↓	↓

● primary effect   + may be a notable effect, but not in all cases   - opposite effect in some cases   ↓ decrease   ↓* generally decreases, but possibility of an increase

Source: FHWA, 2006

Table 14-16. TDM Strategies and Their Relative Effectiveness in Addressing Key Policy Objectives

	Traditional TDM								Land Use and Active Transportation					Transit			Parking			Pricing				Systems Management			
Policy Objectives	**HOV/HOT Managed Lanes**	**Employer Trip Reduction Programs**	**Alternative Work Programs**	**School-based Trip Reduction Programs**	**Event-based Trip Reduction Programs**	**Recreation-based Trip Reduction Programs**	**Car Sharing**	**Vanpool Programs**	**Developer Trip Reduction Programs**	**Land-use Strategies**	**Car-free or Access Restricted Zones**	**Bicycle Facilities and Programs**	**Pedestrian Facilities and Continuity**	**Transit Service Improvements**	**Transit Prioritization and BRT**	**Transit Fare Discounts**	**Parking Information**	**Parking Supply Management**	**Parking Pricing**	**Cordon Pricing**	**Congestion Pricing**	**General Financial Incentives**	**VMT Tax**	**Ramp Metering**	**Integrated Corridor Management**	**Traveler Information**	**Eco-Driving**
Mobility	3	3	3	3	3	3	3	2	2	3	2	3	3	2	3	2	3	0	0	0	0	4	0	0	2	3	NA
Congestion Relief	1	2	2	2	2	2	0	2	2	2	3	2	2	2	2	2	2	3	2	4	4	2	4	3	2	3	0
Air Quality	1	3	3	3	2	2	3	4	2	2	3	3	3	3	3	3	2	3	3	4	4	4	4	0	1	2	2
Economic Development	1	0	2	1	1	1	2	2	0	2	0	2	2	2	2	2	2	0	0	1	1	3	0	NA	1	2	0
Land Use Interaction	2	NA	2	1	1	1	2	1	3	3	3	3	3	2	2	2	2	3	3	2	2	2	3	NA	NA	NA	0
Goods Movement	2	2	2	NA	2	2	NA	2	NA	NA	2	1	1	1	0	0	2	NA	2	3	3	3	3	2	3	2	3
Livability	2	2	4	4	2	2	3	2	2	4	4	4	4	2	2	2	2	3	3	1	1	2	1	0	NA	2	3

4 = Highly Effective 3 = Moderately Effective 2 = Nominally Effective 1 = Likely Effective 0 = Minimal to No Impact

Source: FHWA, 2013

Table 14-17. National Evidence on TDM Program Impacts on Vehicle Trip Reduction

TDM Program or Strategy	High Transit	Moderate Transit	Low Transit
Support, promotion, information	3–5%	1–3%	<1%
Alternative commute services	5–10%	5–10%	1–3%
Financial incentives	10–20%	5–15%	1–5%
Combined Strategies			
With free parking	15–20%	10–15%	3–7%
With paid parking	25–30%	15–20%	N/A

Source: Cambridge Systematics, 2010

V. DATA, MODEL USE, AND RESULTS

The data used for TDM analysis relates directly to the goals established for the program. Table 14-20, for example, shows the data collection plan for the Arlington County, Virginia, TDM program. In this case, the data collection plan relies on the level of participation of county employees and residents in the different TDM strategies. In addition, the data shown in the table is augmented by more traditional data collection efforts that measure traffic counts, transit ridership, and pedestrian/bicycle counts. These data are used to estimate mode share and levels of service for network performance (see chapter 2 on travel characteristics and data). Much of this data collection is undertaken to establish a baseline for monitoring program effectiveness.

Table 14-18. Washington State DOT Assessment of TDM Impacts		
Strategy	**Details**	**Employee Vehicle Trip Reduction Impact**
Parking charges[1]	Previously free parking	20%–30%
Information alone[2]	Information on available single-occupant vehicle alternatives	1.4%
Services alone[3]	Ride matching, shuttles, guaranteed ride home	8.5%
Monetary incentives alone[4]	Subsidies for carpool, vanpool, and transit	8–18%
Services plus monetary incentives[5]	For example, transit vouchers and guaranteed ride home	24.5%
Parking cash-out[6]	Cash benefit offered in lieu of accepted free parking	17%

[1] Reported in Michigan Sustainable Communities, 2013

[2] Schreffler, 1996

[3] Schreffler, 1996

[4] Reported in Michigan Sustainable Communities, 2013

[5] Schreffler, 1996

[6] Shoup, 1997

Source: As reported in Smart Growth America, 2013

Several methods and approaches have been developed to forecast the impacts of TDM programs. The simplest is an elasticity analysis that relates the change in demand to a change in network characteristic, such as cost of travel or frequency of transit service (see chapter 6 on travel demand). In some applications, elasticity-like ratios are applied to reflect the types of urban design characteristics found in a study area. [Ewing and Cervero, 2010] More complicated approaches utilize components of the four-step travel or activity-based models. For example, trip generation is a component of both modeling approaches, and the number of trips generated could be modified (that is, reduced) by the application of TDM strategies. The reduced number of trips generated would then be carried throughout the rest of the model application.

As reported in Gopalakrishna et al. [2012], four primary models are used for TDM analysis:

- *COMMUTER Model*—The EPA COMMUTER Model used a logit model that provides a pivot point tool to predict mode shift changes resulting from measures that change the time and/or cost of travel for a given mode choice. The employer support program component is based on the professional judgment of the model developers, and is in the form of average modal share changes from supportive activities for those modes.
- *TDM Effectiveness Evaluation Model (TEEM)*—This model is a spreadsheet-based model that uses elasticities of demand to estimate potential changes in vehicle trips.
- *Worksite Trip Reduction Model (WTRM)*—This model, developed by the Florida DOT, includes over 100 TDM measures with the ability to group the measures into comprehensive packages.
- *Trip Reduction Impacts of Mobility Management Strategies (TRIMMS)*—TRIMMS combines the features of both the WTRM and TEEM models. TRIMMS uses a constant elasticity of substitution trip demand functions to evaluate measures that can be expressed in cost or time and benchmarking results for "softer" support and informational measures. TRIMMS was developed for a single worksite or a subarea with a predefined travel market.

Gopalakrishna et al. [2012] suggest that TRIMMS is likely the most appropriate model for application in transportation planning efforts. See also Winters et al. [2007] and Bay Area Air Quality Management District [2012] for additional examples of TDM analysis tools.

For more information on TDM programs, see: Association for Commuter Transportation (www.actweb.org), TDM Institute (www.transportation2.org), TRB Committee on TDM, Best Workplaces for Commuters/National TDM and Telework Clearinghouse (http://www.bestworkplaces.org/), TDM Encyclopedia (www.vtpi.org/tdm), and the European Platform on Mobility Management (http://www.epomm.eu/index.php).

Table 14-19. Vehicle Trip Reduction Percentages Related to Monetary Incentives and Other Site Program Conditions

Other Conditions	Percent of Vehicle Trips Reduced by Type of Incentive Offered																	
	Parking Pricing		HOV Discounts		Transit Subsidy		Vanpool Subsidy		Carpool Subsidy		Bike/Walk Subsidy		Travel Allowance		Other Monetary		All
	With	Without	With	Without	With	Without	With	Without	With	Without	With	Without	With	Without	With	Without	
All	24.6	12.3	25.7	13.8	20.6	13.1	15.3	17.2	23.0	16.6	18.2	16.9	19.3	16.0	23.1	16.1	16.9
	Transit Availability																
High	27.0	18.9	26.4	25.1	27.4	22.5	26.2	25.9	n/a	26.0	n/a	26.0	20.3	26.8	38.2	24.9	26.0
Medium	13.7	8.0	19.0	9.6	11.2	13.6	10.5	13.5	20.5	10.5	12.1	12.1	19.6	7.7	15.0	11.5	12.1
Low	47.4	12.9	47.7	12.9	20.3	10.5	10.5	14.4	30.4	13.3	30.4	13.3	17.6	12.1	22.0	12.3	13.8
	Level of Support																
High	24.4	12.5	23.7	16.6	22.8	15.7	14.9	19.6	n/a	19.0	n/a	19.0	20.7	18.1	17.3	19.5	19.0
Medium	27.3	12.9	31.9	13.1	20.4	11.7	11.5	17.1	27.1	14.8	18.2	15.7	20.9	14.3	33.1	13.6	15.9
Low	22.8	9.6	24.0	10.2	17.8	10.0	44.2	13.2	10.5	15.3	n/a	15.0	13.6	15.6	n/a	15.0	15.0
	Transportation Services																
Transit	35.3	2.6	35.3	2.6	35.3	2.0	n/a	18.9	n/a	18.9	n/a	18.9	21.1	16.7	42.4	11.1	18.9
Vanpool	34.1	10.7	34.1	10.7	25.0	17.0	23.1	20.3	n/a	21.3	n/a	21.3	30.7	17.8	13.8	22.1	21.3
Both	23.6	16.1	38.0	14.5	30.2	9.3	16.0	19.3	42.4	16.4	n/a	18.8	3.4	20.0	n/a	18.8	18.8
Co. Vehicles	36.6	14.6	34.8	18.9	34.4	7.6	16.4	27.5	38.9	23.2	n/a	26.2	40.0	15.9	20.7	23.8	24.6
No Services	18.2	11.3	15.6	13.1	13.1	14.2	5.8	14.3	17.7	13.4	18.2	13.3	13.5	13.7	19.2	12.5	16.3

Source: Kuzmyak et al., 2010 Reproduced with permission of the Transportation Research Board.

Table 14-20. Possible Data Collection Activities for Arlington County, Virginia, TDM Program

Data Collection Activity	Biennial/Triennial	Annual	Semi-annual	Quarterly/Monthly
Ongoing Service Tracking				
Employer services participation tracking				X
Residential services participation tracking				X
Commuter store participation and transaction tracking				X
CommuterPage.com server statistics				X
Walk Arlington program statistics and WalkArlington.com server statistics				X
BikeArlington program statistics and BikeArlington.com server statistics				X
Customer information center participation and transaction tracking				X
Carsharing service tracking				X
Customer Feedback Data Collection				
Visitor intercept and/or feedback card with follow-up survey			X	
Commuter Store feedback cards distributed at the time of transactions				X
Commuter Store intercept survey of customers		X		
Commuter information center referral and satisfaction follow-up survey				X
Online follow-up survey CommuterDirect.com customers			X	
Online pop-up survey of random sample of CommuterPage.com customers			X	
Countywide Benchmark and Follow-up Surveys				
Resident survey—telephone and Internet	X			
Resident survey—underrepresented group targeting				
Employee survey—client sites	X			
Employee survey—nonclient sites and underrepresented employer types				
Business/Employer surveys—initial Internet	X			
Business/Employer survey—telephone follow-up with underrepresented groups				
Site plan building occupant survey		X		
Other New Data Collection (in the Future)				
Relocating employer/employee survey				
Resident panel research				
MPO State of the Commute report				
MPO household travel survey				

X = Data collection currently under way

Source: Arlington County Department of Environmental Services, 2012

VI. SUMMARY

Travel demand management (TDM) strategies focus on providing travelers with options for trip-making that do not rely on single-occupant vehicles. With rising travel demands in many metropolitan areas, and with limited abilities to expand the transportation network, transportation planners are considering ways of affecting the demand for travel. This might include reducing the overall demand for travel (e.g., trip reduction ordinances), or influencing when and where this demand occurs on the transportation system (e.g., flextime programs). TDM planning includes articulating goals and objectives, identifying performance measures, and analyzing the likely impacts of TDM strategies. In addition, comprehensive TDM programs include a wide variety of strategies that can be implemented by government agencies or by private organizations. TDM analysis relies on a range of data, from traditional data collection methods, such as traffic and ridership counts, to subjective information such as that obtained from surveys.

Travel demand management is a very important part of a state's or metropolitan area's transportation planning process. Successful implementation often requires careful analysis of the travel desires of those in the travel market, as well as strong coordination and collaboration with a diverse set of agencies and organizations. Given the constraints that many metropolitan areas have with respect to adding additional capacity to the region's highway network, TDM serves as one of the major options available to transportation planners to provide the mobility and accessibility upon which the economic health of the region depends.

In addition, Gopalakrishna et al. [2012] identify some key lessons from the literature on the impact of TDM strategies.

> *One Size Does Not Fit All*—TDM effectiveness is highly dependent on the application setting, complementary strategies, nature of the travel market segment being targeted, and even the 'vigor' with which TDM is implemented and promoted. Unlike many physical improvements, TDM strategies require some amount of education and outreach. This is all to say that the transferability of TDM strategy effectiveness is highly dependent on local conditions.
>
> *TDM Impacts Are Largely Localized*—TDM effectiveness is most readily measured at a localized level, and this appears to be where the greatest impacts can be found. TDM is applied to specific worksites, developments, employment centers, venues, or activity centers. Localities with well-defined travel markets tend to produce the most readily available and significant impacts.
>
> *Travelers Respond to Their Wallets*—Most evaluation studies point to the overwhelming effectiveness of financial incentives and disincentives to manage demand. At one level, this makes sense as price influences demand in a classic microeconomic analysis.
>
> *Parking Influences Travel Choices*—Parking management is another widely accepted strategy to effectively change travel behavior, especially mode shift, time shift, and location shift . . . . Parking supply management can be effective as well. If parking is tight, meaning that all cars cannot be accommodated if everyone drives alone, commuters will adapt by sharing rides, shifting to transit, or even bicycling or walking if the distance allows.
>
> *Packaging Is Key*—TDM strategies are most effective when packaged into logical, complementary packages to realize synergistic effects. On the other hand, some strategies do not complement one another. One example of an unintended consequence from traditional TDM is flex-time and carpooling. Some employers who implement flex-time strategies as an employee perk or to address congestion at parking entrances have found that this can also serve to discourage ridesharing arrangements, which tend to do better with set work hours.
>
> *TDM Is Not a Solution to All Transportation Problems*—TDM can be highly effective at a relatively low cost (as compared to capacity enhancements) when applied in the right place, at the right time for the right travel market. However, TDM, in and of itself, is not adequate to solve congestion, air quality, energy, and other urban woes.

Although many planning processes have developed stand-alone TDM plans, the really successful TDM programs are those that have integrated TDM policies and strategies into the mainstream transportation planning efforts in the state or region. Tables 14-21 to 14-24 show how this can be done.

Table 14-21. TDM in Statewide Planning

Type of Plan	How to Integrate TDM/Role of TDM
Statewide Long-Range Transportation Plans (SLRTP)	• Adopt a "capacity-last" policy setting limits on the amount of highway capacity a state will provide in certain corridors or subareas. • Set vehicle miles traveled (VMT) growth limits or targets for an absolute reduction in VMT, relative to current levels (in support of energy conservation policies).
Land-Use Policies and Plans	• Work with regional and local governments to assess the need for TDM to mitigate the impacts of large-scale developments (Developments of Regional Impacts [DRIs]) on adjacent highways. • Initiate "smart growth" programs to provide technical and policy guidance in local land-use and zoning decisions that align a state's ability and intention to provide state system highway capacity with a locality's need and desire for land development or redevelopment.
Tolling, Pricing, and Taxing Policy	• Implement variably priced high-occupancy toll (HOT) facilities that allocate capacity based on market demand. These pricing strategies help state DOTs better manage demand and achieve better performance of their system. • Note: Some states feel that equity issues and other consequences associated with such pricing measures require additional study and understanding prior to committing to their implementation.
Freight Plans	• Identify, sign, and map key truck routes on roadway segments and corridors that have the appropriate functional and alignment characteristics (e.g., turning radii, adequate shoulders) to accommodate single- and multiple-unit vehicles in the traffic stream. • Identify locations at which low-cost improvements can improve traffic flow and throughput significantly with little or no additions to capacity.
Operations and Intelligent Transportation System (ITS) Plans	• Operate variable signing and other infrastructure control mechanisms to permit flexible system management in peak and off-peak periods of demand by, for example, changing hours of operation, permitting one- or two-way operation, changing vehicle occupancy requirements, etc.
Construction and Development Plans	• Employ variable message signing, flexible signal timing, and public relations campaigns for high-impact capital projects to alert motorists of construction activities, allowing them the opportunity to reroute their trip or to change their travel times. • Form partnerships (highway and transit providers) to increase transit service opportunities, and to mitigate congestion in construction zones.
Multimodal Plans (various state DOT plans that deal with multimodal issues including new infrastructure projects)	• Operate statewide TDM programs and perform planning that includes the means to integrate TDM activities with other state functions. • Incorporate telecommunication technologies that have the potential to improve the efficiency of the transportation system, relieve congestion, decrease energy consumption, and improve air quality by reducing the need to travel.

Source: Gopalakrishna et al., 2012

Table 14-22. TDM in Metropolitan Planning

Plan	How to Integrate TDM/Role of TDM
Metropolitan Transportation Plans	• Large Metropolitan Planning Organizations (MPOs): Make TDM a cornerstone of their long-range plans. • Medium-sized MPOs: Set aside funding for TDM initiatives. • Small MPOs: Explore TDM-based approaches and gauge the interest of member jurisdictions. • Envision that TDM projects can reduce, or at least postpone, the need for capital-intensive projects that increase roadway capacity.
Congestion Management Processes	• MPOs designated as TMAs can demonstrate, as part of their CMP process, that demand management programs have been given due consideration prior to recommending projects that add general-purpose capacity to a given roadway corridor. • Provide a way to analyze TDM and operational strategies for construction projects in non-attainment zones that result in an increase of SOV travel. Travel demand reduction and operational management strategies should be incorporated into the SOV project or committed to by the State and MPO for implementation. • Define specific TDM and Transportation System Management (TSM) strategies for a region's most congested facilities, and prioritize potential TDM and TSM strategies for each facility.
TDM-Specific Plans	• Develop TDM-specific strategic plans to help guide (1) long-range pursuit of TDM initiatives or (2) shorter-term operation of in-house TDM operations. • TDM-focused Task Forces/Working Groups—To further refine TDM-related initiatives, organize specific TDM committees, task forces, or advisory boards to help guide the overall planning process related to TDM. • Articulate regional TDM goals by, (1) recommending TDM activities to meet these goals, (2) guiding investments in TDM activities, (3) defining an administrative structure to oversee the regional TDM program, and (4) establishing evaluation measures.

Source: Gopalakrishna et al., 2012

Table 14-23. TDM in Corridor Planning

Plan	How to Integrate TDM/Role of TDM
Major Investment Studies	• States and regions looking at significant improvements that might add capacity in a given corridor can integrate TDM into planning activities through efforts such as MIS. • Plans include a TDM or Transit/TDM scenario aimed at assessing the effectiveness of mode choice measures in meeting growing travel demands via trip reduction strategies.
New Smart Capacity Project Plans	• Integrate demand management in a holistic manner, to create "smarter" capacity improvements, such as managed lanes.
Reconstruction Plans	• Add enhanced travel options (such as vanpooling and special bus service) and incentives to use them (special discounts or financial rewards). • Expand the nature and number of travel options provided through enhanced travel information services. • Implement temporary demand management infrastructure, such as HOV lanes, during construction.
Congestion Management Process (CMP)	• Address system deficiencies that might be addressed with relatively short-term, low-cost solutions, including TDM. • Convene TDM/CMP Task Force to formulate TDM strategies that can address key bottlenecks on congested facilities.
Integrated Corridor Management Plans	• Inform travelers of approaching congestion and the availability of parallel transit service with parking availability to instigate in-route mode shift.
HOV/HOT System Plans	• Plans, such as HOT corridor studies in Virginia, have integrated TDM and transit supportive measures into the plans in order to maximize the efficiency and person throughput of the enhanced facility.
Interregional Corridor Plans	• Incorporate discussions on interregional travel which crosses state lines and requires special planning activities through special collaboration.
Corridor TDM Program Plans	• Develop plan for relieving congestion in corridors to make travel easier for commuters. • Identify better travel choices that help to foster responsible economic growth.

Source: Gopalakrishna et al., 2012

Table 14-24. TDM in Local Planning

Plan	How to Integrate TDM/Role of TDM
General Plan Circulation Elements	• Include recommendations on TDM in the circulation element of the general plan as a strategy to make local arterials operate more efficiently. • Include TDM as a complement to parking management activities. • Include TDM mitigation requirements for new developments when outlining land-use and zoning policies.
Site Development Review Process	• Codify the role of TDM in the site plan review process via trip reduction ordinances or more informal, negotiated processes.
TMA or TDM Plans	• Elicit TDM planning under the auspices of localized TDM implementing agents, such as Transportation Management Associations (TMAs) or Transportation Management Districts (TMDs).
Municipal TDM Plans	• Develop citywide TDM plans to focus the TDM-specific activities of the municipality. May include a description of current city activities, how these fit into state and regional plans and efforts, and a set of specific implementation objectives for the next several years.
Climate Action Plans	• Develop action plans to address climate change; since the reduction of car use is often a key strategy in climate action plans; TDM often plays a central role. • Include ways that cities and citizenry can operate greener and cleaner (low energy solutions, clean municipal fleets).
Sustainable Urban Transport Plans	• Make TDM the centerpiece by developing transportation solutions that are grounded in sustainability. Plan places travel choices, environmental mitigation, and social inclusion at the top of the plan's goals and objectives.
Future Applications	• Elevate the importance of TDM to a stand-alone planning activity in order to coordinate all related activities at the municipal level. Municipal TDM plans should seek to go beyond traditional TDM (often the focus of site-level mitigation strategies) to include the broad spectrum of travel demand influencing efforts, including parking pricing, neighborhood marketing, special event planning, cordon pricing, and preferential treatments on arterials.

Source: Gopalakrishna et al., 2012

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Statewide Transportation Planning[1]

I. INTRODUCTION

State departments of transportation (DOTs) are responsible for the planning, design, construction, operation, and maintenance of a state's highway system. In addition, most states also have some responsibility for other modes of transportation, such as transit, ferries, and airports. State DOTs provide a critical state-level context to both analyzing transportation needs and resolving transportation problems at an interstate, state, and regional level. The overall connectivity of the individual modes serving a state is an important characteristic of an effective transportation system, and the state DOT sits in a unique position to evaluate the interrelationships among the state's highway, airport, transit, rail, and harbor systems. This is becoming increasingly important as individual state economies become more dependent on national and international economic transactions (for example, as jobs are moved across borders and goods are traded on a worldwide basis).

With many states now experiencing a trend toward more localized control over transportation planning and project implementation, state-level plans provide a necessary context to regional/county/municipal/local transportation plans. An increasing reliance on local, metropolitan, and public-private transportation financing arrangements to replace decreasing state and federal support also suggests the need for such a context. Promoting a systems perspective on transportation needs and solutions creates a need for more, not less, intergovernmental planning and cooperation at the state and metropolitan levels.

Statewide transportation planning includes a wide range of activities and products. Many states, for example, develop statewide plans for individual modes of transportation, such as statewide rail, pedestrian/bicycle, aviation, and transit plans. Other states produce one statewide multimodal transportation plan that outlines the policies and investment strategies to improve overall transportation system performance. Many states undertake planning efforts on issues that could affect the future effectiveness of the transportation system, including but not limited to statewide freight flows, the aging population, and/or declining revenues dedicated to transportation system investment. Still others spend considerable resources on corridor-level studies that identify infrastructure and operations strategies for improving transportation in these critical components of the transportation system.

The 2025 California Statewide Transportation Plan provides a good description of the role of statewide transportation planning (emphasis added by the editor as underlined text):

> *The California Transportation Plan 2025 (CTP) is a policy plan designed to* guide transportation investments and decisions *at all levels of government and by the private sector . . . .*
>
> *It is* consistent with and supports the findings *of the California Commission on Building for the 21st Century's report Invest for California, Strategic Planning for California's Future Prosperity and Quality of Life, the Speaker of the Assembly's Commission on Regionalism's report . . . .*
>
> *This document* provides a vision *for California's transportation system and explores major trends that will likely influence travel behavior and transportation decisions . . . . it then* provides goals, policies, and strategies *to reach the vision . . . .*
>
> *Most notably, the CTP* reflects the shift in transportation planning and project selection responsibilities *resulting from Senate Bill 45 . . . .*

[1] The original chapter in Volume 3 of this handbook was written by Sandra K. Beaupre, AICP, Director, Planning & Economic Development, Wisconsin Department of Transportation, retired. Changes made to this updated chapter are solely the responsibility of the editor.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

The CTP is developed in consultation with the State's 44 Regional Transportation Planning Agencies and provides guidance for developing future regional transportation plans*. . . .*

Additionally, the CTP considers the findings and recommendations of numerous other focused transportation plans *such as the California Aviation System Plan, Interregional Transportation Strategic Plan, Intelligent Transportation System strategic deployment plans, California State Rail Plan, High-Speed Rail Plan, Amtrak's California Passenger Rail System 20-Year Improvement Plan, California Blueprint for Bicycling and Walking, and the Ten-Year State Highway Operation and Protection Plan. [Caltrans, 2006]*

As generalized from this list, statewide transportation planning, (1) provides information to the investment decision-making processes in the state, (2) reflects policy guidance from other state agencies, (3) provides a vision, goals, objectives, and strategies for improving the state's transportation system, (4) responds to legal requirements, (5) acts as guidance for the planning of other agencies in the state, and (6) incorporates the findings of other state planning efforts. Another reason for statewide transportation planning in the United States is that the federal government requires such a process be undertaken on a periodic basis. The federal requirements for such planning and a brief history of the federal role in fostering statewide transportation planning are discussed in the next section.

It is also important to note that statewide transportation planning can examine a wide range of investment options and strategies aimed at making the transportation system more effective and efficient. [Meyer, 1999] In some cases, these strategies are the responsibility of the state DOT (for example, construction or reconstruction of roads on the state highway system), while others, such as smart land-use policies, are the responsibility of other organizations often at different levels of government. This mix of mobility and land-use strategies suggests that not only will state DOT staff need a range of professional expertise, but it is also likely that state transportation planners will devote considerable energy interacting with many different groups and organizations. This interaction will occur not only among the state DOTs and other organizations, but also within the state DOT itself. Thus, for example, those most capable of developing operations strategies will likely be in the DOT traffic operations or traffic engineering groups. To the extent that such strategies are part of a statewide or regional transportation plan, state transportation planners will likely interact closely with these other units within their agency.

State officials are generally most concerned with the facilities and services they manage, that is, those that primarily carry intercity travel. These include many state highways in metropolitan areas that serve intracity and intraregional travel, and in fact often represent the most-used highways in the state. The role each level of government plays in transportation planning and decision making is often defined by the functional classification of the road network (see chapter 2 and chapter 9). State DOTs tend to focus on the interstate highway system and major intercity and interregional routes. Local governments tend to focus on minor arterials, collectors, and local roads. This is not true for some states such as North Carolina where the state DOT has responsibility for most of the roads in the state.

State DOTs also often participate in multistate corridor studies. These studies usually cross the boundaries of many states, following the market boundaries of freight and intercity passenger movement. Many of the earliest multistate studies were conducted in conjunction with international trade routes, specifically the Mexico-United States-Canada trade flows. Today, many corridor studies focus on the interstate movement of people and goods where multistate cooperation will be necessary, not just for international trade. A state DOT's transportation planning program has an important role to play in such studies, ranging from the provision of state-specific data to the consideration of innovative forms of multistate transportation finance.

This chapter next discusses the legislative foundation for statewide transportation planning, with emphasis on the evolution of relevant federal legislation. The following section presents the major steps in statewide transportation planning with examples provided from state planning efforts. This discussion is primarily focused on multimodal transportation planning. The final section then discusses efforts on the part of states to undertake modal planning, that is, planning focused on particular modes, for example, state rail plans, bike and pedestrian plans, and aviation plans.

II. THE ROLE OF THE FEDERAL GOVERNMENT

The history of statewide transportation planning in the United States is closely linked to federal legislation and to the provision of federal dollars for developing a national road system. It is beyond the scope of this chapter to examine such influence in detail; however, it is important to examine some of the benchmark federal laws that have influenced statewide transportation planning in the United States because of the legacy they have left to current practice (see chapter 1 for a more detailed description of the role of the federal government in transportation planning).

The 1921 Federal Highway Act was the first federal law that provided funding to the states to construct a "federal-aid highway network." In 1934, Congress authorized states to use 1.5 percent of a state's annual federal highway apportionment for surveys, plans, and engineering and economic analyses, which was the first time federal funds could be used for such purposes at a programmatic level. This level of federally funded planning support became even stronger with the Federal-Aid Highway and Revenue Acts of 1956, which both authorized the construction of an Interstate Highway and Defense System and provided the means of funding this system through a federal gas tax. With the passage of these acts, states initiated a massive highway building program that dominated statewide transportation planning activities until the 1990s. Given the decades of emphasis on interstate highway planning, as well as the development of a state's own road network, it is not surprising that state DOTs have often had difficulty focusing on new multimodal forms of transportation and their associated program directions.

Perhaps the most important piece of legislation to define the post-Interstate statewide transportation planning context was the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. Even though many states had been conducting statewide transportation planning for many years, this act for the first time required every state to have a statewide transportation planning process and a statewide transportation plan (STP). ISTEA required that the planning process be multimodal in scope, closely linked to transportation planning conducted in metropolitan areas, and reflect goals other than just transportation system performance. The resulting transportation plan was to address, at a minimum, a 20-year planning horizon. In some cases, states reinforced these federal requirements with their own state laws, mandating the inclusion of bicycle, pedestrian, and transit investments in the planning process. ISTEA also required increased attention to the provision of transportation for traditionally underrepresented groups, with specific attention to the environmental impacts of transportation projects on these groups.

Significantly, ISTEA emphasized the shared nature of the transportation investment decision-making process in metropolitan areas. Metropolitan planning organizations (MPOs) were in a unique regional planning position, often actively involved in both resource and land-use planning at the local level. By expanding the role of MPOs in deciding transportation priorities in their regions, it was anticipated that they would provide a broader context—looking beyond purely transportation impacts—when investment priorities were made. ISTEA also required metropolitan transportation plans to be "fiscally constrained," that is, the plan should include only those projects for which expected investment dollars were available. This requirement was an effort to inject a sense of realism to transportation plans and, in the process, encourage the trade-offs needed to provide a realistic program of multimodal transportation projects and services.

In 1998, Congress passed the Transportation Equity Act for the 21st Century (TEA-21), which reaffirmed the basic framework for state DOT and MPO transportation planning as defined by ISTEA. New funding programs were created to support community preservation, transportation enhancement, and environmental mitigation goals. With respect to planning, TEA-21 consolidated the planning factors that had been previously required for statewide and metropolitan transportation planning into seven major categories:

1) Support overall economic vitality of the United States, the states, and metropolitan areas, especially by enabling global competitiveness, productivity and efficiency.
2) Increase the safety and security of the transportation system for motorized and nonmotorized users.
3) Increase the accessibility and mobility options available to people and for freight.
4) Protect and enhance the environment, promote energy conservation, and improve quality of life.
5) Enhance the integration and connectivity of the transportation system across and between modes throughout the state for people and freight.
6) Promote efficient system management and operation.
7) Emphasize the preservation of the existing transportation system [23USC135(h)(1)].

The Safe, Accountable, Flexible, Efficient Transportation Equity Act—A Legacy for Users (SAFETEA-LU) of 2005, continued the requirement that state DOTs prepare STPs. Each state was required to, (1) carry out a continuing, comprehensive, and intermodal statewide planning process, including the development of an STP having at least a 20-year planning horizon, and (2) develop a statewide transportation improvement program (STIP). The STIP was a list of all significant statewide projects to be constructed or implemented using federal dollars over a four-year period. Any MPO-prepared list of projects for its region in the state had to be incorporated into the STIP without modification. SAFETEA-LU further required that the statewide planning process be coordinated with the MPO planning process and include consultation with affected local government officials involved in transportation planning in non-metropolitan areas of the state. Although the MPO transportation plan was to be fiscally constrained, the STP did not have the same stipulation.

Other significant provisions in SAFETEA-LU relating to statewide transportation planning included:

1) State long-range plans had to discuss "potential environmental activities and potential areas to carry out these activities, including activities that may have the greatest potential to restore and maintain the environmental functions affected by the plan." This discussion was to be developed in consultation with federal, state, tribal, wildlife, land management, and regulatory agencies. This consultation involved comparing STPs with appropriate state and tribal conservation plans, maps, and inventories of natural or historic resources.
2) State long-range plans had to be developed in consultation with MPOs, affected nonmetropolitan government officials, and tribal governments. The development of an annual list of transportation projects "shall be a cooperative effort" between the state, the appropriate transit operator, and the MPO.
3) State DOTs were required to enhance their public participation processes by publishing plans and improvement programs, holding public meetings at convenient and accessible times and locations, and employing enhanced visualization techniques when describing plans and programs.
4) States were required to develop a strategic highway safety plan that outlined the road safety issues facing the state. Although this responsibility did not fall to statewide transportation planners, it was clear that the safety plan and the STP were to be consistent and linked together (see chapter 23 on safety planning).

One of the most significant changes in the new law was the requirement that state-level planning promote consistency between transportation projects and locally planned land-use and development activities. SAFETEA-LU modified the fourth TEA-21 planning factor (see above) in the following way:

> *"… protect and enhance the environment, promote energy conservation, improve the quality of life and promote consistency between transportation improvements and state and local planned growth and economic development patterns."*

This provision was consistent with a growing focus of many state-level plans on the relationship between the state long-range planning and local land-use plans. Some states already had laws that required them to conduct their planning processes in a manner consistent with local planning; in other states there was a more direct and explicit requirement for how they interrelated with local plans.

The Moving Ahead for Progress in the 21st Century (MAP-21) law, passed in 2012, introduced a significant new component into statewide and metropolitan transportation planning…. the use of performance measures to monitor progress toward achieving plan goals. MAP-21 incorporated performance goals, measures, and targets into the process of identifying needed transportation improvements and in the project selection process. The long-range plan was to describe the performance measures and targets used in assessing system performance and progress in achieving the performance targets. The law established the following national performance goals for federally supported highway programs:

- *Safety:* Achieve a significant reduction in traffic fatalities and serious injuries on all public roads.
- *Infrastructure Condition:* Maintain the highway infrastructure asset system in a state of good repair.
- *Congestion Reduction:* Achieve a significant reduction in congestion on the National Highway System (NHS).
- *System Reliability:* Improve the efficiency of the surface transportation system.

- *Freight Movement and Economic Vitality:* Improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development.
- *Environmental Sustainability:* Enhance the performance of the transportation system while protecting and enhancing the natural environment.
- *Reduced Project Delivery Delays:* Reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices.

States were responsible for setting performance targets in support of these goals, with the statewide plans describing how program and project selection would help achieve the targets. In addition, MAP-21 required that a national freight network be identified, with incentives for priority projects that advanced the freight performance goal. Although not required, states were encouraged to develop their own freight plan and establish a freight advisory committee, if one already did not exist. The law also stipulated that projects identified in a FHWA-approved freight plan would be eligible for supplemental federal funding. The major impact of MAP-21 on statewide transportation planning was that most state transportation plans were now to focus on the performance goals established by the law, with attention given to how the state was achieving these performance targets.

The Fixing America's Surface Transportation (FAST) Act, passed in 2015, continued the planning requirements established in MAP-21. In addition, it stipulated the following requirements:

- Required the state to submit a report describing the actions to be taken to achieve performance targets if a state DOT did not achieve or make significant progress toward achieving the targets in any performance measurement area after one reporting cycle.
- Expanded the scope of the planning process to include addressing resiliency and reliability as well as enhancing travel and tourism of the transportation system.
- Required state DOTs to incorporate the performance measures of a transit agency not represented by a metropolitan planning organization (MPO) into its long-range transportation plan regardless if it is in an urban or rural area.
- Added language that the long-range transportation plan shall consider public ports and freight shippers.
- Encourages consideration of intermodal facilities that support intercity buses as part of the metropolitan and statewide planning process.

Perhaps most importantly, the act reinforced the requirement for a state DOT to include a description of adopted performance measures and the system performance report in a state's long-range transportation plan. This step is an important component of what chapter 1 called performance-based planning.

III. STATEWIDE TRANSPORTATION PLANNING

Statewide transportation planning identifies the most cost-effective and appropriate transportation strategies to achieve a desired level of system performance for a state's transportation system. The generic transportation planning process described in chapter 1 can be used to illustrate how statewide transportation planning occurs in most states.

Most statewide planning processes begin with a basic identification of the nature of the current system (past trends and current system condition), followed by an analysis of how well that system addresses existing and future travel needs. The next step involves a description of future issues usually identified through public outreach efforts and data analysis, followed by the identification of potential solutions. Alternatives are evaluated against predetermined criteria to identify the most cost-effective investment strategy for the state. Finally, a capital program is developed. This planning process is continuous, that is, plans are developed, financed, and implemented, then evaluated and reconsidered again in the next planning cycle, all done in a publicly transparent manner.

Although the planning process varies by state according to tradition, state law, and the capabilities of the state DOT, several aspects of statewide planning are common from one state to another. The basic steps in statewide transportation planning processes are not that different from any other public planning process. The biggest difference is primarily the scope of a state planning effort, either encompassing a large geographic area such as an intercity corridor or the entire state itself. Following the planning framework presented in chapter 1, the basic steps in a statewide transportation planning process include:

1) Define the focus and boundaries of the planning effort.
2) Identify issues and opportunities.
3) Define vision and goals.
4) Identify and using system performance measures.
5) Collect and analyzing system performance and condition data, leading to a needs assessment.
6) Analyze individual transportation system alternatives for targeted performance characteristics.
7) Evaluate transportation system alternatives to compare relative benefits and costs.
8) Prioritize programs and projects.
9) Monitor system and program performance.

Each of these steps will be described in more detail in the following sections. In some cases, other chapters in this handbook describe in greater detail the approaches that could be used to accomplish a particular task. These chapters are referenced in the text; the material is not repeated here.

It is important to note that statewide transportation planning is conducted in a very "open" way. Over time, state DOTs have moved toward more ongoing public engagement, and as recent federal laws have emphasized, more attention is being given to public input and potential impacts on underrepresented groups. This input also includes interaction with the state's MPOs, as well as with state natural resource agencies, in particular, the agency responsible for the state air quality implementation plan. Air quality management plans are required under federal law for those areas that have not attained national ambient air quality standards. These plans can have considerable influence on the development of future transportation facilities and services. Although primarily affecting projects in air quality nonattainment areas (as defined by the U.S. Environmental Protection Agency), the Clean Air Act Amendments of 1990 required that transportation plans, programs, and projects must conform with air quality implementation plans developed by state environmental agencies. Many states now have DOT representation on interagency conformity workgroups and MPO/state resource planning groups that direct air quality policy.

A. Defining the Study Focus and Boundary

The purpose of the planning process, its focus, and study boundaries need to be defined early in the process. For example, will a planning effort address all transportation systems and modes in the study area, or does it focus simply on those systems that are the responsibility of the state DOT? Will it provide specific project recommendations as an outcome, or is it intended simply to establish overall policy directions? In some cases, state law is very specific about the responsibilities of the state DOT, as well as the products and timing of the statewide transportation planning process. In addition, federal law defines the general characteristics of a state's transportation planning process, and often influences which major state systems receive priority given the availability of federal funds.

Statewide transportation plans can take many forms. This is not surprising given the changing context of statewide transportation planning and the different perspectives that states have on what an STP should accomplish. Some examples include:

- *Policy Plans*—These plans usually include broad goal statements to establish the general direction of the DOT, but often they do not include specific implementation activities, maps, or projects. Policy plans are considered flexible enough to direct departmental activities as well as promote more general societal goals and objectives. However, state-level policy plans are often criticized for not identifying specific actions (and thus the funding that follows such actions) or not providing specific timeframes for achieving planning goals.

- *Strategic Plans*—Sometimes called business plans, these plans address the internal operations of the state agency. Such plans are often prepared after an overall policy plan has been developed and tend to direct agency resources toward shorter-term, targeted priorities.
- *Investment or Financial Plans*—These plans can be tailored to fit the agency's budget process or can be used to detail longer-term, project-specific expenditure plans. They are often tied to specific program performance goals.
- *Medium-Range Transportation Project Plans*—These programs provide a 6- to 10-year project programming schedule, where the first 3 to 4 years include the projects that the DOT will actually design and construct, and the latter years provide those projects that will likely move into construction during the planning period. The project descriptions for these latter projects are often fairly general with no more than a project location, stage of completion, and total budget allocation.
- *Systemwide or Corridor-Level Plans*—System-level plans are usually based on a statewide or regional perspective. Corridor plans are defined by major transportation routes and often include a "beyond the pavement" view of such issues as access, intensity of development, and land uses.

In general, each of these plans can be used by the state DOT or other state-level planning organizations to develop and communicate the strategic direction for the agency. They can also serve as a vehicle to illustrate and justify future needs; guide program and project development activities in the agency; communicate with political leaders and the general public about transportation issues; and monitor overall system and investment performance goals.

The following examples illustrate different approaches for defining the transportation plan and planning process and the study boundaries established for state DOT responsibility.

1. California

California statutes require the California DOT to develop a California Transportation Plan (CTP) that includes:

a) Policy statements describing the state's transportation policies and system performance objectives.

b) Strategic elements that incorporate broad system concepts and strategies synthesized from adopted regional plans . . . . that is, the state plan will not be project-specific.

c) Economic forecasts and recommendations to achieve concepts, strategies, and performance objectives.

California law also directs designated regional transportation agencies to adopt 20-year regional transportation plans. Under the guidance of the California Transportation Commission, these regional plans, the CTP, and all other transportation plans developed by local units of government must be consistent. The Commission cannot program projects that are inconsistent with these adopted regional transportation plans. In addition to these requirements, California state law also directs a large portion of its state funding to the regions for investment decisions.

2. Indiana

The Indiana Department of Transportation (INDOT) through the 2030 Long-Range Plan defines the state's transportation system by the level of system management responsibility—state, MPO, and small urban and rural areas. The state system focuses on those routes that move people and goods between the major activity centers considered important to the state's economy.

The Indiana long-range plan is based on a corridor classification system that includes: (1) statewide mobility corridors, which are defined as corridors that provide "safe, free-flowing, high-speed corridors" serving major metropolitan areas and surrounding states, (2) regional corridors, designed to provide mobility within regions of the state, and (3) local access corridors, which include the remainder of the highway system.

Highway corridors are evaluated on the basis of the following elements:

- Accessibility measures between major urban areas.
- Designation as a principal arterial on the Federal Highway Administration (FHWA) functional classification system.

- Designation as part of the National Highway System.
- High volumes of commercial traffic and commodity movements.
- Concentrations of high passenger vehicle traffic volumes.

The Indiana statewide planning emphasizes the networks that serve major metropolitan areas, have higher design standards and higher speeds, serve longer-distance trips, exhibit large through-traffic volumes (both commercial and commuter), and do not allow nonmotorized vehicle access. The Indiana state highway system focuses on directly connecting metropolitan areas with a population of 25,000 or more.

3. Minnesota

Minnesota is another example of how states define their responsibilities for a state's transportation system. As noted in the plan, the transportation policy framework "focuses on multimodal solutions that ensure a high return-on-investment while considering the context of place, and how land use and transportation systems should be better integrated." [MnDOT, 2012] The plan is organized by six major questions:

- Where are we going?
- Where are we now?
- What is directing this plan?
- How will we guide ourselves moving forward?
- What comes next for MnDOT?
- How do I get more information?

The plan adopts a multimodal perspective on the state's transportation system, even though the state DOT only has responsibility for a portion of it. Table 15-1 shows the extent of the state's transportation system.

Figure 15-1 shows the key elements of the state's transportation system, that is, those elements that the state DOT focuses on. The state's role in modal areas where it does not have primary responsibility is to support and encourage that mode's use. For example, MnDOT's role in rail and waterways includes developing plans that guide funding allocation, administer highway/railroad construction projects, and develop freight-related data sources. In aviation, the state serves as a promoter of both general and commercial aviation through technical and financial assistance, educational activities, and statewide planning and research. Note in the figure that the DOT has designated a system of interregional and regional travel corridors as part of the state highway network. These corridors were designed to connect key trade centers in the state based on population and business density, and receive priority investment consideration from the DOT.

The Minnesota statewide transportation plan also illustrates another characteristic of statewide transportation planning as it relates to study boundaries. The plan relies on and references other DOT plans that have focused on more specific modal issues. For example, the plan is linked to the state aviation system plan, statewide bicycle system plan, statewide freight system plan, 20-year state highway investment plan, statewide ports and waterways plan, statewide pedestrian system plan, state rail plan, and the greater Minnesota transit investment plan. In some ways, the statewide plan serves as a means of integrating the key concepts and recommendations from each of these plans. [MnDOT, 2015]

4. Virginia

The Virginia Department of Transportation (VDOT) uses Corridors of Statewide Significance (CoSS) as a way of identifying potential multimodal transportation strategies and to guide local land-use planning and transportation investments. The characteristics of a CoSS include:

- *Multimodal*—Must involve multiple modes of travel or must be an extended freight corridor.
- *Connectivity*—Must connect regions, states, and/or major activity centers.
- *High Volume*—Must involve a high volume of travel.
- *Function*—Must provide a unique statewide function and/or address statewide goals. [VDOT, 2015a]

Table 15-1. Minnesota's Transportation System, 2012	
Streets, Roads, and Highways	**141,482 miles**
State trunk highways	11,896 miles
County state, aid highways	30,548 miles
Other county roads	14,348 miles
Municipal state-aid streets	3,321 miles
Other city streets	18,837 miles
Township roads	58,101 miles
Other public roads	4,431 miles
Bicycles and Trails	
Designated trails	More than 3,800 miles including 22 state trails.
Bike sharing	1,328 bicycles and 146 stations (as of July 2012).
Bus and Light Rail Transit	
Twin Cities area (7 counties)	218 bus routes and one light rail transit corridor with another under construction.
Greater Minnesota	70 of 80 (non-Twin Cities metro) counties with countywide transit service, 8 counties with municipal service only, 2 counties with no service.
Intercity bus	87 destinations served in the state as well as every metropolitan area in the Midwest.
Rail	
Freight	4,458 track miles (19 railroad companies).
Commuter	Northstar commuter rail line.
Air	
Passenger and Cargo	135 airports, 8 with airline service.
Waterways	
Great Lakes	4 ports on Lake Superior.
Rivers	5 ports on 222 miles of the Mississippi River system (including the Minnesota and St. Croix rivers).
Miscellaneous	
Carsharing	2 systems (HOURCAR and Zipcar).

Source: MnDOT, 2012

Unique statewide corridor functions include: (1) evacuation routes or providing critical network redundancy, (2) security and national defense routes (military access, Strategic Highway Network (STRAHNET), Strategic Rail Corridor Network (STRACNET)), (3) tourism routes, (4) truck routes, (5) state bicycle routes or interregional trails, and (6) support for economic development. Figure 15-2 shows Virginia's corridors of statewide significance.

As noted in the guidance for identifying these corridors, "the perspective of the state may differ from that of regional planning bodies in that the state is concerned with transportation throughout the Commonwealth, whereas MPOs and regional planning commissions appropriately focus on more regional interests. The state must also ensure that regions are connected and that interstate needs are addressed." As further noted, the intent of the statewide multimodal network was not to replace regional plans, but to "connect the dots" among regional and modal agency plans. Further explanation of Virginia DOT's corridor-based planning process can be found at: http://vtrans.org/vtrans_multimodal_transportation_plan_2025_needs_assessment.asp.

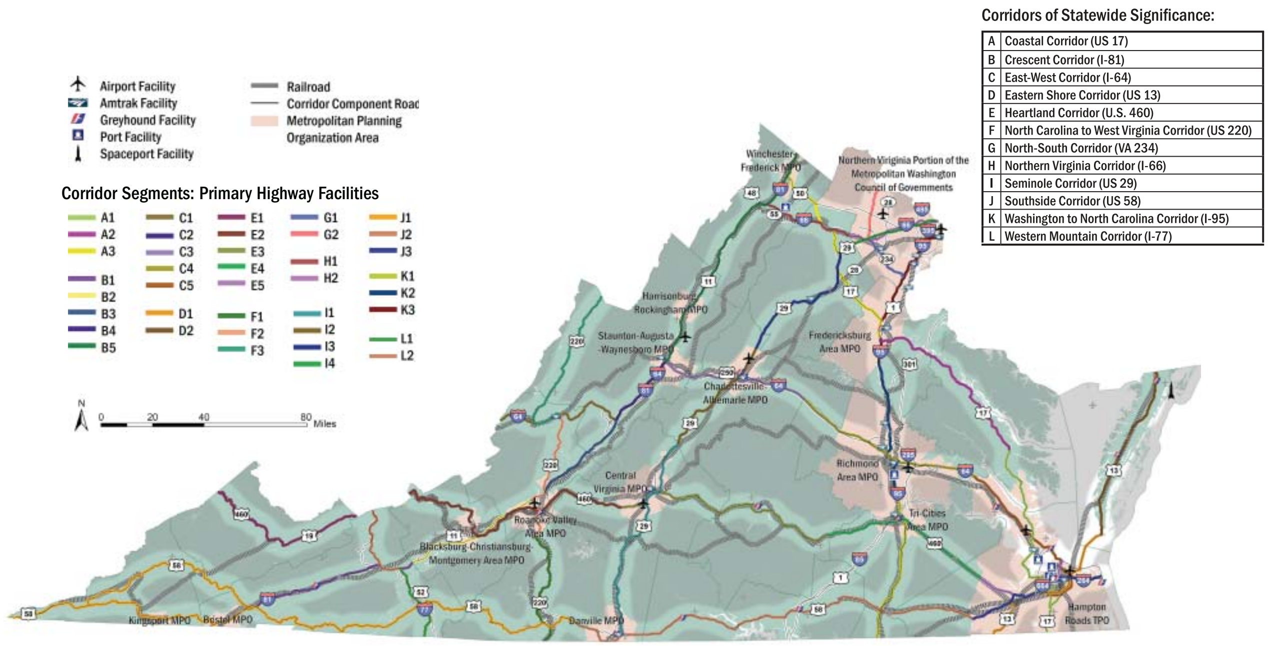
5. Michigan

In its 2030 STP, the Michigan Department of Transportation (MDOT) examined travel flows in the state and how these flows related to and affected economic development. Major corridors were identified that connected the state's most important economic centers and that served the majority of the state's population. Figure 15-3 shows how MDOT used a geographic information system (GIS) to illustrate how much of the state's population was within 20 miles, centered on the state-identified corridors. Thirty-five percent of the state highway miles are located in the corridors, carrying 72 percent of annual vehicle miles and 96 percent of the truck ton-miles on the state highway system. Ninety-seven percent of the rail ton-miles, 94 percent of the state's commercial airports, and 95 percent of the state's intercity bus terminals are also in the corridors. [Michigan DOT, 2012a]

Figure 15-1. Key Elements of Minnesota's Transportation System

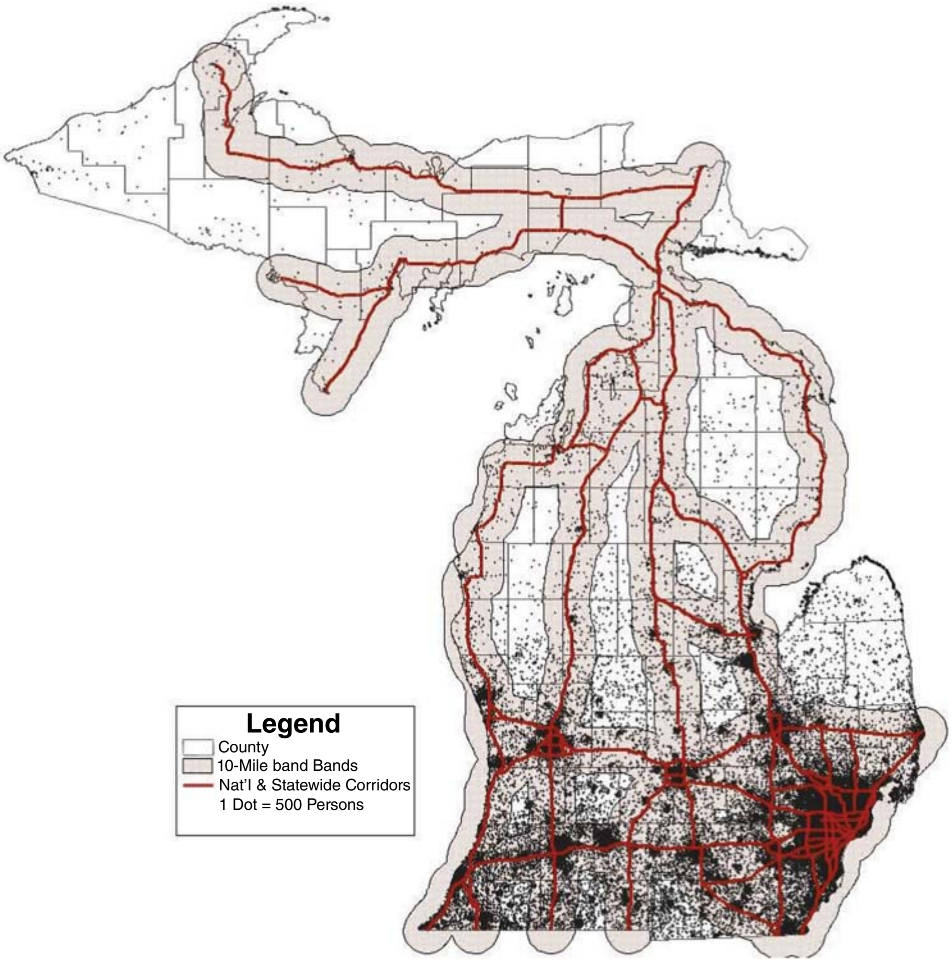
Source: MnDOT, 2012

Figure 15-2. Virginia's Corridors of Statewide Significance



Source: Virginia DOT, 2015a

Figure 15-3. Corridors of Highest Significance (COHS) and Population Location, Michigan



Source: Michigan DOT, 2012a

The 19 corridors have a major impact on supporting both the state's population and economy. Approximately 93 percent of Michigan's population and approximately 99 percent of Michigan's employment base resides within the geographic area centered on the corridors.

The update to the plan, the 2035 statewide plan, reaffirmed these corridors as a major focus of statewide transportation planning. As noted in the update:

- Both the rail track miles and the rail ton-miles increased their percent usage of national/international and statewide corridors by 1 percent. Rail value by mile held steady at 97 percent.
- The percent of usage of national/international and statewide inclusive airports increased 7 percent.
- Overall, water cargo tonnage decreased almost 25 percent from 2003 to 2009. The percentage of the overall statewide total, within the COHS, increased from 85 to 94 percent.
- The economic recession of 2008–2009 had a negative impact on both cross-border passenger car traffic (commuters and recreational trips) and commercial (truck) traffic. However, since January of 2009, combined passenger car traffic at Michigan's border crossings has been increasing at the rate of 0.66% per month, or 7.89% per year, and combined truck traffic has been increasing at the rate of 0.70% per month (8.5% per year) while the value of trade carried by those trucks has been increasing at an average rate of 1.5% per month (18% per year).

- Overall, U.S./Canada trade moved by truck was up $16 billion (5 percent) from 2006 to 2011. Current forecasts indicate a continued slow improvement in passenger car traffic over the next 20 years. Commercial traffic over the next 20 years is expected to reach volumes double that observed in the pre-recession period. [Michigan DOT, 2012b]

The Michigan example aptly illustrates the concept of targeting investment priorities on key elements of the transportation system, and of monitoring what happens over time.

B. Identifying Transportation Issues and Opportunities

Most states begin a transportation planning process with a "scan" of the key issues facing the state's transportation system, sometimes even before the vision and goals are defined. Key stakeholder and public input is then used to redefine the vision and goals of the planning process. In fact, many states continue to redefine their vision and goal statements throughout the planning process. This process can be a key framing element for the overall planning process, and should be tied closely to the early engagement of public and private stakeholders.

1. Florida

Florida is one of the few states that has adopted a very long-range perspective for its statewide transportation plan. The 2060 Florida Transportation Plan (FTP) was the first statewide transportation plan for Florida to cover a 50-year period. [FDOT, 2010] Per the plan, "This longer horizon enables all transportation partners to work toward a future transportation vision addressing both today's challenges and tomorrow's opportunities." The 50-year time horizon also focuses attention on some of the key issues that will influence the transportation system of the future. For example, some of the issues identified in the FTP included:

Diverse Population: Florida is leading the nation in two important demographic changes—the aging and increasing diversity of the population. By 2030, 26 percent of Floridians will be over the age of 65, compared with about 20 percent nationally. The number of students, visitors, disabled persons, and others with specific mobility needs will continue to grow.

Innovation Economy: Florida's economy is increasingly driven by innovation. While traditional strengths in agriculture and tourism remain, Florida's future economy will rely on emerging industries such as aerospace, clean energy, life sciences, and creative industries. These industries tend to develop in clusters around vibrant communities, universities, and research laboratories, where they can gain access to skilled workers.

Global Markets: Market reach for Florida businesses is shifting from local and regional to global. Global trade patterns will shift following the widening of the Panama Canal and anticipated increases in trade from Asia, Latin America, and other markets. This could position Florida as a crossroads for both north-south and east-west trade. Florida's ability to connect to global markets and tap into this trade flow will be a critical driver of future prosperity, yet Florida must compete with other states aggressively pursuing this opportunity.

Emerging Megaregions: The key unit of economic competition is shifting from metropolitan areas to megaregion networks of urban and rural areas connected through economic relationships and infrastructure. The Florida peninsula may be one of about 10 megaregions driving U.S. growth in the global economy. The connections between Miami and Jacksonville or Orlando and Tampa, for example, may become more important than differences between them. Northwest Florida could become part of this megaregion or may become more integrated with the western Gulf Coast from Alabama to Texas.

Shifting Development Patterns: The sprawling development pattern of the past 50 years may give way to higher density development focused in urban centers. Florida's diverse population desires a range of choices for where to live—vibrant cities, quiet suburbs, small towns, and rural places—but with distinctive characteristics and easy access from homes to jobs, schools, shopping, and services.

Higher-Density, Mixed-Use Urban Development and Rural Employment Centers: These land-use patterns connected with multimodal transportation corridors and separated by open spaces will be a key emphasis of development over the next 50 years.

Technological Revolution: Rapidly changing technologies will reshape the way Floridians live, work, and travel. Communication technologies will reduce the need for some trips to work, meetings, shopping, and schools—but at the same time, they may increase the number of small packages moving throughout the state on a daily basis.

New Vehicle Technologies: Small electric vehicles, smart cars, trucks, new large aircraft, high-speed railways, enhanced transit systems, mega-containerships, and next generation launch vehicles and spacecraft will reshape existing travel options and provide new options for moving people and freight.

Environmental Stewardship: Florida's environment will be under increasing pressure if urban development fragments, encroaches on, or replaces important natural lands, agricultural lands, and open spaces. In addition, population growth will strain water supplies, and growth in travel and industrial development will impact air and water quality. A changing global climate may impact Florida more than any other state due to its many miles of coastline and its low elevation. How Florida responds to these environmental challenges will be a key determinant of its future quality of life and economic competitiveness.

Changing Role of the Public and Private Sectors: Florida's public agencies will redefine their roles to meet the challenges of the next 50 years, while also trying to meet public requirements and expectations with increasingly constrained revenue sources. The private sector will continue to expand its role as a leader or partner with the public sector in accomplishing specific priorities. [FDOT, 2010]

2. Hawaii

One of the common approaches for identifying key trends and issues affecting a state transportation system is to develop issue papers that examine how key aspects of the future will influence future transportation system performance. Hawaii DOT's update of its statewide transportation plan is an example of this approach. As part of the update, 10 emerging issue papers were developed on the following topics:

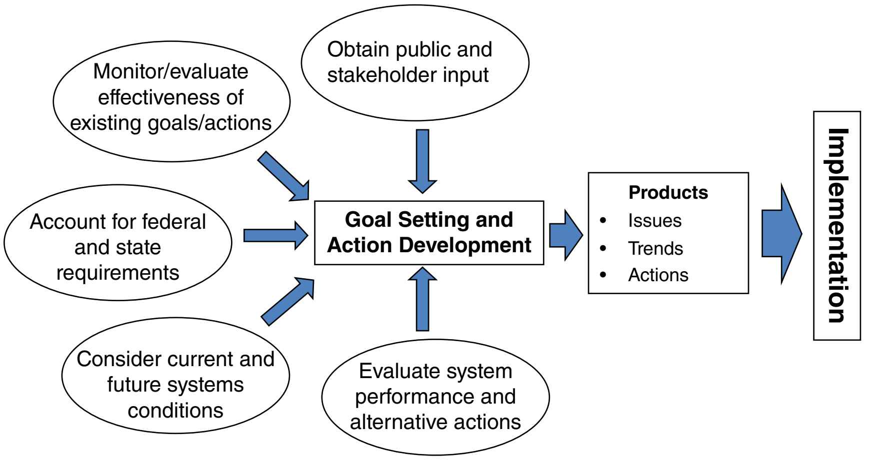
- Federal planning factors
- Climate change and sea level rise
- Aging population and transportation
- Fuel and energy scenarios for Hawaii
- Land-use planning
- Integration of planning and design: context sensitive solutions, Complete Streets, smart growth, and transit-oriented development
- Transportation security
- System preservation and asset management
- Financial scenarios
- Environmental coordination: Linking planning and environmental review

C. Formulating a Vision, Goals, and Objectives

Vision, goals, and objectives can be developed from a variety of sources. For example, Figure 15-4 shows the sources of information used by the Montana DOT in defining the goals and objectives (called actions) for its transportation plan update. As shown, the process of setting goals and developing actions relies on system performance and alternative actions, current and future system conditions, the relationship to federal and state program requirements, the effectiveness of existing goals and actions, and input from the public and other stakeholders.

Many DOT mission and vision statements are defined in state statute. An example is the Wisconsin Department of Transportation, whose statutory mission is to manage state and federal aid for "planning, promotion and protection activities in highways, motor vehicles, traffic enforcement, aeronautics, railroads, waterways, specialized transportation services, mass transit systems, and any other transportation mode." [Wisconsin Statutes] This very broad mission was

Figure 15-4. Information Sources for Goals and Actions, Montana DOT



Source: Montana DOT, 2008

created in 1973, yet each state plan update has reexamined and retained the vision for the state's transportation program. Most states reevaluate and redefine vision statements each time a plan is updated to reflect the planning challenges and opportunities for the time horizon addressed by the planning study.

Transportation planning goals and objectives do not address just transportation system performance but also reflect the values and objectives of society at large, including the overall quality of life in the state, economic development, land-use planning, and social justice goals. As a result of these broader social goals, transportation planners at the state level often redesign their outreach to target groups representing interests that often do not participate in the plan development process. The increasing use of the Internet and websites is not only the result of enhanced technology, but also addresses the need to reach a growing transportation stakeholder base. However, state DOT outreach efforts and public engagement programs need to recognize that not all population groups have access to the Internet and websites.

The following examples illustrate the type of vision statement and goals found in statewide transportation planning today:

1. Minnesota

The Minnesota 2012 STP developed a vision statement that was the result of extensive public outreach as well as an examination of the factors and trends likely to affect future system performance. The vision statement reads:

> ***Minnesota's Multimodal Transportation System Maximizes the Health of People, the Environment, and Our Economy***
>
> The system:
>
> - Connects Minnesota's primary assets—the people, natural resources, and businesses within the state—to each other and to markets and resources outside the state and country.
> - Provides safe, convenient, efficient, and effective movement of people and goods.
> - Is flexible and nimble enough to adapt to changes in society, technology, the environment, and the economy.
>
> ***Quality of Life***
>
> The system:
>
> - Recognizes and respects the importance, significance and context of place—not just as destinations, but also where people live, work, learn, play, and access services.
> - Is accessible regardless of socioeconomic status or individual ability.

Environmental Health

The system:

- Is designed in such a way that it enhances the community around it and is compatible with natural systems.
- Minimizes resource use and pollution.

Economic Competitiveness

The system:

- Enhances and supports Minnesota's role in a globally competitive economy as well as the international significance and connections of Minnesota's trade centers.
- Attracts human and financial capital to the state. [MnDOT, 2012]

The plan identified specific strategies to realize the vision.

2. Hawaii

The Hawaii DOT identified eight goals that formed the overall direction for the plan.

Goal 1: Mobility and Accessibility—Create and manage integrated multimodal transportation systems that provide mobility and accessibility for people and goods.

Goal 2: Safety—Enhance the safety of the air, land, and water transportation systems.

Goal 3: Security—Ensure the secure operation and use of the air, land, and water transportation systems.

Goal 4: Environment—Protect Hawaii's unique environment and quality of life and mitigate any negative impacts.

Goal 5: Economy—Ensure that the air, land, and water transportation facility systems support Hawaii's economy and future growth objectives.

Goal 6: Energy—Support the state's energy goal of 70% clean energy, which includes 40% produced by renewable energy and 30% from increased energy efficiency, enhancing the reliability and security of energy sources.

Goal 7: Funding—Create secure, flexible, and sustainable revenues for funding sources for transportation needs.

Goal 8: Planning—Implement a statewide planning process that correlates land use and transportation while supporting decision making and programming for Hawaii's integrated, comprehensive, multimodal transportation systems.

Each goal was followed by several objectives (too numerous to repeat here). As an example, one of the objectives for the "environment" goal was to "Implement sustainability and livability practices in existing and new facilities," with "sustainability" defined as: "Respect the culture, character, beauty, and history of the state's island communities; strike a balance among economic, social, community, and environmental priorities; and meet the needs of the present without compromising the ability of future generations to meet their own needs." See HDOT [2013] for a complete list of the objectives.

3. Maryland

Maryland DOT defined the vision and mission of the state DOT and of the transportation plan as being:

> Provide a well-maintained, sustainable, and multimodal transportation system that facilitates the safe, convenient, affordable, and efficient movement of people, goods, and services within and between population and business centers. [MdDOT, 2014]

The Maryland Transportation Plan identified the following goals as directing future transportation investments:

Safety & Security: Enhance the safety of transportation system users and provide a transportation system that is resilient to natural or man-made hazards.

System Preservation: Preserve and maintain the state's existing transportation infrastructure and assets.

Quality of Service: Maintain and enhance the quality of service experienced by users of Maryland's transportation system.

Environmental Stewardship: Ensure that the delivery of the state's transportation infrastructure program conserves and enhances Maryland's natural, historic, and cultural resources.

Community Vitality: Provide options for the movement of people and goods that support communities and quality of life.

Economic Prosperity: Support a healthy and competitive Maryland economy.

The nature of state government today—short-term programming and funding, annual fiscal constraints, and the like—provides great challenges to the visioning and goal-setting process of long-term planning. However, because it can now take up to 10 years or more to plan, design, and build major transportation facilities, this long-term perspective has become critical to state-level planning.

D. Identifying and Using System Performance Measures

The next step in the planning process is identifying and using system performance measures. In some instances, such measures have already been established through other planning efforts, and thus the task is simply to apply them to the current study. In other cases, planning-specific performance measures will need to be developed to focus on the most important system performance characteristics identified by key stakeholders. This step could occur in a different sequence depending on the specifics of the study.

Since the enactment of ISTEA and certainly with the passage of MAP-21, many transportation agencies have become interested in developing system and policy performance measures for STPs. Performance measures are different from goals, objectives, and evaluation criteria in that they represent a small number of selected indicators monitored over time to determine changes in system performance (see chapter 7 for more discussion on performance measures). The intent in using performance measures is to provide agency decision makers, key stakeholders (such as the legislature), and the general public with some notion of how system performance is changing over time and to relate this change to state investment in the transportation system. The types of performance measures can vary widely, primarily depending on the type of information desired by key decision makers (see [South Carolina DOT, 2013] for a good example).

1. Maryland

A good example of using performance measures for the monitoring of a state's entire transportation system is found in the Maryland DOT, which produces an annual report on transportation system performance. [Maryland DOT, 2014a] The measures cover a wide range of issue areas. In addition, Figure 15-5 shows an interesting feature of this annual report. For those performance measures that show appreciable change over time, the Maryland DOT provides an explanation. Thus, the report indicates not only what is happening to system performance, but also provides explanations as to why.

2. Michigan

Performance measures can serve different purposes. However, to be effective, performance measures should be chosen with certain characteristics in mind. The following list from the Michigan DOT (MDOT) provides a good point of departure for the issues that need to be considered when selecting performance measures:

- *Currently used?* Is the measure currently being used in any form in the agency?
- *Data availability.* Does the agency have the capacity to collect and provide the data to support the measure?
- *Analytical capability.* Does the agency have the capacity to analyze the data supporting a specific measure?
- *Clarity.* Does the measure provide meaningful and easy-to-understand outputs?

Figure 15-5. Performance Measurement in Maryland

Goal: System Preservation

SHA & MDTA: Percent of Roadway Miles with Acceptable Ride Quality*

The traveling public has identified acceptable ride quality (i.e., the smoothness or roughness of the pavement) as a priority. Ride quality facilitates mobility, efficiency and safe movement of people and goods within Maryland.

*Ride quality is represented by the International Roughness Index (IRI). The SHA inventory of mainline directional miles, which is a component of this measure, now include routes of less than one mile in length so that the SHA network is more accurately and completely represented.

**2013 data is premliminary and subject to change.

Why Did Performance Change?

- Continued focusing on improvement in roadways with deficient ride quality while beginning to focus attention on tracking other performance measures in anticipation of MAP-21 rulemakings on nationwide performance measures
- Values from 2004 through 2011 were updated to reflect the SHA inventory of mainline directional miles, excluding ramps, but now including routes less than one mile in length so that the SHA network is more accurately and completely represented
- Continued implementation of SHA operations and business plan strategies designed to effectively maintain ride quality with limited resources
- Continued identification of cost-effective projects in high demand SHA highways
- MDTA implemented further improvements to the annual inspection program and implemented an aggressive System Preservation program
- MDTA continued to use pavement preservation treatments where needed to address ride quality and extend the service life of the MDTA roadway network

What Are Future Performance Strategies?

- Increase the use of more durable materials in high demand SHA roadways
- Continue to expand the use of recycled materials (e.g., concrete, asphalt) in SHA roadway projects in a responsible manner
- Continue to implement the Federal Highway Administration and SHA Pavement Preservation Program that will strategically utilize system preservation activities
- Target low surface friction locations on SHA roadways
- MDTA will develop network condition, budget and treatment reports to address the "best value for money" by treating pavements before they fall below acceptable ride quality levels

Source: Maryland DOT, 2014a

- *Public interest.* To what extent is the public interested in the performance measure area?
- *Control/causality.* To what extent does the agency control affect changes in performance results through decisions and actions?
- *Reporting value.* To what extent is the measure valuable in communicating what is important and a priority to the public, stakeholders, and/or internal staff?
- *Decision value.* Can the measure be used in a predictive fashion to inform decision-making processes, such as serving as an early warning system?
- *Management value.* Can the measure be used to support agency accountability?
- *System measure.* Can the measure be applied statewide or to the overall transportation system?
- *Corridor measure.* Can the measure be applied to corridor-level system performance, such as characterizing differences among corridors? [MDOT, 2006]

Table 15-2 shows the performance measures for monitoring the goals and objectives of the Michigan STP.

3. Colorado

The STP for Colorado has four major goals: improve safety, preserve infrastructure condition, improve system performance, and maintain roadways and facilities. The adopted performance measures relating to these four goals include: [CDOT, 2015a]

Safety

Highways

Number of fatalities

Fatality rate

Table 15-2. Performance Measures Linked to Plan Objectives, Michigan
Stewardship • Improve and sustain 95% of all freeway bridges in good or fair condition. • Sustain 85% of all non-freeway bridges on the trunkline system in good or fair condition. • Reduce the number of trunkline bridges that are structurally deficient. • Improve or sustain 90% of trunkline pavements in fair or better condition based on sufficiency. • Improve or sustain 90% of trunkline pavements in fair or better condition based on International Roughness Index. • Improve or sustain 90% of trunkline pavements with a remaining service life value of 3 years or higher. • Increase the percentage of trunkline railroad crossings that are related in fair or better condition. • Maintain 100% of all tier 1 airport primary runway pavements in good or better condition. • Minimize the portion of the rural transit and the specialized transit fleet that is operating past its useful life. • Preserve existing intercity passenger rail transportation services. • Preserve existing rural intercity bus service. • Preserve existing local bus services including specialized transit service. • Maintain 90% of all trunkline carpool parking lot pavements in good or fair condition.
Safety and Security • Reduce crash severity on all roadways, statewide. • Reduce crash severity on the state trunklines. • Reduce crash severity on the local roadways. • Ensure that safety projects provide the maximum return for funding dollars. • Enhance and increase protective measures and implement effective border continuity.
System Improvement • Increase percent of route miles along corridors of national/international significance having acceptable level of service. • Expand MichVan access.
Efficient and Effective Operations • Reduce delays: Minimize disruption to mobility resulting from incidents.

Source: MDOT, 2014

Number of serious injuries

Serious injury rate

Bikes and Pedestrians

Number of bicyclist and pedestrian fatalities involving motorized vehicles

Number of bicyclist and pedestrian serious injuries involving motorized vehicles

Infrastructure Condition

Bridges

Condition of National Highway System (NHS) bridges

Condition of state highway bridges

Risk-Based Asset Management Plan measures for bridges

Highways

Pavement condition of the interstate system

Pavement condition of the NHS, excluding interstates

Pavement condition of the state highway system

Other Assets

Risk-Based Asset Management Plan measures for other assets (measures for buildings, intelligent transportation systems (ITS) equipment, roadway fleet, culverts, geohazards, tunnels, traffic signals, and walls)

Transit

Transit Asset Condition

System Performance

Interstates, National Highway System, and State Highway system

Interstate Performance—Planning Time Index (PTI)

NHS Performance excluding Interstates—PTI

Colorado Freight Corridors Performance—PTI

Transit

Transit Utilization—Ridership statewide for small urban and rural "transit grantees"

Transit Connectivity—Revenue service miles provided

Maintenance

Level of service (LOS) for snow and ice removal

Overall Maintenance Level of Service (MLOS) for the state highway system

The plan also provided aspirational targets for each of the measures.

Given the importance of performance measures for identifying system performance and providing important input into the decision-making process, the selection of which measures to monitor is often part of a state DOT's public and stakeholder outreach effort. This is especially true if the performance report is directed at a particular audience, such as the state legislature.

E. Needs Assessment

Most state DOTs want to develop a data-driven plan. Traditionally, this has meant focusing on and evaluating transportation system performance, including standard condition deficiencies and network operations performance. State DOTs have been collecting these types of data for many years, and thus have good databases to determine overall trends as well as identify specific locations where deficiencies exist. However, even with this history of data collection, the statewide transportation planning process is often subject to the following five types of data-related challenges: data accessibility, data quality and timeliness, data interoperability, data redundancy, and staff delegation and cooperation. [Guo and Gandavarapu, 2009]

Adequate data for other modes that interact with the state highway system are often lacking, including transit performance data, commuter or intercity rail data, movement of freight on the state highway, and other modal data. In part, this is due to different governmental agencies or private-sector organizations that collect, analyze, and control the performance data, thus making these data difficult to obtain by the DOT.

A typical transportation system database for a state DOT is extensive and contains data for both the condition and operational performance of the state's transportation infrastructure. Of growing interest is the development and use of system maintenance and operations data in transportation planning. Many states generate such data, but because the data are used for so many different types of activities, they are often collected, stored, and analyzed by different units within the DOT. As noted in chapter 8, the growing interest in asset management approaches to investment decision making also leads to a focus on effective database management, and therefore a potential strong linkage between asset management and statewide transportation planning.

For transportation planning purposes, data are used to identify transportation needs (for example, poor pavement quality or congested road segments), as well as provide input into the analysis and evaluation of different investment strategies. It is beyond the scope of this chapter to inventory the range of data that might be used for transportation planning purposes (see chapter 2). However, some examples provide an indication of what types of data are useful for state transportation planners.

1. Hawaii

Hawaii DOT's STP illustrates a common characteristic of statewide transportation planning. As shown in Figure 15-6, the STP uses data and recommended actions from other plans undertaken in the state, in this case plans for water, air, and land transportation systems. Each of these plans has its own planning process and data sources, and therefore there is no need to replicate the analysis results in the statewide planning process.

2. Oregon

The Oregon DOT has developed a coordinated set of data management systems designed to provide information to those setting investment priorities. The Oregon Transportation Management System (OTMS) is the overarching program responsible for managing highway pavement, bridges, highway safety, traffic congestion, public transportation facilities and equipment, intermodal transportation facilities, and systems and traffic monitoring for highways. The vision of OTMS is to "integrate information, analyses and analysis tools to help decision makers prioritize Oregon's transportation needs." [Oregon DOT, 2015] The individual management systems that are part of the OTMS include:

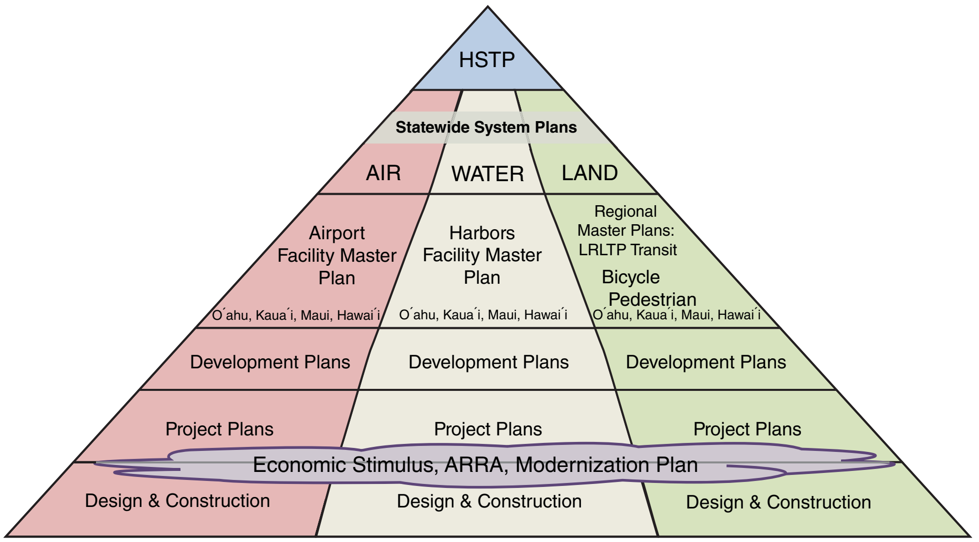
Integrated Transportation Information System

Bridge Management System

Pavement Management System

Congestion Management System

Figure 15-6. Using Other Plans as Input into the Statewide Transportation Plan, Hawaii



Source: Hawaii DOT, 2013

Intermodal Management System

Safety Management System

Traffic Systems Monitoring System

Combined, these management systems provide roadway inventory data and data on other transportation infrastructure features, analyze and summarize these data, identify and track performance measures, identify needs, help determine strategies and actions to address those needs, and monitor and evaluate the effectiveness of strategies and actions that are implemented.

3. Utah

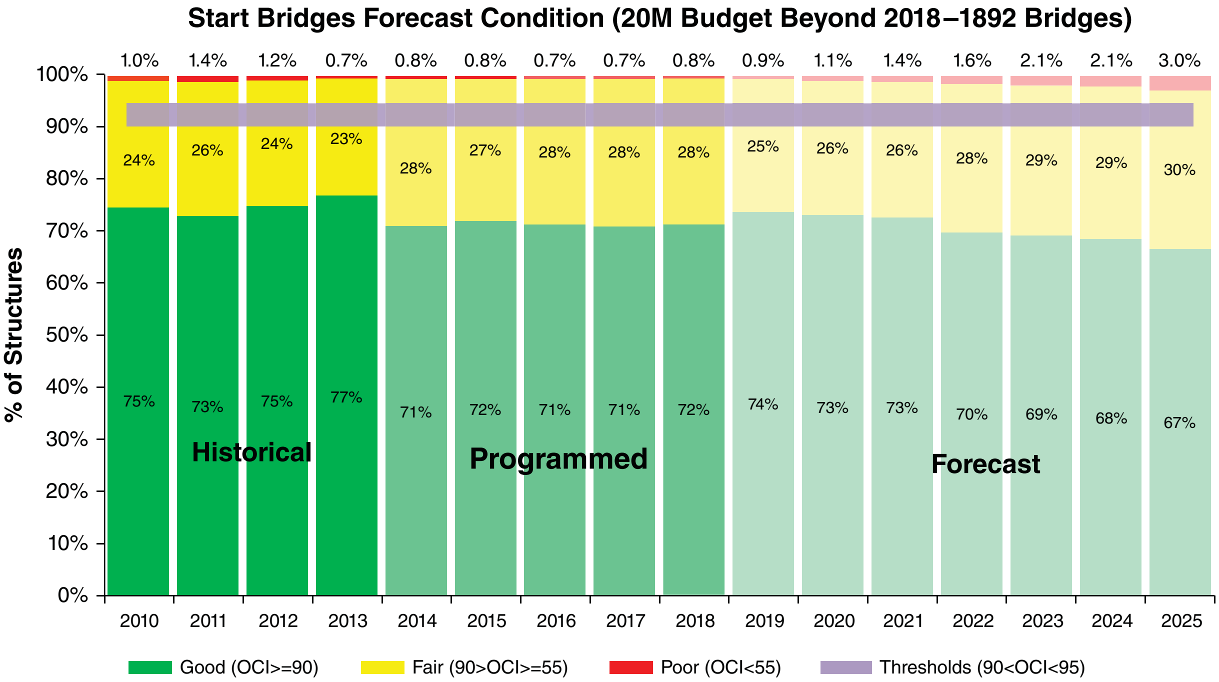
The Utah DOT has been a national leader in developing an asset management system that feeds directly into investment decision making. The DOT data portal provides data and trend information on 57 different assets and system performance characteristics that might be of use to transportation planners. [Utah DOT, 2015] Access to this data allows state DOT planners and asset managers to quickly obtain trend data such as those shown in Figure 15-7, and by using deterioration functions, estimate future condition as well.

4. Colorado

The Colorado STP illustrates the concept of a needs assessment. Transportation investment needs are generally defined as the dollars required to meet the performance goals of the STP. The following categories of needs and the data sources used are from CDOT's needs and gaps technical memorandum:

- *Asset management and maintenance:* Asset management includes replacing and rehabilitating existing and future transportation facilities on a long-term basis, including preventative maintenance. Maintenance includes the everyday and annual maintenance of the transportation system; for example: snow plowing, equipment maintenance, and minor road and bridge repairs. The CDOT Program Distribution, the results of the most recent CDOT Asset Management Delphi process (budget setting), and the CDOT Transportation Deficit Report were used to determine the needs.
- *Expansion:* Investments that add capacity to the multimodal transportation system by enhancing existing facilities or creating/building new infrastructure and services. The needs were determined through

Figure 15-7. Bridge Condition Trends and Extrapolation, Utah DOT



Source: [Utah DOT, 2015b]

Metropolitan Planning Organization (MPO) (2035 or 2040) and Regional Transportation Plan (2040) documents, lists developed by the Transportation Planning Regions (TPRs), CDOT Region project lists and data, and other existing lists of projects. The team also used safety data from CDOT (known as level of service for safety, or LOSS), travel time data and speed data (for the National Highway System (NHS) only) from the Federal Highway Administration, and information from environmental documents and MPO plans. Projects were screened and validated as potential needs based on criteria that included safety, low travel speeds, congestion levels, environmental document completion, and regional input. The input received from regional planners assisted in providing context for long-term economic vitality and development needs.

- *Safety:* Safety is generally enhanced with every project. The safety category includes education and targeted safety focused projects such as rail crossings and safety hot spots. CDOT created maps and a database showing the severity and locations of crashes and congestion, and evaluated the potential of projects to address these issues.
- *Bicycle/Pedestrian:* CDOT is conducting an inventory of bicycle/pedestrian facilities on and along the state highway system that will include a route system that serves recreational and commuter markets and that provides connectivity between attractions, work locations, and population centers. The route system will require bicycle/pedestrian compatible features such as wider shoulders and lanes, signs, new bridges, and sidewalks. These needs will be developed and analyzed once the inventory is complete.
- *Rural, Small Urban, and Interregional Public Transportation:* A preliminary analysis of rural and interregional transit needs was prepared for the plan. This includes costs for operations such as driver salaries, vehicle maintenance and fuel, as well as capital costs for regular fleet replacement and rehabilitation. Transportation Planning Regions plan for services that reach a variety of travel markets, including commuting, low-income, elderly, and disabled populations in low population density areas. In addition, expansion investments were also considered to address unmet current needs or meet anticipated future needs, based on demographic or socioeconomic growth projections. CDOT is conducting a more detailed transit needs analysis that will be completed in the future. The needs as identified represent the current level of funding going to rural and small urban transit through CDOT and existing funding for interregional transit. The current analysis does not include MPO interregional or high speed rail needs. [CDOT, 2015b]

This information is then compared to expected revenues, and the revenue shortfall is estimated for satisfying all of the DOT's needs. Table 15-3 shows such a table for the Colorado needs assessment.

5. North Carolina

The North Carolina DOT (NCDOT) conducted a similar needs assessment as Colorado's. It too listed the methods and data used to develop the needs estimates, shown in Table 15-4. However, one of the unique aspects of the NCDOT needs assessment was its recognition in its analysis that "needs" can often be related to the level of service (LOS) desired for state-owned facilities. For example, if a current facility is operating at LOS E and the desired LOS is B, this implies a certain level of investment to reach the desired target LOS B. However, if LOS C is acceptable, not as much investment is likely needed. Table 15-5 shows this impact of different assumed levels of service for the definition

Table 15-3. Gap Analysis 2016–2025, Colorado DOT

Category	Needs	Revenue	Gap	Annual
Highway Asset Management	$5,840,780,000	$3,761,544,700	($2,079,235,300	($207,923,530)
Highway Maintenance	$2,745,610,000	$2,544,000,000	($201,610,000)	($20,161,000)
Highway Expansion	$8,620,080,000	$661,517,754	($7,958,562,246)	($795,856,225)
Highway Operations	$321,640,000	$257,978,544	($63,661,456)	($6,366,146)
Highway Safety	$1,203,000,000	$1,013,710,723	($189,289,277)	($18,928,928)
Transit	$384,177,826	$384,177,826	-	-
Flexible	-	$1,720,616,554	$1,720,616,554	172,061,655
Total	$19,115,287,826	$10,343,546,100	($8,771,741,726)	($877,174,173)

Source: CDOT, 2015b

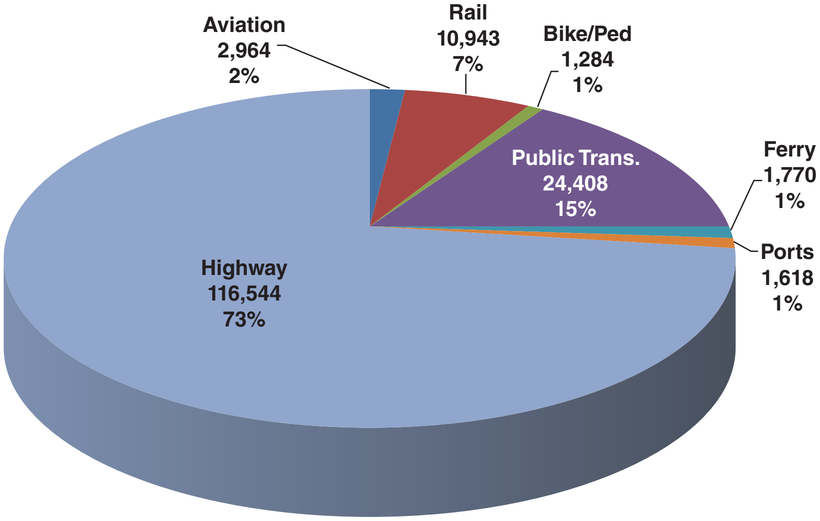
Table 15-4. Needs Estimation Methods, North Carolina DOT	
Mode/Mode Element	**Estimation Method**
Highways-Pavement	10-year estimate developed with pavement management system software and pavement inventory database.
Highways-Bridges	Estimate developed with bridge management system software and bridge database.
Highways-Maintenance	Developed from maintenance needs estimate for biannual maintenance condition assessment report.
Highways-Expansion, Metropolitan	MPOs provided listing of highway needs per most recent long range plan for metro areas. Coordinated with listing of costs to complete for loops and intrastate road improvements.
Highways-Expansion, Non-Metropolitan	Developed from analysis of roadway characteristics database in GIS format, applying traffic growth rates and segment capacities developed by the SPOT, and applying cost improvement matrix. Coordinated with listing of costs to complete for loops and intrastate road improvements.
Highways-Modernization	Developed from analysis of roadway characteristics database in GIS format, screened against minimum tolerable standards and applying cost improvement matrix.
Highways-Safety	Developed through estimates formulated for safety prioritization program, extended to 30-year period.
Highways-ITS	Developed from updated ITS program requirements, including both capital and operating costs.
Public Transportation	Developed from review and analysis of historic department funding role and review of programmatic needs; coordinated with program prioritization estimates.
Bicycle/Pedestrian	Developed from review of nearly 100 planning reports and review of programmatic needs; coordinated with program prioritization estimates.
Rail	Developed from listing of freight and passenger projects identified in new Rail System Plan, with costing of capital and operating requirements.
Ferries	Developed from listing of infrastructure assets and operating costs estimated for each facility/service.
Ports	Developed from 10-year capital needs estimate and historical operating budget, allocated to goals, and extrapolated to 30 years, excludes any major new strategic investments to ports.
Aviation	Developed from current listing of project needs and state funding participation.

Source: NCDOT, 2012

Table 15-5. Illustration of How Needs Vary with Assumed Level of Service (LOS), North Carolina ($ Millions)					
Mode/Sub-Mode	**LOS A**	**LOS B**	**LOS C**	**LOS D**	**Target LOS**
Aviation	$2,964	$2,775	$2,080	$1,461	$2,218
Rail-Passenger	$9,599	$8,042	$2,225	$1,129	$2,733
Rail Total	$10,943	$9,117	$3,031	$1,660	$3,539
Bike-Ped	$1,285	$1,029	$773	$341	$773
Public Transportation	$24,408	$20,384	$17,338	$14,736	$20,384
Ferry	$1,770	$1,593	$1,416	$708	$1,593
Ports	$1,619	$1,295	$971	$648	$1,295
Highways-Bridges	$10,144	$8,115	$6,086	$4,058	$7,921
Highways-Pavement	$25,534	$21,385	$14,471	$10,214	$19,309
Highways-Roadway Maintenance	$17,440	$13,952	$10,464	$6,976	$11,395
Highways-Safety	$2,499	$1,999	$941	$1,000	$1,999
Highways-Modernization	$4,028	$3,222	$2,417	$1,611	$2,244
Highways-Expansion, Non-Metro	$10,412	$8,330	$6,247	$4,165	$8,582
Highways-Expansion, Metro	$45,311	$36,249	$27,187	$18,124	$40,564
Highways Total	$116,543	$94,192	$68,519	$46,617	$93,030
Grand Total	$159,532	$130,386	$94,128	$66,172	$122,833

Source: NCDOT, 2012

Figure 15-8. Distribution of Investment Needs by Mode, North Carolina



Source: NCDOT, 2012

of need. As can be seen, there is a significant difference in the needs estimate depending on which LOS one assumed. Figure 15-8 is another common presentation of data in a needs assessment.

F. Analyzing Transportation System Alternatives

The development and analysis of different investment alternatives and/or scenarios is the core of the technical approach for statewide transportation planning. Analyzing different plan alternatives allows the DOT and the public to assess the implications of different policies, programs, and funding approaches. This part of the process is critical to the overall success of the plan, as it allows members of the public to play an important role in identifying, analyzing, and selecting alternative plans. The level of sophistication of the analysis tools used to analyze alternative system alternatives varies by state. In some cases, state DOTs have developed a statewide traffic demand model and/or a statewide freight model that can be used to forecast performance outcomes. Chapter 6 on demand modeling and chapter 22 on freight transportation provide an overview of the structure and use of such models. The following example from Ohio provides an overview of some of the key aspects of statewide travel demand forecasting.

1. Ohio

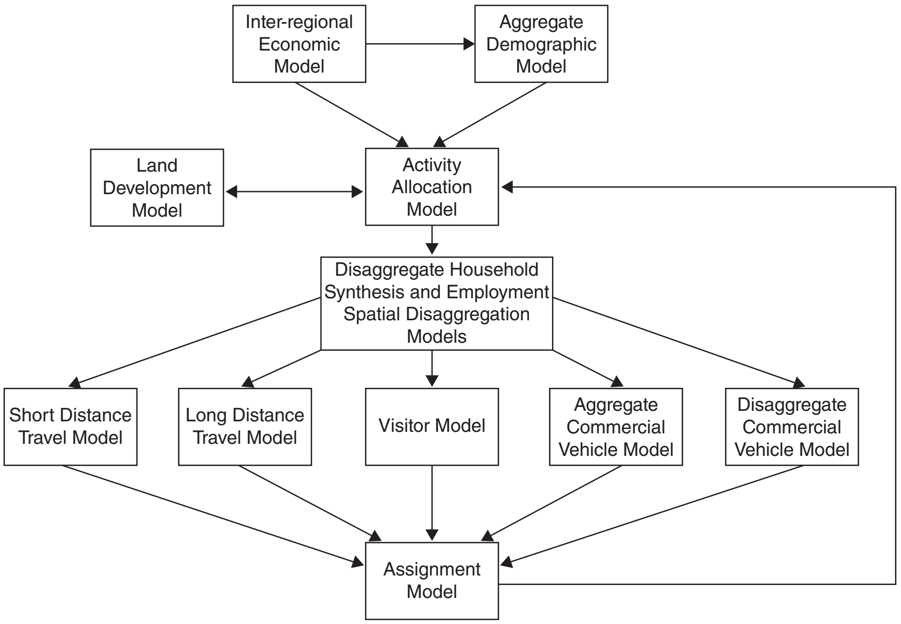
The Ohio DOT began the development of a statewide travel demand model in the late 1990s to "provide the ability to analyze large multi-region corridors, to conduct consistent system-wide analysis and to provide a traffic forecasting tool in the rural areas of the state not covered by the urban MPO models." [Ohio DOT, undated] Interestingly, the Ohio DOT first surveyed key decision makers who would be relying on the results of demand modeling to determine the most desired outputs of the model. The three priority issues were:

- Reducing/minimizing/avoiding roadway congestion and delay.
- Sustaining and improving the state economy.
- Including freight planning, particularly with regard to the management of truck traffic and the potential for shifting it to other routes and modes.

The following factors were considered desirable, if they were cost-effective to provide:

- Support multimodal/intermodal options for travel, passenger, and freight.
- Improve conditions for non-auto (and non-single-occupant auto) mode services.
- Maintain/improve safety.

Figure 15-9. Ohio Integrated Economic, Land Use, Transport Model

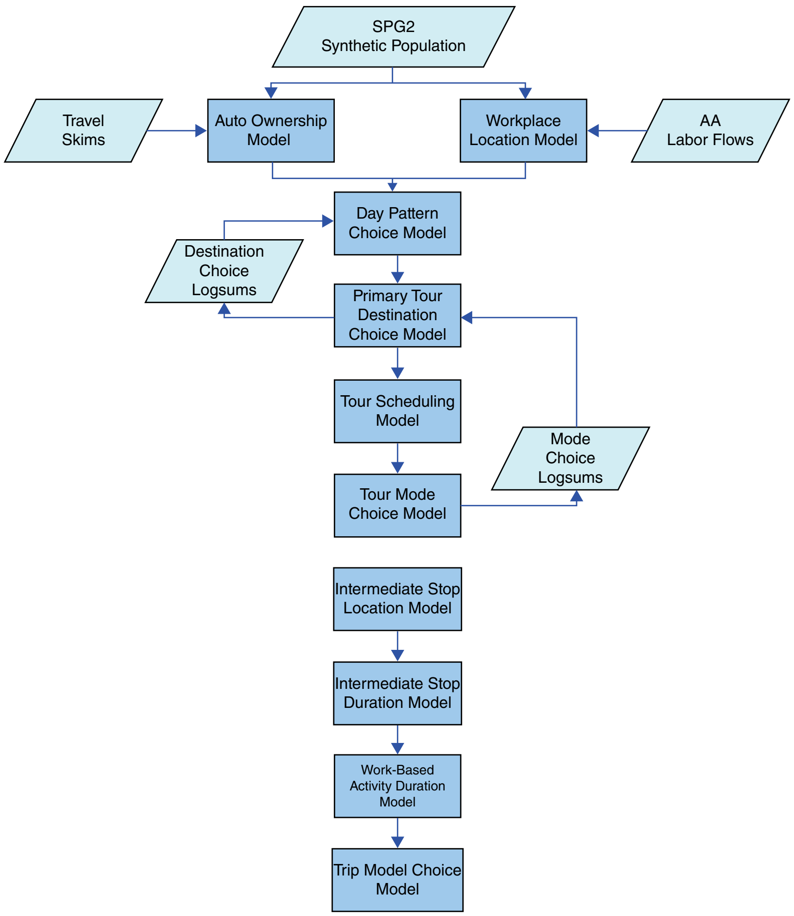


Source: Courtesy of the Ohio DOT [Ohio DOT, undated]

- Mitigate the impacts of new development and related access management.
- Maintain/improve air quality.
- Reduce conflicts between modes

The model structure chosen to provide these capabilities is shown in Figure 15-9. As indicated, the model includes the typical traffic forecasting element of such models, but it also links to a state economic model and a demographic model. The basic modeling approach uses trip tours or more generally an activity-based model (see chapter 6 on travel demand) as seen in Figure 15-10. The types of output from the model include estimates on: vehicle miles traveled; vehicle hours traveled; crashes; level of service; delay; growth rates; air pollution emissions; volume to capacity ratios; duration, extent and location of congestion; vehicle operating costs; value of time; cost of travel time for both persons and transported goods; and origin-destination flows.

Figure 15-10. Ohio Short Travel Distance Demand Model

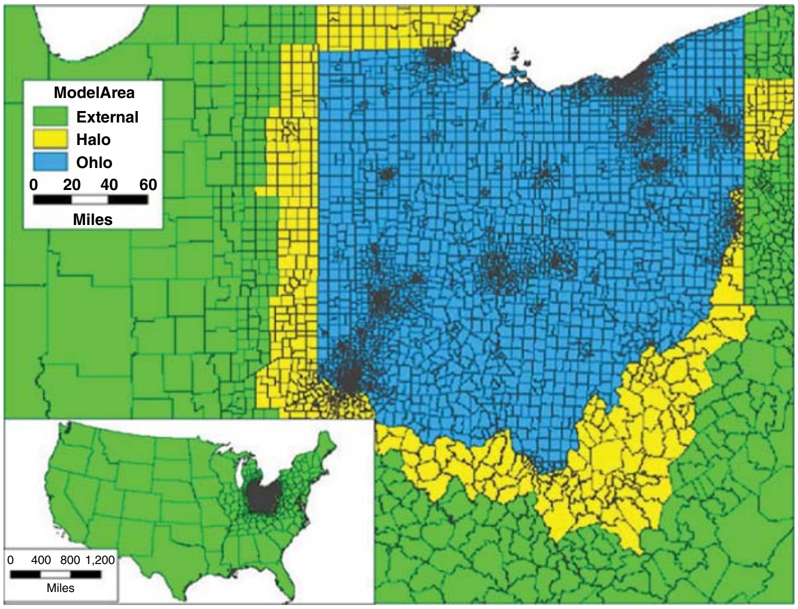


Source: Parsons Brinckerhoff, 2010

One of the implications of using a statewide travel demand model is that the zone structure for the analysis will be large. In addition, the zones representing origins or destinations outside of the state will be even larger. Figure 15-11 shows the traffic analysis zone structure used in the Ohio model. As can be seen, the farther away from Ohio one gets, the larger the zones, eventually resulting in entire states being a zone. For freight models, an even larger zonal system is often used to represent freight flows going outside the country.

There are very few states with models at the level of sophistication as found in Ohio. However, many states are developing models that are similar, and that can be used to support agency planning and decision making.

Figure 15-11. Ohio Demand Model Analysis Zones



Source: Parsons Brinckerhoff, 2010

2. Rhode Island

Scenario analysis is becoming another tool that states are using to analyze future investment options. Scenarios are often viewed as being slightly different than alternatives. A scenario reflects a specific context for transportation investment—for example, focusing transportation investment in existing communities, emphasizing bottleneck removal, or examining the implications of limited availability of petroleum-based fuel in the future. Given each scenario, specific alternatives can be developed that best reflect the characteristics of that scenario.

The Rhode Island Department of Administration (on behalf of the Rhode Island Department of Transportation) developed an STP that used two different types of scenarios—one relating to alternative patterns of development (and the consequent impact on system performance), and another on different levels of investment in the transportation system. [RIDOA, 2012] With respect to the land-use scenarios, three different assumptions were examined.

- *Current Trend:* Assume current population and employment projections as assigned to the traffic analysis zones (TAZs) for use in forecasting VMT and emissions. The trend at the time showed 55 percent of the growth going to TAZ's inside the urban area and 45 percent outside (55/45 split).
- *Sprawl Scenario:* Assume the rural area absorbs more of the population and employment growth (20 percentage points more of the 2000–2030 growth than in the Current Trend scenario for a 35/65 split).
- *Compact Scenario:* In this scenario, the urban area absorbs more of the population and employment growth (30 percentage points more of the 2000–2030 growth than in the Current Trend scenario for an 85/15 split).

Table 15-6 shows the results of incorporating these different scenario assumptions into the statewide travel demand model.

3. South Carolina

The South Carolina Department of Transportation (SCDOT) developed five investment scenarios as part of its statewide transportation plan. These scenarios were:

- *Baseline:* Allocate resources to focus on the core highway system. Baseline resembles the current program distributions.
- *Multimodal System:* Allocate resources to maintain and expand highway, transit, rail, and nonmotorized systems linking cities and towns.
- *Serve the Economic Drivers:* Investment to support business attraction and retention, with resources focused on ports, distribution facilities, airports, and leisure destinations.

Table 15-6. Scenario Analysis for Land Development Patterns, Rhode Island										
Growth Scenarios	**Population 2030**		**Employment 2030**		**Daily Vehicle Miles Traveled 2030**			**Transit Ridership 2030**		
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Total**	**Urban**	**Rural**	**Total**
Current Trend (55/45)	855,947	284,596	438,084	77,964	16,390,489	10,355,817	26,746,306	108,475	835	108,310
Sprawl Scenario (35/65)	836,433	304,110	417,482	98,566	15,810,783	11,345,517	27,156,300	104,789	998	105,787
Change from Current Trend	−19,514	19,514	−20,602	20,602	−579,706	989,700	409,700	409,994	−3,686	−3,523
Percent	−2.3%0	6.9%	−4.7%	26.4%	−3.5%	9.6%	1.5%	−3.4%	19.5%	−3.2%
Compact Scenario (85-15)	882,545	257,998	441,857	74,191	16,502,947	9,970,877	26,473,824	110,765	778	111,543
Change from Current Trend	26,598	−26,598	3,773	−3,773	112,458	−384,940	−272,482	2,290	−57	2,233
Percent	3.1%	−9.3%	0.9%	−4.8%	0.7%	−3.7%	−1.0%	2.1%	−6.8%	2.0%

Source: Rhode Island Department of Administration, 2012

- *Reduce System Size:* Transfer ownership of roughly 50 percent of the nonfederal-aid highway system to counties and municipalities over the lifetime of the plan. There are approximately 10,000 nonfederal-aid roadways miles that carry less than 200 vehicles per day.
- *Preservation:* Focus on maintaining highways and bridges at a high level of preservation and reliability. Less focus on congestion and multimodal expansion.

Figure 15-12 shows the results of the scenario analysis. The percentages indicate the degree to which each scenario achieved the goals of minimizing highway user costs, improving pavement condition, reducing congestion, keeping bridges in good condition, and supporting nonmotorized and transit options. As noted in the plan,

> *No one individual investment scenario optimally addresses the future performance of the state's transportation system. Allocating limited resources to efficiently address a multitude of transportation needs throughout South Carolina is a top priority of SCDOT. While SCDOT cannot address all the transportation needs alone, it is clear that a narrower focus will be necessary to achieve measureable gains in any of the Plan goal areas. A more strategic focus can include shifting a greater share of funding to system preservation while relying on non-federal funding sources to address mobility needs, as well as targeting investment to priority networks that support state mobility needs and economic competitiveness, such as the Interstate system and the Statewide Strategic Corridor Network.*

Figure 15-12. Alternative Investment Scenario Analysis, South Carolina

	Highway User Cost	Pavement Condition	Congestion	Bridge in Good Condition	Nonmotorized and Transit Support
Baseline	52%	35%	70%	84%	19%
Multimodal	47%	29%	70%	81%	51%
Economic Drivers	52%	27%	72%	82%	21%
Reduce Size	57%	37%	72%	87%	37%
Preservation	52%	64%	68%	78%	19%

Source: South Carolina DOT, 2014

4. Virginia

The Virginia DOT example is typical of the alternative investment plan analysis approach toward transportation planning. As noted earlier, VDOT adopted a strategic corridors approach for statewide transportation planning. Guidelines were developed that provided a template for analyzing these corridors, including the following information:

Analysis of Existing Corridor

Purpose: *To compile information on the current state of the facility/corridor.*

Items discussed include:

- Existing facility type(s)/cross-section(s).
- Current travel demand along the facility. This includes the traffic volumes of passengers, vehicles, and trucks; and depending on the level of analysis, bikes, and/or pedestrians.
- Degree and type of freight movement (if applicable).
- Level of service (LOS) and capacity analysis along the existing corridor.
- Safety/crash analysis.
- Manner by which the facility fits within and connects to the rest of the transportation system.
- Other existing non-highway modes of transportation (such as a nearby rail facility).

Needs Assessment

Purpose: *To develop the purpose and need for improvements along the corridor.*

Items discussed include:

- Specific goals of the study.
- Selection of the facility as a Strategic Highway Corridor.
- Need for improvements along the facility as they relate to the corridor's function as a Strategic Highway Corridor.
- Future travel demand along the corridor (autos, trucks, and/or freight movement, and depending on the level of analysis, bikes, and/or pedestrians).
- LOS and capacity analysis of the future travel demand.

Alternatives Development and Analysis

Purpose: To develop and analyze alternatives that meet the goals, intent and purpose and need of the corridor study.

This task is performed in coordination and collaboration with key stakeholders and the general public. Depending on the purpose and need and the intent of the study, the level of effort will vary. For example, if the primary focus of the study is determining the appropriate access management techniques that should be implemented along a corridor, alternatives may be developed solely for accomplishing this goal. Likewise, if the corridor study is a tiered environmental impact statement (tiered EIS), alternatives developed might be approximately 100-miles long and 2,000-feet wide. Alternatives include a no-build alternative along with several potential build alternatives. In addition, other modes of transportation may be examined as necessary, depending on the intent of the corridor study, such as a tiered EIS.

An analysis of each of the alternatives developed will occur to determine the best solution(s) that meet(s) the purpose and need and goals of the study. The analysis may include items such as:

- Mobility benefits
- Economic benefits
- Environmental impacts

- Indirect and cumulative impacts
- Cost-effectiveness benefits
- Effects on other components in the transportation system
- Travel forecast (if applicable)

5. Arizona

The Arizona DOT's transportation plan, *What Moves You Arizona*, is a good example of a plan that provides a strategic, performance-based perspective on transportation needs as well as in the identification of project priorities. The planning process established a set of performance measures to identify transportation needs and to serve as evaluation criteria for individual projects. Through outreach to key stakeholders, this process identified the differing weights assigned to individual performance measure categories by important decision makers. The different weights were then used for the individual performance measure categories.

Needs were determined by examining the consequences of three different investment strategies:

- *Preservation:* Activities that protect transportation infrastructure by sustaining asset condition or extending asset service life; preservation includes regular maintenance and resurfacing of pavements, replacing aged transit vehicles, upgrading rail track, and airport runway rehabilitation.
- *Modernization:* Highway improvements that upgrade efficiency, functionality, and safety without adding capacity; examples of modernization activities include widening of narrow lanes, access control, bridge replacement, hazard elimination, lane reconstruction, aviation upgrades, and bus system upgrades.
- *Expansion:* Improvements that add transportation capacity through the addition of new facilities and or services; expansion activities include adding new highway lanes, expanding bus service, construction of new highway facilities, and adding rail passenger service or facilities. [ADOT, 2011]

Highways

Three major analysis methods were used to determine needs.

HERS-ST : The Highway Economic Requirements System—State Version (HERS-ST) model, developed by FHWA, was used to determine 25-year State Highway System needs. A roadway condition database known as the Highway Performance Monitoring System (HPMS) provides the input information for this analysis (see chapter 2).

NBIAS: Bridge needs were analyzed with the National Bridge Investment Analysis System (NBIAS) model. The NBIAS model forecasts bridge performance and identifies improvements based on economic indicators.

New Facilities and Other Capital State Highway System Needs: New capital needs built on new rights of way cannot be determined from HERS-ST or the NBIAS. ADOT identified proposed new projects from existing state DOT plans, from the regional long-range transportation plans from the state's MPOs, and other planning sources. The new location highway needs totaled $15.8 billion over the life of the plan.

In addition, the above tools do not estimate noncapital needs such as routine maintenance. These were estimated separately.

Transit

For public transportation needs, the following analysis approaches were used:

Urban Preservation Needs (or "State-of-Good-Repair" Needs): These needs focused on bus and light rail vehicle replacement and rehabilitation, as well as the maintenance and rehabilitation of supporting infrastructure. Needs were estimated by comparing Arizona's share of transit assets in relationship to the 2010 Federal Transit Administration's (FTA) National State-of-Good-Repair Study and the needs-based report from the American Association of State Highway and Transportation Officials.

Urban Transit Expansion: Metropolitan-area transportation plans, along with the most recent 2008 Arizona Statewide Transportation Investment Strategy, was used to estimate expansion needs.

Rural Preservation and Expansion: These needs had already been estimated in a recent ADOT Rural Transit Needs Study.

Freight Rail

Several sources were used to estimate long-term freight rail investment needs in the state, including recent state transportation plans, the Arizona State Rail Plan, ADOT's 2009 Railroad Inventory and Assessment, a Multimodal Freight Analysis Study, and interviews with railroad officials.

Passenger Rail

The passenger rail needs focused on state-of-good-repair, modernization, and expansion requirements that were obtained from the Federal Railroad Administration's High Speed Rail Strategic Plan, ADOT's Statewide Rail Framework Study, Maricopa Association of Governments' (the MPO for Phoenix) Commuter Rail Strategic Plan, an Amtrak Report on Accessibility and Compliance with the Americans with Disabilities Act of 1990 and internal route performance reports conducted by ADOT staff.

Aviation

The Arizona State Airports System Plan (SASP) was used to identify costs to improve the state's airport system. In addition to the projects identified in the SASP, airport-specific capital projects and costs were identified by examining each airport's master plan

Operating Costs

Cost estimates for operating the highway and bridge network, and providing transit services were based on prior work conducted by the DOT. In addition, the operating costs associated with matching federal aid programs were also included in the overall needs assessment.

Once the needs were identified, ADOT compared different investment scenarios:

- *Alternative Investment Choice (AIC) A, Highway Focus:* AIC A focuses on preserving the state's highway system with limited system expansion. Preserving the system had surfaced from extensive public outreach efforts as the more important goal of the transportation plan.
- *Alternative Investment Choice (AIC) B, Expanded Travel Choices:* This scenario shifts funding from preservation to expansion and provides some non-highway funding to non-highway investments such as transit, rail, aviation, and other modes. Highway investments are focused on the interstate system, and approximately 10 percent of all state funding is allocated to other transportation choices, such as transit and passenger rail.
- *Recommended Investment Choice (RIC), Combination of Investment Choices:* The RIC combines elements from AIC A and AIC B. For example, like AIC A, the RIC emphasizes state highway system preservation and modernization. Like AIC B, funding is shifted from highway expansion to non-highway modes (that is, rail and transit) to provide mobility options. [ADOT, 2011]

Table 15-7 shows the percent allocation of state dollars for each scenario.

Table 15-7. Distribution of Funding by Scenario, Arizona DOT

Improvement Category	AIC A Funding	AIC B Funding	RIC Funding
Highway Preservation	34%	17%	34%
Highway Modernization	22%	10%	29%
Highway Expansion	41%	52%	27%
Non-highway Improvements	3%	21%	10%
Total	100%	100%	100%

Source: ADOT, 2011

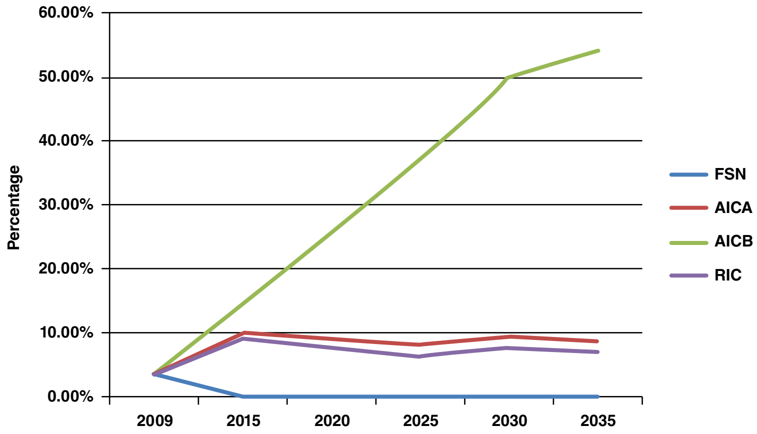
ADOT examined the impacts of each scenario on different condition and performance measures. Figures 15-13 to 15-15 show some of the forecasted impacts. In each of these figures, the "full state needs" scenario is also shown. This scenario is the base case for comparison purposes and represents meeting as many needs as possible with expected revenues.

ADOT also assigned a "grade" for each scenario with respect to its ability to achieve plan goals. Identifying the grades for each goal area included significant interaction with ADOT staff, individual stakeholders, a technical advisory committee members, and the steering team. Table 15-8 shows the grades that were assigned. One of the major purposes of assigning grades was to explain the impacts of different investment scenarios in terms that the public could understand. It is interesting to note that even the highest level of investment was generally rated as being just above average in meeting the needs.

Each of the examples above—and almost every statewide transportation planning effort—relies on computer models for producing the analysis that feeds into the evaluation process. It is beyond the scope of this chapter to discuss the different types of analysis models that can be used for forecasting both person and freight flows (see chapters 6 and 20, respectively). Forecasted traffic-flow information, however, is used in a variety of ways by a state DOT. Customers include not only the planning unit, but also other groups concerned with design, performance monitoring, and traffic engineering. Table 15-9 shows the types of data that are the products of traffic forecasting and how these products are used as noted by the Vermont Agency of Transportation.

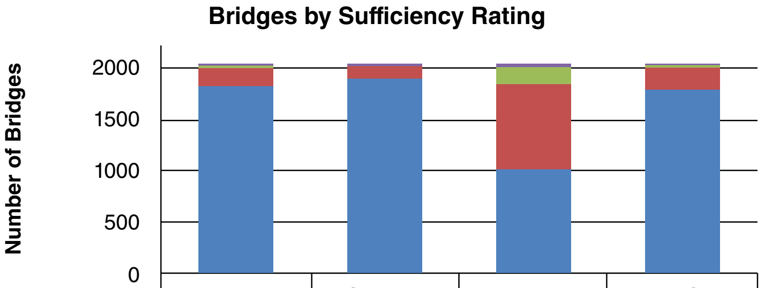
One of the challenges facing DOTs in developing long-range plans is the relationship between statewide travel demand models and those models developed by MPOs. Assumptions made by the state about growth and traffic into and out of urban areas should match those of MPOs. In some states, this coordination has not always occurred. The primary application of the regional models is to provide a tool to update long-range transportation plans and develop project-level forecasts for highway design purposes. However, MPO models often do not consider the systemwide growth in traffic generated from statewide forecasts. The Wisconsin DOT used an expert panel review process involving planners and technicians from both the DOT and the state's MPOs to reach a consensus on traffic growth rates for both the urban areas and the statewide model.

Figure 15-13. Percentage of ADOT Roadway Miles Below "Good" Threshold



Source: ADOT, 2011

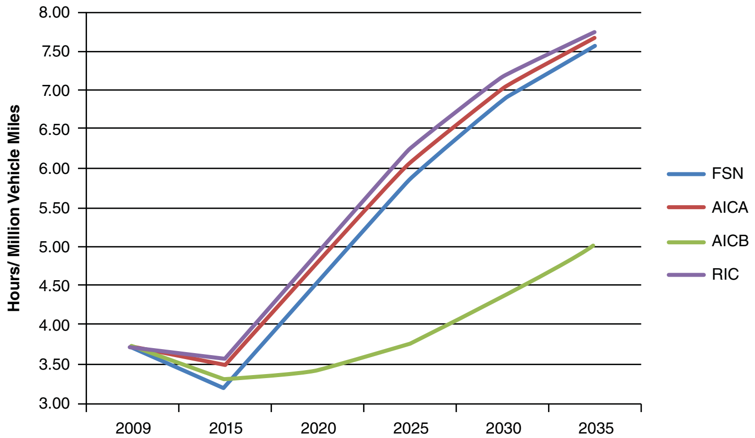
Figure 15-14. Bridges by Sufficiency Rating



	Initial	FSN and A	B	RIC
0% to 25%	13	8	24	9
25% to 50%	16	0	163	18
50% to 75%	184	133	833	218
75% to 100%	1817	1889	1010	1785

Source: ADOT, 2011

Figure 15-15. Estimated Travel Delay



Source: ADOT, 2011

Table 15-8. Grading the Level of Achieving Plan Goals, Arizona

Goal Area	ADOT Existing Investment Strategy	Alternative Investment Choice A	Alternative Investment Choice B	Recommended Investment Choice
Improve mobility/accessibility	B	D	C+	C–
Preserve and maintain system	B+	A	D	A–
Support economic development	C+	D	B–	C–
Link transportation and land use	C–	C–	B	C+
Consider the environment and natural resources	B–	B–	B+	B+
Enhance safety and security	C+	C–	B–	B–
Investment in non-highway modes	D	D	C+	C

Source: ADOT, 2011

Transportation interest groups and the public continue to have an interest in the models used by state DOTs, the assumptions that drive the modeling process and the use of model results. In many cases, the technical capabilities of forecasting models available for use in long-range planning at the state level have not kept up with these expectations—particularly in the areas of modeling of land-use decisions, modeling transportation trade-offs and incorporating freight data. As more and more data are generated for state-level forecasting purposes, DOTs are challenged to maintain the quality and integrity of their basic database and to provide resources to update system data continually—all within the context of reduced resources.

The following state DOT websites provide good examples of the web-based resources that are now available to planners in obtaining data that can be used in transportation planning studies.

Florida DOT, Geographic Information Systems Roadway Characteristics Inventory, http://www.dot.state.fl.us/planning/statistics/gis.

Massachusetts DOT, Data, http://www.massdot.state.ma.us/planning/Main/MapsDataandReports/Data.aspx.

Michigan DOT, Intermodal Data, http://mdotcf.state.mi.us/public/tms/idm.cfm.

Minnesota DOT, Traffic Forecasting & Analysis, http://www.dot.state.mn.us/traffic/data/coll-methods.html#WIM.

Washington State DOT, Maps and Data, http://www.wsdot.wa.gov/mapsdata.htm.

G. Evaluating Transportation System Alternatives

In evaluating different state transportation system alternatives, planners synthesize the information associated with each alternative and compare their impacts. Because of the aggregate nature of the alternatives and scenarios investigated, state DOTs very seldom conduct detailed evaluation as is done in metropolitan plans or for that matter in state DOT-sponsored corridor studies. This is the case primarily because the scale of the transportation system and the many different kinds of modal strategies being considered makes a quantified evaluation process very difficult. Often the most information provided is similar to that described earlier from the Arizona statewide plan example, which included both quantitative estimates for such things as pavement and bridge condition, as well as a subjective assessment (that is, letter grades).

However, when state DOTs focus on one mode as they do in state modal plans (discussed later) or when they focus on a particular region of the state, one often sees evaluation results as shown in Figure 15-16. This figure comes from the Georgia DOT where a key state initiative developed a portfolio for strategic transportation investment in the state. Given that the Atlanta metropolitan area was the most complex from a transportation perspective, and given the Atlanta MPO had a travel demand model capable of estimating travel demands, the DOT produced the evaluation results shown in the figure.

Different methods and approaches for evaluating alternatives can be found in chapter 7.

Table 15-9. Traffic Forecasting Products and Customers: Vermont

Type of Forecast	Available Methods	Applicability	Key Data Requirements	Advantages	Disadvantages
Future year population and employment in the corridor study area	Statewide travel demand model	Appropriate "baseline" forecast	Existing data	Existing, consistent statewide forecast of population and employment by town	Assumptions underlying forecast may not fully reflect local conditions
	Trend analysis	Appropriate in absence of other data Can be tempered with judgment on expected future trends	Historical trends in study area population, employment, development permits	Reflects past/current trends	Assumes past/current trends will remain consistent in the future
	Build-out analysis	Appropriate for towns with rapid growth/approaching build-out in analysis period, or for studies taking long-term (>20 years) perspective	Study area zoning (allowable densities, types of uses) Locations of existing development Locations with environmental constraints to development	Reflects current local plans and policies Supports a "worst- case" scenario of growth	Not possible in towns without zoning; difficult without electronic zoning map Forecast year development may be much less than build-out.
	Estimate future development based on known plans	Best for short term studies, or area with slow change Can be combined with longer-term estimation methods	Permitted or planned developments (industrial park expansion, subdivision applications)	Realistic pictures of near-term future development	Likely to underestimate 20-year development
	Expert judgment (e.g., Delphi/expert panel method)		Past trends Permitted/planned developments Knowledge of corridor economic and planning environment	Can combine other methods and data to arrive at a consensus	Subjective—Different "experts" are likely to disagree
	Scenario planning	Best for regions that want to conduct proactive and long- term planning for future growth	Varies; may utilize other planning and forecasting tools	Involves public and stakeholders in discussing alternate futures and their potential impacts	Process involving significant effort

(*continued*)

Table 15-9. (*Continued*)

Type of Forecast	Available Methods	Applicability	Key Data Requirements	Advantages	Disadvantages
Specific locations of future year development	Know plans methods	(see above)			
	Build-out analysis	(see above)			
	GIS-based forecasting tools	Examine changes in development patterns based on major trans. Investments and land use policies Provides inputs to detailed trans. model, GIS-based environment analysis	Areawide population and employment control forecasts Planned land use/zoning Developmental constraints Transportation accessibility measures	Rational/consistent method for allocating development	Data and resource-intensive to develop and apply
Future traffic volumes on study area roadways	VTrans statewide travel demand model	Baseline traffic growth projections on major roads	Existing data	Accounts for forecast statewide development patterns and transportation network improvements	Not available for roads not included in statewide model
	VTrans growth factors	Baseline traffic growth projections	Existing data	Based on historic trends on roadway	Assumes historic growth trends will continue in future
	Traffic impact study	Assess impacts of growth policies regarding specific major developments, or general locations of development in corridor	Locations, type, and size of new high-trip generators Trip generators rates (ITE manual or other source)	Accounts for traffic impacts specifically from study area development Can account for seasonal trip generation, e.g., from recreational sources	Needs to be added to background traffic levels Caution required to avoid double-counting
	Rural Traffic Shed Model	Forecast traffic volumes from development in a "traffic shed" area served by a single major road	Future land use and development by "traffic shed" Trip generation rates associated with various land uses	Similar to an areawide trip generation study	Not tested in Vermont
Intersection performance (delay, LOS) given future traffic volumes	*Highway Capacity Manual* (HCM) Chapters 16 and 17	Estimates delay, LOS, V/C, queue lengths at controlled intersections	Traffic volumes (including turning movements) Control type through and turn lanes	Standard, widely applied methodology	Requires detailed traffic and geometric data for each intersection analyzed
Road segment performance (speed, LOS) given future traffic volumes	HCM Chapter 20	Estimates speeds, LOS for roadway segments	Traffic volumes, lane and shoulder widths, trucks, directional split, passing zones, free flow speed	Standard, widely applied methodology	Requires traffic and geometric data for each road segment analyzed LOS is subjective depending upon expectations for road

Corridor performance and delay	HCM Chapter 29	Combines intersection and segment level techniques; most applicable for urban, multimodal corridors	See above	Can account for demand-shifting between modes (e.g., highway and transit) and parallel facilities	Analysis procedures can estimate under severely congested conditions
Overall corridor travel time given future traffic volumes	Ski corridor travel time model (combines intersection and road segment methods)	Best analyzing inter-sections improvement, roadway segment improvements, changes in study area trip generation	Same data requirements as for HCM analysis Requires corridor travel time data for validation	Proven overall corridor-level measure of travel time performance Sensitive to development traffic and mitigation measure	Does not provide reliable estimates under severely congested conditions
	Statewide travel demand model	Primary use is forecasting traffic volumes statewide-Not roadway-specific travel times	Change in capacity for roadway corridor	Reflects statewide travel patterns	Not sensitive to intersection or small-scale improvements Limited accuracy of speed estimation May require calibration for corridor-specific application
	Statewide travel demand model—Enhanced for corridor studies	Best for analyzing: shifting growth within study area locations, adding links to roadway network, major capacity upgrades	Refined level of detail on road network, study area population and employ-ment	Can account for shifting of growth or trip generation within study area, traffic diversion to alternate facilities	May involve considerable effort Not sensitive to intersection or small-scale movements
Crash reductions from safety and operational improvements	NCHRP Report 500 – information on effectiveness of strategies	Analyze potential safety benefits of various roadway and operational improvements	Existing conditions Improvement being proposed Traffic volumes	Low cost/easy to apply	Results reported from other studies—actual benefits may vary widely depending upon context
Traffic reductions from alternative mode strategies	Sketch-plan assessment of mode shifts	Analyze vehicle traffic reduction or nonmotorized traffic increases from transit service, bicycle/pedestrian facilities, TDM strategies, pedestrian friendly development	Observed or modeled travel behavior changes from similar strategies in other areas	Can provide quantitative estimate for this factor	May be difficult to find research for comparable situations
	Stated-preference surveys	Ask people to state choices for alternative modes under different scenarios	Survey—original data collection	Can reflect specific facility/ service improvement being proposed	Can be expensive to administer Survey must be carefully designed, otherwise people may overstate choices

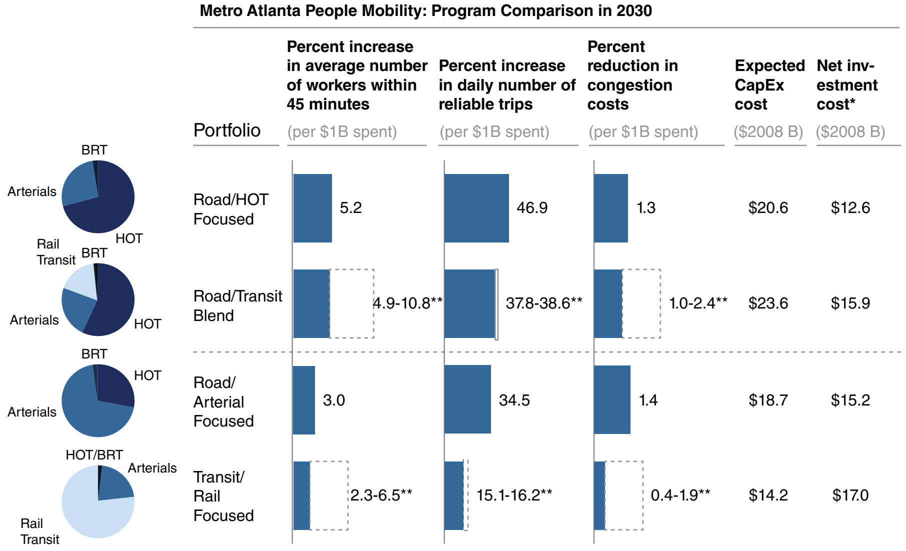
(*continued*)

Table 15-9. (*Continued*)

Type of Forecast	Available Methods	Applicability	Key Data Requirements	Advantages	Disadvantages
Congestion and safety benefits of access management strategies	NCHRP Report 420	Predict changes in crash rates based on addition of driveways, intersection spacing, median treatments	Number of unsignalized and signalized intersection per mile Type of median	Estimates based on empirical data	Crash rates and strategy impacts likely to vary depending upon context
	HCM Chapters 16 and 17	Analyze delay at new/improved controlled intersections	(see above)		
Environmental and community impacts of transportation and development patterns	Qualitative assessment	Conduct sketch-level assessment of impacts of corridor strategies, based on professional and stakeholder knowledge	Various background data on existing conditions Proposed transportation and land-use strategies	Low cost/easy to apply	Subjective—will vary by person; nonquantifiable
	GIS-based community impact assessment tools	Scenario analysis of alternative transportation and development patterns producing indicators such as land developed, impermeable surface area, transit access, walkability, energy consumption	Existing and future land use/development patterns (GIS-based) Transportation network data Other land use, environmental data	Can assess a wide range of community impacts related to future development patterns	Data and resource-intensive Have primarily been applied in metropolitan area applications, not for rural areas
	Detailed analysis methods	Most appropriate for specific projects, typically conducted as part of the NEPA process	Varies depending upon impact and method	Provides in-depth information on impact	Often data/resource intensive
Visual/aesthetic impacts	Visual preference surveys	Assess visual/aesthetic preferences	Images of different types of development or roadway design alternatives	Low cost—can use existing images/examples from other areas	Does not show what actual project of development would look like
	Computer visualization techniques-land use	Develop computerized representations of alternative development scenarios	Planned land use, including location of development, density, other physical design parameters	Powerful tool to communicate visual/aesthetic impacts related to development scenarios/alternatives	Requires detailed data Building design/architecture may not resemble actual development
	Computer visualization techniques-transportation facilities	Development computerized representations of alternative transportation facility designs	Landscape/background Transportation facility design	Powerful tool to communicate visual/aesthetic impacts related to development scenarios/alternatives	Requires detailed data Most appropriate for detailed project analysis, not corridor planning

Source: Vermont Agency of Transportation, 2005

Figure 15-16. Example Evaluation of Different Investment Portfolios, Georgia DOT



* Includes CapEx and 20-year O&M costs, less expected revenue (e.g., tolls, fare recovery)

** Upper end of range reflects benefit of aggressive coordinated development in employment centers and enhanced demand management programs, which is more likely to occur with transit investments

Source: Georgia DOT, 2010

H. Prioritizing Programs and Projects

The most sophisticated models, the best public involvement process, and the most comprehensive view of statewide transportation planning cannot ensure that programs and projects will be implemented. As a result, the link between system planning and the state DOT project programming process is one of the most important relationships in investment decision making. As noted earlier, the development of a statewide transportation improvement program (STIP) is a requirement of the federal government. The following examples illustrate typical approaches for prioritizing projects.

1. Minnesota

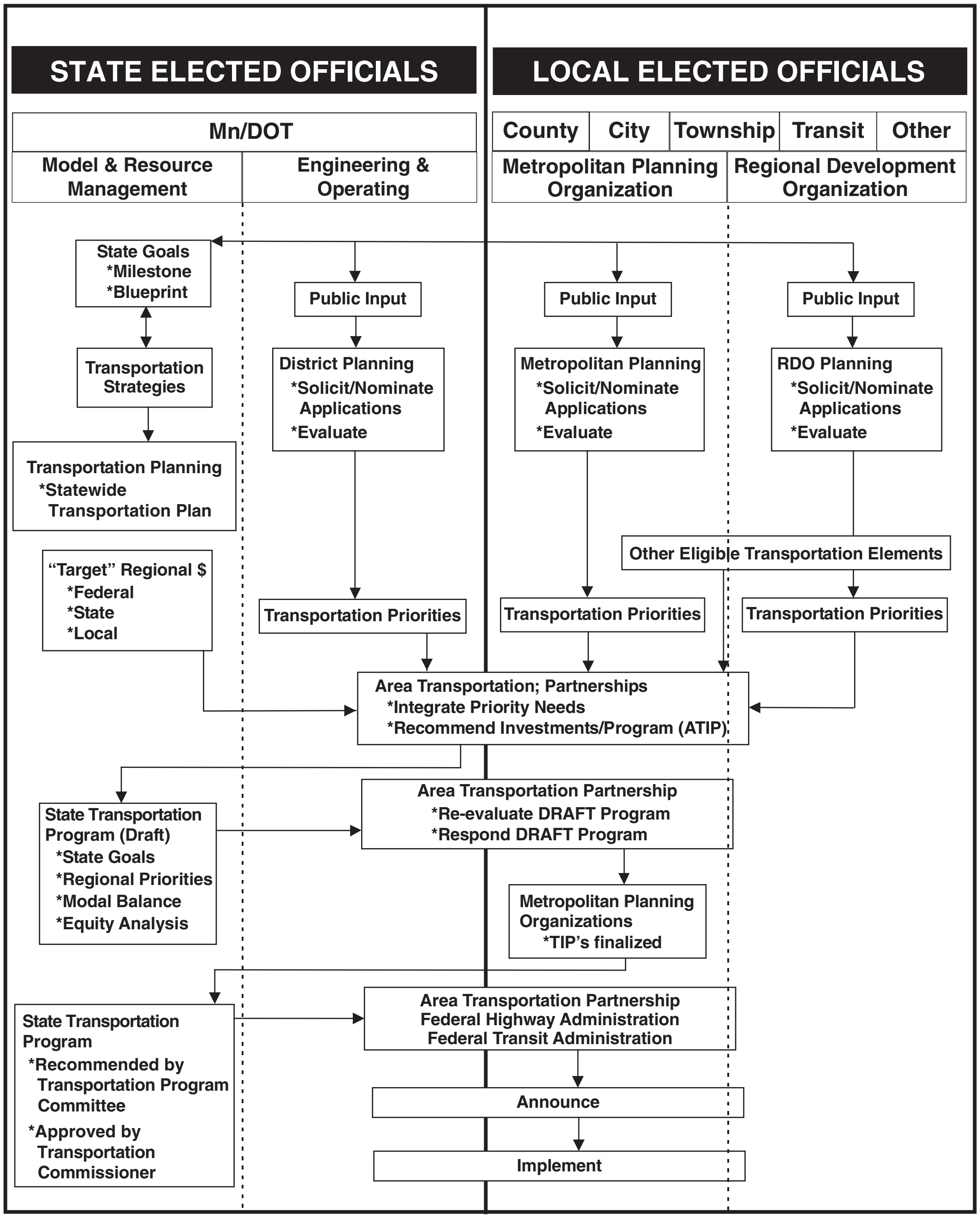
In many cases, identifying project priorities involves many different agencies and levels of government. Figure 15-17 presents Minnesota's decision-making process for transportation investment, which includes units within the DOT, as well as metropolitan planning and regional development organizations. [MnDOT, 2014] The STIP, the product of this process, is not finalized until all of the input from these many different sources is incorporated. The Area Transportation Partnerships (ATPs) shown in the figure are subregional groups enabled by MnDOT to develop a regional transportation improvement program for their area of the state. Participants include representatives from MnDOT, MPOs, Regional Development Commissions (RDCs), counties, cities, tribal governments, special interests, and the public.

One of the main purposes of the STP is to identify projects for STIP programming. The process of moving a project from the plan to the program, that is, identifying the priorities associated with individual projects and overall programs, varies from state to state. In some cases, and for specific programs, measures of effectiveness or impact indicators are used to identify projects of greatest benefit to the state. For example, the priorities for projects funded with federal safety dollars must be established using benefit-cost analysis. The performance measures and evaluation criteria established earlier in the process can also be used as input. In other cases, decision-making bodies, such as state transportation commissions, establish overall priority category priorities and choose projects that best meet these priorities.

2. Colorado

The Colorado STIP is a rolling four-year plan, that is, each year a new year's worth of projects is added to the STIP as the initial year is put into construction. The Colorado Transportation Commission ultimately approves the STIP, but the process that precedes the Commission includes many other agencies and groups. Each CDOT region holds county meetings to review transportation needs and funding availability developed as part of the regional plans. After the county meetings, the CDOT region holds at least one meeting, open to the public, to discuss prioritizing projects

Figure 15-17. Minnesota's Transportation Investment Process



Source: MnDOT, 2014

within that region. [CDOT, 2015c] Although the process is very much a "bottom-up" process for identifying projects, the Commission still has the responsibility for deciding project priorities, and it does so by considering the following four criteria:

- *System Quality:* Maintaining the functionality and aesthetics of the existing transportation infrastructure.
- *Mobility:* Providing for the efficient movement of people, goods, and information.
- *Safety:* Reducing fatalities, injuries, and property damage for all users of the system through services and programs.
- *Program Delivery:* Providing for the successful delivery of Colorado DOT projects and services.

As noted in the plan, these specific categories and associated performance measures allow the Transportation Commission and Colorado DOT to make trade-offs to best allocate limited financial resources. In addition, Colorado relies to a large extent on substate and corridor studies (350 corridors have been identified in the state) to define transportation needs.

3. Vermont

In response to state legislation, the Vermont Agency of Transportation developed a quantitative prioritization process for choosing projects in the STIP. The scoring methodology differed by project type. [VTrans, undated]

Paving Projects

- *Pavement condition index (20 points):* Weighted based on condition; more points are assigned for higher levels of deterioration.
- *Benefit/cost (60 points):* The B/C is provided by the pavement management system. Factors include optimal treatment, traffic volume, and type of traffic (trucks).
- *Regional priority (20 points):* Does the regional planning commission support the project from a local land-use and economic development perspective?

Bridges

- *Bridge condition (30 points):* Weighted based on condition of major inspected components (deck, superstructure, substructure, and culvert); more points assessed for higher levels of deterioration. The condition is determined by the most recent inspection.
- *Remaining life (10 points):* Correlates the accelerated decline in remaining life to condition.
- *Functionality (5 points):* Compares roadway alignment and existing structure width, based on roadway classification, to accepted state standards. Too narrow or poorly aligned bridges are safety hazards and can impede traffic flow.
- *Load capacity and use (15 points):* Is the structure posted or restricted? What is the inconvenience to the traveling public if the bridge is out of service? What is the average traffic use on the structure?
- *Waterway adequacy and scour susceptibility (10 points):* Are there known scour issues or concerns? Is the structure restricting the natural channel? Are channel banks well protected or vegetated?
- *Project momentum (5 points):* Points are assigned if the project has a clear right-of-way (ROW), has all environmental permits, and the design is ready and waiting for funds to become available.
- *Regional input and priority (15 points):* Does the regional planning commission support the project from a local land-use and economic development perceptive?
- *Asset benefit/cost factor (10 points):* This compares the benefit of keeping a bridge in service to the cost of construction. The "benefit" considers the traveling public by examining the traffic volume and the length of a detour if the bridge were posted.

Roadway

- *Highway system (40 points):* This factor looks at the Highway Sufficiency Rating and network designation. Interstates are held to the highest standard, followed by non-interstate primary and then off-primary roads. The Highway Sufficiency Rating considers traffic, safety, width, subsurface road structure, and more.
- *Cost per vehicle mile (20 points):* This is the project cost divided by the estimated number of miles vehicles will travel on the project. This is a relatively easy method to generate a benefit/cost ratio for comparing similar projects.

- *Regional priority (20 points):* The top regional planning commission (RPC) roadway project is assigned 20 points. The score is reduced for lower RPC priorities. Projects listed as priority #10 and lower get two points.
- *Project momentum (20 points):* This factor considers where the project is in the development process and anticipated problems such as right of way or environmental permitting.
- *Designated downtown project:* Per state law, VTrans awards 10 bonus points to the base score for projects within a designated downtown development district.

Traffic Operations (Intersection Design)

- *Intersection capacity (40 points maximum):* This factor is based on Level of Service (LOS) for the intersection and the number of intersections in the coordinated system. Projects with a lower LOS and that are part of a larger coordinated system receive higher scores for this category.
- *Accident rate (20 points maximum):* This factor is based on the critical-accident ratio for the intersection. Projects with higher critical-accident ratios receive higher scores.
- *Cost per intersection volume (20 points maximum):* This factor uses the estimated construction cost and average-annual-daily traffic through the intersection. VTrans calculates the construction cost of the project for each anticipated user through the intersection. Projects with lower costs per intersection volume receive higher scores for this category.
- *Regional input and priority (20 points maximum):* This factor is based on the ranking of projects from the RPCs/MPO. The RPCs/MPO rank the projects based on criteria they develop. Projects with higher regional rankings receive higher scores for this factor.
- *Project momentum (10 points maximum):* This factor considers: (1) where the project is in the development process, (2) anticipated problems such as right of way or environmental permitting, and (3) funding.

Transportation Alternatives

Points are awarded for transportation alternatives based on the proposal submitted by applicants.

Public Transit

Proposals are rated based on the following measures: mobility improvements, environmental benefits, operating efficiencies, project coordination, regional connectivity, local financial commitment, and sustainability of funding continuation.

Aviation

Projects for publicly owned airports are scored with the following possible points.

- Airport activity (number of operations and based aircraft) (0 to 100 points)
- Population served & local government support (0 to 24 points)
- Economic development (0 to 40 points)
- Project type (runway type, paving, navigation, etc.) (0 to 120 points)
- FAA priority & standards ranking (0 to 120 points)
- Previous federal/state funding (0 to 200 points)
- Cost/benefit for projects less than $75,000 (100 points)
- Resource impacts (0 to 40 points)
- Local interest/support (0 to 20 points)

Rail

Projects use the following criteria for scoring freight rail projects.

- *General Safety*—Safety of the rail system is critical to evaluating projects. Safety can involve bridge condition based on inspection, rail crossings, ROW, security, etc.
- *Railroad Freight Operations*—This measures the increase in ton-miles or car-miles and economic impact.
- *Railroad Passenger Operation*—Does the project increase the efficiency of the passenger rail service or expand passenger rail service and will the improvement have the potential to increase ridership?
- *Line Conditions*—Consideration is given if the project increases the Federal Railroad Administration track condition. Does the proposed project address clearance and/or weight limitations?
- *Priority Route*—Consideration is given if the project is on the of the rail priority routes based on the Statewide Rail Plan.
- *Vermont-Based Activity*—Consideration is given for carloads and passengers in Vermont and/or rail jobs created in Vermont.
- *Economic Development*—Consideration is given to projects that fit into regional economic development plans.
- *Documented Nonstate Funding Opportunities*—Does the project have a source of funding that does not require a state match?
- *Resource Impacts*—Does the project require environmental mitigation or mitigate environmental issues?
- *Regional Scope*—Consideration is given if the project increases competition, partners with other states, or improves intermodal connections.
- *Utilization of Resources*—Consideration is given if the project schedule is one year or less.

Safety

The DOT uses the Highway Safety Improvement Program (HSIP), which prioritizes safety projects in the state (see chapter 23 on transportation safety). Agency staff reviews the top 50 crash locations, and determines possible improvements. A cost/benefit analysis is conducted to determine the maximum safety improvement for limited dollars.

It is important to remember that the development of the STIP, as well as many other planning documents, must satisfy the federal and state laws and regulations that guide such development. In the United States, state DOTs can self-certify that the STIP satisfies such laws.

Chapter 7 provides an overview of methods that can be used to prioritize projects.

I. Monitoring System and Program Performance

The political process now demands greater accountability for the use of state funds. Providing measurable and understandable performance metrics is now a critical piece of the overall plan development process. Many states are providing these metrics through quarterly report cards, dashboard measurements and program compasses designed to be outcome-oriented, customer-service focused, and legislatively responsive. The following three states have developed performance-based statewide transportation plans and are reporting on the status of the system as it relates to defined performance measures.

1. Michigan

Figure 15-18 shows a very typical format for monitoring system condition and performance. The Michigan DOT has been producing such information for many years, and has found that its dissemination has been very effective at explaining to the public and key stakeholders the challenges facing the state's transportation system.

Figure 15-18. System Performance Monitoring by the Michigan DOT

Measure *(Click on a measure to get more information.)*	Status	Change fron Last Report	Change over Last 5 Year
Freeway Bridge Condition	Green	⇔	↑
Non-freeway Trunkline Bridge Condition	Green	↑	↑
Reduction of Structurally eficient Trunkline Bridges	Green	⇔	↑
Trunkfine Pavement Condition Based on Sufficiency	Yellow	↓	⇔
Trunkline Pavement Condition Based on International Roughness Index	Green	↓	↑
Trunkline Pavement Condition Based on Remaining Service Life	Yellow	↓	↓
Trunkline Railroad Crossings	Green	⇔	↑
Tier 1 Airport Primary Runway Pavements	Yellow	↓	⇔
Rural and Specialized Transit Fleet Condition	Green	↑	↑
Level of Intercity Passenger Rail Services	Green	⇔	↑
Rural Intercity Bus Access	Green	⇔	⇔
Level of Local Bus Transit Services	Green	⇔	⇔
Carpool Lot Condition	Green	⇔	↑
Statewide Crash Severity Reduction	Green	↑	↑
Trunkline Crash Severity Reduction	Yellow	⇔	↑
Local Roadway Crash Severity Reduction	No Standard	↑	↑
Safety-funded Project Return on Investment	Green	↑	↑
Road Agencies Serviced with Interoperable Communication Equipment	No Standard	↑	Not Available
Percentage of Program Dollars Spent on Protective Efforts	Green	↑	⇔
Acceptable Level of Service on (Inter-)Nationally Significant Corridors	No Standard	⇔	⇔
Michivan Access Expansion	Green	⇔	↑
Manage Traffic Incidents Timely	Green	⇔	Not Available

GREEN	Current status is at 90% or greater of target
YELLOW	Current status it between 75% and 90% of target
RED	Current status is less than 75% of target

↑	Condition Improving
↓	Condition Declining
⇔	Condition Staying About the Same

Source: MDOT, 2014

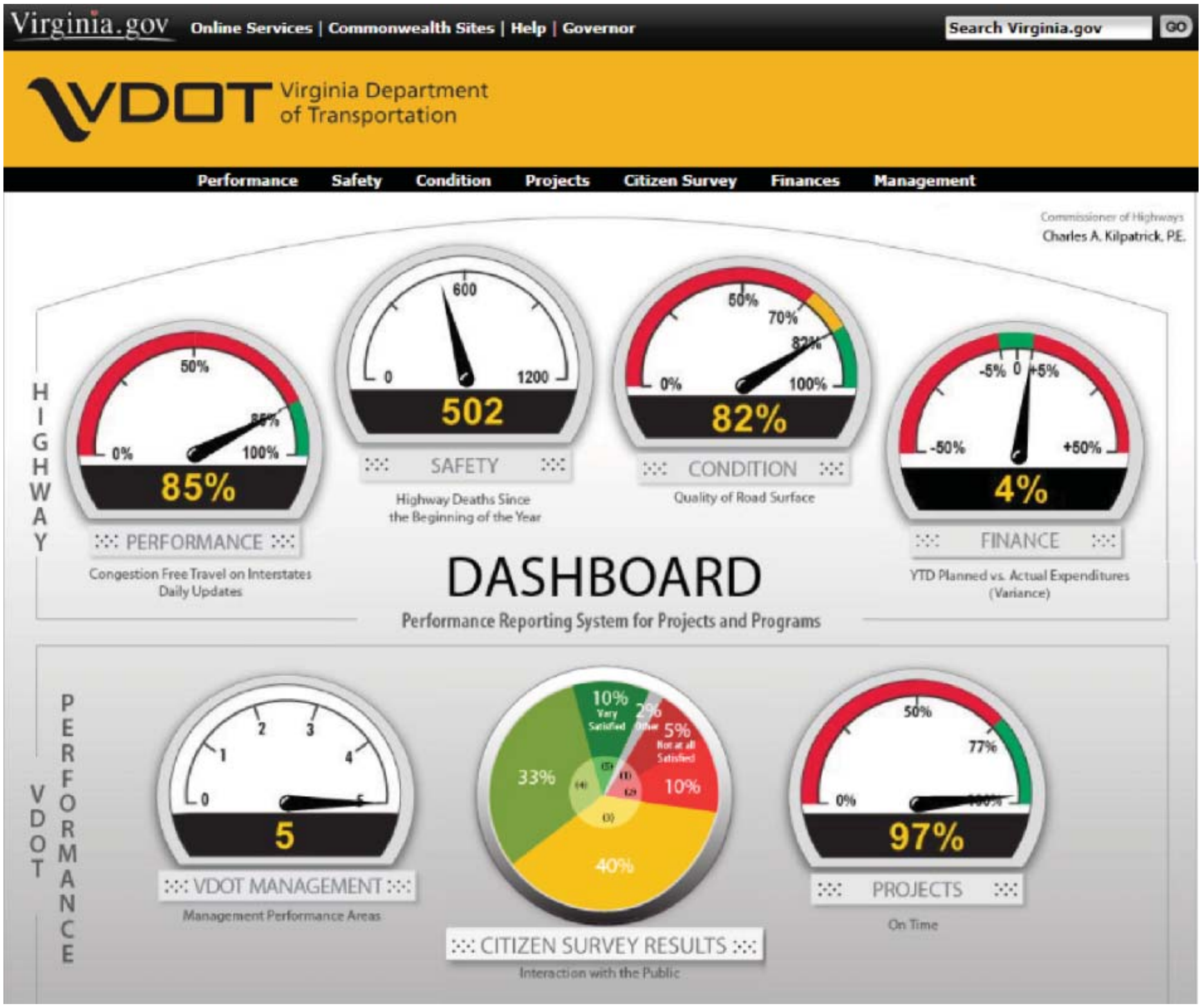
2. Virginia

In response to a state government financial crisis in 2002, VDOT was charged with restoring the overall financial accountability of its programs and services. VDOT responded by providing performance data in an understandable, user-friendly way available to both the legislature and the public. Through the development of reporting documents such as a quarterly report card and a project dashboard (a simple graphical presentation of data that can be used to drill down to underlying information), and as part of the goals and recommendations in Virginia's long-range transportation plan, VDOT developed a mechanism to link financial accountability and performance goals.

The VDOT Project Dashboard is a web-based tool that provides an overview of projects and contracts for the public (see Figure 15-19). The measures included on this website are:

- Environmental compliance measures, including compliance on construction/maintenance projects and number of complaints reported by month.
- Finance measures, including forecast versus actual revenues, planned vs. actual cash balances, labor expense, and contract balances.
- Safety measures, including crash and fatality data for the past 12 months compared to the five-year average.
- Engineering measures, including performance on time for project design and advertising, and accurate estimation of project costs.
- Construction measures, including measures for on-time, on-budget performance for both active and completed construction projects.
- Maintenance measures, including percent of years' pavement resurfacing plan complete, bridge conditions, and progress toward annual maintenance spending plan goals.
- Operation measures, including access to roadway information or incidents, construction work zones, weather conditions, and traffic cameras.

Figure 15-19. Virginia DOT's Dashboard Monitoring System



Source: Virginia DOT, 2015b

These measures were designed to address concerns raised by the legislature and public on the accountability of VDOT in delivering programs efficiently and effectively. These measures are not multimodal, but they do address the fundamental mission of the DOT—emphasizing core values of on-time project delivery, public safety, and environmental compliance. The experience of VDOT in providing specific actions in its state-level policy plan linked to performance measures and financial accountability is not unique and reflects a new environment and focus for state DOTs.

3. Washington State

One of the earliest and most extensive reporting of a state's transportation and program performance is found in the state of Washington with the DOT's *Gray Notebook*. The Gray Notebook provides annual overviews on bicycle and pedestrian safety, pavement conditions, highway maintenance, environmental compliance, tolling, and construction cost trends. Semi-annual overviews of travel time trends and freight rail, and quarterly reports on such topics as incident response, and ferries and passenger rail usage are also provided. Reports are provided on targeted projects. Figure 15-20 shows a typical page from the Gray Notebook.

IV. STATEWIDE MODAL PLANS

The previous discussion presented statewide transportation planning primarily from the perspective of the steps necessary to prepare a statewide multimodal transportation plan. Often, however, states undertake planning that focuses on specific modes of transportation, such as rail, freight, bicycle/pedestrian, aviation, and state transit plans. In almost

Figure 15-20. The Gray Notebook Performance Report, Washington State DOT

Policy goal/Performance measure	Previous period	Current period	Goal	Goal met	Five-year trend *(unless noted)*	Desired trend
Safety						
Rate of **traffic fatalities** per 100 million vehicle miles traveled (VMT) statewide (Annual measure: calendar years 2012 & 2013, data for 2013 considered preliminary)	0.77	0.77	1.00	✓		↓
Rate of **recordable incidents** for every 100 full time WSDOT workers (Annual measure: calendar years 2013 & 2014)	5.7	5.4	5.3	—		↓
Preservation						
Percentage of state **highway pavement** in fair or better condition by vehicle miles traveled (Annual measure: calendar years 2012 & 2013)	91.9%	92.6%	90.0%	✓		↑
Percentage of **state bridges** in fair or better condition by bridge deck area (Annual measure: fiscal years 2013 & 2014)	91.7%	91.8%	90.0%	✓		↑
Mobility (Congestion Relief)						
Highways: Average (Weekday) vehicle **hours of delay** statewide at **maximum throughput speeds**[1] (Annual measure: calendar years 2012 & 2013)	30.9 million	32.4 million	N/A	N/A		↓
Highways: Average **incident clearance times** for all Incident Response program responses (Calendar quarterly measure: Q3 2014 & Q4 2014)	12.2 minutes	13.2 minutes	N/A	N/A	(Five-quarter trend)	↓
Ferries: Percentage of trips departing on time[2] (Fiscal quarterly measure: year to year Q2 FY2014 & Q2 FY2015)	96.6%	96.4%	95%	✓		↑
Rail: Amtrak Cascades on time performance[3] (Annual measure: calendar years 2012 & 2013)	72.6%	76.9%	80%	—	(Three-year trend)	↑
Environment						
Number of WSDOT **stormwater management facilities** constructed (Annual measure: fiscal years 2013 & 2014)	169	189	N/A	N/A		Not applicable
Cumulative number of WSDOT **fish passage barrier improvements** constructed (Annual measure: calendar years 2012 & 2013)	270	285	N/A	N/A		↑
Stewardship						
Cumulative number of Nickel and TPA **projects completed,** and **Percentage on time**[4] (Calendar quarterly measure: Q3 2014 & Q4 2014)	361/ 87%	364/ 87%	90% on time	—	(Five-Quarter trend)	↑
Cumulative number of Nickel and TPA **projects completed,** and **Percentage on time**[4] (Calendar quarterly measure: Q3 2014 & Q4 2014)	361/ 91%	364/ 91%	90% on budget	✓	(Five-Quarter trend)	↑
Variance of total project costs compared to **budget expectations**[4] (Calendar quarterly measure: Q3 2014 & Q4 2014)	under budget by 1.7%	under budget by 1.9%	on budget	✓	(Five-Quarter trend)	Not applicable

Source: Washington State DOT, 2015

every case, the steps described above are similar to those used for developing a modal plan. The modal planning process starts with some sense of what the problems and issues are. This then leads to a set of goals and objectives, the identification of performance measures, analysis and evaluation of different alternatives and options, and eventually the selection of a preferred investment strategy and/or the identification of other state actions to address the problems identified. Table 15-10 shows the type of information that is needed in a statewide rail plan, in response to a federal law requiring states to develop such a plan, the Passenger Rail Investment and Improvement Act of 2008 (PRIIA).

Table 15-10. State Rail Plan Elements Outlined in PRIIA	
Planning Step	**Elements to Include**
Inventory	Role of rail in state's surface transportation system Proposed high-speed rail corridors
Review of rail lines	Significant rail line segments not currently in service
Passenger rail service objectives	Minimum service levels for all routes
Transportation, economic, and environmental impacts of rail	Congestion mitigation Trade and economic development Air quality Land use Energy use Community impacts
Long-range rail investment program	Freight capital projects with public and private benefits and correlation between the two Consideration of funding
Public financing issues	Current capital and operating funding sources Prospective capital and operating funding sources
Rail infrastructure issues	Reflecting consultation with all relevant stakeholders
Review of intermodal connections and facilities	Freight intermodal Freight facilities Seaports Prioritized options to maximize integration of modes
Review of publicly funded safety and security projects	Safety, including projects funded under 23 U.S.C. Section 130 (grade-crossing protection)
Performance evaluation of passenger rail	Evaluation of performance Possible improvements Strategies to achieve improvements
High-speed rail plan	Compilation of high-speed rail studies Funding plan for recommended corridors
Compliance with Section 22102	Demonstrate qualifications under 49 U.S.C. Section 22102 (State has organized itself to support rail planning)

Source: Texas DOT, 2010

Similar to statewide multimodal transportation planning, modal planning relies on the involvement of many different stakeholders in the process. Not only can stakeholders provide feedback on the different strategies that are being considered, but also much of the data needed for analysis often come from sources outside of the public domain. Private companies can often provide some of this information for planning efforts that directly affect their industry.

One of the reasons state DOTs conduct mode-specific planning is that funding categories are often mode-specific. Thus, for example, an illustration from Texas for statewide rail planning relates to the rail-specific funding sources that can be used to make improvements in the state's rail system. The same is often true for aviation, pedestrian and bicycle, and state transit planning. Even though modal plans establish funding priorities for specific types of projects, it is important that these plans be integrated into the state's multimodal transportation plan. Given the interconnectivity of a typical state's transportation system, what happens on the rail system can directly affect the highway network, such as the shifting of freight to trucks. Thus, even though a state develops plans for the major modes, the STP needs to be the point where policies and investment strategies are connected.

V. SUMMARY—CONTINUING STATE PLANNING CHALLENGES

State transportation departments and the long-range plans they develop will continue to evolve to meet society's changing expectations. Gone are the days when the transportation engineers used their expertise to recommend solutions to mobility problems. Calls for accountability and transparency in both decision making and project implementation will only grow greater as public resources decline. As transportation planning and decision making involves more interest groups and greater societal expectations, DOTs are being challenged to develop the necessary technology and skills to meet the demands. Some of these challenges include:

Improving the connection between state-level transportation plans and local land-use decisions. Traffic and economic activity at the local level drive the demand for transportation services at the regional and state level, yet land-use decisions are often made in a strictly local level. There is a growing expectation among major transportation stakeholders that transportation investments reflect more than mobility and economic development goals, but state DOTs are often ill-equipped to use their planning and programming decisions effectively to guide development, direct mode choice, or meet the needs of the disabled or walking public. By better connecting state- with regional- and local-level planning decisions, especially MPO planning activities such as data and analysis sharing, consensus on goals, and joint funding, DOTs may begin to improve this connection.

Better links between planning and implementation. Most states are beginning to address the need to improve plan implementation, but new techniques and analysis tools are needed. Plans must be designed from the beginning with projects that can be implemented and outcomes measured; however, some plan outcomes cannot be effectively measured because the data are not available or the DOT does not control the service. One way to better link plan recommendations and projects at the state and regional level is to use corridor plans (see chapter 17). These plans usually generate locally acceptable priorities, and focus on fairly well-defined projects.

The freight planning challenge. As reflected in federal legislation, freight planning is receiving increased national interest. States have a unique system planning perspective given freight movements across urban boundaries, interregional boundaries and interstate boundaries. However, the challenges of quality and timely freight data, inadequate communication between the state and freight shippers, the lack of control over intermodal/port investment decisions, and the lack of designated funding for freight planning and implementation still characterize much of the statewide freight planning activities in the United States (see chapter 22).

Financial planning and accountability. There continues to be a gap between the public's expectations for transportation and the willingness to financially support those expectations. States consider many interests when conducting statewide transportation planning. States often struggle with the development of a 20- or 25-year plan that must be constrained by existing resources, particularly when it can take a decade or more to actually build new facilities. In addition, states must adopt the projects developed through the MPO planning process, even when additional resources are assumed in a financially constrained MPO plan to be coming from state and federal funding programs.

In a similar fashion, the political process has required more accountability for taxpayer dollars, often demanding that measures be developed for programs that are not easily measured. Many of the performance measures required by state legislatures are driven by budgetary data and press releases rather than by meaningful measures of the service provided by the state system. As resources continue to be constrained, there is more pressure to develop alternative funding mechanisms—including public/private partnerships, joint state/local government funding agreements, and tolling options (see chapter 5). Some states continue to have issues with who controls and maintains these facilities? How are revenues collected at the local level? How are basic transportation services for the most needy being adequately and fairly provided under these arrangements?

What does it mean to be multimodal? For many state DOTs, a multimodal, state-level policy plan addresses overall transportation system goals for the state. The development of individual modal plans can then carry out these overall goals. The vision is multimodal, but the implementation is modal. In part, this is due to the nature of the funding available for transportation. Each modal program comes with separate modal funding, with little ability to move dollars to meet priorities. Even with comprehensively planned corridor plans at the regional level, funding is often available for the highway recommendations, but not for nonhighway recommendations. These funding arrangements are also reflected in the organization of DOTs, with each mode in a separate organizational structure managing a separate program and allocating separate funds. Many DOTs have not organized themselves to respond to a multimodal agenda.

For state department of transportation (DOT) planners, the transportation planning process has changed dramatically during the last 20 years. However, to those viewing the state transportation planning process from outside a DOT, change seems slow. No matter the perspective, both would agree that transportation planning has an important role in guiding state-level transportation investment, which in turn helps shape how people live and work. Statewide transportation planning, along with the transportation planning that occurs in metropolitan areas, will likely play an even greater role in shaping the form and function of society in the future.

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Metropolitan Transportation Planning[1]

I. INTRODUCTION

Urbanized areas in the United States with populations of 50,000 or more are required to participate in a federally mandated transportation planning process. In many other countries and in U.S. nonmetropolitan areas, regional planning agencies (RPAs) have similar responsibilities as their urban counterparts. In the United States, the planning agency responsible for carrying out the transportation planning process in urbanized areas is called the metropolitan planning organization (MPO), which is designated by the governor of the state. The 1973 U.S. federal law that required MPOs defined them as a "forum for cooperative transportation decision making for the metropolitan area." The MPOs (and RPAs) thus provide an institutional mechanism for regional collaboration, coordination, and decision making in the provision of transportation infrastructure and services.

This chapter will focus on metropolitan transportation planning, which encompasses the communities included in an urbanized area. Urbanized areas can be quite small, such as Pascagoula, Mississippi, the smallest urbanized area in the United States with a 2010 population of 50,428 (ranked 497th). Or they can be very large, such as the New York City region with a 2010 population of 18.4 million (ranked 1st). Given that each urbanized area and community is unique, it is not surprising that transportation plans vary from one region to another. Most transportation plans, however, share common challenges on issues such as transportation mobility, accessibility, environmental quality, system preservation, maintenance, safety, security, and management and operations. The transportation planning process provides much-needed information and knowledge for regional and local decision makers in dealing with these issues.

Although federal law and regulations require the MPO planning process to consider topics of national interest, the process must also be responsive to community interests and local laws. The regional transportation planning process is valuable because it integrates and links the planning efforts of communities in a region, such as local land-use plans, economic development strategies, and environmental/natural resource plans. Transportation planning must also take into account other laws such as state and local land-use laws, the Clean Air Act, the Americans with Disabilities Act (ADA), and Title VI of the Civil Rights Act of 1964 (see chapter 1).

This chapter presents an overview of the metropolitan transportation planning process and associated requirements. The next section provides an historical overview of how metropolitan transportation planning has evolved. Various aspects of this planning process are discussed, including organization and institutional aspects, essential elements of the planning process, and the technical tools required for successful planning. The key concepts presented provide a better understanding of the complexities of the planning environment. The chapter also describes how metropolitan areas create transportation plans as well as the role that planners play in the process. The reader should note that much of this chapter will focus on medium to large metropolitan areas, defined as urbanized areas over 250,000 population. Those interested in transportation planning for smaller urbanized areas are referred to chapter 18 on local and activity center planning.

II. LEGISLATIVE CONTEXT FOR U.S. METROPOLITAN TRANSPORTATION PLANNING

The form and substance of transportation planning in a typical metropolitan area has been influenced by many factors, including the history of planning, the relative roles of state and local government agencies, the planning culture

[1]The original chapter in Volume 3 of this handbook was written by Jane Hayse, Director for Livable Communities, Atlanta Regional Commission, retired. Changes made to this updated chapter are solely the responsibility of the editor.

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of the region, and the types and perceived magnitudes of the transportation problems being faced. It is thus difficult to present a generalized transportation planning process describing all such efforts in every metropolitan area. One influence in particular, however, has provided a strong impetus for transportation planning in the United States—at least over the past 50 years—and has resulted in some commonality among metropolitan and regional planning processes. Perhaps more than any other influence, the federal government has had the greatest impact on the structure and policy context for transportation planning as practiced in the United States. The national governments of other countries have varying influences over transportation planning in their countries as well—in France, for example, the national government plays a strong role, whereas in Canada the major influence is at the metropolitan and provincial levels.

It is beyond the scope of this chapter to provide an exhaustive listing of all federal laws and regulations that have influenced metropolitan transportation planning (see Weiner [2010], chapter 1 and chapter 4). However, several federal laws stand out with respect to their impact on the substance and style of today's transportation planning process in U.S. metropolitan areas. Some terminology and language embodied in 1960s legislation, for example, is still commonly used today. Thus, it is important to begin this chapter with an understanding of the key themes and contributions of these benchmark laws in transportation planning history.

A. The Early Years

The motor vehicle and its need for reliable roads has had a profound impact on the transportation policy landscape of the United States and most other nations. With the rapid motorization of society in the early 1900s, Congress recognized the need to support the creation of roads that served a "federal purpose." In most cases, this federal purpose focused on rural roads (postal routes, for example) and highways connecting cities. City roads or highways that served primarily urban areas were considered the responsibility of city governments.

In anticipation of post-World War II population growth and needed support for national economic recovery, Congress passed the Federal-Aid Highway Act of 1944, which authorized the construction of a national highway system. This act together with the Federal Highway Revenue Act of 1956 was the beginning of the National System of Interstate and Defense Highways (the interstate highway network) and the use of federal gas taxes to pay for it. This era of interstate highway construction fostered a growing interest in transportation planning (especially statewide transportation planning), and particularly on the need to plan and design major intercity highways to meet future demand.

Of significance to metropolitan transportation planning, the state highway departments' early focus in constructing the interstate system was primarily on rural connections between major cities. Most of the urban portions of this system were not designed and constructed until the late 1950s and early 1960s. For many cities, the move toward constructing urban interstate highways caused growing concern about the corresponding impact on the city and its residents. One response to this concern was to provide more support for metropolitan-level transportation planning.

B. Toward a Balanced Transportation System

Almost all of the federal interest in transportation during the 1950s and 1960s was on highways; very little policy interest was given to public transit or other modes such as walking or bicycling, which were viewed strictly as a local issue. Beginning with the Housing Act of 1961, however, small-interest federal loans were made available to city transit systems that were on the verge of disappearing given low ridership and competition from the automobile. It was not until the Federal-Aid Highway Act of 1962 that the concept of a multimodal transportation system, and thus the need for multimodal transportation planning (then called a balanced transportation system), was first established. This 1962 act contained significant provisions still in effect today. Federal aid was provided to those areas with a population of 50,000 or more to establish "a continuing and comprehensive transportation planning process carried out cooperatively by state and local communities." This 3C (continuing, cooperative, and comprehensive) process still underpins metropolitan transportation planning in the United States today. [FHWA and FTA, 2007]

The act defined *comprehensive* to include the following factors:

- Economic factors affecting development
- Population

- Land use
- Transportation facilities including those for mass transportation
- Travel patterns
- Terminal and transfer facilities
- Traffic control features
- Zoning ordinances, subdivision regulations, building codes, etc.
- Financial resources
- Social and community-value factors, such as preservation of open space, parks, and recreational facilities; preservation of historical sites and buildings; environmental amenities; and aesthetics

Cooperative was defined as cooperation among federal, state, and local government agencies and among units within each level of government. *Continuing* was defined as requiring periodic reevaluation and updating of transportation plans.

The 1962 act was followed by the Urban Mass Transportation Act of 1964, which established the first formal program for federal assistance to transit agencies with matching funds provided on a two-third federal/one-third local share basis. Through this act, transit planning was further integrated into metropolitan transportation planning and decision making, and represented a first step to make multimodal planning truly consider more than the just the automobile mode in the planning process. The Federal-Aid Highway Act of 1970 continued to reinforce the need for metropolitan transportation planning by stating that "no highway project was to be constructed in any urban area of 50,000 population or more unless the responsible local officials of such urban area … have been consulted and their views considered with respect to the corridor, the location, and the design of the project." This act began an evolution in transportation planning in which metropolitan and local officials have increasingly received more authority over transportation priorities, requiring state transportation agencies to share what once was their sole responsibility over highway construction.

By the mid-1970s the need for metropolitan transportation planning had been clearly articulated in federal and many state laws. The Federal Highway Act of 1973 formally created MPOs in urbanized areas with populations of 50,000 or more to be funded through the federal-aid transportation program. The act increased the role of local officials in the transportation decision-making process, allowing them to choose projects with concurrence from the state transportation agencies. Transportation projects funded with federal funds now had to come from the 3C planning process as defined in the 1962 act. The 1973 act also allowed transit projects to be funded from the Highway Trust Fund and increased the federal share of such projects to 80 percent.

In 1975, the Federal Highway Administration (FHWA) and the Urban Mass Transit Administration (UMTA), now the Federal Transit Administration (FTA), created joint transportation planning regulations for metropolitan areas. A long-range transportation plan and a transportation improvement program (TIP) were now a regulatory requirement as was the development of a unified plan work program (UPWP) for areas with populations of 200,000 or more. Transportation planning based on the 3C process continued to be reinforced.

C. The Modern Era

Significant changes in the focus and substance of metropolitan transportation planning occurred during the 1990s. This occurred for many reasons. The interstate highway system, begun in 1956, was nearing completion and federal attention turned to what type of program should replace it. In particular, federal interest began to focus on how to better improve existing transportation system performance, rather than expand capacity. More emphasis was placed on multimodal solutions. In addition, policy interest continued to link transportation decision making to issues such as economic development and air quality. The Clean Air Act Amendments (CAAA) of 1990, for example, greatly strengthened the relationship between metropolitan transportation planning and Clean Air Act requirements. States were required to develop state implementation plans (SIPs) reflecting the severity of an urbanized area's nonattainment of the National Ambient Air Quality Standards (NAAQS). MPOs had to demonstrate that their long-range transportation plans and TIPs conformed to the SIPs. This conformity was determined by forecasting mobile source emissions over the life of the plan and the TIP, and showing that the planned projects did not worsen air quality. Significant financial sanctions were included in the legislation if a metropolitan area was unable to create a conforming plan.

From a transportation perspective, the landmark transportation legislation of the 1990s was undoubtedly the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). The legislation stated that it was in the "national interest to encourage and promote the development of transportation systems embracing various modes of transportation in a manner which will efficiently maximize mobility of people and goods within and through urbanized areas and minimize transportation-related fuel consumption and air pollution." ISTEA's vision was for an integrated planning process, taking into account local plans, financial resources, and expectations. The requirements of ISTEA provided a closer linkage between the 3C process, the Clean Air Act, and statewide planning.

For metropolitan transportation planning, ISTEA called for:

- A proactive and inclusive public involvement process.
- Consideration of specific planning factors to ensure that the transportation planning process reflected a variety of issues and concerns, such as land-use planning, energy conservation, environmental management, and major investment studies to address significant transportation problems in a corridor or subarea that might involve the use of federal funds (the requirement for a major investment study was later rescinded in the Transportation Equity Act for the 21st Century (TEA-21)).
- Development and implementation of management systems including: congestion management, intermodal management, pavement management, bridge management, safety management, public transportation facilities and operations management systems (some later rescinded or made optional).
- Development of financial plans for implementing the transportation plan and TIP.
- Assurance that the transportation plan and TIP conform to the SIP pursuant to the standards of the CAAA.

ISTEA emphasized multimodal solutions, which included both people and goods movement along with an ability to "flex" federal funds from one program category to another based on the particular metropolitan area's needs. For the first time, MPOs were required to financially constrain their long-range plans and TIPs; that is, the number of projects in a plan was limited to those for which funds were reasonably expected to be available from federal, state, and local sources. Other requirements included: The long-range plan had to be at least 20 years in duration, the TIP had to be updated at least every two years, and it had to cover a minimum three-year timeframe. See [Lane and Waldheim, 2011] for an overview of the practices MPOs use in updating the TIP.

As noted above, ISTEA identified specific factors that were to be considered as part of the transportation planning process. The factors, arrayed in three general groupings, were:

Mobility and access for people and goods

- International border crossings and the promotion of access to critical areas and activities.
- Road connectivity from inside to outside of metropolitan areas.
- Enhancement of efficient freight movement.
- Expansion and enhancement of transit services and use.

System performance and preservation

- Congestion relief and prevention.
- Preservation and efficient use of existing transportation facilities.
- Transportation needs identified through the implementation of management systems.
- Preservation of rights-of-way.
- The use of life-cycle costs in the design and engineering of bridges.

Environment and quality of life

- Overall social, economic, energy, and environmental effects of transportation decisions.
- Consistency of planning with energy conservation measures.
- Relationships between transportation and short- and long-term land-use planning.
- Programming of expenditures on transportation enhancement activities.
- Capital investments that increase transit system security.

The actual process of how MPOs considered these factors varied from one locale to another and required an integration of different issues at all levels of planning. Long-range plans, for example, had to be developed with significant input from the public and be coordinated with transportation providers, such as regional airport managers, ports, freight carriers, and others. Input into the planning process could occur through formal public hearings, access to public records, a proactive and open process of public engagement, and interagency consultation for air quality and conformity issues.

MPOs with populations greater than 200,000, designated as *transportation management areas (TMAs),* had additional requirements. These MPOs were required to develop a congestion management system (CMS) to provide ongoing "information on the performance of the transportation system and on alternative strategies to alleviate congestion and enhance mobility." [USDOT, 1995] Most importantly, the CMS was to emphasize the management of existing facilities through the use of non-single-occupant vehicle capacity-adding improvements. Solutions such as regional traffic management using traffic management centers and travel demand reduction programs were to be considered. The CMS was to provide for a continuous program of data collection and system monitoring.

The next major federal law affecting transportation planning was the Transportation Equity Act for the 21st Century (TEA-21) passed in 1998. TEA-21 reduced the ISTEA planning factors to seven:

1) Support the economic vitality of the metropolitan area, particularly by enhancing global competitiveness, productivity, and efficiency.
2) Increase the safety and security of the transportation system for motorized and nonmotorized users.
3) Increase the accessibility and mobility options available to people and freight.
4) Protect and enhance the environment, promote energy conservation and improve the quality of life.
5) Enhance the integration and connectivity of the transportation system, across and between modes, for people and freight.
6) Promote efficient system management and operation.
7) Emphasize the preservation of the existing system.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), signed into law in 2005, changed the timelines for producing long-range plans and TIPs. In air quality nonattainment and maintenance areas, the long-range transportation plan was to be adopted every 4 years, while in attainment areas the time period remained 5 years. The plan still had to have at least a 20-year time horizon. For TIPs, the timeline changed to an adoption of at least every 4 years, with the TIP having at least 4 years of projects and strategies included.

Several TEA-21 planning factors were revised. The most significant difference between TEA-21 and SAFETEA-LU planning factors was the separation of safety and security into two distinct factors. This change reflected the concerns for security due to natural disasters and terrorist threats. In addition, the environmental factor was modified to include greater consistency between transportation plans and economic growth. SAFETEA-LU further emphasized the importance of public engagement in the planning process by requiring MPOs to produce a public participation plan, use visualization techniques as part of the outreach efforts, and make plans readily available electronically to the general public.

D. Era of Performance-Oriented Decision Making

The Moving Ahead for Progress in the 21st Century (MAP-21) law, passed in 2012, introduced a significant new component into metropolitan transportation planning. The federal government required each MPO (and state transportation agency, see chapter 15) to develop and use a performance-based planning process. Specifically, each MPO was required to:

- Establish and use a performance-based approach to transportation decision making and the development of transportation plans.
- Establish performance targets that are consistent with national goals and performance management measures, and coordinated with state and local public transportation providers.
- Integrate into the metropolitan transportation planning process other performance-based transportation plans or processes.
- Include officials of public agencies that administer or operate public transportation systems in the structure of the MPO.
- Include in the long-range transportation plan a description of the performance measures and performance targets used in assessing the performance of the transportation system.
- Include in the plan a system performance report and subsequent updates evaluating the condition and performance of the transportation system with respect to the established performance targets.
- Use multiple scenarios during the development of the plan if so desired.
- Include in the TIP a description of the anticipated effect of the TIP toward achieving the performance targets established in the plan, linking investment priorities to the performance targets.

Performance-based planning had been an important trend in transportation planning since the early 1990s when ISTEA mandated the creation of management systems to support investment decisions. Today, updating transportation plans partially means integrating performance measures into the planning process and the document itself. In the future, the plans will be reporting on the progress made in achieving the performance targets.

The Fixing America's Surface Transportation (FAST) Act of 2015 reinforced the focus on performance-based planning for MPOs. Other notable requirements from this law included:

- Metropolitan transportation plans and TIPs should provide for facilities that enable an intermodal transportation system, including pedestrian and bicycle facilities, facilities that support intercity transportation (including intercity buses, intercity bus facilities, and commuter vanpool providers), and the identification of public transportation facilities.
- The plan must include consideration of the role that intercity buses may play in reducing congestion, pollution, and energy consumption in a cost-effective manner; and strategies and investments that preserve and enhance intercity bus systems (including those that are privately owned and operated).
- Representatives of a transit provider are provided equal authority as other MPO officials in official MPO business.
- Tourism and the reduction of risk of natural disasters should be considered as part of the transportation planning process. The scope of the planning process should include improving transportation system resiliency and reliability, reducing (or mitigating) the stormwater impacts of surface transportation, and enhancing travel and tourism.
- Public ports and certain private providers of transportation, including intercity bus operators and employer-based commuting programs must be a "reasonable" opportunity to comment on the transportation plan.
- MPOs that serve a transportation management area (TMA as defined by the Environmental Protection Agency) are allowed to prepare a congestion management plan (distinct from the congestion management process) that will be considered in the MPO's transportation improvement program. Any such plan must

include *regional goals* for reducing peak hour vehicle miles traveled and improving transportation connections, must identify *existing services and programs* that support access to jobs in the region, and must identify *proposed projects and programs* to reduce congestion and increase job access opportunities (emphasis added).

III. INSTITUTIONAL STRUCTURE FOR METROPOLITAN TRANSPORTATION PLANNING

Transportation plans represent a blueprint for effective transportation investment in study areas. Because future development patterns and the characteristics of an area's transportation system are the result of numerous decisions by public officials, private companies, and individuals, it is important to provide a forum for discussion and debate on the appropriate future for the area (see chapter 3 on land use and urban design). The process of developing a transportation plan provides better information for decision makers, as well as opportunities for input from numerous groups and individuals who have a stake in the future of their community.

Because the transportation plan is the result of a collaborative process, many contribute to its development through the MPO structure. Key contributors include regional agencies, local government(s), advocacy groups, private sector representatives, transit operators, federal agencies, tribal nations, state agencies, professional associations, and the public. The role of the transportation planner in this institutional environment is particularly important. The planner must not only be able to conduct technical analysis, but also understand the needs of the stakeholders and how to convey key concepts to those not well-versed in technical problem-solving approaches.

A. Core Characteristics of an MPO

Although the characteristics of MPOs reflect the varying requirements and circumstances of individual states, there are some common responsibilities. According to federal guidance, each MPO should:

- Establish and manage a fair and impartial setting for effective regional decision making in the metropolitan area.
- Evaluate transportation alternatives, scaled to the size and complexity of the region, to the nature of its transportation issues, and to the realistically available options.
- Develop and update a long-range transportation plan for the metropolitan area covering a planning horizon of at least 20 years that fosters: (1) mobility and access for people and goods, (2) efficient system performance and preservation, and (3) quality of life.
- Develop a TIP based on the long-range transportation plan designed to serve the area's goals using budget, regulations, operations, management, and financing tools.
- Involve the public and all significantly affected subgroups. [FHWA, 1999]

Federal regulations spell out the basic requirements for MPOs, and several key characteristics are important to note. The MPO is a metropolitan area's transportation policy-making and planning body and must include representatives of local, state, and federal government agencies and of other transportation authorities. The MPO must ensure that federal spending on a transportation program occurs through the 3C process. The MPO is initially designated by the state's governor and the local units of government through a formal agreement. Although different organizational arrangements can be made to host this process, at a minimum, the basic structure should include a policy board and a defined planning area boundary.

1. MPO Policy Boards

The MPO can be a stand-alone organization, a council of governments, a unit within a city or county government, or a separately elected body. The following examples show the often complex nature of MPO decision making.

Stand-Alone Agency, Members Appointed. The Metropolitan Transportation Commission (MTC), the MPO for the San Francisco, California, metropolitan area is a stand-alone organization. Of the 21-member policy board, 16 commissioners are appointed directly by local elected officials. The two most populous counties, Alameda and Santa Clara Counties, each have three representatives on the commission. The county board of supervisors selects one member; the mayors of the cities within the county collectively appoint another; and the mayors of the biggest cities in these two counties—Oakland in Alameda County and San Jose in Santa Clara County—each appoint a representative. The city and county of San Francisco are represented by two members, one appointed by the county board of supervisors and the other by the mayor. San Mateo County and Contra Costa County each have two representatives on the commission, with the county's board of supervisors selecting one representative, and the mayors of the cities within that county appointing another. The four northern counties of Marin, Napa, Solano, and Sonoma Counties each appoint one commissioner; and two voting members represent regional agencies—the Association of Bay Area Governments (ABAG) and the Bay Conservation and Development Commission (BCDC). Finally, three nonvoting members represent federal and state transportation agencies and the U.S. Department of Housing and Urban Development. [MTC, 2015]

Another stand-alone agency example is the Metropolitan Council ("council") for the Minneapolis-Saint Paul, Minnesota, metropolitan region. Created in 1967, the council, in conjunction with its Transportation Advisory Board as further detailed below, is the designated MPO for the seven-county Twin Cities area, which covers seven counties and 180+ communities. The council has 17 members, all appointed by the governor and confirmed by the state senate. The 17 consist of the chairperson (serving at large) and 16 members each representing individual geographic districts.

Because the council is an appointed body and not elected, a Transportation Advisory Board (TAB) was considered necessary to meet the requirements of the federal law requiring the governing bodies of all MPOs to include local elected officials as part of the decision-making process. The TAB consists of 33 members: ten elected city officials, one member from each county board in the metropolitan area (for a total of 17 [51%] elected officials), the commissioner of the Minnesota Department of Transportation, the commissioner of the Pollution Control Agency, one member of the Metropolitan Airports Commission, one person appointed by the council to represent nonmotorized transportation, one member representing the freight transportation industry, two members representing public transit, one citizen representative from each council district (for a total of eight), and one council member. The TAB chair is appointed by the council from among the 33 members (more information can be found at http://metrocouncil.org/Transportation/Publications-And-Resources/Transportation-Planning-and-Programming-Guide-2013.aspx).

The council fills a regional planning role, developing a long-range comprehensive development guide for the metropolitan area along with system plans for transportation, aviation, wastewater and water resources, and regional parks. Beyond its planning functions, the council also fills an operational role. It owns and operates much of the transit system, operating over 900 buses across almost 140 routes (95% of the bus trips in the region), plus two light rail lines, and a commuter rail line. It operates eight regional wastewater treatment plants, serving 108 of the region's communities, processing 250 million gallons of wastewater daily. It coordinates and helps fund 53 regional parks and park reserves covering 54,000 acres and 340 miles of regional trails.

Stand-Alone Agency, Members Elected. The MPO can also be a stand-alone elected body. The MPO in Portland, Oregon, is such an example. Known as Metro, the organization is governed by a council president elected regionwide and six councilors elected by district. The Metro council president and council members focus on matters of regional concern. The Metro council establishes policies for, and oversees the operation of, Metro's programs and functions. It develops long-range plans and ensures the financial integrity of Metro by adopting an annual budget and establishing fees and other revenue measures. Importantly, because of state enabling legislation, Metro has more powers on land-use management than a typical MPO in other parts of the country. [Portland Metro, 2015]

Council of Government. Many MPOs are part of a council of governments (COG) or a regional development organization, such as the Atlanta Regional Commission (ARC) in Atlanta, Georgia, or the North Central Texas Council of Governments (NCTCOG) in Dallas-Ft. Worth, Texas. ARC's Policy Board includes:

- Each county commission chairman in the region.
- One mayor from each county (except Fulton County) chosen by a caucus of mayors from each county.
- A mayor from the northern half of Fulton County elected by a majority vote of the mayors of all municipalities located within the northern half of Fulton County, and the mayor of a municipality within the southern half of Fulton County elected by a majority of the mayors of all municipalities located within the southern half of Fulton County.
- The mayor of the city of Atlanta.

- The president, presiding officer, or a member of the City Council from the city of Atlanta, elected by a majority vote of the members of the City Council.
- A resident from each of the ARC districts, elected by the public members of the Board. Members at large may hold no elective or appointed public office nor be employed by any of the political subdivisions of the area. The total number of members at large is fifteen (15).
- If the commissioner of the Georgia Department of Community Affairs determines that an additional member or members of the ARC board are necessary to comply with applicable laws or regulations, the board may elect such additional member(s), who shall be nonvoting. [ARC, 2015]

In the Dallas-Ft. Worth region, the MPO is housed in the region's Council of Governments. However, the policy committee, known as the Regional Transportation Council, is an independent transportation policy body for the MPO. As of March, 2016, NCTCOG had 238 member governments including 16 counties, numerous cities, school districts, and special districts. Each member government appoints a COG voting representative from its governing body. These voting representatives make up the General Assembly, which annually elects the Executive Board. The Executive Board, composed of 13 locally elected officials, is the policy-making body for all activities undertaken by the Council of Governments, including program activities and decisions, regional plans, and fiscal and budgetary policies. [NCTCOG, 2015]

Existing Government Agency. The MPO can be hosted within an existing city or county government, such as the Metropolitan Planning Commission (MPC) in Savannah, Georgia. The MPC is a joint planning agency for the city of Savannah and Chatham County. Each governmental body appoints seven members to the policy board. Two of these members are the city and county managers. These 14 members serve without pay and represent government, private enterprise, and citizens' interest groups. [MPC, 2015]

As illustrated by the above examples, MPO policy board membership varies based on the type of organization. MPOs strive for balanced representation on their decision-making body because it provides the greatest level of support for transportation investment decisions. This balance often is represented geographically, governmentally, and by sector (public and private sector representatives).

2. MPO Committees

Most MPOs have an established committee structure for their decision-making processes. Committees often develop and comment on proposed policies and plans. Typically, an MPO will have a technical committee made up of local public works or planning staffs, transit agency staff, and state DOT staff. In addition, many MPOs have a citizen advisory committee(s) to obtain public review and comment on MPO products. Most MPOs, and particularly large agencies, also rely on advisory committees of interested citizens, local experts, and academicians for a variety of technical and policy issues. Examples include committees that focus on environmental justice, bicycle and pedestrian movement, freight, and/or a travel demand modeling user group.

The ARC, for example, heavily relies on its planning team structure to provide input into policies and strategies for its long-range plan development. Besides the Executive Committee, the ARC has the following technical committees: Aging Advisory Committee, Aging and Health Resources Committee, Budget Audit Review, Strategic Relations Committee, Community Resources Committee, Land Use Coordinating Committee, Transportation and Air Quality Committee, Transportation Coordinating Committee, and the Regional Transit Committee.

3. MPO Professional Staff and Planning Partners

Just as the MPO boards differ in composition, MPO staffs vary as well in that they may be county or city staff or employed by a council of governments. Most importantly, the MPO staff is responsible for providing information and technical support to board members and advisory committees. They are responsible for preparing documents and managing the planning process. This includes fostering interagency consultation and facilitating public input and feedback.

Managing the planning process is a critical function of the MPO staff because the process is designed to foster the involvement of many stakeholders. Because most MPOs are not implementing agencies, it is important that they build strong relationships with the state DOT, regional transit agencies, and toll authorities, as well as with other transportation organizations responsible for constructing capital projects and operating the transportation system.

No single agency has the responsibility for constructing, operating, and maintaining the entire transportation system. The MPO must work with all responsible agencies and the public to maintain an effective 3C planning process.

Two professional organizations provide good information on the latest activities of MPOs in the United States—the Association of Metropolitan Planning Organizations (AMPO) (http://www.ampo.org) and the National Association of Regional Councils (NARC) (http://narc.org).

B. MPO Planning Products

The metropolitan transportation planning process produces information in many different forms. For example, MPOs often undertake subarea or corridor studies focusing on the transportation needs in a particular part of the metropolitan area. They might undertake studies on topical issues, for example, studies on freight movement, pedestrian and bicycle flows, the aging of the population, and growth management policies. In many cases, MPOs participate in environmental studies for individual projects. Most MPOs also have extensive public outreach efforts that disseminate information on the region's transportation system and possible improvement strategies. There are, however, several work products that must be produced by the MPO to satisfy federal guidelines and which are, therefore, common across all MPOs in the United States. These include the unified planning work program (UPWP), long-range transportation plan (LRTP), the TIP, and the annual listing of obligated projects. In addition, there are several other mandatory requirements that are discussed in this section.

1. Unified Planning Work Program (UPWP)

The MPO is required to develop a UPWP every year. This work program not only details the annual work activities of the MPO, but also captures the planning work conducted by the metropolitan area's transportation planning partners, such as transit authorities, local governments, and the state DOT. The UPWP is meant to be a compilation of all transportation planning work conducted under the 3C planning process.

Metropolitan areas designated as transportation management areas (TMAs) are required to have more detail in their UPWPs than non-TMA agencies. Typical UPWPs include:

- Planning tasks and studies to be conducted during the year.
- All federally funded studies and other relevant studies being carried out by state and local governments, regardless of funding source.
- Identification of funding sources for each work task.
- A schedule of activities.
- Agency responsibility for each task or study.

The UPWP is approved by the MPO policy board each year. State DOTs may submit a simplified version in their required statewide planning work program. Most MPOs post the UPWP on their website, which thus becomes a good source of information of the MPO's program of work for the near future.

2. Long-Range Transportation Plan (LRTP)

As noted earlier, the LRTP forms the basis for transportation investment decisions in a metropolitan area. It must have a planning horizon of at least 20 years and be updated at least every 5 years (every 4 years for air quality nonattainment areas). An important aspect of the plan is to articulate the vision for the region through policies and objectives. This vision denotes the link between transportation and regional land use, economic development, housing, and employment patterns. The plan should identify the performance measures used to assess system performance and the evaluation criteria used to determine the effectiveness of individual projects and strategies. The plan must also be "financially feasible" meaning that there are sufficient funds for a project to be planned, built, operated, and maintained throughout the life of the plan.

The development of the LRTP should provide many opportunities for public comment and outreach. More detail on the elements of the long-range plan will be presented later in this chapter.

3. Transportation Improvement Program (TIP)

While the LRTP articulates the region's vision and identifies possible improvement strategies, the TIP details how the highest priority projects will advance over the next four years. It also programs federal funds over the short-range to reflect the priorities of the plan. Projects cannot receive federal funds unless they appear in the TIP because the TIP is the instrument for matching strategies or projects with available funds.

In addition, the TIP must also be financially constrained by year. For air quality nonattainment areas, only projects with available or committed funding can appear in the first two years of the TIP. Thus, it is important that the TIP represent a staged, multi-year multimodal program of projects for the metropolitan area. It must also reflect public comment. The TIP also differs from the long-range plan because it must be approved by the governor and be incorporated into the statewide transportation improvement program (STIP) developed by the state department of transportation (DOT). The development of the TIP will be described in more detail later in this chapter.

4. Annual Listing of Obligated Projects

MPOs produce an annual listing of projects "for which federal funds have been obligated in the preceding year." [FHWA and FTA, 2007] This list "shall be published or otherwise made available by the metropolitan planning organization for public review. The listing shall be consistent with the categories identified in the transportation improvement program." Federal law clarified and reinforced this requirement by stating that the annual listing "shall be a cooperative effort of the state, transit operator, and MPO" and "shall include investments in pedestrian walkways and bicycle transportation facilities for which federal funds have been obligated in the preceding year."

5. Transportation Management Area (TMA) Requirements

Transportation management areas receive a guaranteed suballocation of federal funding. The MPO rather than the state DOT selects projects for the TIP. TMAs, however, must also meet several additional requirements. As described in later sections, these requirements further enhance and add to the complexity of the planning process in these areas.

IV. THE TRANSPORTATION PLANNING PROCESS

As noted earlier, a typical transportation planning program includes a variety of planning activities that could result in many different products. The LRTP, however, is one of the most important products of this program. Given typical differences in metropolitan areas, the regional transportation plan becomes a unique document oriented to the needs and aspirations of a particular metropolitan area. A successful plan provides an important foundation for future planning activities, such as problem identification and study boundary definition for corridor studies and major modal system plans. The long-range plan should also address broader regional issues that influence transportation, such as land use and economic development.

The framework for the transportation planning process described in chapter 1 and shown in Figure 1-1 presented the major steps in metropolitan transportation planning. The following sections are organized by the major planning steps outlined in this figure.

A. Basic Principles

At the outset of any transportation planning activity, the planner must be sensitive to the following issues:

Uncertainty in predicting the future. Many factors, often outside the control of transportation agencies, affect the demand for transportation and the performance of the transportation system. This is especially true when looking 20 to 25 years into the future (and more so with longer time horizons). Uncertainty is inherent in such questions as: What vehicle and/or fuel technology changes could significantly influence travel behavior during the next several decades? What will be the cost of fuel in 20 years? Are population and employment forecasts reasonable? The plan must acknowledge and incorporate uncertainty into its analyses and recommendations.

Limitations of the analysis process. Travel demand and land-use models are important tools for transportation planning. Although these models continue to improve, the ability to forecast travel behavior is often beholden to the assumptions made on those factors influencing travel decisions. Travel behavior is complex and difficult to explain fully with mathematical tools. Transit use, carpooling, and nonmotorized travel are particularly difficult for models to handle. Models are usually calibrated on past travel patterns that may not be continued into the future, thus adding another challenge to the analysis process. However, even with these limitations, a travel demand model is essential for analyzing transportation solutions (see chapter 6 for a discussion of travel demand models).

Influence of the political process. The MPO is, in essence, a political forum where local officials and transportation agency representatives strive to reach consensus. Elected officials often have political agendas that might predispose them toward one transportation solution, such as a new highway or a light rail line. In addition, elected officials tend to focus on issues with more immediate effect and often find it difficult to relate to discussions on issues that will occur 25 years into the future. The planner must understand the characteristics of political decision making in presenting plan information. Effective communication and political skills are just as necessary to the planner as technical skills.

The preceding considerations can be applied to any type of transportation planning. For long-range transportation planning, in particular, the following factors become important.

A plan needs to recognize and provide an understanding of the interconnectivity of the different modal networks in the region's transportation system. For example, most metropolitan areas have a road network also used by bus services. Thus, achieving a reasonable level of service on the highway system becomes an issue as much for transit mobility as for highway congestion reduction. These same roads may be designated as part of a strategic road network because they connect to important economic activities. In addition, bicycle and pedestrian systems are important in an urban environment in part because they provide important connections to transit systems. Such intermodal connectivity should be an important concern for the transportation planning process.

A long-range plan must have a time horizon of at least 20 years. Major capital investments, such as new highways or transit lines, may take upwards of 10 years or longer to complete. Land-use patterns also tend to develop over long timeframes. A 20-year time horizon provides a sufficient timeframe to consider longer-term effects. Most MPOs use a 25-year time horizon, and more recently some MPOs have been developing 40- and 50-year plans. Some issues, such as climate change and the corresponding impacts on transportation system performance, are even extending this timeframe out to 2100 (although no MPOs have yet adopted such a long time horizon for its plan).

A plan should be both multimodal and intermodal. All modes must be considered (thus the term *multimodal*) as part of the planning analysis—auto travel, transit services, freight movement, bicycle and pedestrian travel, and others that are important to the metropolitan area. Modal connections, that is, where transfers are made (thus the term *intermodal*), also become an important focus of attention.

The link to land-use planning is critical. As noted in chapter 6, transportation demand is a derived demand, meaning that travel occurs because travelers are trying to accomplish an activity at a trip's destination. Thus, a transportation plan needs to be linked to expected land-use patterns in the study area. This becomes an important challenge for a long-range, metropolitan-level plan because a regional land-use plan or context must be provided to conduct the analysis. How MPOs do this varies across the country (see chapter 3 on land use and urban design).

Federal law requires that the long-range plan be financially constrained. The plan must include a financial element that describes the assumptions made to forecast future revenues. The cost of the projects in the plan must not exceed the expected revenues available to provide the planned improvements.

Given the uncertainty about future funding sources, many MPOs have created a vision plan in addition to a financially constrained plan. The vision plan, often called an aspirations plan, can take many forms, often part policy and part project-specific. A vision plan allows a region to determine what additional financial resources are required to meet all the needs for this vision beyond what is forecast to be available. In many cases, the projects that are listed in this vision plan are considered illustrative of what can be done if additional resources are made available (and often become the focus of public referenda to obtain the funds to support the plan).

The plan must have broad input from all interested and key stakeholders. Opportunities for public participation in the planning process must be provided throughout the process, and MPO planners must be responsive to the input provided.

All planning factors in federal legislation must be addressed. As noted earlier, the federal government plays an important role in establishing the approach and substance of metropolitan transportation plans. Many of the sections found in a typical transportation plan are there to satisfy federal requirements.

The plan should address environmental justice issues. The Environmental Justice Executive Order 12898 of 1994 states that federally funded plans should not unduly burden low-income and minority populations. Coupled with Title VI Civil Rights laws, this executive order leads to an analysis of transportation plans and TIPs on disadvantaged communities. This analysis is part of the long-range transportation planning process, and often accompanies the plan as an appendix or as a section in the plan itself.

The plan must take into account all planning studies conducted by the MPO and other planning partners since the last plan update. The results of these studies should be analyzed from a regional perspective and be incorporated into the plan as appropriate. Subarea, corridor, and modal studies provide important sources of projects and strategies to be considered when developing a long-range transportation plan.

B. Defining Study Boundaries

Federal law requires that the state and local decision makers agree on MPO planning boundaries, and that defining the boundary should be a cooperative process among the representatives of the local governments contained within the urbanized area, the state's governor, and any adjacent MPOs. The MPO planning boundary must include the entire urbanized area boundary as identified in the latest decennial census and the contiguous geographic area likely to become urbanized within 20 years. In many instances, MPO planning efforts will have different study boundaries depending on the study purpose. For example, in Atlanta, the ARC, (1) develops the LRTP based on the census-defined urbanized area, (2) conducts planning as the state-designated regional commission in 10 counties (whose boundaries are not contiguous with the urbanized area), (3) has 19 counties in the agreed-upon MPO structure, (4) does transportation planning in a 15-county planning boundary for ozone analysis, and (5) conducts planning in a 20-county planning boundary to satisfy air quality requirements for particulate matter.

For planning efforts that are not at a regional scale, MPOs often define the focus of a planning effort based on a variety of factors. For example, a recent review of the congestion management process (CMP) in 10 MPOs showed how differently the targeted network is defined (see Table 16-1). [ARC, 2015a]

C. Identifying Transportation Issues and Opportunities

The planning framework offered in chapter 1 began with an effort to understand the problem(s) facing a particular community or region. In special planning cases, such as those relating to safety or air quality, analysis often precedes the identification of specific issues in order to understand the transportation component of the problems being faced. For example, for safety, many states conduct preliminary data analysis to identify what types of crashes should be of greatest concern to the planning study. Because of the continuing nature of metropolitan transportation planning, this step in the planning process occurs through the normal planning activities of the MPO. Information on critical issues affecting transportation system performance is constantly being fed back into the planning program.

Some typical issues/threats/challenges/opportunities that have been identified by MPOs as part of the transportation planning process include:

Metropolitan Council, Minneapolis–St. Paul, Minnesota

Challenges and Opportunities

- Land use and development patterns affect the stewardship of the transportation system.
- Transportation investments can help sustain and strengthen the region's economic competitiveness.
- The region's population and employment are going to grow, leading to more travel.
- Highway congestion is a reality of economic growth and can be managed and eased.

Table 16-1. Targeted Road Networks for Congestion Management Processes, Various Metropolitan Areas	
Agency	**System Coverage**
Metroplan Orlando, Florida	• Systemwide evaluation is performed (Level 1), leading to the identification of potentially congested roadways/intersections (Level 2), from which evolve detailed corridor or intersection studies (Level 3).
Maricopa Association of Governments, Phoenix, Arizona	• Freeway corridors identified in the Performance Measurement Framework report. • Transit facilities and services. • Bicycle and pedestrian facilities. • Arterial streets that either currently experience significant congestion or are projected to experience significant congestion in the future or make up part of a corridor or activity area that is subject to current or future congestion.
North Central Texas Council of Governments, Dallas-Ft. Worth, Texas	• A corridor inventory of 25 regional limited access facilities.
Mid-America Regional Council, Kansas City, Missouri	• All National Highway System routes. • All other routes with average daily mid-block traffic volumes of 25,000 or more for segments of 2 miles or more in length. • All routes with high levels of transit service.
Delaware Valley Regional Planning Commission, Philadelphia, Pennsylvania	• Congested corridors segmented into subcorridors. • Sketch corridors likely to become congested in the future that serve key regional roles. • Corridors based on CMP Analysis Points, Transportation Refinement Layers, and Community Refinement Layers.
Genesee Transportation Council, Rochester, New York	• All interstate highways, principal, and minor arterials. • Collector roads in the vicinity of special event venues.
Chicago Metropolitan Agency for Planning, Illinois	• Expressways and tollways. • Regionally important roads. • Regionally important transit systems.

Puget Sound Regional Council, Seattle, Washington	• Based on the Metropolitan Transportation System (regionally significant multimodal transportation facilities that provide access to activities crucial to the social or economic health of the region).
	• Additional layers added to the CMP to reflect multimodal or freight considerations, including:
	  • Core freeway and HOV network.
	  • Washington State Department of Transportation (WSDOT)-identified bottlenecks.
	  • Top 25 regional "key" arterials identified by Regional Traffic Operators Committee.
	  • Key transit corridors identified by transit stakeholders.
	  • T1 and T2 truck freight routes identified in regional Freight and Goods Transportation System.
	  • Critical infrastructure and significant emergency management routes.

Regional Transportation Commission, Las Vegas, Nevada	• Major interregional corridors and major arterial corridors connecting cities to the base congestion management network. • Only regionally significant corridors considered as candidates for the network. • The initial network was refined from the list of candidate corridors to include facilities with "existing or potential recurring congestion;" professional judgment was used to identify corridors with existing congestion and those likely to become congested.
Hampton Roads Transportation Planning Organization, Virginia	• Principal arterials (interstates, freeways, or other expressways). • Minor arterials. • Roadways classified as collectors based on network connectivity, access to major activity centers, and input from jurisdictions. • Major roadways expected to be constructed in the future.

Source: ARC, 2015a

- People and businesses are demanding more and better travel options.
- Transportation decisions impact communities and the environment, and thus should be made responsibly.
- Access to jobs and opportunity is an issue of equity.
- Traditional transportation needs are greater than the resources available.
- There is a need to innovate and make strategic decisions. [Metropolitan Council, 2015]

Denver Regional Council of Governments (DRCOG), Colorado. DRCOG identified the following factors that the transportation system will respond to, influence, and be impacted by:

- *Economic and population growth.* The population of the Denver region is expected to increase from about 2.9 million in 2010 to more than 4.3 million in 2035, an increase of about 50 percent.
- *Location of growth.* Most of the expected increase in the region's population and employment will occur within the urban growth boundary/area. In addition, much of it will be concentrated in urban centers. However, the majority of this growth will occur in locations far from the Denver Central Business District (CBD).
- *Less efficient development patterns*. Developments with circuitous streets and poor pedestrian connections, and those with separated residential and commercial areas can result in an increased reliance on the automobile.
- *Lower development densities.* Many residential areas are developed at lower housing unit densities and cannot be served cost-effectively with conventional public transit.
- *Development near airports.* Several residential subdivisions have developed within the influence area of the region's airports. This may give rise to future noise impact issues that could hinder the regional airport system's ability to grow or respond to changes in the service market.
- *Automobile dominance.* The automobile (including cars, vans, pick-ups, and sport utility vehicles) is the region's dominant form of household transportation. And for most trips, the automobile contains only a single occupant, the driver.
- *Increased travel*. The rate of annual VMT growth was not as high between 2000 and 2010 as it was in previous decades, but is currently forecast to steadily increase through 2035.
- *Jobs/housing balance.* In areas that lack a good balance of jobs and housing, there are fewer opportunities to live close to work.
- *Difficult to institute change.* Changing personal travel habits is difficult, particularly when people are not aware of options, viable options do not exist, and benefits are not clearly understood.
- *Growth of elderly and disabled population*. Both the elderly and disabled populations are growing at rates faster than the general population.
- *Limited existing transportation system capacity*. Without improvements and expansion, the region's existing transportation system cannot provide a desirable level of mobility to meet expected demand.
- *Increased congestion.* The number of congested miles is expected to more than double between 2006 and 2035.
- *Impacts of expansion and construction*. The ability to widen a roadway or provide a rapid transit corridor is more costly and politically difficult when additional right-of-way is needed. Often this requires residential and business acquisitions that may cause community and economic impacts.
- *Increase in traffic crashes.* The number of crashes on the roadway system increased by about 3 percent annually between 1990 and 2005.
- *Mobility options for persons without a car.* According to the 2000 Census, about 67,000 households in the Denver region did not have an automobile available.
- *Recreational traffic*. Thousands of people travel to and from recreational activities in the mountainous areas of Colorado, both within the region and adjacent to it. Traditionally, they travel around the same general time. Roadways such as I-70 and US-285 experience extreme congestion during weekend peak periods, such

as Sunday afternoons. Local communities are greatly affected by this congestion, which impacts the ease of making local trips, emergency response to traffic crashes, and noise, air, and water quality.

- *Air quality.* Pollutant emissions from mobile sources, (e.g., automobiles and trucks), are a major contributor of air pollutants. Even with continued technological improvements to automobile pollution control equipment, expected VMT growth may jeopardize air quality.
- *Water quality.* Water pollution is caused by many factors related to regional development, including the construction and operation of the transportation infrastructure. Growth in traffic can cause increased runoff of pollutants created by brakes and tires.
- *Limited funds.* Financial resources for transportation over the next 24 years of the plan are currently expected to be far less than needed to maintain the current transportation system to high standards, let alone expand it. Transportation funding has simply not kept pace with the continued growth in travel demand or the recent dramatic increase in transportation construction cost. [DRCOG, 2011]

To illustrate the regional nature of transportation issues in an environmentally sensitive area and as well to show such a list for a smaller MPO, the following challenges and opportunities were identified in the transportation plan for the Berkshire Regional MPO in western Massachusetts.

Berkshire Regional Planning Commission, Pittsfield, Massachusetts

- *Livability:* Livable, sustainable communities offer residents a variety of different modes of transportation, without almost complete reliance on using automobiles. Some of the alternate modes include rail, bus, bike, vanpools, carpools, and walkways. Livable communities reduce the need to frequently travel far by including housing, jobs, shopping, education, and recreation.
- *Climate change and air quality conformity*: The Berkshires are expected to experience warmer temperatures, less snow pack/ice retention and cycles of subsequent drought and flooding impacts, changes in weather patterns and its resulting increase in storm severities, an increase in frequency and severity of heat waves, and shifts and alterations in the distribution of natural plant and animal assemblages—A preliminary study of greenhouse gas (GHG) emissions in Berkshire County suggests that the transportation sector accounts for 39 percent of GHG emissions.
- *Hazard mitigation, severe weather, & water quality:* Berkshire County is affected by a number of natural hazards including flooding, severe winter weather, tornados, and wildfires. Localized flooding causes most of the county's natural hazard damage. Poorly maintained transportation infrastructure and inadequately sized storm water systems contribute significantly to hazardous flooding conditions. Deferring maintenance (grading, ditching, culvert repair, and so forth) because of budget constraints results in soil erosion and pavement damage.
- *Critical animal habitat:* Highway construction, urban and residential development, and other physical alterations reduce natural habitat. Roads isolate wildlife populations into smaller units that are more vulnerable to threats including predators and inbreeding. [Berkshire Regional Planning Commission, 2011]

D. Formulating a Vision, Goals, and Objectives

A critical step for metropolitan transportation planning early in the process is creating a regional or community vision. This process has many dimensions, ranging from expected or desired future land-use patterns to desired transportation system characteristics. For example, the Metropolitan Washington Council of Governments, Washington, DC, has adopted the following vision statement for the region's transportation system. Note the multimodal nature of the vision, as well as the linkage to growth.

- The Washington metropolitan region's transportation system will provide reasonable access at reasonable cost to everyone in the region.
- The Washington metropolitan region will develop, implement, and maintain an interconnected transportation system that enhances quality of life and promotes a strong and growing economy throughout the entire region, including a healthy regional core and dynamic regional activity centers with a mix of jobs, housing, and services in a walkable environment.

- The Washington metropolitan region's transportation system will give priority to management, performance, maintenance, and safety of all modes and facilities.
- The Washington metropolitan region will use the best available technology to maximize system effectiveness.
- The Washington metropolitan region will plan and develop a transportation system that enhances and protects the region's natural environmental quality, cultural and historic resources, and communities.
- The Washington metropolitan region will achieve better inter-jurisdictional coordination of transportation and land-use planning.
- The Washington metropolitan region will achieve an enhanced funding mechanism(s) for regional and local transportation system priorities that cannot be implemented with current and forecasted federal, state, and local funding.
- The Washington metropolitan region will support options for international and interregional travel and commerce. [National Capital Region TPB, 2015]

In many ways, although the creation of a vision statement can provide planners with some sense of community desires at the beginning of the process, perhaps the major benefit of the visioning process is the participation of many different stakeholders in creating the vision itself. By discussing and debating the different factors that should be included, stakeholders learn about the many facets of transportation that will be important during the planning effort. In one area in particular—the consideration of future land-use patterns—creating a vision provides an important input into the technical aspects of the planning process.

Developing goals and objectives is another key step in the plan development process in that they provide more detail on how the plan's vision will be accomplished. Developing goals and objectives should be informed by substantial input from the MPO policy board, stakeholders, and interested citizens. It is not the planner's role to define goals and objectives, but rather to facilitate a community process that results in a goals statement, translate them into the language of planning, and then use them to guide the technical process. Given the comprehensive nature of transportation planning, goals and objectives should be developed in concert with regional development policies or land-use plans, and should also reflect federally-required planning factors.

Some examples of MPO transportation planning goals and objectives follow:

Southeast Wisconsin Regional Planning Commission (SEWRPC). The Southeast Wisconsin Regional Planning Commission (SEWRPC), the MPO for the Milwaukee, Wisconsin, metropolitan area provides a good example of what MPOs often do to develop a vision statement. As noted by the MPO, "using a visioning and scenario planning approach, the VISION 2050 effort was designed to obtain greater public input into the specific design and evaluation of "sketch" year 2050 land use and transportation scenarios, detailed alternative plans, and the final plan, as well as to expand public knowledge on the implications of existing and future land use and transportation development in Southeastern Wisconsin." [SEWRPC, 2014]

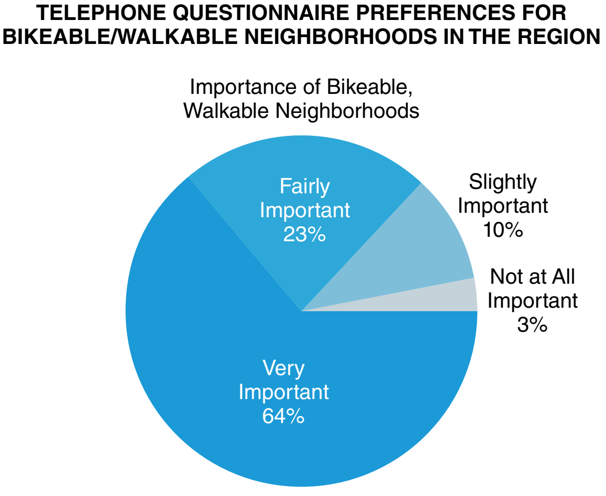
Outreach efforts included a regularly distributed VISION 2050 e-newsletter, periodic brochures, media contacts and news releases, and extensive public outreach to minority and low-income groups and organizations, business groups, service groups, community and neighborhood groups, environmental groups, and others. The MPO partnered with eight nonprofit, community organizations to conduct targeted outreach to their constituents. This outreach effort was largely designed to reach and engage minority populations, people with disabilities, and low-income individuals. A telephone questionnaire was used to obtain preferences from the region's citizens with respect to key transportation, community, and social attributes of the region. Figures 16-1 and 16-2 illustrate some of the results of this survey.

Capital Region Transportation Planning Agency (CRTPA), Tallahassee, Florida. The Capital Region Transportation Planning Agency, the MPO for the Tallahassee, Florida, metropolitan area adopted the following vision statement for its transportation plan.

> *"Create an integrated regional multimodal transportation network that provides the most options for moving people and goods economically, effectively and safely while protecting the environment, promoting economic development and maintaining a high quality of life with sustainable development patterns." [CRTPA, 2012]*

Bend Metropolitan Planning Organization, Bend, Oregon. The update of the Bend, Oregon, metropolitan transportation plan identified goals and objectives to help "set the tone and guide the development and selection of transportation solutions for the MTP … and serve to guide implementation of the plan." [Bend MPO, 2014] The goals for the transportation plan were:

Figure 16-1. Results of Visioning Survey, Importance of Bikeable and Walkable Neighborhoods, Milwaukee, Wisconsin



Source: SEWRPC, 2014

Mobility and Balance

- Provide a variety of practical and convenient means to move people and goods to, from and within the MPO area.
- Develop a transportation system that serves the needs of all travel modes, provides intermodal connectivity, and provides a range of transportation options throughout the MPO area.

Safety and Efficiency

- Address traffic congestion and problem areas by evaluating the broadest range of transportation solutions.
- Serve the existing, proposed, and future land uses with an efficient and safe transportation network.
- Design and construct the transportation system to enhance safety for all modes.

Accessibility and Equity

- Provide people of all income levels with a wide range of travel options within the MPO area.
- Support all Americans with Disabilities Act (ADA) requirements and policies.

Land Use

- Integrate land use and transportation by encouraging land-use patterns that provide efficient, compact uses of land that facilitate a reduced number and length of trips.
- Promote development patterns that preserve the life of the existing transportation system.
- Promote development that does not rely on primary access to the state transportation system.

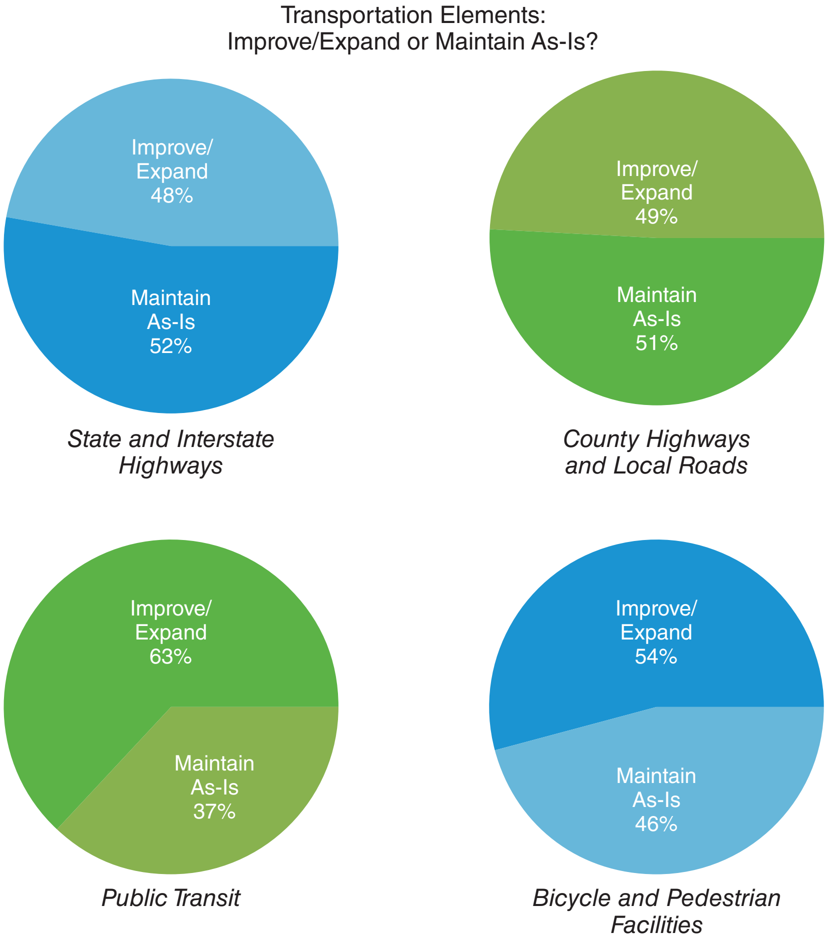
Environment and Livability

- Recognize and respect the natural and historical features over which transportation improvements pass to minimize adverse impacts.
- Design transportation improvements that protect the environment by preserving air and water quality, minimizing noise impacts and encouraging energy conservation.
- Use context sensitive design principles when designing and locating transportation facilities.

Economic Development

- Implement transportation improvements that foster economic development and business vitality.
- Develop a transportation network with transportation options that enhance linkages between centers of employment, education, medical facilities, and neighborhoods.
- Recognize the importance of intermodal connections and maintain adaptable approaches to trends and opportunities that enhance intermodal connections.

Figure 16-2. Results of Visioning Survey, Preferences for Road Improvement, Milwaukee, Wisconsin



Source: SEWRPC, 2014

Financially Responsible

- Coordinate and design transportation improvements to assure the expenditure of resources in the most cost-effective manner.
- Maximize the ability to leverage alternative and multiple funding sources for transportation system improvements.

Metropolitan Council, Minneapolis–St. Paul, Minnesota. In its recent update of the long-range transportation plan, the Metropolitan Council of Minneapolis-St. Paul, Minnesota, developed an extensive list of goals, objectives, and strategies for improving transportation system performance in the Twin Cities region. The transportation goals and objectives were closely linked to the adopted vision statement for the region's future that was based on the following five principles:

- *Stewardship* advances the Council's longstanding mission of orderly and economic development by responsibly managing the region's natural and financial resources and making strategic investments in our region's future.
- *Prosperity* is fostered by investments in infrastructure and amenities that create regional economic competitiveness, thereby attracting and retaining successful businesses, a talented workforce, and consequently, wealth.
- *Equity* connects all residents to opportunity and creates viable housing, transportation, and recreation options for people of all races, ethnicities, incomes, and abilities so that all communities share the opportunities and challenges of growth and change.

- *Livability* focuses on the quality of our residents' lives and experiences in our region, and how places and infrastructure create and enhance the quality of life that makes our region a great place to live.
- *Sustainability* protects our regional vitality for generations to come by preserving our capacity to maintain and support our region's well-being and productivity over the long term. [MetCouncil, 2015]

The corresponding transportation goals, objectives, and strategies for this vision provide an excellent overview of the types of goals that a large metropolitan area might consider (see appendix A).

Atlanta Regional Commission (ARC), Georgia. The latest update of the ARC's regional plan focused on three major policy themes—world-class infrastructure, healthy livable communities, and competitive economy. [ARC, 2016] These three themes served as the foundation for the identification of strategies in the regional plan. Each policy area had a range of goals relating to a mix of land-use, transportation, economic development, and social program strategies. For example, the following goals and transportation-related strategies were listed for the respective policy area:

World Class Infrastructure

Goal: Ensure a comprehensive transportation network.

- Expand managed toll lane program.
- Expand region's transit network.
- Maintain the existing transportation system and improve arterial roads and highways.

Healthy Livable Communities

Goal: Develop walkable and vibrant communities.

- Invest in equitable and improved access to a variety of housing, including options for aging in place.
- Promote equitable transit-oriented development.
- Develop a regional trail network for bicyclists and pedestrians.
- Create walkable communities through the Livable Centers Initiative.

Competitive Economy

Goal: Build the region as a globally recognized hub of innovation and prosperity.

- Improve the movement of freight.
- Boost economic development around Atlanta's airport.

The Atlanta regional plan provides an example of a plan that identifies the interrelationship among the many different planning issues facing a community, and how transportation strategies can play an important role in achieving each.

This step in the planning process—the formulation of community vision, goals, and objectives—should have significant public engagement opportunities in order to lend credibility to the planning process. MPOs and regional planning agencies often spend considerable time providing the public and key stakeholders with a variety of opportunities for input into the visioning, goals, and objectives process. Often, goals and objectives are revisited as the planning process proceeds, reflecting new information or new participants in the planning process.

E. Identifying and Using System Performance Measures

Performance measures are a set of indicators or measures used to monitor the performance of the transportation system over time. The number of performance measures should be limited to a select few that reflect the information desired by decision makers in determining future directions in transportation investment. Given their importance to local decision makers, these performance measures are also usually part of the criteria used to evaluate different investment strategies.

Performance-based transportation planning can provide better quality and more goal-relevant information to an inherently political decision-making process. By educating and informing the public, in part through the use of customer-oriented outcome measures, decision making can begin to favor more objective evaluation and debate. It is widely agreed that system policies, goals, and objectives are a critical starting point for developing a performance-based planning approach. The concept of outcome measures and the important role of customer perception and satisfaction are now a well-established part of most transportation planning efforts.

In metropolitan planning applications, performance measures need to be readily understood by decision makers and by the public. This supports the concept of a hierarchy of measures, with the measures providing basic information on how the system performs. Some examples of performance measures for different categories of goals include:

- *Accessibility:* Percent of the population within *x* minutes of *y* percent of employment sites, whether special populations such as the elderly are able to use transportation, whether transportation services provide access for underserved populations to employment sites, and whether services are Americans with Disabilities Act (ADA) compliant.
- *Mobility*: Average travel time from origin to destination, change in average travel time for specific origin-destination points, average trip length; percentage of trips per mode (known as mode split), time lost to congestion, transfer time between modes, and percent on-time transit performance.
- *Economic Development*: Jobs created and new housing starts in an area as a result of new transportation facilities. new businesses opening along major routes, percent of region's unemployed who cite lack of transportation as a principal barrier, and economic cost of lost time.
- *Environmental Quality of Life*: Environmental and resource consumption, tons of pollution generated, and fuel consumption per vehicle mile traveled.
- *Sprawl*: Change in difference between urban and suburban household densities; decrease in acres of wetlands; changes in air quality, land use, or mobility.
- *Safety*: Number of crash incidents or economic costs of crashes.
- *Reliability*: Repeatability of trip travel times. It is affected by non-recurring events such as incidents, work zones, special events, weather, or natural disasters.

Table 16-2 shows the performance measures for the Madison, Wisconsin area metropolitan planning program. As noted by the MPO, "the proposed indicators for the Madison area include both "outcome" metrics that measure the effects of system investments and decisions (for example, travel time, mode of transportation, roadway and bridge conditions, # of crashes) as well as "output" metrics that measure the level of activity of a program or supply of a service or facility (for example, transit revenue hours of service, miles of multi-use paths)." [MadisonArea MPO, 2012]

Metropolitan areas in California are subject to state legislation requiring the identification of performance targets as part of the transportation planning process and the periodic monitoring of progress toward these targets. These targets become evaluation criteria for assessing the effectiveness of the transportation plan's recommended actions. Table 7-9 showed how the updated metropolitan transportation plan [ABAG and MTC, 2013] helped achieve the targets… or not. Note that the presentation was organized in terms of those targets met or exceeded, those where progress is being made, and those where the trends are in the wrong direction.

A similar but separate analysis was done looking at the plan's social equity impacts on communities of concern. The conclusions from this analysis were:

- Alongside displacement pressures, housing, and transportation affordability are forecast to continue to be key challenges for low-income households in the future.
- While air quality will improve in the region overall with improved technologies, increased vehicle traffic and congestion in communities of concern raise safety concerns for those areas where walking and biking are more common modes of travel.
- Travel times to jobs and other destinations will increase slightly for communities of concern compared to today, due to higher levels of congestion in the urban core and some trips shifting from driving to transit, walking, and biking. [ABAG and MTC, 2013]

Table 16-2. Performance Measures, Madison, Wisconsin	
Mobility and Accessibility—Improve regional mobility and accessibility for all persons while maintaining a balance between the two sometimes competing concerns. Balanced System—Achieve a balanced transportation system through investment.	• Travel Time to Work (by mode) • Mode of Transportation to Work • Miles of Congested Roadways (based on Level of Service) • Transit Revenue Hours of Service • % of Urbanized Area and Population • Served by Transit (weekday, weekend) • Miles of Bike Lanes and Multi-use Paths
Mobility of Freight—Enhance mobility and safety for goods movement to support the local economy while maintaining community livability.	• Miles of Congestion on Truck Routes • Miles of Rail Track with Speed Restrictions • Freight Tonnage by Mode
System Preservation—Maintain the region's transportation infrastructure and preserve transportation corridors, particularly rail corridors, for possible future travel uses by other modes.	• Roadway and Path Pavement Condition • Bridge Structure Condition (sufficiency rating and weight restriction) • Avg. Age of Metro Transit Bus Fleet • Miles of Metro Vehicle Service between • Unplanned Road Calls
Safety—Improve transportation safety through design, operations and maintenance, system improvements, support facilities, public information, and law enforcement efforts.	• Total Vehicle Crashes by Severity vs. VMT • Metro Transit Bus Crashes per 100,000 • Vehicle Miles Traveled • Total Bicycle and Pedestrian Crashes and Fatalities
Management/Operations—Apply ITS and utilize TDM and TSM strategies to respond to traffic congestion, make efficient use of existing roadway capacity, and make the transportation system more reliable, convenient, and safe. Congestion Management—Consider all mobility options and operational strategies (ITS, TDM, TSM) in congested corridors before adding capacity for general purpose travel lanes or building new facilities.	• Vehicle Miles of Travel (VMT) • Freeway Congestion Duration • Total Annual Transit Passenger Trips • Transit Passengers per Revenue Hour • Transit System On-Time Performance • # of New Commuters Registered with the MPO's Rideshare etc. Program • # of State Vanpools and # of Employers Participating in Commute Card Program • [See also CMP Performance Monitoring Plan]
Interconnected System—Encourage and facilitate connections between various modes of travel.	• # of Park-and-Ride Lots and Usage • Inter-City Bus Trips per Day, Cities Served • Airport Passenger Volume
Environmentally Responsible—Preserves and restores environmental and ecological systems and minimizes energy consumption to the extent feasible.	• Ozone and PM 2.5 Levels • Transportation-related GHG Emissions

Source: Madison Area MPO, 2012

It should be noted that the transportation profession is debating how to best define desirable performance of the transportation system. For example, more traditional measures would focus on travel speed, levels of service, and capacity measures, where higher speeds, greater levels of service, and more capacity would be defined as more desirable. Especially in urban areas, such a result might not be the best outcome. For example, higher speeds do not mix well with pedestrian and bicycle travel on the same road. With many communities adopting Complete Streets and traffic calming policies, transportation performance measures need to be considered very carefully in terms of the potential outcomes if investments are made to achieve "optimal" performance.

Chapter 7 on evaluation and prioritization methods, chapter 15 on statewide planning, and chapter 17 on corridor planning provide additional discussion on performance measures. See also chapter 9 on road and highway planning and chapter 19 on site impact analysis for a discussion on non-traditional performance measures and in particular on recent efforts to define a multimodal performance metric.

F. Collecting and Analyzing Land-Use, System Performance, and Condition Data

Transportation planning is analysis-driven. The ultimate investment recommendations are based on a sound assessment of the advantages and disadvantages of each alternative. In addition, analysis is strongly dependent on the availability of high-quality data relating to every aspect of an alternative's performance and its relationship to the surrounding community. Data can range from large demographic and census population files to site-specific traffic counts.

It is beyond the scope of this chapter to provide a detailed description of typical data and data sources used in metropolitan transportation planning (see chapter 2 for a more comprehensive presentation of transportation system data and chapter 3 for land-use and urban design data). However, it is important for those interested in metropolitan transportation planning to understand some of the key characteristics of data collection and management.

The types of data used in a metropolitan transportation planning process will vary by the kinds of issues being examined and the ability of state and local agencies to collect the data. The following list of data on the website for the Pima Association of Governments (Tucson, Arizona) gives an indication of the range of data that can be found in a typical MPO: [PAG, 2015]

- Regional, aerial, and orthophotographic coverages.
- Travel demand forecasts and traffic count information (such as annual traffic counts, traffic volume forecasts, commuting and travel characteristics, and transportation system performance measures).
- Air quality and watershed management data.
- Population estimates and projections.
- Land use and socioeconomic information.
- Census program coordination, information, and demographic analyses.

As the amount of data for transportation planning has increased dramatically during the past several decades, MPOs have developed methods to organize and manage the data. Most of the data sources on the PAG list, and similarly for other MPOs, are based on a geographic information system (GIS) platform. GIS analysis has become a fundamental tool for metropolitan planners. By combining data with a geographic representation, the planner is able to undertake more in-depth technical analysis of transportation issues.

GIS is particularly helpful in linking transportation strategies with land-use strategies. Testing various alternative development scenarios through GIS tools allows for quick assessments of the varying implications of different combinations of transportation investment strategies and land-use patterns. The visual representations are also critical for general public understanding of the differences among the scenarios. An FHWA study that examined the use of GIS tools in transportation planning concluded:

> *GIS tools help support the public process of creating and identifying preferred alternative scenarios*. Planners have found GIS methods helpful in creating realistic land-use scenarios with the input of local staff, stakeholders, and the general public. They also have found the results useful in communicating the implications of

alternative transportation and development choices. As a result, people are able to make better informed decisions.

GIS technology is enabling the development of more detailed and sophisticated land use and environmental data and analysis tools. Integrated regional land-use databases are becoming more common. At the same time, GIS facilitates the development of detailed, parcel-level land-use databases that support environmental and community indicator models. GIS further provides data display capabilities to communicate information to policy makers and the general public.

Even with the use of GIS tools, the comprehensive integration of data sources remains a challenge in most areas. Land-use data, such as comprehensive plans, zoning and existing development, are maintained by local jurisdictions. Especially for smaller jurisdictions with limited resources, these are often still in hard copy format. Also, data formats are often incompatible among different jurisdictions in the same metropolitan area. In most parts of the country, regional land-use databases still require significant effort to construct and maintain. [http://www.gis.fhwa.dot.gov]

In recent years, efforts have been made to develop database sharing tools, which allow for easy exchange of information. For example, the Transportation, Economic, Land Use System (TELUS) is an information-management and decision-support tool that has been designed for use by MPOs. Funded by the U.S. DOT, TELUS is available for free to MPOs. Some key TELUS components include automated TIP monitoring, mapping, economic analysis, and land use assessment. MPOs also design and build their own custom data and reporting systems.

For up-to-date information on GIS applications in transportation planning, see http://www.gis.fhwa.dot.gov.

G. Analyzing Transportation System Alternatives

An analysis usually begins by examining current transportation system conditions. This includes an inventory of the physical conditions of different transportation facilities and systems, coupled with data on existing performance. Data would be collected on such transportation systems as freeways/limited access roads, strategic arterial roads, high-occupancy vehicle (HOV) networks, transit services and route structure, "smart" corridors served by ITS, bicycle networks, and pedestrian networks.

A needs assessment requires the planner to analyze the performance of the current transportation system as well as expected performance with improvements. Typically, a travel demand model is run for the current year and future year. A "no-build" run is produced for future years, assuming no improvements are made to the current system or often incorporating projects for which projects have already been committed. These runs are analyzed based on key evaluation criteria, such as mode split, vehicle miles traveled, and vehicle hours traveled. For studies of individual facilities or smaller study areas, it is important to analyze subarea or corridor-level measures as well. By understanding how the transportation system performs—with and without the planned improvements—planners can assess the need to change or refine strategies and investments.

Most transportation planning studies use some form of travel demand model as part of the analysis process. Travel models tend to fall into two groups—demand network models and simulation models. Simulation models are increasingly being used for facility and corridor analysis, and, in recent years, new simulation models have been developed for regional applications as well (see chapter 6 on travel demand modeling).

Since most regional models are calibrated and validated whenever actual data are available (at least once every 10 years with census data), the model's ability to replicate current conditions reasonably well is a prerequisite to forecasting into the future. This often requires model updates or limited modifications during the years between census periods. Note that this timeframe for model update might now change with the adoption of the continuous census data collection strategy in the United States, known as the American Community Survey (see chapter 2 on data collection and analysis).

Model advancements now allow planners to address tolling and other pricing schemes when testing future scenarios. Certain ITS and operational improvements, however, remain a challenge to many models. Chapter 6 on travel demand modeling provides detail on how travel demand models are formulated and used as part of the transportation planning process. This information will not be repeated here. However, some aspects of how models are used in metropolitan transportation planning deserve some attention, and are discussed below:

1. Model Assumptions

Many assumptions often have to be made concerning key input variables for the models themselves. This is especially true when applying models to an urban area, where many different factors can influence travel behavior. Although the information is somewhat dated, the Metropolitan Transportation Commission (MTC) in the San Francisco Bay metropolitan area identified the following key areas where assumptions on future values had to be made when developing its travel demand model for a plan update. These are still valid today. [MTC, 1998]

- Fuel price and availability
- Parking costs
- Auto operating costs
- Bridge tolls
- Transit fares
- Travel behavior assumptions
- Vehicle peaking factors
- Vehicle occupancy factors
- Interregional commuter behavior
- Demographic assumptions
- Network assumptions

To this could be added assumptions relating to vehicle behavior (connected vehicle technology, for example) and the influence on travel behavior of the Internet and social media.

In each case, the assumptions relate to expected future conditions. For example, in developing a plan for the year 2045, what will parking and auto operating costs, tolls, and transit fares be 30 years in the future? These are critical variables for forecasting which mode travelers will choose. Similarly, the degree to which traffic flow will peak during the day, the level of vehicle occupancy, and the amount of interregional commuting will affect which network links will be most congested.

Of particular importance, future population and employment must be forecast not only at a regional level but also distributed into smaller zones, usually by traffic analysis zone (TAZ). These forecasts must be made for specific time intervals all the way to the end of the plan horizon period. This may mean a five-year, 10-year, or even one 20-year forecast depending on the size and concerns of the MPO. See chapter 3 on land use and urban design.

2. Scenario Planning

Scenario planning has gained popularity in recent years. Its popularity and success is due in part to its approach of looking at different "what if?" alternatives before deciding on a particular policy direction. For example, scenario planning could look at the effects on transportation investment of different land-use patterns, different pricing assumptions, increasing risks associated with extreme weather, and different lifestyle decisions. Alternatively, different investment scenarios could be examined to determine the effect on system performance, such as on accessibility and mobility indicators. Not only does scenario planning provide key members of the community, such as business representatives, elected officials, and advocates, with the ability to define important trends and trade-offs, it also allows planners to identify which common investments across all scenarios should be undertaken, no matter which future occurs.

Scenario planning follows several steps.

- *Step 1: Research the driving forces*. Understand existing conditions and development trends.
- *Step 2: Determine patterns of interaction.* Consider how the driving forces combine to determine future conditions. A matrix helps to identify these outcomes.

- *Step 3: Create scenarios.* Planners should think through the implications of different strategies in different future environments.
- *Step 4: Analyze the implications.* Scenario planning is a tool for decision making. Showing the difference in the scenario outcomes through the use of visual tools enables the public to comprehend the impacts.
- *Step 5: Evaluate scenarios.* Scenarios can be measured against one another by previously agreed-upon indicators.
- *Step 6: Monitor implications.* Scenario planning is an ongoing process and should be reassessed due to changing conditions. [FHWA, 2011]

A good example of how scenarios can be used in transportation planning comes from Washington, DC. The Transportation Planning Board, the MPO for the Washington region, defined three scenarios in its update of the region's transportation plan based on different combinations of forecasted or desired land-use and transportation characteristics. These forecasts or desired directions were:

- *Constrained Long-Range Plan Land Use:* A cooperative forecast undertaken with the region's communities assumed that from 2015 to 2040, 25 percent of new households and 35 percent of new jobs would be located in targeted growth areas (TGAs).
- *Constrained Long-Range Plan Land Use Aspirations Forecast:* The aspirational (that is, desired) forecast assumed that 57 percent of new households and 58 percent of new jobs are located in TGAs.
- *Constrained Long-Range Plan Transportation Network*: Road and transit investments in the constrained investment plan.
- *Constrained Long-Range Plan Transportation Aspirations Network:* Variable pricing applied on an additional 740 new highway lane miles and 186 existing lane miles. Bus Rapid Transit (BRT) and circulator services are assumed with 274 new buses and approximately a 20 percent increase in service hours. [Kirby, 2013]

Table 16-3 shows the different combination of forecasts and transportation network assumptions that were the basis for the tested scenarios.

The types of analysis that occur in scenario analysis are shown in Figures 16-3 and 16-4. Not surprisingly given the assumed investment in transportation services or targeting of land use, those scenarios that concentrated land uses, provided more transit service, or made the use of the single-occupant motor vehicle more expensive saw the greatest increases in non-motor-vehicle use and the most reduction in vehicle delays.

The Delaware Valley Regional Planning Commission (DVRPC), the MPO for the Philadelphia, Pennsylvania, metropolitan area used scenario analysis to examine the impact of alternative investment levels on system performance and condition. The three scenarios included:

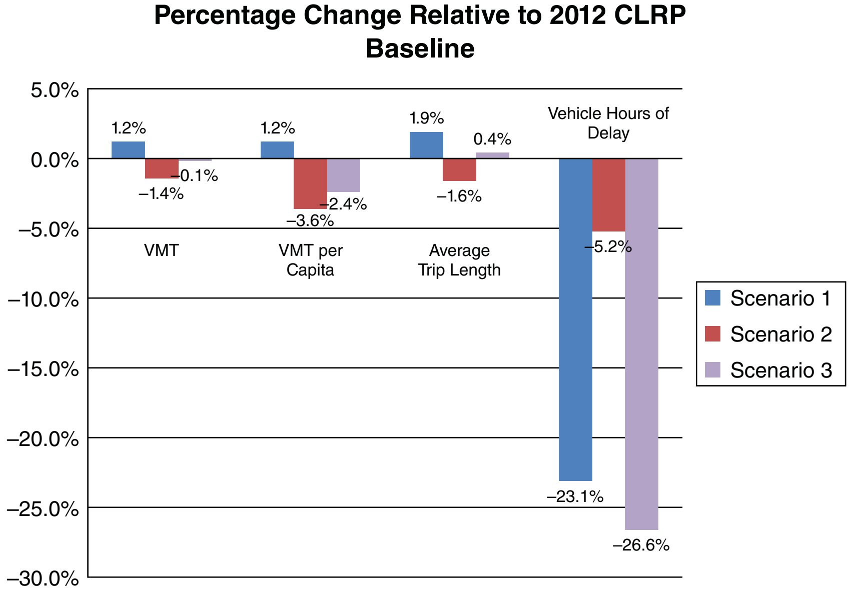
- The "high" scenario was a best-case situation for transportation funding in the region. This scenario assumed a 35 percent increase in reasonably anticipated funding over the life of the Connections 2040 Plan.
- The "medium" scenario was considered the likely investment level for transportation infrastructure. It was based on a continuation of present funding levels.
- The "low" scenario was a worst case development for regional transportation funding; this scenario assumed a 20 percent decrease compared to current transportation funding levels. [DVRPC, 2013]

Table 16-3. Combinations of Land Use and Transportation (CLRP) Assumptions for Scenario Definition, Washington DC

	Land Use	Transportation
2040 Baseline	Cooperative Forecast	2012 CLRP
Scenario 1: Transportation component only	Cooperative Forecast	CLRP Aspirations
Scenario 2: Land use component only	CLRP Aspirations	2012 CLRP
Scenario 3: Constrained Long-Range Plan (CLRP) Aspirations	CLRP Aspirations	CLRP Aspirations

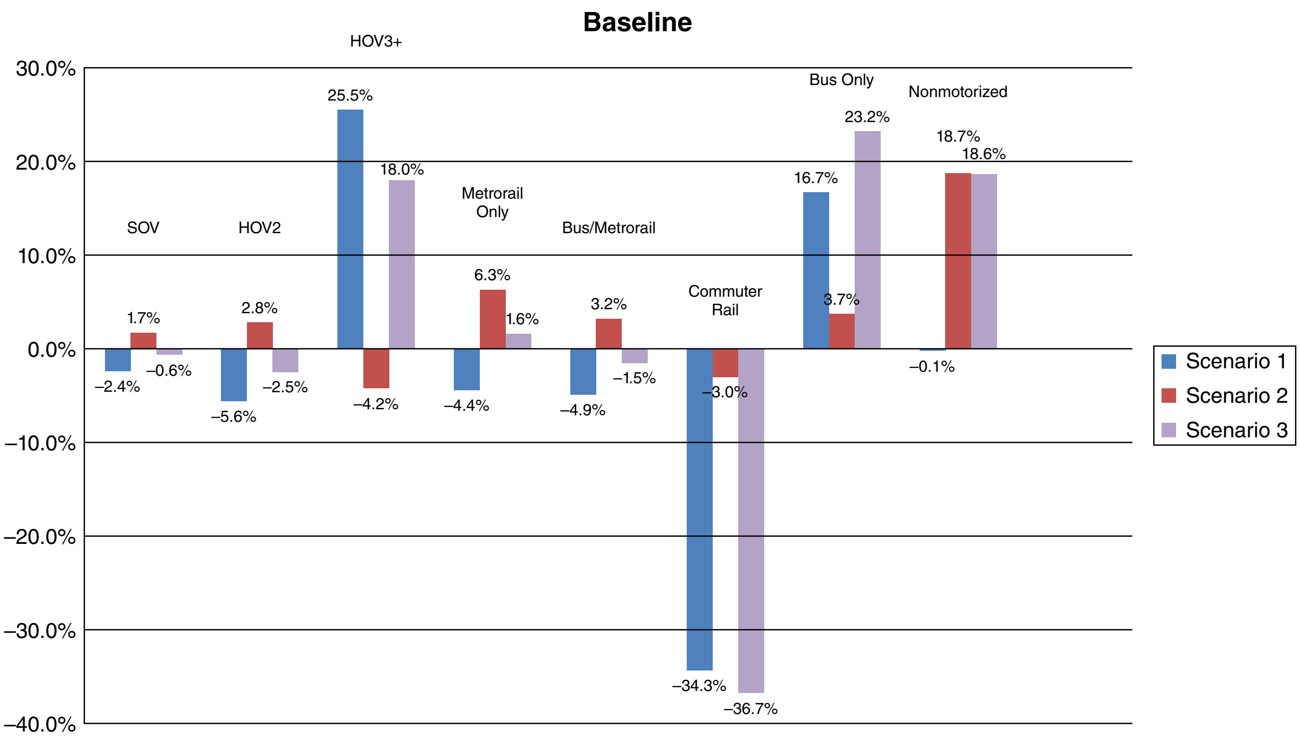
Source: Kirby, 2013

Figure 16-3. Scenario Analysis, System Performance, Washington, DC



Source: Kirby, 2013

Figure 16-4. Scenario Analysis, Mode Choice, Washington, DC

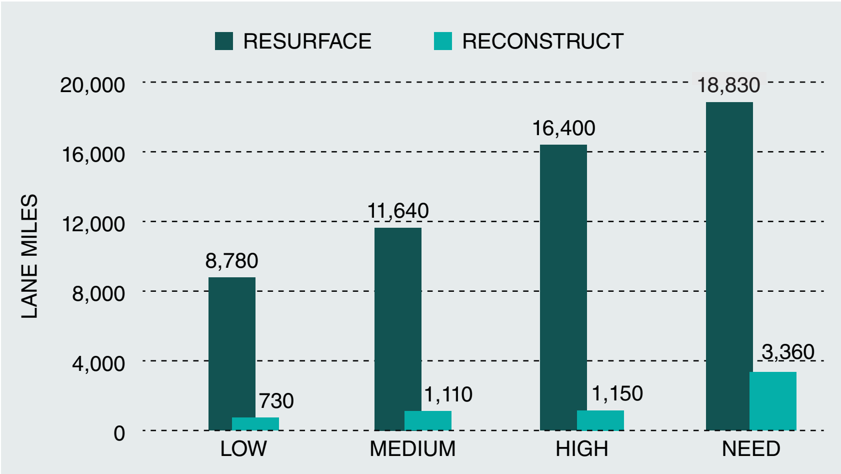


Source: Kirby, 2013

Figures 16-5 and 16-6 show the implications of varying levels of investment. Experience has shown in many states that providing this type of information to decision makers is very influential in getting them to understand the consequences to the transportation system of not raising revenues.

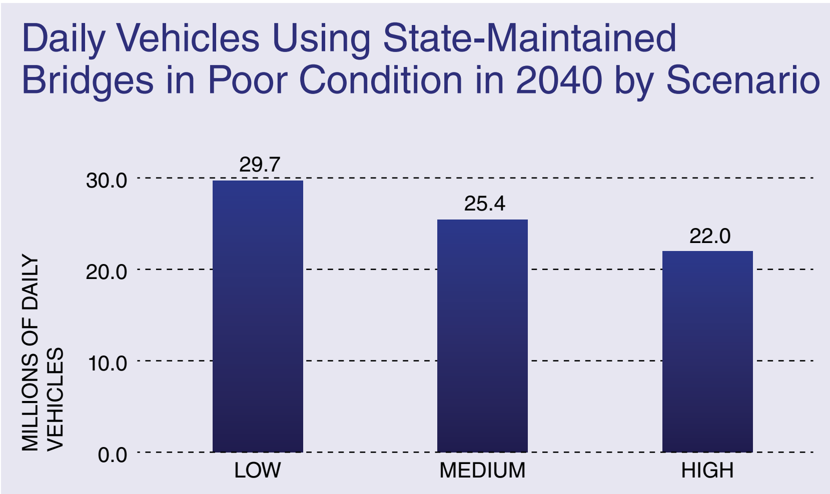
For information on scenario use in transportation planning, see [DVRPC, 2003; FHWA, 2011; Oregon DOT, 2013; Montana DOT, 2015] and visit: http://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/scenario_planning_guidebook.

Figure 16-5. State-Maintained Lane Miles of Reconstruction and Resurfacing, 2014–2040 by Scenario, DVRPC



Source: DVRPC, 2013

Figure 16-6. Daily Vehicles Using State-Maintained Bridges in Poor Condition in 2040 by Scenario, DVRPC



Source: DVRPC, 2013

H. Evaluating Transportation System Alternatives

Evaluation is the process of determining the desirability of different courses of action and presenting this information to decision makers in a comprehensive and useful form. Determining the desirability of an alternative requires, (1) defining how value is to be measured, (2) estimating the source and timing of the benefits and costs of the proposed actions, and (3) comparing these benefits and costs to determine a level of effectiveness for that alternative. Evaluation thus provides information to decision makers on the estimated impacts, trade-offs, and major areas of uncertainty associated with the analysis of alternatives. Not only does the magnitude of the impact have to be determined, but those who are positively or negatively affected should also be identified. [Meyer and Miller, 2014]

Thinking about the evaluation process should begin very early in planning because the evaluation criteria drive analysis and data collection activities. For example, if decision makers want to know how different alternatives compare with respect to traveler hours of delay, then both data collection and the results of analysis need to produce that information.

Multimodal transportation planning presents a special challenge to the evaluation process. As noted in a review of innovative practices, "multimodal transportation planning is best carried out when all modes are analyzed simultaneously and interactions among the modes are accounted for." [Transmanagement, 1998] Being able to compare modal

Table 16-4. Questions That Form the Basis of Evaluation
Given that a primary purpose of planning is to inform decisions, the following types of questions often define an evaluation process …
• What is the type of information decision makers want and need to make decisions regarding the benefits and costs associated with different decision options?
• What is the absolute magnitude of the benefits and costs associated with each alternative under consideration?
• What are the benefits and costs relative to all of the alternatives?
• How do the benefits associated with each alternative relate to the alternative's costs?
• To what extent does each alternative achieve the goals and objectives originally specified in the planning study?
• How will different groups perceive the absolute and relative impacts of each alternative?
• How do the benefits and costs of each alternative affect different population groups in the study area?
• What are the economic, community, and environmental impacts of each alternative?
• Are there uncertainties associated with the estimates of benefits and costs that could affect the overall determination of the "best" alternative? If so, how might these uncertainties change key assessment factors?
• What is the overall funding needed to implement each alternative? What is the life cycle cost and the funding needed over the life cycle of each alternative?
• What institutional, legal, or organizational changes are needed, if any, to implement an alternative?

Source: Meyer and Miller, 2014

alternatives in a way that does not bias the results toward one of the modes is a significant goal of the evaluation process.

Although the evaluation process—and the criteria used to compare alternatives—will be targeted on the issues being addressed in the planning study, there are some evaluation questions common to almost every planning study. Table 16-4 lists these questions. The information needed to answer these questions, however, will differ from one study to another.

Presenting the evaluation results in an understandable way is important to the success of the planning process. Tables 16-5 to 16-8 show the traditional way of presenting results. As shown, the evaluation information is divided into major categories—transportation system supply, trip-making behavior, transportation system demand, costs, and natural environment. The cells of the table contain numerical values or percentages, and are compared to a base case.

Some MPOs like to use subjective assessments or symbols to represent the level of magnitude of impact of the evaluation criteria in order to make the relative values more meaningful to decision makers. The effectiveness of either approach depends on the decision makers' level of comprehension and the relative difference in values of the evaluation measures (for example, it is hard to determine the relative value of two pedestrians versus three pedestrians in a walkable community evaluation category).

The reader is referred to chapter 7 on evaluation for more detailed information on the methods and tools that can be used for this stage of the planning process. In addition, [DVRPC, 2003; FHWA, 2011; Oregon DOT, 2013; and Montana DOT, 2015] are excellent references for those interested in scenario planning.

I. Prioritizing Projects and Program Development

Transportation planning leads to the identification of the most cost-effective strategies or projects identified during the process. In many planning studies, it is left to sponsoring agencies or to the policy-making board of the MPO to determine whether to fund the recommended actions. As noted earlier, in the United States, the LRTP must also include a financial plan, which takes a long-range look at how transportation investments are to be funded in relation to the needs over the time horizon of the plan. Funding sources must be identified, including funding sources

Table 16-5. Congested Vehicle Miles Traveled by Source, Sacramento, 2008–2035			
Travel Source	**2008**	**2020 Plan**	**2035 Plan**
Region Total			
Household-generated commute congested VMT (CVMT)[1]	1,711,500	1,767,100	2,128,300
Household-generated other CVMT	921,100	988,200	1,159,500
Total Household-Generated CVMT	2,262,600	2,745,300	3,287,800
Commute share of household-generated CVMT	65%	64%	66%
Commercial CVMT[2]	489,100	525,300	682,900
Externally generated CVMT[3]	175,800	208,000	308,000
Total CVMT	3,297,500	3,478,600	4,278,700
Per capita rates			
Population	2,215,000	2,519,900	3,086,200
Jobs	969,800	1,072,200	1,330,000
Household-generated CVMT per capita	1.19	1.09	1.07
Commercial vehicle + External CVMT per job	0.69	0.68	0.75
Total CVMT per capita	1.49	1.38	1.39
Percent Change in Congested VMT per Capita or per Job, Compared to 2008			
Household-generated CVMT per capita	n/a	−6.3%	−10.4%
Commercial vehicle + External CVMT per job	n/a	−0.2%	8.7%
Total CVMT per capita	n/a	−7.3%	−6.9%

[1]Household generated CVMT is cumulative vehicle travel by residents of the region on roadways which are at-or-above capacity, for their travel within the region. Household-generated CVMT is split into commute and other shares.

[2]Commercial vehicle VMT is cumulative vehicle travel for moving goods, services, and freight within the region. It includes commercial travel in passenger vehicles, light trucks, and vans as well as in larger trucks.

[3]Externally generated VMT is cumulative vehicle travel from residents outside the region, but who travel to destinations within the region, or travel through the region.

Source: Sacramento Area Council of Governments, 2012

Table 16-6. Comparison of Transit and Driving Accessibility within 30 Minutes from Environmental Justice (EJ) and Non-Environmental Justice Areas				
	Percent of Regional Total Accessible within 30 Minutes by Transit		**Percent of Regional Total Accessible within 30 Minutes by Car**	
Type of Accessibility 2005	**From EJ Area**	**From Non-EJ Area**	**From EJ Area**	**From Non-EJ Area**
Jobs 2008	7.1%	5.8%	49.8%	34.4%
Jobs 2035	10.5%	6.3%	47.4%	33.0%
Medical Jobs 2008	10.7%	6.7%	52.0%	36.3%
Medical Jobs 2035	11.1%	7.0%	49.0%	34.2%
Higher Education Enrollments, 2008	13.7%	8.4%	68.0%	45.3%
Higher Education Enrollments, 2035	17.7%	8.2%	70.2%	45.2%
Park Acres, 2008	5.5%	4.0%	40.6%	32.5%
Park Acres, 2035	5.5%	3.8%	39.4%	31.5%

Source: Sacramento Area Council of Governments, 2012

Table 16-7. Plan Area CO_2 Equivalent Emission Estimates for 2005, 2020, and 2035				
	CO_2e per capita (lbs. per day)	Modeled CO_2, Reductions	Off-Model Reductions[1]	Total Reductions from 2005
2005	23.0	n/a	n/a	n/a
2020	20.8	−9%	−1%	−10%
2035	19.7	−14%	−2%	−16%

[1]Off-model reductions account for effects of TSM, ITS, and TDM projects not accounted for in modeled network

Source: Sacramento Area Council of Governments, 2012

Table 16-8. Transit, Bicycle, and Walk Travel in Region, 2008 and Plan				
Mode of Travel		**2008**	**2035 Plan**	**2035 from 2008**
Weekday Person Trips by Mode[1]				
Transit trips		110,200	391,900	326,700
Bicycle trips		152,300	228,800	1,126,600
Walk trips		626,700	1,024,200	
Total trips		889,200	1,644,900	1,452,300
Per Capita Rates				
Population		2,215,000	3,086,200	3,348,000
Transit trips		0.05	0.13	0.10
Bicycle trips		0.07	0.07	0.034[2]
Walk trips		0.28	0.33	
Total trips		0.40	0.53	0.43
Percent Changes in Non-Private Vehicle Trips per Capita				
From 2008				
Transit trips		n/a	155.2%	96.1%
Bicycle trips		n/a	7.8%	−4.4%[3]
Walk trips		n/a	17.3%	
Total transit/bike/walk trips		n/a	32.8%	8.1%
From 2008 Plan				
Transit trips		n/a	30.1%	n/a
Bicycle trips		n/a	20.8%	n/a
Walk trips		n/a		n/a
Total transit/bike/walk trips		n/a	22.9%	n/a

[1]Estimates of weekday person trips by mode from regional travel demand model

[2]SACOG Plan, 2008

[3]Commercial and external travel was combined in the 2008 Plan

Source: Sacramento Area Council of Governments, 2012

for maintenance and operations of highways, transit, and all other transportation investments. Anticipated revenues from all available sources need to be included, such as federal, state, local governments, and other funding sources. The plan compares the anticipated revenues against costs of the transportation strategies to determine if there are enough funds to cover the proposed investment.

Determining funding feasibility is thus dependent on having good cost estimates. Cost estimates include those costs associated with preliminary engineering, right of way, construction, operation, maintenance, and environmental mitigation. Cost estimates associated with a project when first placed in the LRTP will most likely change as the project moves from concept to implementation (see chapter 5 on transportation finance and funding, and chapter 7 on evaluation for more discussion on cost estimation).

Forecasting future revenue streams for a long-range plan is a difficult challenge for MPOs. For example, the MPO must make a 20- to 25-year forecast of revenues, which for federal funds goes well beyond the 5- to 6-year statutory authorization period. The current approach to this dilemma is to forecast federal funds based on historic trends for the region, even though federal funding categories and project eligibility have been known to change over time. Nearly all federal transportation funding comes from FHWA or FTA, with funds allocated through formula or discretionary earmarks. The highway funding categories form the core of the federal transportation funding program. Each funding category has specific eligibility requirements although the trend in federal funding has been to allow funds to be flexed from one category to another. When exercised, this flexing option is most often used to flex highway funds to transit purposes.

State transportation revenues must also be included in the forecast. It thus becomes important to understand the state budget process, the likelihood of tax increases, the factors that could influence increasing or decreasing revenues from motor fuel taxes, the use of financial bonding (and thus the need to pay back debt), and the feasibility of road tolls.

Local government revenue forecasts are often the most problematic. Over the time horizon of the LRTP, local governments may supplement their revenues through local option sales taxes, property or other tax increases, and/or impact fees. Because most of these revenue sources depend on voter approval, it is very difficult to estimate with any certainty the availability of such funds in future years (see chapter 5 on transportation finance and funding for more discussion on revenue forecasting).

The financial plan for the TIP is more stringent than that for the LRTP. The state DOT and transit authorities must furnish expected revenue to the MPO to support the programming process. In air quality nonattainment areas, all regionally significant projects must be included in the TIP, regardless of funding source. The TIP must be financially constrained by year. Given this constraint, only projects with demonstrated revenue sources can be advanced. Additionally, in air quality nonattainment and maintenance areas, funds for projects in the first 2 years of the TIP/STIP must be available or committed. In addition to forecasting federal, state, and local revenues, the MPO must also account for any public/private partnerships or other innovative funding proposed by a project sponsor.

Once available revenue and expected project costs are available, the planning process must now identify which projects should receive priority and be programmed in the TIP. There are often more worthy projects than funding available, and this is certainly true for moving transportation projects from the long-range plan into the TIP. Thus, some means for establishing priorities must be developed. The most basic purpose of the TIP is to show the program of projects, strategies, and investments that will be funded over the next 4 to 5 years. It is the one document the public requests most often because it reflects the highest-priority transportation initiatives of the region.

The TIP must be updated at least every 4 years, although many metropolitan areas update more often as priorities change. Each MPO is required to have an amendment process for the TIP which must be documented in the region's public involvement/participation plan. Amendments occur quite often because of changes in engineering design and changes in priorities and costs. Some amendments require significant effort of the part of the MPO staff. For example, in nonattainment areas, amendments that change roadway capacity require a new conformity determination for air quality.

Good information sharing among the planning partners, such as the local governments, state DOT, and transit operators, is necessary for this tracking to be successful. MPOs should adopt policies to reprogram funds that are not being used in a timely way. San Francisco has a "Timeliness of Funds" policy and St. Louis, Missouri, MPO has a "Reasonable Progress" policy. Both policies are essentially "use it or lose it" policies. Delays in highway projects may provide an opportunity to move transit projects ahead without losing the federal funds allocated to the metropolitan area.

Prioritizing projects to move from the plan to the TIP is often the most difficult and contentious aspect of TIP development. Project recommendations can be developed in a number of ways. Project selection should be based on their level of achievement of the goals, objectives, and policies for the region, and thus MPOs often use a scoring system to determine which projects should be forwarded into the TIP. Some examples follow:

Puget Sound Regional Council (PSRC), Seattle. An example of such a scoring process from the Puget Sound Regional Council (PSRC) in Seattle is found in Table 16-9. The MPO board approved the testing of prioritization criteria to assess the effectiveness of the process and the level of understanding. The criteria included:

- *Air Quality*: Air quality impacts to health, the environment, and climate, as well as potential shifts toward cleaner fuels.
- *Freight*: Extent to which projects provide benefits to freight users of the transportation system (travel time and reliability) as well as a reduction in conflicts with other modes of travel, improves access to freight-related areas, and improves key freight-related facilities.
- *Jobs*: Extent to which projects support existing and new businesses and job creation.
- *Multimodal*: Extent to which projects provide alternatives to driving alone. The measure also addresses the extent to which projects incentivize or facilitate individual's use of those alternatives.
- *Puget Sound Land and Water*: Land- and water-related environmental issues, including storm water, hydrological function, critical areas and habitats, and the construction practices and materials in projects.
- *Safety and System Security*: Extent to which projects provide for safer travel, a likely reduction in fatalities or serious injury, and improved system security.
- *Social Equity and Access to Opportunity*: Extent to which projects improve mobility and/or reduce negative impact to minority, low income, elderly, youth, people with disabilities, and non-vehicle-owning populations, and whether they support access to opportunities.
- *Support for Centers*: Extent to which projects support existing and new population and employment in centers. In addition, the measure addresses the extent to which projects support transit-oriented development, development of housing in centers, accessibility to/from/within the center, and compatibility with the character of the community in which a project is located.
- *Travel*: Extent to which projects reduce congestion and delay, and improve flow. [PSRC, 2014]

<table>
<tr><th colspan="4">Table 16-9. Example Scoring for Freight Component of Plan Projects, Puget Sound Regional Council, Seattle</th></tr>
<tr><td></td><td colspan="3">Purpose: System performance benefits for freight. How well does the project provide benefits to freight-related system users by improving travel time, reliability, and efficiency for freight haulers (all freight modes)? and how well does the project reduce conflicts?</td></tr>
<tr><td rowspan="3">Points</td><td colspan="2">3</td><td>The project improves a facility identified as a freight bottleneck through the Washington State DOT's Truck Performance Measures program or other adopted agency plan.</td></tr>
<tr><td colspan="2">1</td><td>The project reduces conflict between freight modes (truck and rail), e.g., grade separation or bridge openings.</td></tr>
<tr><td colspan="2">1</td><td>The project reduces conflict with freight and one or more passenger modes, e.g., through separation of modes such as a pedestrian overpass or separated parallel bicycle facility.</td></tr>
<tr><td></td><td colspan="3">Purpose: Access to freight-related areas. How well does the project support planned development in Manufacturing and Industrial Centers (MICs) and other freight-related areas?</td></tr>
<tr><td rowspan="5">Points</td><td rowspan="2">Choose 1</td><td>2</td><td>The project improves access within or to more than one MIC (or between a MIC and a Regional Growth Center).</td></tr>
<tr><td>1</td><td>The project improves access within or to one MIC.</td></tr>
<tr><td colspan="2">1</td><td>The project improves access to an area identified in the Regional Freight Strategy as a freight generator.</td></tr>
<tr><td colspan="3">Purpose: Improves key freight facility. How well does the project serve designated Freight and Goods Transportation System routes?</td></tr>
<tr><td colspan="2">2</td><td>The project is on a designated T-1 or T-2 route.</td></tr>
<tr><td>Total</td><td colspan="2">10 (max)</td><td></td></tr>
</table>

Source: PSRC, 2014

Interestingly, in the final version of the prioritization approach, both numerical scores and pie symbols (full, 3/4, 1/2, 1/4, and empty) were used to convey the relative worth of the projects.

Berkshire Regional Planning Commission (BRPC). The Berkshire RPC has adopted an approach similar to that at the PSRC although in a much easier format. Every project is assigned a score of 1 point for each of the following criteria, for a total maximum of 3 points. Those projects have 3 points are given highest priority in the programming process. The three criteria are:

- *Regional Connectivity:* Projects that meet this threshold address a transportation link where there is no alternative route of comparable length. In general, these routes are classified within the National Functional Classification System as arterials.
- *Industrial and Commercial Access:* It is important that transportations investments facilitate freight movements. Projects that meet this threshold improve heavily traveled truck routes and access significant employment centers. Projects along NHS routes automatically meet this threshold.
- *Safety:* The most hazardous five percent (5%) of intersections within the region, based on reported crashes converted to an equivalent property damage calculation are eligible for Highway Safety Improvement Program (HSIP) funds. Projects that meet this threshold contain at least one intersection that is HSIP eligible. Projects with the same score are not listed in a particular order of priority. [BRPC, 2011]

Houston-Galveston Area Council (H-GAC). H-GAC uses both subjective and quantitative scoring criteria, including benefit/cost analysis, to rank the projects being considered for the TIP. [H-GAC, 2014] Table 16-10 shows the criteria and how they are estimated. They are replicated here in their entirety because the list provides a good example of many of the types of scoring points found in practice today.

Figure 16-7 shows the relationship between system goals, measures, and outcomes, and the types of projects selected as part of the capital program. This figure comes from Edmonton, Alberta, Canada, where the implementation of a light-rail transit line linked directly to goals of shifting mode splits in the region and in transforming Edmonton's urban form.

Chapter 7 provides more examples of approaches for prioritizing projects. In addition, chapter 5 on transportation finance, chapter 15 on statewide planning and chapter 17 on corridor planning describe project prioritization.

V. MONITORING SYSTEM AND PROGRAM PERFORMANCE

This step in the transportation planning process provides a feedback loop into the early stages of the next round of transportation planning. Performance measures and other means of assessing on a continual basis the performance and condition of a region's transportation system constitute the core of performance-based planning, which in the United States is now the predominant model of transportation planning. This is shown in the example below.

The Broward County's (Florida) new long-range transportation plan has identified numerous measures that will be used to monitor the progress in achieving plan objectives. This monitoring strategy is shown in Table 16-11.

The plan also noted that subjective measures, such as aesthetics and quality of life, are important to a plan's implementation and are monitored through the public outreach and education process.

VI. PUBLIC ENGAGEMENT

Public participation and engagement is one of the most important elements of the MPO transportation planning process. Public participation enhances the planning process by incorporating the needs of the community, and thus improving the decision-making process. There are many audiences that should have the opportunity to provide input into the regional planning process. These audiences can be as diverse as those simply having an interest in transportation, those doing business in the region, or organized advocacy groups. With the growing awareness of the importance of freight movement and the role of the private sector, private transportation providers should also have the opportunity to participate. Examples include private transit providers, freight and rail operators, and taxicab operators. Planners should also provide participation opportunities for low-income, minority, and elderly populations.

Table 16-10. Scoring Method, Houston-Galveston Area Council

Roadway/Mobility (Non-ITS) Projects—Planning Factors		
Planning Factors 50% and Benefit/Cost 50%		
Regional Impact	40 pts	• 20 pts—NHS/Principal Arterial or • 10 pts—Designated Evacuation Route + • 10 pts—Designated Heavy Cargo Route • 10 pts—Fixed Route Transit Corridor or used by other transit services outside of fixed route service areas.
Design/Corridor Mobility	40 pts	• 20 pts—Includes construction of raised medians, innovative intersections (e.g., roundabout, diverging diamond, single point urban interchange, etc.), or other significant safety/access management technique • 10 pts—Project includes a Ped/Bike Accommodation that meets or exceeds AASHTO standards • 10 pts—Project includes a significant ITS or other integrated technology component to increase facility efficiency and reliability
Community	20 pts	• 10 pts—Project is a recommendation in a Regional or local plan/study • 10 pts—Project provides needed connection or capacity identified in adopted Thoroughfare Plan

Benefit/Cost Methodology—Roadway/Mobility (Non-ITS)	
	B/C Methodology
Project Type(s): Roadway—Added Capacity *Data:* 2025 and 2040 Network Effects (Vehicle Hours of Travel and Travel Speeds) and Projected Facility Volumes *Source:* H-GAC 2040 Regional Travel Demand Model	• VHT savings grow from 2025 through 2045, or until facility reaches capacity • 2025–2045 VHT benefits monetized and discounted to 2015.
Project Type(s): Roadway—TSM (Intersection Improvements, Roadway Grade Separations), Roadway—Access Management *Data:* 2025 and 2040 Projected Facility Volumes and Travel Speeds *Source:* H-GAC 2040 Regional Travel Demand Model	• VHT savings calculated using TTI's delay lookup tables • VHT savings grow from 2025 through 2045, or until facility reaches capacity • 2025–2045 VHT benefits monetized and discounted to 2015.
Project Type(s): Roadway—TSM (Auxiliary Lanes) *Data:* (a) Estimated Capacity Increase (b) 2025 and 2040 Projected Facility Volumes and Travel Speeds *Source:* (a) Florida DOT, (b) H-GAC 2040 Regional Travel Demand Model	• Travel time savings grow from 2025 through 2045, or until facility reaches capacity • 2025–2045 VHT benefits monetized and discounted to 2015.
Project Type(s): Roadway—TSM (Railroad Grade Separations) *Data:* (a) Observed RR Crossing Delay, (b) 2025 and 2040 Projected Facility Volumes and Travel Speeds *Source:* (a) Sponsor, (b) H-GAC	• Observed delay (VHT) escalated to 2025 based on observed traffic count and projected 2025 facility volume • VHT savings grow from 2025 through 2045, or until facility reaches capacity • 2025–2045 VHT benefits monetized and discounted to 2015.
Project Type(s): Freight Rail *Data:* Estimated At-Grade Crossing Delay Reduction *Source*: Sponsor	• 2025–2045 20-year VHT benefits monetized and discounted to 2015.

(*continued*)

Table 16-10. (*Continued*)

Safety Projects	• Crash Cost Savings
Project Type(s): Safety Data: (a) Crash statistics for intersection/facility, (b) 2025 and 2040 Projected Facility Volumes and Travel Speeds Source: (a) Crash Records Information System (CRIS) or other comparable, (b) H-GAC 2040	• Estimate reduction in crash rates due to project design • Use model volumes to forecast 2025–2045 accident reductions, benefits monetized and discounted to 2015.
Asset Management/Operations (State or Good Repair Projects), Operating/Life-Cycle Cost Savings	
Project Type(s): Safety Data: Varies Source: Sponsor	• 20-year analysis of operating and/or maintenance (life-cycle) costs • Benefits monetized and discounted to 2015.

ITS/Operations Projects—Planning Factors, Answer yes or no			
Congestion/Safety			
30 pts max	5		**Incident/Event Management** • Will the system be an integral part to an incident management system?
	5		• Is the system on the National Highway System or other component of H-GAC's congestion mitigation process (CMP) network?
	5		• Will the system provide notification of a potential problem to facility users? (e.g., dynamic message signs, mobile device alerts, etc.)
	5		• Will the system give priority to emergency vehicles?
	5		• Will the system give priority to transit or high-occupancy vehicles?
	5		• Will the system utilize dynamic management of the facility to enhance travel time reliability? (e.g., ramp metering, variable speed limits, variable pricing, etc.)
Coordination			
40 pts max	10		**System Migration/Expandability** • Can the system expand the regional communications network?
	5		• Will the system NOT utilize proprietary systems that will not integrate with other systems in the region?
	15	5	**Integration and Information Sharing** • Will the system tie into a centralized operations center?
		10	• Will the system tie into another agency's systems to allow for the sharing of data?
		15	• Will the system allow for potential control by another agency in the event of a primary agency's loss of system control?
	5		• Will the system collect and provide data available for traveler information access?
	5		• Will the system allow for collection of data to address performance measures?
Asset Mgmt/Efficient Operations			
30 pts max	10		**Continuity of Operations** • Will the proposed system enhance continuity of operations in the event of a disruption?
	5		• Will the system allow for interagency redundancy?
	screen		**System Lifecycle/Maintenance Issues** • Is the projected lifespan of the system being installed five (5) years or greater?
	10		• Do you have a funded operations and routine maintenance program in place? (Please provide a 5-year budget as described in the financial plan worksheet.)
	5		• Does the project improve the efficiency of operations/maintenance expenses? (e.g., real-time system health/equipment condition, malfunction detection/diagnosis, etc.)

<table>
<tr><th colspan="4">Table 16-10. (Continued)</th></tr>
<tr><td colspan="4">Transit—Planning Factors, Answer yes or no</td></tr>
<tr><td colspan="4">Planning Factors 50% and Benefit/Cost 50%</td></tr>
<tr><td rowspan="3">Coordination/ Gaps in Service</td><td rowspan="3">30 pts</td><td>15</td><td>Connectivity to Other Modes
• 10 pts—Provides connection to other transit services (Fixed Route/Commuter/Rail/Demand Response/etc.)
• 5 pts—Provides pedestrian and bicycle accommodations</td></tr>
<tr><td>10</td><td>Documentation of Coordination (agreements/communications) with participating/affected:
• 5 pts—Local Gov’ts (counties/cities)
• 5 pts—Public transportation providers</td></tr>
<tr><td>5</td><td>• Project serves unmet need identified in Regional Coordinated Transportation Plan (RideTheGulfCoast.com) or other locally developed plan.</td></tr>
<tr><td>Ridership Plan</td><td colspan="2">20 pts</td><td>• Documentation showing expected ridership and potential growth. Backed by supporting data, reasonable and viable ridership given type of service and area to be served.</td></tr>
<tr><td rowspan="2">Economic Development</td><td rowspan="2">20 pts max</td><td>10</td><td>Transit Oriented Development:
• 10 pts—Project is intrinsic part of a joint-use development.
• 5 pts—Project demonstrates potential for adjacent transit-supportive development.</td></tr>
<tr><td>10</td><td>Improved Access to Opportunities
• 5 pts—Project is located in an area that meets the minimum recommended activity density threshold per acre (determined by analysis of population and employment density based on center type).
• 5 pts—Project provides access to job opportunities, unmet or enhanced needs.</td></tr>
<tr><td rowspan="3">Safety, Security & Operations</td><td rowspan="3">15 pts max</td><td>5</td><td>• Project plan details safety measures that will be taken to provide for safe services and connections.</td></tr>
<tr><td>5</td><td>• Project plan details safety and security measures that will be present at the facility or on the equipment.</td></tr>
<tr><td>5</td><td>• Use of intelligent transportation systems and other operation/service enhancing technologies.</td></tr>
<tr><td rowspan="3">State of Good Repair</td><td rowspan="3">15 pts max</td><td>5</td><td>• The bus or facility being replaced/repaired/maintained meet the life expectancy thresholds established by FTA or Preventive Maintenance Schedules recommended by the manufacturer or existing maintenance plan.</td></tr>
<tr><td>5</td><td>• Project addresses maintenance needs to maintain FTA State of Good Repair requirements.</td></tr>
<tr><td>5</td><td>• Project addresses need for expanded capacity.</td></tr>
<tr><td colspan="4">Benefit/Cost Methodology – Transit Projects</td></tr>
<tr><td colspan="2"></td><td colspan="2">B/C Methodology</td></tr>
<tr><td colspan="2">Project Type(s): Transit
Data: Various project related data (P&R spaces, ridership, etc.)
Source: Sponsor</td><td colspan="2">• Estimate vehicle miles traveled reduction from mode choice model or other appropriate method.
• Calculate annualized cost per VMT reduced over analysis period.</td></tr>
</table>

(*continued*)

Table 16-10. (*Continued*)

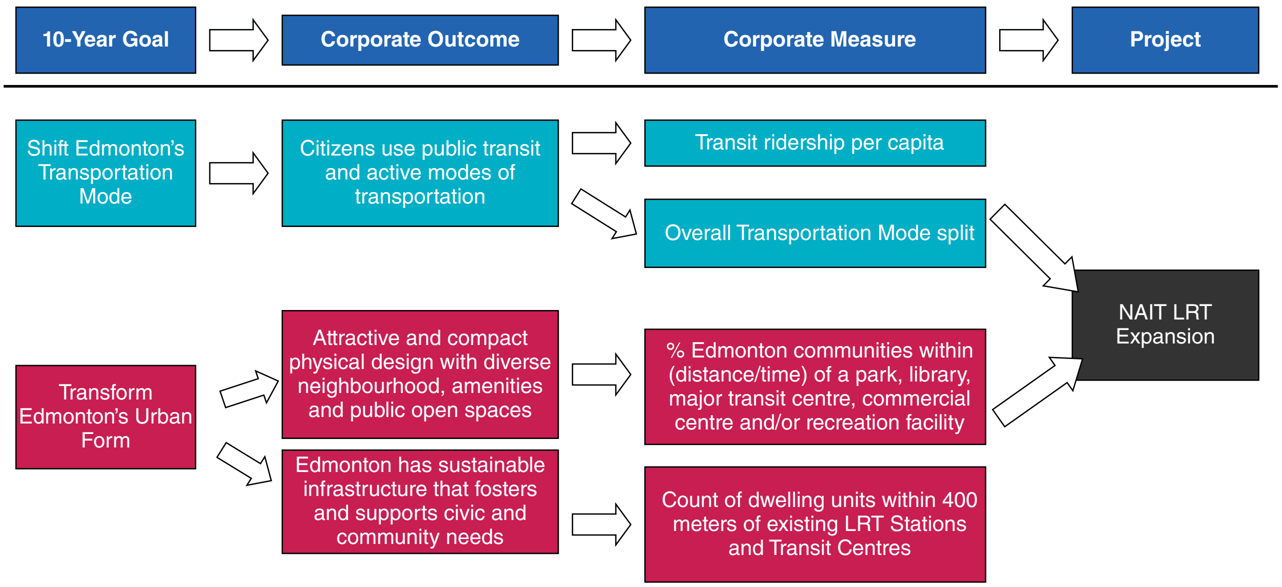
Pedestrian and Bicycle Projects—Planning Factors, Answer yes or no			
Planning Factors 75% and Benefit/Cost 25%			
Connectivity Economic Development	55pts max 20 pts max	15	**Barrier Elimination** Proposed facility: • Provides safe and convenient routes across barriers, such as freeways, railroads, and waterways; or • Closes a gap in the existing bicycle network that aligns with a regional bikeway shown on the Regional Bikeway Concept Map.
		15	**Pedestrian/Bicycle Facility Connections** • Proposed facility directly connects to existing pedestrian and bicycle facilities.
		15	**Transit Connections Plan** Proposed facility will be awarded: • 15 points if it directly links to a transit connection; • 10 points if it is within 0.25 miles of a transit connection; • 5 points if is within 0.26 to 0.50 miles of a transit connection; or • 3 points if the project sponsor demonstrates a potential for future connection to a transit system.
		10	**Connections to Regional Destinations** Proposed facility will be awarded: • 10 points if it provides connections to, or within, activity centers; or • 7 points if it is located outside of an activity center, but directly connects to one or more points of interest.
Pilot Project		5	• The proposed facility will be awarded 5 points if it is a pilot or first-time facility (no other facility of this type exists within a jurisdiction).
Safety	15 pts max	15	Proposed facility: • Provides pedestrian and/or bicycle facilities along a major corridor that are separated from vehicular traffic by a barrier or provides dedicated bicycle facilities along a low-volume, low-speed roadway that parallels a major corridor (within 1/2-mile) • Provides a new or improved pedestrian and/or bicycle connection to a school; • Provides exceptional accommodations for pedestrians and/or bicyclists at intersections; mid-block crossings; or at locations where there have been two (2) or more documented collisions between pedestrians/bicyclists and motor vehicles over the past five (5) years; and/or • Corrects existing pedestrian and bicycle facilities that do not comply with current ADA standards. The project will be awarded: • 15 points if three or more of the aforementioned characteristics are met; • 10 points if two of these characteristics are met; or • 5 points if one of these characteristics is met.
Existing Plans/Studies	5 pts max		• Proposed facility is identified within an H-GAC Special Districts Study, an H-GAC Livable Centers Study, or a comparable multi-jurisdictional or local plan or study.
Funding Leverage	5 pts max		Proposed facility leverages additional funding: • Sponsor has committed to provide more than 20% of local match; and/or • Sponsor has leveraged funding through partnerships to meet or exceed the 20% match.

Table 16-10. *(Continued)*

Pedestrian and Bicycle Projects—Planning Factors, Answer yes or no		
Planning Factors 75% and Benefit/Cost 25%		
Underserved Population Access	10 pts max	If all or part of the proposed facility is located within a Census Tract that has a higher proportion of the following populations than the regional average: • Minority populations • Low-income households • Senior populations (over 65) • Limited educational attainment • Zero automobile ownership • Female head of household • Limited English proficiency The project will be awarded: • 3 points if one of the aforementioned indicators is above the regional average; • 7 points if two of the aforementioned indicators are above the regional average; or • 10 points if three or more of the aforementioned indicators are above the regional average.

Source: HGAC, 2014

Figure 16-7. Linking Capital Projects with Goals, Measures, and Outcomes, Edmonton, Alberta, Canada



Source: City of Edmonton, 2012

TEA-21 called for MPOs to develop a documented public involvement process. This document was to state how the public would be involved in transportation issues and the planning process. The document was also to include information regarding public review of changes or amendments to the TIP or long-range plan. SAFETEA-LU and MAP-21 continued to stress public involvement by requiring MPOs to develop and use a public participation plan. This plan must provide reasonable opportunities for interested parties to comment on the content of the LRTP and TIP. The participation plan must be developed in consultation with all interested parties. All key documents produced by the MPO should be available to the visually impaired as well as in languages spoken in the region.

Chapter 24 presents greater detail on the different types of public involvement strategies and tools that can be used in regional transportation planning.

Table 16-11. Measures to Monitor Plan Progress, Broward County, Florida	
Move People	
Maintain infrastructure	• All operating and maintenance costs for existing and proposed facilities/services are fully funded through existing or reasonably expected revenue sources.
Achieve Level of Service standards	• Increase the proportion of facilities, by mode, operating at or exceeding Level of Service (LOS) standards.
Improve accessibility for all users of the system	• Increase the number of jobs within 30 minutes in-vehicle travel time (IVTT). • Reduce gaps in sidewalk and bicycle lane networks.
Shorten project delivery	• Reduce the number of projects requiring right-of-way.
Maximize transit ridership	• Increase transit mode share.
Create Jobs	
Reduce travel time to economic centers	• Reduce average in-vehicle travel time to central business districts, ports, and regional shopping centers.
Promote new development	• Increase transit service to redevelopment areas.
Minimize the cost of travel	• Reduce the amount of time and money spent by all travelers.
Maximize private investment	• Reduce net cost of public expenditure.
	• Increase community/public involvement.
Strengthen Communities	
Ensure benefits and cost are equitable	• Increase number of viable transportation alternatives.
	• Increase the number of jobs within 30 minutes IVTT.
Reduce accidents, injuries, and fatalities	• Reduce the number of transportation-related accidents, injuries, and fatalities for all modes.
Promote redevelopment	• Increase the number of public/private partnerships where the majority of residents make 50% less than the median income.
	• Increase the number of jobs within 30 minutes IVTT.
Ensure projects consider aesthetic improvements	• Increase the number of projects addressing aesthetics.
Provide options for nonmotorized travel	• Increase the number of sidewalk miles.
	• Increase the number of bicycle lane miles.
	• Reduce gaps in sidewalk and bicycle lane networks.
Promote environmental sensitivity	• Reduce energy consumption by person miles traveled.
	• Reduce tons of ozone precursors and greenhouse gases from mobile sources.

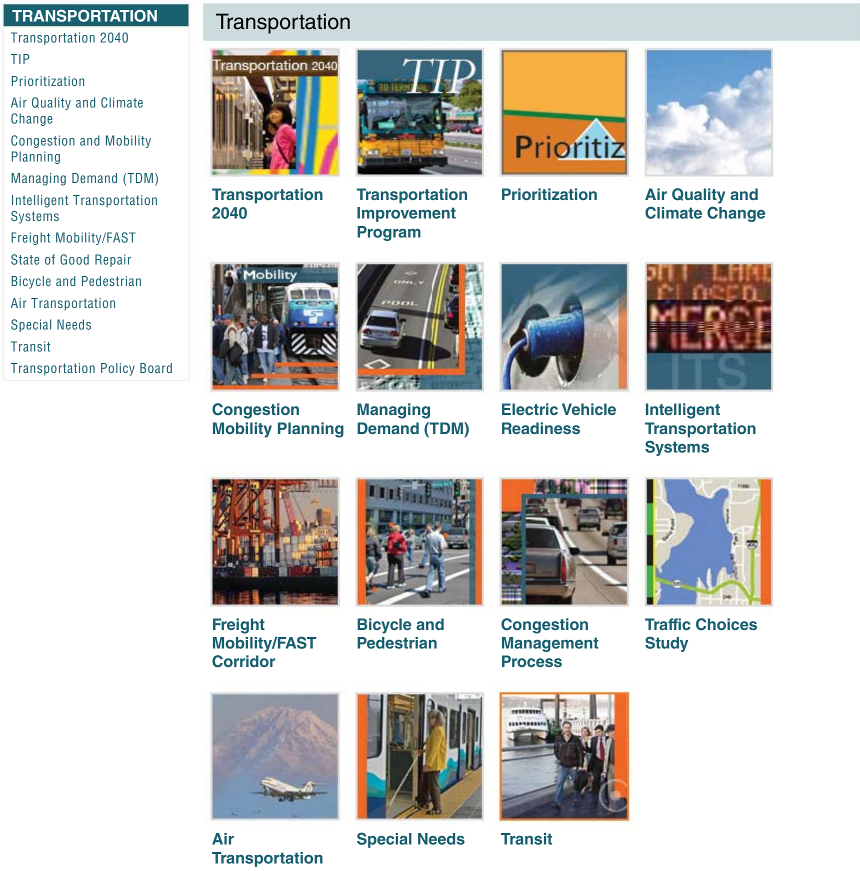
Source: Broward County MPO, 2014

VII. SPECIAL TOPICS FOR METROPOLITAN TRANSPORTATION PLANNING

Transportation planning is a dynamic process, both in responding to the changing context of a metropolitan area and in addressing new issues as they are added to the regional agenda. While some of the new issues result from federal and state policies, others become important because of the challenges facing the metropolitan area and its local communities. Figure 16-8, for example, is from the website of the Puget Sound Regional Council, Seattle, Washington. It shows the different types of planning studies and efforts that a typical large MPO would focus on. A more detailed list comes from SANDAG in San Diego, California. The following studies show a range of topics that a large MPO might get involved in.

- *State Route 11 and Otay Mesa East Port of Entry*—Improving the efficient movement of people, goods, and services between the United States and Mexico.
- *Riding to 2050, the San Diego Regional Bike Plan*—Establishing a network of regional bikeway corridors and proposes programs to support bicycling as a practical means of transportation.

Figure 16-8. Typical Planning Issues/Studies Faced by a Large MPO



Source: Puget Sound Regional Council, http://www.psrc.org/transportation

- *2050 Regional Transportation Plan*—Providing a balanced vision for the evolution of the region's transportation system through 2050.
- *San Diego Forward: The Regional Plan*—Providing a single vision for the San Diego region and an implementation program to make the vision a reality.
- *Chula Vista Light-Rail Corridor Improvements*—Palomar Street Grade Separation Study: Examining a grade separation project along a light rail line.
- *2014 Regional Transportation Improvement Program*—Providing a list of projects over a four-year period to be constructed or implemented.
- *Regional Complete Streets Policy*—Charting a course for addressing the needs of everyone, regardless of mode of travel, in all transportation projects developed by SANDAG.
- *I-15 Integrated Corridor Management*—Promoting individual transportation systems to be operated and managed as a unified corridor network.
- *San Ysidro Intermodal Transportation Center Study*—Identifying a multimodal concept for a world-class transportation center in the vicinity of the San Ysidro Port of Entry.
- *Call Box Motorist Aid Program*—Examining a free motorist aid service designed to help travelers who experience vehicle problems while on the highway.
- *Border Health Equity Transportation Study: A Case Study of the San Ysidro Community*—Looking at mobility challenges in San Ysidro, with particular emphasis on public health.
- *Smart Growth Trip Generation and Parking Study*—Identifying trip generation rates and parking demand associated with smart growth developments.

- *Work-Related Travel Survey*—Providing input into identifying and prioritizing transportation infrastructure projects.
- *I-5 South Multimodal Corridor Study*—Analyzing conceptual alternatives for multimodal improvements along I-5 between SR 54 and Chula Vista.
- *State of the Commute*—Tracking transportation progress throughout the San Diego region.
- *Intelligent Transportation Systems*—Managing performance of local and regional transportation systems.
- *Transportation Enhancement Activities Program*—Supporting smart growth development described in the Regional Comprehensive Plan.

The following special topics provide an overview of issues many MPOs are facing, and will continue to face, in the years to come. In fact, many MPOs have been dealing with these issues for several years.

A. Congestion Management Process (CMP)

The congestion management process (CMP), previously referred to as the congestion management system (CMS), was first introduced under ISTEA and was the only one of the seven management systems not made optional under later legislation. TMAs are required to develop a CMP that "provides for effective management of new and existing transportation facilities through the use of travel demand reduction and operational management strategies." [FHWA, 2014] The CMP provides decision makers with important information about congestion and thus focuses attention on improving the overall efficiency of the highway network. An important aspect of the CMP provision is that it calls for periodic monitoring and evaluation of congestion reduction strategies.

Because the CMP process forms the basis for the long-range plan and TIP development, the CMP must be implemented regionwide and be developed cooperatively with the MPO's planning partners. In air quality nonattainment areas, federal funds may not be advanced … for any highway project that will result in a significant increase in the carrying capacity for single-occupant vehicles unless the project is addressed through a congestion management process.

See chapter 10 on transportation systems management and operations for more information on the CMP process.

B. Security

After the terrorist attacks of September 11, 2001, greater emphasis was placed on security planning for metropolitan transportation systems. Because of its role in convening various agencies, the MPO can be a key organization in regional security planning, although security organizations will clearly take the lead. In addition, security is a planning factor that MPOs must consider in developing plans and programs.

The basic elements of a transportation-related security strategy include:

- *Prevention*—This could include facility design, surveillance, monitoring and sensing technologies.
- *Response/Mitigation*—Effective routing for emergency vehicles and evacuation of large numbers of people are part of this element.
- *Monitoring*—Public information becomes critical in this element.
- *Recovery*—The transportation system must go back to normal levels of operation as quickly as possible.
- *Investigation*—This element is primarily a police activity.
- *Institutional Learning*—Conducting an assessment after the incident allows all parties to obtain feedback and take steps to prevent new threats. [Meyer, 2006]

Although the structures of MPOs vary across the country, the role of the MPO as a leader in regional decision making establishes it as a strong choice to participate in security planning. The role the MPO plays in overall systems operation and maintenance are the same for security planning. There are five defined roles that an MPO may wish to serve.

- *Traditional Role*—Primary responsibility with security projects rests with the region's operating and security agencies.
- *Convener*—The MPO acts as a forum for security plans to be discussed and coordinated with each other.
- *Champion*—The MPO aggressively works toward a regional consensus on security planning.
- *Developer*—The MPO develops regional security plans.
- *Operator*—The MPO is responsible for implementing security strategies.

Because of the nature of security planning and the agencies involved with enforcement and protection, the process of considering security as part of the transportation planning process is very much a collaborative process, involving not only the owners and operators of the transportation system, but also agencies whose primary concern is protecting the nation's infrastructure.

C. Safety

MPOs should incorporate safety into the long-range transportation planning process by providing a forum for safety partner involvement, as well as including a concern for safety throughout all of its planning activities. This can enhance communication and understanding among transportation planners and safety practitioners about the planning processes and opportunities to include safety in long-range planning. Long-range plans should consider the safety of all users in the transportation system including pedestrians, bicyclists, motorists, transit riders, and heavy vehicles.

MPOs include safety as one of the criteria used in prioritizing projects for the TIP. Examples include:

- The Nashville, Tennessee, Area Metropolitan Planning Organization allocates 10 points out of 100 to safety and security concerns.
- The Puget Sound Regional Council in Seattle assigns 10 points out of 90 possible points for safety impacts.
- The Boston MPO provides 29 points out of a possible 154 points (19 percent) to safety considerations.
- The Mid-Region Metropolitan Planning Organization, the MPO for Albuquerque, New Mexico, assigns 7 out of 65 points (11 percent) to safety.
- The Denver Regional Council of Governments (DRCOG) assigns safety points that vary by type of project. For example, for roadway capacity and operational improvement projects, 7 out of 100 points are assigned to safety benefits; pedestrian and bicycle projects can earn 12 out of 100 points for their safety benefits.
- The Bi-State Regional Commission, the MPO for the Quad City metropolitan area of Illinois and Iowa, gives safety 20 percent of the project score for highway projects. The scoring is based on the project's past crash history, severity of the crashes, and crash rate.

MPOs are increasingly adding safety planning to their core mission work programs. An example is the Mid-America Regional Council (MARC) in Kansas City. MARC is part of the Destination: Safe Coalition, which is a partnership between local agencies such as the Kansas Highway Patrol, Missouri Highway Patrol, the state DOTs, and numerous other safety advocates. This coalition provides a framework for establishing the region's safety priorities, as well as coordinating implementation activities. See chapter 23 for more detail on safety planning.

D. Management, Operations, and Intelligent Transportation Systems (ITS)

Transportation management and operations (M&O) refers to an integrated program to optimize the performance of existing (and programmed) infrastructure by implementing multimodal, intermodal, and often cross-jurisdictional systems, services and projects designed to preserve capacity and improve security, safety, and reliability. Federal law requires transportation plans for metropolitan areas to provide "operational and management strategies to improve the performance of the existing transportation facilities to relieve vehicular congestion and maximize the safety and mobility of people and goods."

Through the use of technology, such as ITS, GIS, and GPS, coordination and collaboration can occur among jurisdictions and agencies. Most importantly, regional collaboration and coordination means operations-oriented planners within transportation and public safety agencies working with MPO planners to create regional operations policies and programs. Data sharing, funding and resource sharing, and development of the regional ITS architecture are a few of the key ways operations professionals can work with metropolitan planners.

Some examples of regional M&O projects include work zone management programs, regional incident management programs, special event management, regional signal coordination, HOV lane development, emergency response and security planning, and the development of regional traffic management centers. The MARC in Kansas City, for example, has established Operation Green Light, which is a regional effort to improve traffic flow and reduce vehicle emissions. This M&O project coordinates traffic signal timing plans between the state DOT and 17 area cities. The effort requires new communication equipment and software so traffic signals can communicate with each other and a central operations center. Ultimately, enhancements to signal timing will improve the flow of traffic on key arterials in the region as well as contribute to reduction in harmful air emissions. See chapter 10 for further discussion of transportation systems management and operations.

Federal law also requires metropolitan areas to have a regional ITS architecture, a framework that outlines how information processing, communication technologies and advanced control strategies will be applied consistently throughout the region to improve transportation system performance. Many MPOs have taken primary responsibility for preparing these plans. Any ITS project that requires federal funding must be consistent with this regional architecture. The ITS architecture should include an operational concept that explains the roles and responsibilities of participating agencies. It also should include agreements required for operations. Any ITS project funded in the region's TIP must be a part of the regional ITS architecture. Therefore, the metropolitan planner must be aware of key ITS strategies and work with local governments to plan and program the most cost-efficient projects.

An example of the types of strategies and actions that can be included in a regional M&O strategy comes from San Diego. The SANDAG "Smart Growth Tool Box" includes the following strategies. [SANDAG, 2013]

Systems Development Measures

- Improve the current system by enhancing convenience and travel speed of bus and rail services.
- Implement new transit services that will improve transit in more areas and offer new service types designed to attract new riders to transit.
- Enhance the transit customer experience to make transit easier, safer, and more enjoyable to use.
- Continue to develop and enhance active transportation through bicycle and pedestrian facilities and bike lockers, and implementation of the Regional Bicycle Plan.
- Continue to develop and enhance safe routes to schools plans and strategies.

Transportation System Management (TSM) Measures

- Pursue multimodal integration and performance-based management, including performance monitoring and real time modeling/simulation.
- Enhance traveler information capabilities.
- Improve freeway and arterial management.
- Improve transit service management—bus and light rail, including regional scheduling system (RSS), regional transit management system (RTMS), positive train control (PTC), and centralized train control (CTC).
- Support electronic payment services including Compass Card, FasTrak® Open Road Tolling, and smart parking systems.
- Consider advanced technologies including wireless detection, real-time multimodal modeling, and simulation, etc.

Transportation Demand Management (TDM) Measures

- Support iCommute—the regional TDM program.
- Support the region's TDM strategy—outreach, education, and financial incentives.
- Encourage TDM programs, including regional vanpool, carpool, buspool, school services (SchoolPool), telework and alternative work schedules, bicycle encouragement programs; and multimodal solutions including first- and last-mile solutions, Compass Card integration, and 511 advanced traveler information services.
- Implement new ways of planning corridors and considering construction mitigation.
- Utilize performance monitoring.

See chapter 10 on transportation systems management and operations planning.

E. Freight Mobility

Transportation planning historically has focused on passenger transportation, with little attention given to the movement of freight and goods. Beginning in the early 1990s, with a growing concern for freight movement being incorporated into federal transportation legislation, many MPOs began to conduct freight planning. Many added a freight advisory committee to its planning structure, and included freight-oriented prioritization criteria in the programming process. A freight-related performance measure is now part of the federally required system monitoring requirements, with many MPOs, including several additional measures relating to freight movement. Given the importance of the freight and logistics to a regional economy, it seems likely that freight planning will continue to be an important concern to transportation planners in future years.

See chapter 22 on freight planning for further information.

F. Asset Management

Asset management is a set of guiding principles used to make informed resource allocation decisions. Resource allocation refers to funds spent on programs, projects, and activities. The entire life cycle of transportation projects must be considered. Preservation, operations, and capacity expansion are the three types of investment categories where asset management is most relevant.

The update of the long-range plan provides an opportunity to set policy goals relating to system preservation and resource allocation. By establishing performance measures as part of the planning process, a system for monitoring assets can be established. The metropolitan planner must also have a good understanding of analysis tools used in asset management, such as system physical conditions, real-time operations data, crash statistics, and pavement and bridge management systems. See chapter 8 for more discussion on asset management.

G. Environmental Justice

Three basic principles serve as the foundation for environmental justice:

1) To avoid, minimize, or mitigate disproportionately high and adverse human health and environmental effects, including social and economic effects, on minority and low-income populations.
2) To ensure the full and fair participation by all potentially affected communities in the transportation decision-making process.
3) To prevent the denial of, reduction in, or significant delay in the receipt of benefits by minority and low-income populations. [FHWA, 2015]

Recipients of federal aid are required to certify, and the U.S. DOT must ensure nondiscrimination under Title VI of the Civil Rights Act of 1964 and many other laws, regulations, and policies. In 1997, the U.S. DOT issued its *DOT Order to Address Environmental Justice in Minority Populations and Low-Income Populations* to summarize and expand upon the requirements of Executive Order 12898 on Environmental Justice. This executive order applies to all policies, programs, and other activities that are undertaken, funded, or approved by FHWA, FTA, or other U.S. DOT agencies. Processes and activities covered by this order include:

- Policy decisions
- Systems planning
- Metropolitan and statewide planning
- Project development and environmental review under NEPA
- Preliminary design
- Final design engineering
- Right of way
- Construction
- Operations and maintenance

MPOs can help local officials understand how Title VI and environmental justice requirements improve planning and decision making. To certify compliance with Title VI and address environmental justice, MPOs need to:

- Enhance their analytical capabilities to ensure that the LRTP and TIP comply with Title VI.
- Identify residential, employment, and transportation patterns of low-income and minority populations so their needs can be identified and addressed and the benefits and burdens of transportation investments can be fairly distributed.
- Evaluate and—where necessary—improve their public involvement processes to eliminate participation barriers and engage minority and low-income populations in transportation decision making.

See chapter 7 on evaluation for further discussion on environmental justice.

H. Travel Demand Management

Travel demand management (TDM) is a general term for various strategies that increase transportation system efficiency. TDM focuses on reducing the demand for single-occupant vehicle travel. The availability of information about transportation services and conditions has been shown to influence travel demand. Information affects demand by influencing the choices that people make about how, when, where, whether, and which way they travel to their destinations.

Managing demand goes beyond encouraging travelers to change their travel mode from driving alone to a carpool, vanpool, public transit vehicle, or other commute alternative. Managing demand is about providing all travelers, regardless of whether they drive alone, with choices of location, route, and time of travel, not just mode of travel. Real-time traveler information systems can be used at employment centers and to manage critical shifts in demand such as occur for special events, tourist activity, incidents and emergencies, schools, shopping centers, recreation areas, medical facilities, and weather problems.

See chapter 14 for more information on travel demand management.

VIII. SUMMARY

Metropolitan areas have become a major focus of the nation's economic activity and the center of the social, political, and governmental functions in our society. The importance of these areas has steadily increased since 1920, when, for the first time, the majority of the U.S. population lived in an urban area. Recognizing the need for the coordinated and cooperative provision of infrastructure, the federal government and, in some cases, state governments have required local governments to plan for the future infrastructure expansion needed to support regional population growth. Nowhere has this influence been more pronounced than in transportation.

Metropolitan-level transportation planning provides the vision and the blueprint for a region's transportation investment strategy. In addition, the transportation planning process usually includes a wide variety of studies and public outreach activities that encompass a range of transportation issues facing a metropolitan region and its communities. In today's environment of more local control and responsibility for the funding and provision of transportation services, metropolitan transportation planning becomes a critical part of a region's strategy to prepare for future challenges. The metropolitan transportation planning process is vital to the success of these areas. It provides opportunities to reach consensus and resolve conflicts.

Planning is a continuous process. The reason for reconsidering priorities and updating transportation plans is that no one can forecast the future with certainty. For nearly 40 years, the MPO has proven itself to be the organization where disparate groups can come together and reach consensus on the future transportation system for a metropolitan area.

How will the MPO as an institution be effective for the next 40 years? The MPO must continually monitor its work and reinvent itself to accommodate changing needs in the region. Political climates change, as do MPO staffs. Even planning partners change as new organizations or authorities are created by state legislatures.

The MPO must continue to be the region's leader in technical tools and data. It must be seen as the "go to" organization for answers to regional transportation questions. The MPO must remain objective in its analysis of various alternatives, with recommendations made from sound technical data. The MPO is the regional leader and can command influence over many planning activities. Key policies developed by the MPO will determine land-use and economic development decisions that have great impact on growth and a region's quality of life.

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Table Appendix A. Goals, Objectives, and Strategies from Minneapolis-St. Paul, MN [MetCouncil, 2015]

Goal	Objectives	Strategies
Transportation System Stewardship		
Sustainable investments in the transportation system are protected by strategically preserving, maintaining, and operating system assets.	Efficiently preserve and maintain the regional transportation system in a state of good repair. Operate the regional transportation system to efficiently and cost-effectively connect people and freight to destinations	Regional transportation partners will place the highest priority for transportation investments on strategically preserving, maintaining, and operating the transportation system.
		Regional transportation partners should regularly review planned preservation and maintenance projects to identify cost-effective opportunities to incorporate improvements for safety, lower-cost congestion management and mitigation, transit, bicycle, and pedestrian facilities.
		The Council and regional transit providers will use regional transit design guidelines and performance standards, as appropriate based on Transit Market Areas, to manage the transit network, to respond to demand, and balance performance and geographic coverage.
		Airport sponsors will prepare a long-term comprehensive plan (LTCP) for each airport every five years and submit it to the Metropolitan Council for review to ensure that plans for preservation, management and improvement of infrastructure at each airport are consistent with the regional aviation system plan.
Safety and Security		
The regional transportation system is safe and secure for all users.	Reduce crashes and improve safety and security for all modes of passenger travel and freight transport. Reduce the transportation system's vulnerability to natural and man-made incidents and threats.	Regional transportation partners will incorporate safety and security considerations for all modes and users throughout the processes of planning, funding, construction, operation.
		Regional transportation partners should work with local, state, and federal public safety officials, including emergency responders, to protect and strengthen the role of the regional transportation system in providing security and effective emergency response to serious incidents and threats.
		Regional transportation partners should monitor and routinely analyze safety and security data by mode and severity to identify priorities and progress.
		Regional transportation partners will support the state's vision of moving toward zero traffic fatalities and serious injuries, which includes supporting educational and enforcement programs to increase awareness of regional safety issues, shared responsibility, and safe behavior.
		The Council and regional transit providers will provide transit police services and coordinate with public safety agencies to provide a collaborative approach to safety and security.
		Regional transportation partners will use best practices to provide and improve facilities for safe walking and bicycling, since pedestrians and bicyclists are the most vulnerable users of the transportation system.
		Airport sponsors and air service providers will provide facilities that are safe, secure and technologically current.

Table Appendix A. (*Continued*)		
Goal	**Objectives**	**Strategies**
Access to Destinations		
People and businesses prosper by using a reliable, affordable, and efficient multimodal transportation system that connects them to destinations throughout the region and beyond.	Increase the availability of multimodal travel options, especially in congested highway corridors. Increase travel time reliability and predictability for travel on highway and transit systems. Ensure access to freight terminals such as river ports, airports, and intermodal rail yards. Increase transit ridership and the share of trips taken using transit, bicycling and walking. Improve multimodal travel options for people of all ages and abilities to connect to jobs and other opportunities, particularly for historically under represented populations.	Regional transportation partners will continue to work together to plan and implement transportation systems that are multimodal and provide connections between modes. The Council will prioritize regional projects that are multimodal and cost-effective and encourage investments to include appropriate provisions for bicycle and pedestrian travel.
		Local units of government should provide a system of interconnected arterial roads, streets, bicycle facilities, and pedestrian facilities to meet local travel needs using Complete Streets principles.
		The Council, working with MnDOT through their Enhancing Financial Effectiveness (EFE) efforts, and other relevant jurisdictions, will continue to maintain a Congestion Management Process for the region's principal arterials to meet federal requirements. The Congestion Management Process will incorporate and coordinate the various activities of MnDOT, transit providers, counties, cities and transportation management organizations to increase the multimodal efficiency and people-moving capacity of the National Highway System.
		Regional transportation partners will promote multimodal travel options and alternatives to single occupant vehicle travel and highway congestion through a variety of travel demand management initiatives, with a focus on major job, activity, and industrial and manufacturing concentrations on congested highway corridors and corridors served by regional transit service.
		The Council will work with MnDOT and local governments to implement a system of MnPASS lanes and transit advantages that support fast, reliable alternatives to single-occupancy vehicle travel in congested highway corridors.
		The Council will support an interagency approach to preserving right-of-way for future transportation projects that are consistent with the Transportation Policy Plan.
		Regional transportation partners will manage and optimize the performance of the principal arterial system as measured by person throughput.
		Regional transportation partners will prioritize all regional highway capital investments based on a project's expected contributions to achieving the outcomes, goals, and objectives identified in Thrive MSP 2040 and the Transportation Policy Plan.
		The Council will support investments in A-minor arterials that build, manage, or improve the system's ability to supplement the capacity of the principal arterial system and support access to the region's job, activity, and industrial and manufacturing concentrations.
		Regional transportation partners will manage access to principal and A-minor arterials to preserve and enhance their safety and capacity. The Council will work with MnDOT to review interchange requests for the principal arterial system.

(*continued*)

Table Appendix A. (*Continued*)		
Goal	**Objectives**	**Strategies**
People and businesses prosper by using a reliable, affordable, and efficient multimodal transportation system that connects them to destinations throughout the region and beyond.	*(Objectives Repeated)* Increase the availability of multimodal travel options, especially in congested highway corridors. Increase travel time reliability and predictability for travel on highway and transit systems. Ensure access to freight terminals such as river ports, airports, and intermodal rail yards. Increase transit ridership and the share of trips taken using transit, bicycling and walking. Improve multimodal travel options for people of all ages and abilities to connect to jobs and other opportunities, particularly for historically under represented populations.	The Council and regional transit providers will expand and modernize transit service, facilities, systems, and technology, to meet growing demand, improve the customer experience, improve access to destinations, and maximize the efficiency of investments.
		Regional transportation partners will invest in an expanded network of transitways that includes but is not limited to bus rapid transit, light rail, and commuter rail. Transitway investments will be prioritized based on factors that measure a project's expected contributions to achieving the outcomes, goals, and objectives identified in Thrive MSP 2040 and the Transportation Policy Plan.
		The Council will provide paratransit service complementary to the region's regular route transit system for individuals who are certified by the Council under the Americans with Disabilities Act (ADA).
		The Council and regional transit providers will provide coordinated transit options, including general public dial-a-ride and vanpool subsidies, in areas of the region not served by regular-route transit. Service levels for these options will be based on available resources and needs.
		Regional transportation partners should focus investments on completing Priority Regional Bicycle Transportation Corridors and on improving the larger Regional Bicycle Transportation Network.
		Regional transportation partners should fund projects that provide for bicycle and pedestrian travel across or around physical barriers and/or improve continuity between jurisdictions.
		Regional transportation partners will provide or encourage reliable, cost-effective, and accessible transportation choices that provide and enhance access to employment, housing, education, and social connections for pedestrians and people with disabilities.
		The Council, MnDOT, regional railroad authorities, and railroad companies will pursue short- and long-term improvements to accommodate future freight and passenger rail demand.
		The Council and MnDOT should work together with cities and counties to provide efficient connections from major freight terminals and facilities to the regional highway system, including the federally designated Primary Freight Network.
		The Council and airport sponsors will maintain a system of reliever airports to augment the Minneapolis-Saint Paul International Airport that are accessible within reasonable travel times from all parts of the metropolitan area.

Table Appendix A. (*Continued*)		
Goal	**Objectives**	**Strategies**
Competitive Economy		
The regional transportation system supports the economic competitiveness, vitality, and prosperity of the region and state.	Improve multimodal access to regional job concentrations identified in Thrive MSP 2040. Invest in a multimodal transportation system to attract and retain businesses and residents. Support the region's economic competitiveness through the efficient movement of freight.	The Council and its transportation partners will identify and pursue the level of increased funding needed to create a multimodal transportation system that is safe, well maintained, offers modal choices, manages and eases congestion, provides reliable access to jobs and opportunities, facilitates the shipping of freight, connects and enhances communities, and shares benefits and impacts equitably among all communities and users.
		The Council will coordinate with other agencies planning and pursuing transportation investments that strengthen connections to other regions in Minnesota and the Upper Midwest, the nation, and world including intercity bus and passenger rail, highway corridors, air service, and freight infrastructure.
		The Council and its partners will invest in regional transit and bicycle systems that improve connections to jobs and opportunity, promote economic development, and attract and retain businesses and workers in the region on the established transit corridors.
		The Council, MnDOT, and local governments will invest in a transportation system that provides travel conditions that compete well with peer metropolitan areas.
		The Council, Metropolitan Airports Commission, MnDOT, and other agencies will work together to maintain a strong regional airport system, including maintaining the Minneapolis-Saint Paul International Airport as a major national and international passenger hub and reliever airports that serve business travel.
		The Metropolitan Airports Commission should periodically update its airport economic impact studies and commercial air-service competition plan to determine facility and service improvements needed at the region's airports to foster a competitive regional economy.

(*continued*)

Table Appendix A. (*Continued*)

Goal	Objectives	Strategies
Healthy Environment		
The regional transportation system advances equity and contributes to communities' livability and sustainability while protecting the natural, cultural, and developed environments.	Reduce transportation-related air emissions. Reduce impacts of transportation construction, operations, and use on the natural, cultural, and developed environments. Increase the availability and attractiveness of transit, bicycling, and walking to encourage healthy communities and active car-free lifestyles. Provide a transportation system that promotes community cohesion and connectivity for people of all ages and abilities, particularly for historically under represented populations.	Regional transportation partners recognize the role of transportation choices in reducing emissions and will support state and regional goals for reducing greenhouse gas and air pollutant emissions. The Council will provide information and technical assistance to local governments in measuring and reducing transportation-related emissions.
		The Council and MnDOT will consider reductions in transportation-related emissions of air pollutants and greenhouse gases when prioritizing transportation investments.
		Regional transportation partners will plan and implement a transportation system that considers the needs of all potential users, including children, senior citizens, and persons with disabilities, and that promotes active lifestyles and cohesive communities. A special emphasis should be placed on promoting the environmental and health benefits of alternatives to single-occupancy vehicle travel.
		Transportation partners will protect, enhance, and mitigate impacts on the cultural and built environments when planning, constructing, and operating transportation systems.
		Regional transportation partners will use a variety of communication methods and eliminate barriers to foster public engagement in transportation planning that will include special efforts to engage members of historically underrepresented communities, including communities of color, low-income communities, and those with disabilities to ensure that their concerns and issues are considered in regional and local transportation decision making.
		Regional transportation partners will avoid, minimize, and mitigate disproportionately high and adverse impacts of transportation projects to the region's historically underrepresented communities, including communities of color, low-income communities, and those with disabilities.

Corridor Planning[1]

I. INTRODUCTION

A corridor refers to a relatively well-defined geographic area that handles travel flows, usually centered around one or more major transportation facilities (for example, a freeway, commuter rail line, or express bus services). The corridor is often defined in terms of serving a travel shed within which trips are focused in a general linear pattern. Corridor plans determine the need for facilities or services among activity centers or other logical termini, as well as identify transportation investments to complement existing or planned land use. Traditionally, corridors were oriented radially from the suburbs to the center city. With the rapid growth in population and employment in the suburbs during the past 40 years, many corridor studies now focus on suburb-to-suburb trip patterns.

Corridor planning can focus on many different characteristics of corridor system performance. For example, corridor planning can address high-crash locations, increasing levels of congestion, restricted freight movements, changing land-use patterns, and the individual or cumulative effects of each on the current or future corridor transportation system. In this sense, a corridor plan is targeted geographically on needs within the corridor.

The decision to conduct a corridor study should consider its relationship to the regional transportation plan (RTP) update process and whether the study can provide typical solutions to problems found throughout the region. A corridor study conducted at the right time and with clear objectives could thus provide important information to the metropolitan transportation investment decision-making process and the RTP update. Decisions resulting from a corridor plan may lead directly to project definitions, design, and environmental analyses requiring a degree of detail that may be absent from a broader planning process.

This chapter examines the different characteristics of corridor planning, the reasons why corridor plans are conducted, and the steps typically followed. The following topics are covered: the rationale for conducting corridor planning; types of corridor studies that occur in practice, usually defined by geographic scale (for example, local, regional, state, and multistate); the relationship between transportation corridor investments and land use/urban design; major components of a corridor study, with examples provided from recent studies; and types of recommendations that typically result from corridor studies.

II. NATURE OF CORRIDOR TRANSPORTATION PLANNING

An example of the purposes and characteristics of corridor planning comes from the Washington State Department of Transportation (WSDOT), which notes that such studies "bring together the goals and expectations of all groups involved in the project." [WSDOT, 2015] The description continues,

> *"corridor studies typically respond to a specific problem (high accident locations and corridors, high levels of existing or future congestion, significant land-use changes, etc.) and often involve more than one mode. These studies identify existing and future deficiencies and evaluate alternative solutions. The recommended alternative usually includes a facility description including environmental, operational, and other impacts (with proposed mitigation, if applicable). Corridor planning is accomplished using a long-range outlook (at least 20 years)."*

[1] The original chapter in Volume 3 of this Handbook was written by Donald R. Samdahl, P.E., PTP, Principal Fehr & Peers. Changes made to this updated chapter are solely the responsibility of the editor.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

Reasons for a Corridor Study

- Developing a strategy to address current or future transportation problems.
- Relating a corridor strategy to a larger system plan.
- Identifying land use strategies that complement transportation investments.
- Identifying improvements to include within a local or regional plan.
- Setting the conditions for setting aside right-of-way within the corridor.
- Allowing more detailed cost estimates to be prepared.

The travel shed nature of a corridor helps define the length and breadth of the study area. Typically, an existing roadway or transit facility will serve as the spine of the corridor, but the travel shed will be much larger than just the immediate areas surrounding the facility. Corridor transportation facilities connect major activity centers and lead to other destinations. Examples of corridors include connections between two cities or segments of major transportation facilities that connect to other facilities (for example, a freeway between two connecting freeways). Corridors may range in length from a few miles in an urban area to hundreds of miles for statewide or multistate areas. From a modeling perspective, the corridor is also defined with traffic analysis zones (TAZs) to expedite the use of travel demand models in analyzing travel demand in the corridor. These TAZs represent the different land-use, trip-generating activities in the corridor (see chapter 2 on data collection and analysis, chapter 3 on land use, and chapter 6 on travel demand modeling).

A corridor plan should have readily understandable beginning and ending points, often referred to as logical termini. These boundaries help focus the analysis and avoid confusion with other transportation plans. Narrowly focused corridor plans examine an individual facility and the immediate surrounding area. However, many corridor plans encompass a broad geographic area that includes all of the travel movements within the corridor. Larger corridor plans within urban areas can have boundaries 5 to 10 miles from the specific facility being studied, while statewide and multistate corridor plans may encompass a swath of up to 50 miles in width.

Corridor plans can focus on the infrastructure characteristics of a single mode, such as a highway, commuter rail line, or bus routes. However, in most cases, corridor studies examine a combination of modes, especially those studies funded by state and federal agencies where such a multimodal examination of alternative modes is required. An important point of departure for such studies is to identify the potential corridor travelers and then determine how they will likely travel in the corridor.

Corridor plans can be conducted at various points within the transportation planning process. Most corridor plans are initiated in response to identified needs arising from a metropolitan or statewide planning process. These broader plans help set the framework for transportation needs, but typically do not examine the detailed facility requirements or services needed within a corridor. Corridor plans can provide the next level of transportation evaluation leading to specific recommendations on transportation investments. In addition, an important characteristic of many corridor studies is the relationship between the corridor study and environmental review processes.

The types of questions posed in a corridor study on I-25 in northern Colorado illustrate the types of questions that many corridor studies should ask at the beginning of the planning effort (see Table 17-1). [Northern Colorado Communities, 2001] Note that these questions relate to land use, transportation, environmental/natural resources, and regional character. Several of these questions are relevant to general corridor studies, while others may be most appropriately asked in the context of a detailed environmental process.

In many instances, the completion of a corridor study permits environmental reviews to be accomplished and project development to proceed. Follow-on, facility-level studies will then examine the detailed design requirements and project-level impacts of the recommended corridor plan. This environmental connection to corridor planning is discussed later in the chapter.

Table 17-1. Questions Forming the Basis of Corridor Planning, Northern Colorado Land Use
• Pattern of New Development: What patterns of new development are possible in the corridor, and how do they affect other issues? • Property Rights: How should individual property rights be protected? • Agricultural Activities: How does agricultural activity relate to regional character, and will new development conflict with continuing agricultural use? • Market Considerations: What type, intensity, and pattern of development is the market likely to generate in the corridor over the next 10-20 years, and how does this support or conflict with a regional vision?
Transportation • Capacity and Expansion: How much capacity does I-25 have to accommodate new development, and what are the effects of transit, roadway, or other possible improvements? • Right-of-Way: What are the ROW requirements for future expansion? • Access: Where should access be provided or limited, and how will individual community access control plans relate to regional goals? • Local Network: What local network improvements will be necessary to serve the corridor in the future, and how will frontage roads and parallel service affect the network? • Interchange Design and Spacing: What changes to existing interchanges are necessary? If there is a need for new interchanges, where should they be located, and how should they be designed to address safety and access goals? • Travel Modes: What modes of travel will the corridor accommodate, and what are the development and design requirements? • Linkages: How should communities near the corridor be connected to I-25 and areas along the corridor? • Consistency and Coordination: How will recommendations of RTPs and local and subarea transportation plans and studies be integrated with the corridor plan?
Environment and Natural Resources • Preservation of Natural Resources: Where and how should natural resources be preserved? • Drainage, Wetlands and Watercourses: How should drainage, wetlands, floodplains, flood fringes, and watercourses be preserved, and how will they be integrated into new development? • Scenic Views: Where are the most significant views, and how should they be preserved?
Regional Character • Land-Use Regulations and Policies: How should the plan deal with plans, policies, and regulations that may be in conflict with regional goals? • Transferable Development Rights: What role will transfer of density units (TDUs) play in implementation of the plan's objectives? • Local Control and Regional Consistency: How should local control be balanced with regional consistency? • Design Regulations: What is the appropriate level of design regulation for new development on a regional basis? • Approved Development and Zoning: Are there conflicts between regional goals and local zoning, and if so, how can those conflicts be resolved?

Source: Northern Colorado Communities, 2001

Key Points about Corridor Plans

- One size does not fit all—tailor the corridor plan to the problems being addressed.
- Clearly articulate why the corridor study should be conducted, when it should be initiated, and how the issues will be considered.
- Relate the corridor plan to regional decisions that set the context for the issues being examined.
- Identify logical termini for the study.
- Identify key stakeholders and a public involvement process for informing these stakeholders.
- Identify a timeline for completion of the study.
- Focus on developing and documenting relevant and accurate information that leads to decisions being made within the corridor.

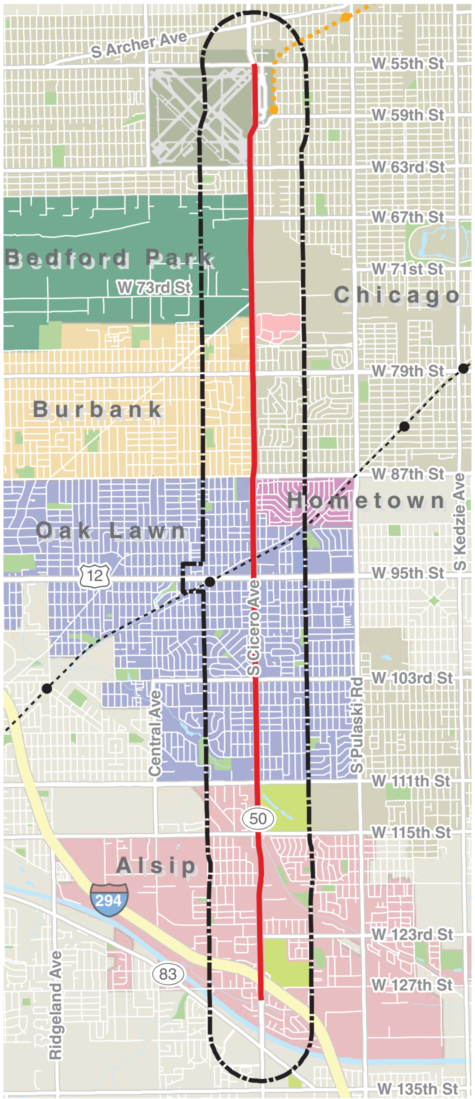
A. Types of Corridor Plans

Table 17-2 shows how corridor plans can be used to address transportation issues at the local, regional, statewide, and multistate level. Several examples of corridor plans are shown in Figure 17-1. Local plans are illustrated by the 9-mile

Table 17-2. Types of Corridor Plans

Corridor Plan Type	Typical Characteristics
Local	• Usually single facility focus • Often single mode (highway, transit, nonmotorized) • 2-3 miles in length • Often land use/urban design component • Limited environmental analysis
Metropolitan	• Major highway or transit facility • Single or multiple modes • Several parallel facility options • Several miles in length • Often land use/urban design component • Detailed environmental studies
Statewide (intra-state)	• Major highway or rail facility (new or expanded) • Single mode with modal options (e.g., transit, with options of commuter rail, intercity rail, or intercity bus) • Several alignment options (new facilities) • Many miles in length • Sometimes local land use component • Detailed environmental studies
Multistate	• Major highway or rail facility (new or expanded) • Intermodal focus, including freight operations • Several alignment options (new facilities) • Detailed environmental studies • Potentially complex institutional coordination processes

Figure 17-1a. Cicero Avenue Corridor Study, Chicago and Suburbs



Source: Southwest Conference of Mayors, 2014

Figure 17-1b. Mid-County Corridor Study, Montgomery County, Maryland

Source: Montgomery County DOT, 2015

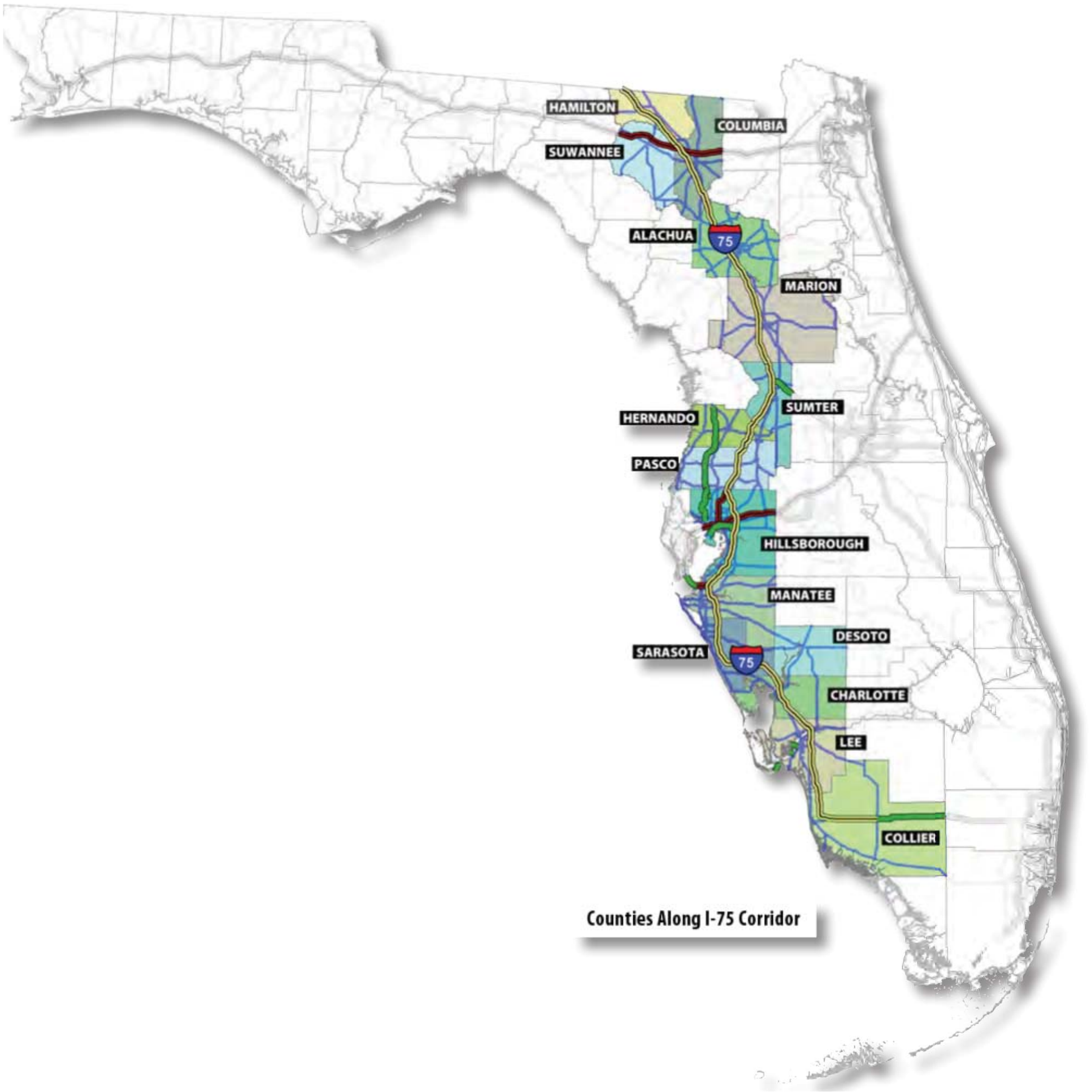
Cicero Avenue corridor (Figure 17-1a) running through the city of Chicago and five southwest suburban communities. [Southwest Conference of Mayors, 2011] Areas within one-half mile were considered as areas of influence and impact. The objectives of the corridor study included:

- Create a cohesive identity for the corridor.
- Maximize the potential of each community's assets along the corridor, including economic activity centers, transportation infrastructure, and natural resources such as trails.
- Optimize mobility and efficiency of all modes of travel.
- Increase safety for nonmotorized users of the corridor, especially at crossings and transit access points.

A steering committee of leaders from the corridor communities along with the involvement of state and local transportation agencies provided guidance to the study. The committee helped identify improvement projects and implementation priorities.

Figure 17-1b shows the study area for the Mid-County Corridor Study in Montgomery County, Maryland. [Montgomery County DOT, 2015] The study was part of a planning/environmental analysis of alternative

Figure 17-1c. I-75 Corridor Study, Florida



Source: Florida DOT, undated

transportation strategies to improve the performance of the corridor's transportation system. The objectives of the study were to:

- Improve vehicular safety.
- Enhance the efficiency of the roadway network and improve the connections among economic centers.
- Accommodate planned land use and future growth.
- Provide bicycle and pedestrian connections.
- Enhance emergency response.

The I-75 Corridor Study in Florida is an example of a statewide corridor plan (Figure 17-1c). [Florida DOT, undated] The study corridor includes 15 counties, containing 4.5 million residents, 24 percent of Florida's total population. The purpose of the I-75 study was to assess the travel demand and freight movements along the corridor against four measures: transportation, emergency management, homeland security, and economic development. Some of the strategies considered ranged from adding capacity to parallel corridors to implementing managed lanes to encouraging travel demand management (TDM) programs.

A multistate corridor plan is illustrated by the Tennessee to Canada I-81 corridor study (see Figure 17-1d). [Cambridge Systematics, 2012] The 855-mile corridor is a major freight corridor with from 11 to 57 percent of the traffic flow on individual segments being trucks. A memorandum of understanding was signed by six states laying out the overall study and the respective responsibilities of the state DOTs, as well as including the 14 metropolitan planning organizations (MPOs) in the corridor. The study recommended that opportunities for coordinated policy and action among the I-81 states be pursued including a review of each state's policies, goals, and strategies on such things as congestion, commercial vehicle safety, promoting connectivity of modes and planning; establishing a central data and information repository using data collection standards and formats developed by the coalition states; and conducting additional studies of critical near-term issues such as coordinated multistate truck origin-destination surveys and studies to identify shared management, investment, and modal strategy opportunities.

Figure 17-1d. I-81 Multistate Corridor Study

Source: Cambridge Systematics. 2012

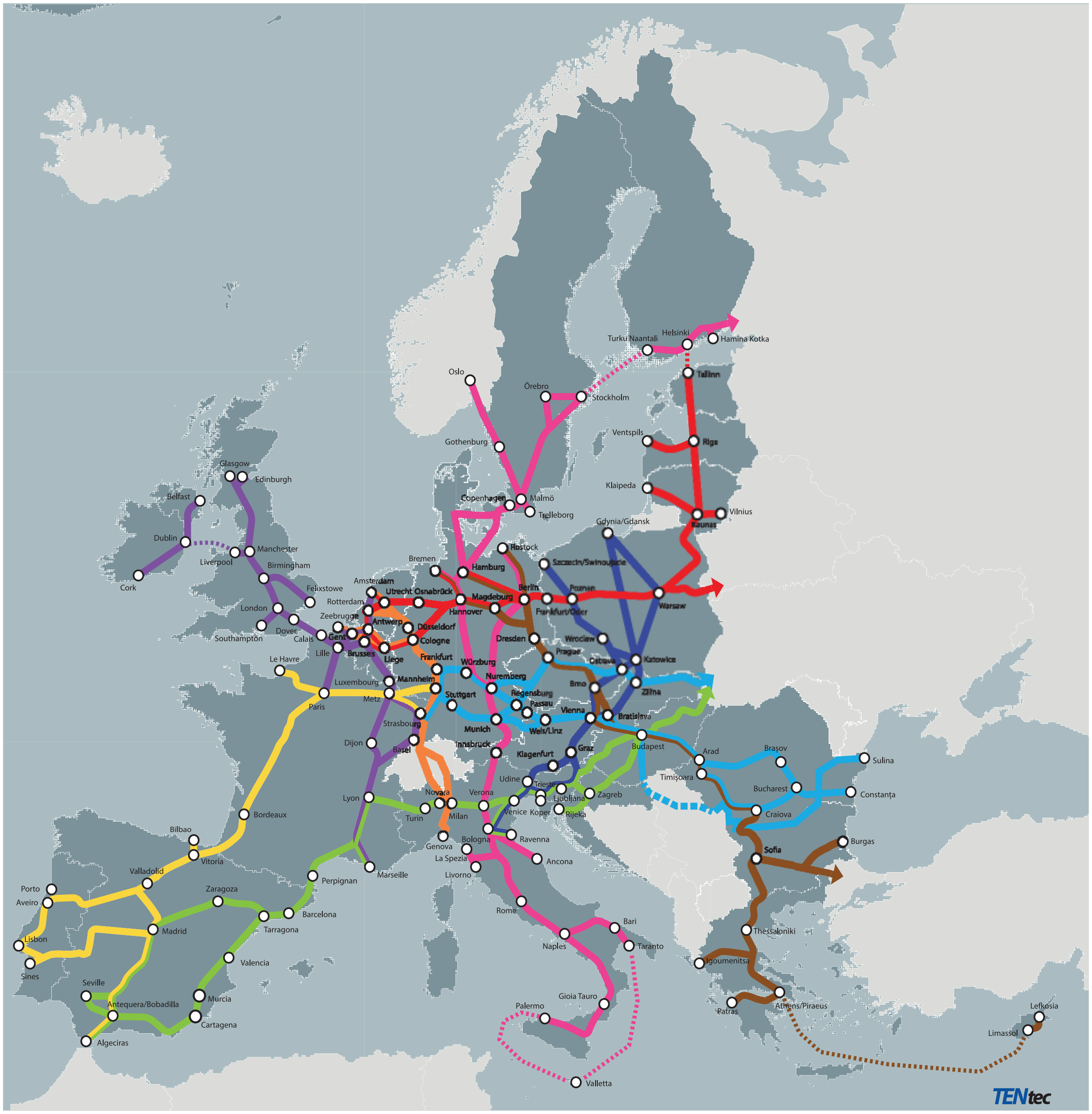
Finally, Figure 17-1e shows that corridor studies can be undertaken at the continental level. This figure shows the major European corridors targeted by the European Union (EU) for major transportation investment. [EU, 2015] The intent of the corridor investment program is to:

- Strengthen the basis for trade flows and citizens' mobility within the Union and with external markets.
- Reinforce territorial, social, and economic cohesion in the Union.
- Enhance the infrastructure basis for an efficient and sustainable mobility system, which stands for future-oriented and high-quality transport services for passengers and freight. [EU, 2015]

Questions that planners should ask when identifying corridor boundaries include: [as amended from WSDOT, 2007]

- What are the logical boundaries for which the study is being conducted?
- What issues are dominant in the area?
- What seem to be the natural travel markets today and likely in the future?
- Is there a perception that the issues are greater than current data suggest?
- Are there population groups, in particular environmental justice populations, that rely on the corridor transportation system even though they do not live adjacent to the corridor?
- Are there major activity centers that rely on the corridor for mobility and accessibility even though they are not adjacent to the corridor?

Figure 17-1e. European Transport Corridors Targeted for Major Investment



Source: EU, 2015

- Are there junctions with major routes and local roads, or connections to other modes?
- Are there environmental issues that would require a larger than expected study area, for example, watershed issues that might occur downstream?
- How do jurisdictional boundaries, neighborhoods, environmental features, and route functions relate to each other?
- How are the data aggregated or disaggregated in the study area such that zones or districts can be used as building blocks for a corridor study area?

As has been emphasized in other chapters in this handbook, transportation planning must reflect and relate to other types of plans for the community, region, or state. Corridor plans are no different. For example, they must fit within the context of local, metropolitan, and statewide transportation plans. Table 17-3 illustrates this relationship between corridor plans and other types of planning studies. Note that the table is not intended to be a comprehensive listing of all the plans that might relate to corridor planning. Each of these plans provides important information to decision makers for a particular study area; however, each plan might influence the results of other studies as well. As an example,

Table 17-3. Relationship of Corridor Plans to Other Planning Processes

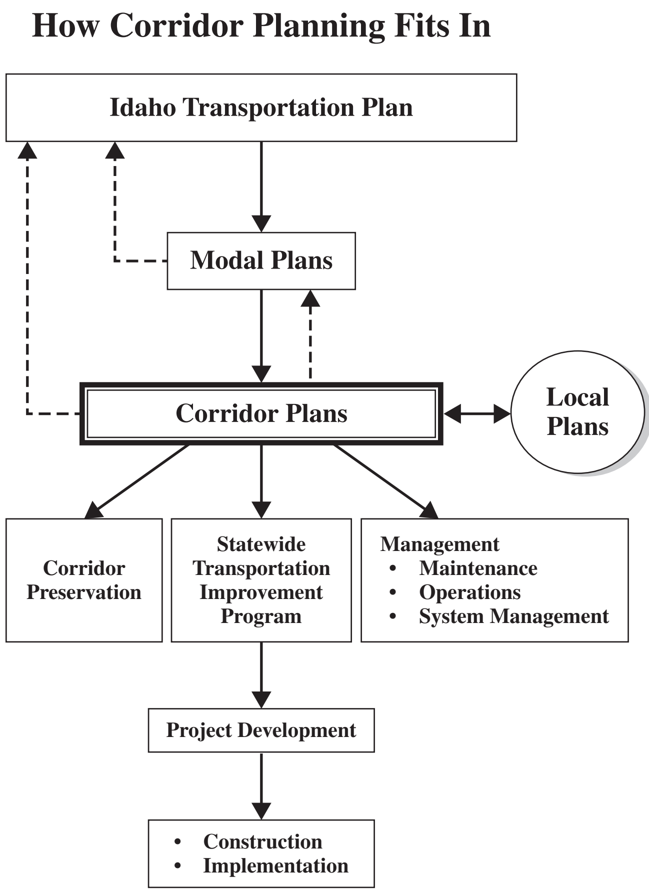
Type of Plan	Relationship to Corridor Planning Studies
Metropolitan transportation plan (MTP)	Identifies short/long range actions for regional transportation improvements. Financially constrained. Corridor plan will help refine projects to include within plan.
Statewide transportation plan	Describes how the state will accommodate efficient movement of people and goods. Corridor plan helps provide reference points for specific statewide actions. Statewide plan can provide policy guidance to corridor planning activities.
Regional and statewide TIPs	Develops program of projects proposed for federal and state funding. Corridor plans may be used as a basis for including projects within the TIP.
Regional, strategic or vision plans	Used to identify a long-term vision of transportation improvements that can set the context for the financially constrained MTP. Corridor plans may be initiated in response to these plans or provide input into the regional vision.
Local agency comprehensive plans	Focused on the definition of land use and transportation improvements by local governments. Corridor planning efforts can provide direct input to the composition of projects within a comprehensive plan. Local plans can provide constraints on alternatives to be considered within a corridor plan.

Source: Smith, 1999, Reproduced with permission of the Transportation Research Board.

Figure 17-2 shows how corridor studies fit into the overall transportation planning and decision-making processes in the Idaho Transportation Department.

Corridor plans are most commonly tied to some combination of federal environmental planning requirements through the National Environmental Policy Act (NEPA) requirements, a metropolitan transportation plan, or a statewide transportation plan. Planners should coordinate upfront with NEPA reviewing authorities/entities (including federal/state/local) to also help minimize the likelihood of re-conducting technical studies. This coordination can be anything from a simple phone call to keep the party in the loop to asking for assistance in writing the study scope. These relationships are further described in the following sections.

Figure 17-2. Relationship of Corridor Planning to Other Decision-making Processes, Idaho



Source: Idaho Transportation Department, 2006

B. National Environmental Policy Act (NEPA)

The 1969 NEPA established a process for examining the environmental impacts of actions involving federal funding (see chapter 4 on environmental analysis). Many corridor planning studies in the United States examine projects that might be federally funded and thus require a close relationship to the NEPA process. One of the key decisions early in the planning process is to determine what, if any, relationship there needs to be with NEPA requirements and with associated government participants (such as natural resource agencies).

NEPA has three classes of actions that define the level of documentation needed to meet federal requirements: (1) Class I–Environmental Impact Statement, (2) Class II–Categorical Exclusions, and (3) Class III–Environmental Assessments. Environmental impact statements (EISs) are required where the proposed actions will significantly affect the environment. Conversely, Categorical Exclusions (CEs) are appropriate where no significant environmental impacts are anticipated. Studies that do not meet one of these two extremes fall into the Environmental Assessment (EA) category.

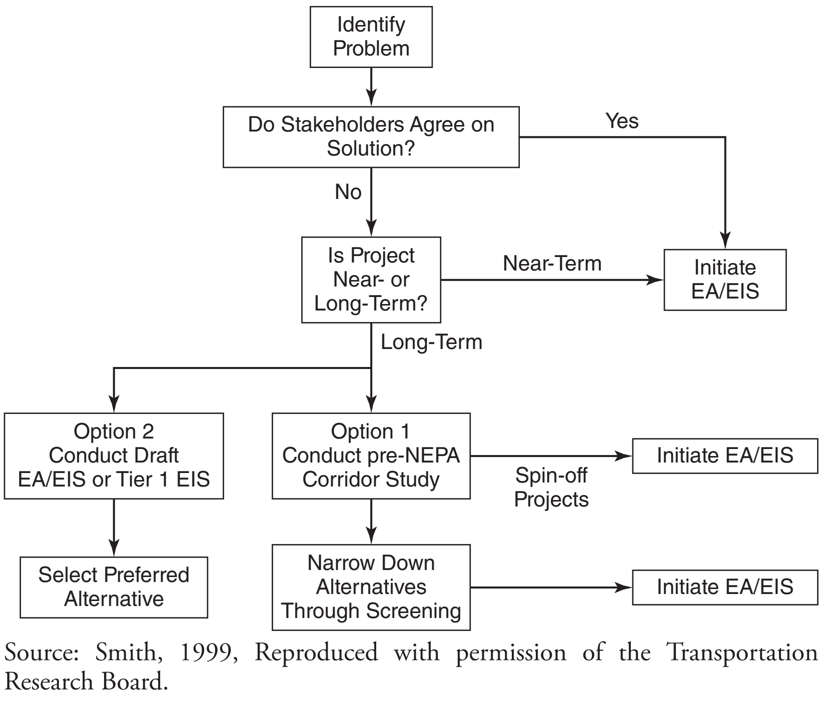
The decision on whether to prepare NEPA documentation and, if so, how detailed it should be, depends on the decision-maker needs for information, project timing, and funding. A decision to follow the NEPA process is often made to make the project eligible for federal funding. At other times, the decision to not follow the NEPA process is made if it is known that future phases of a project (for example, design) will rely on state or local funding rather than federal funding, or if the project is to be fast tracked (also with local funds). Delaying a decision to enter into an EA/EIS study for a long-term solution might also occur because, after a study is completed, the FHWA or FTA (for example) could require a supplemental study be conducted if no progress has been made in implementing the approved project. This is done to ensure impacts are still defined appropriately and mitigated, if necessary. Thus, if some aspects of a project are unclear or controversial, it might make sense to postpone a study until the possibility of a supplemental study is reduced.

Corridor plans can go through several life cycles. For example, a transportation agency might begin with a general feasibility study, which when completed could lead to more in-depth corridor studies. Initial feasibility studies may be conducted outside of the NEPA process, with their purpose being primarily to determine whether there is a need for more detailed study. Such studies should make sure that ideas or concepts developed in the study should transfer to, and be understood in, any future NEPA process. It is also important to publicly disclose these early decisions to avoid having to re-conduct technical studies if the corridor moves into a NEPA process (assuming the regulatory time limitations associated with how long the technical analysis remains valid are not exceeded).

Often corridor plans evolve through a tiered environmental process. The first-tier in this process frames and narrows the scope of the corridor for more detailed examination in a second tier study. For example, a first tier analysis might address the overall needs in a corridor spanning several miles. Florida DOT's Efficient Transportation Decision Making (ETDM) process is a good example of the purpose and need screening for a corridor. [FDOT, 2015a] This process is designed to identify any fatal flaws to a potential corridor improvement before it moves forward in the project development phase. Subsequently, second-tier studies would analyze shorter sections of the corridor at a greater level of detail.

Figure 17-3 shows how corridor studies and NEPA are related. At several points during corridor planning a decision can be made to initiate a NEPA process. Considerations include whether the stakeholders agree on a solution early in the process and whether the project will result in specific actions. More defined solutions and near-term actions are most likely to find their way into a formal environmental process leading to a project decision. In addition, because of the environmental approval process that often follows the completion of a corridor study, planners often find many natural resource agencies involved in varying capacities in corridor studies. Figure 17-4, for example, shows the organizations that were involved with the Inter-County Connector study conducted by the Maryland State Highway Administration.

Figure 17-3. Relationship between Corridor Studies and NEPA



Source: Smith, 1999, Reproduced with permission of the Transportation Research Board.

Corridor plans looking at longer-term solutions may or may not follow a formal NEPA process depending upon the decisions anticipated and the expected level of environmental impacts. If the plan is truly looking at establishing a strategic direction in the corridor rather than identifying specific projects, it may be prudent to defer the formal environmental process to a later date. NCHRP Report 435 provides a detailed description of how the NEPA process should be integrated within the corridor planning process. [Smith, 1999]

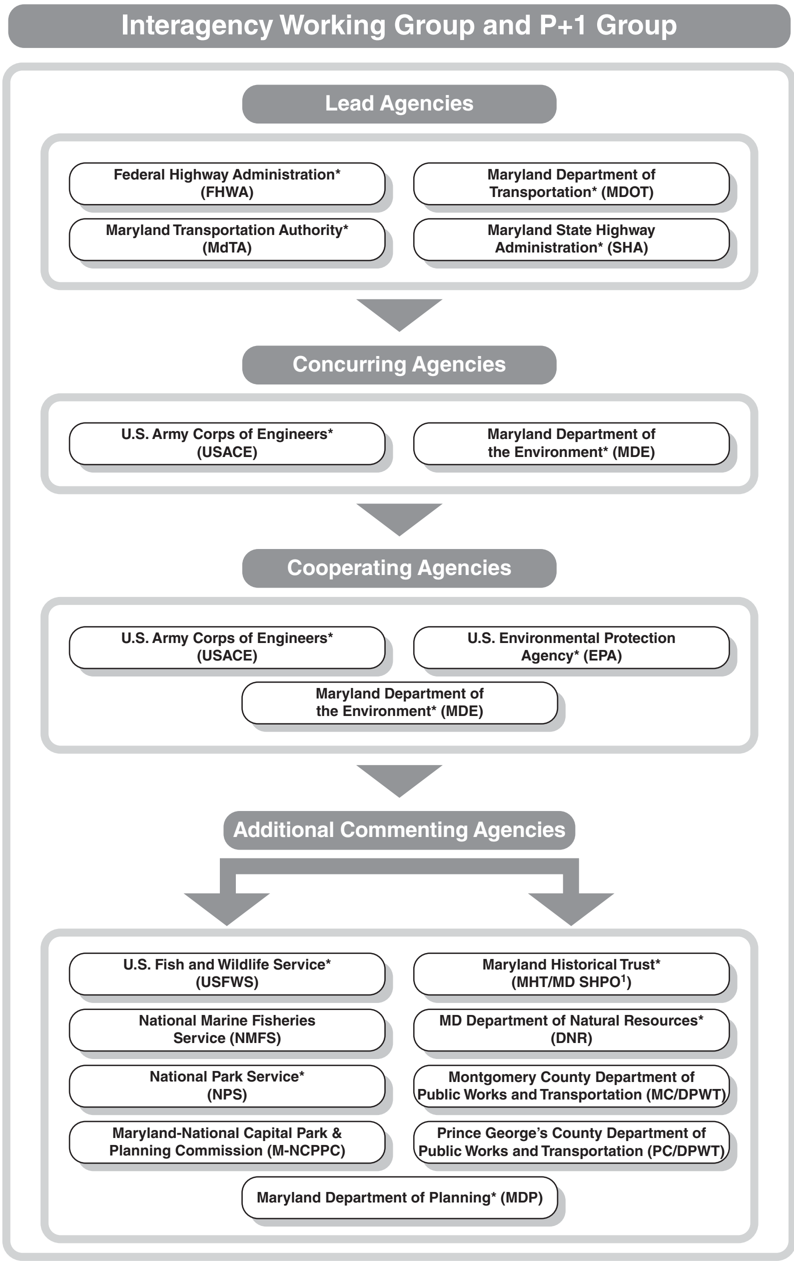
C. Regional Transportation Plan (RTP)

RTPs establish long-range transportation goals and directions for a metropolitan area's transportation system (see chapter 16 on metropolitan transportation planning). In this context, "region" includes both metropolitan areas as well as nonmetropolitan regions of a state. RTPs typically include a long-range vision and a financially constrained set of projects. A corridor plan can help define the scope and magnitude of projects listed in the RTP.

At the same time, the RTP often serves as the catalyst for conducting corridor plans. The RTP defines specific long-range, multimodal corridor needs and establishes some general priority on implementation. A well-crafted corridor planning process can then refine the feasibility of alternatives within a corridor and establish a decision process to make the selected alternative(s) a reality. In metropolitan areas, the metropolitan transportation planning process can provide insights into transportation needs and solution strategies to be considered in a corridor study. Figure 17-5, for example, shows how corridors in the Philadelphia metropolitan area, whose eventual analysis provided input into the update of the metropolitan transportation plan, have been defined. A similar concept is shown in Figure 17-6, where corridors were defined as an important input into the regional transit plan in Knoxville, Tennessee. [Knoxville TPO, 2013] The purpose of the Knoxville study was to:

- Expand transit opportunities for existing transit users, nondrivers, and promote transit use by new riders.

Figure 17-4. Institutional Responsibilities for the Environmental Component of the Inter-County Connector, Maryland

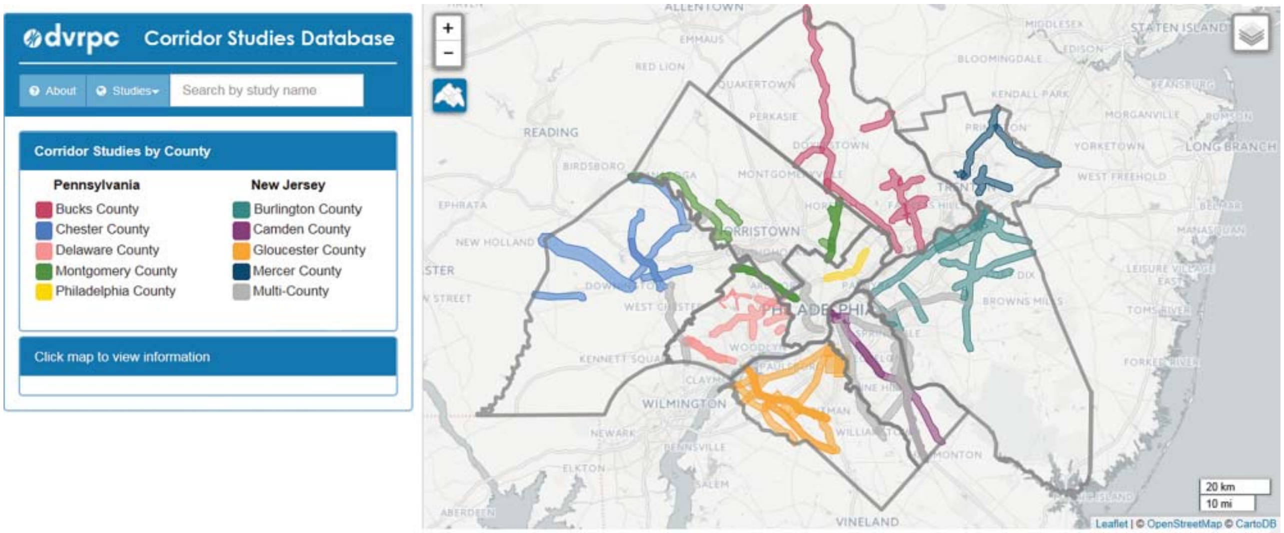


[1] - State Historic Preservation Officer
* - Included in P+1 (Principals Plus One) group

Source: Maryland DOT, 2006

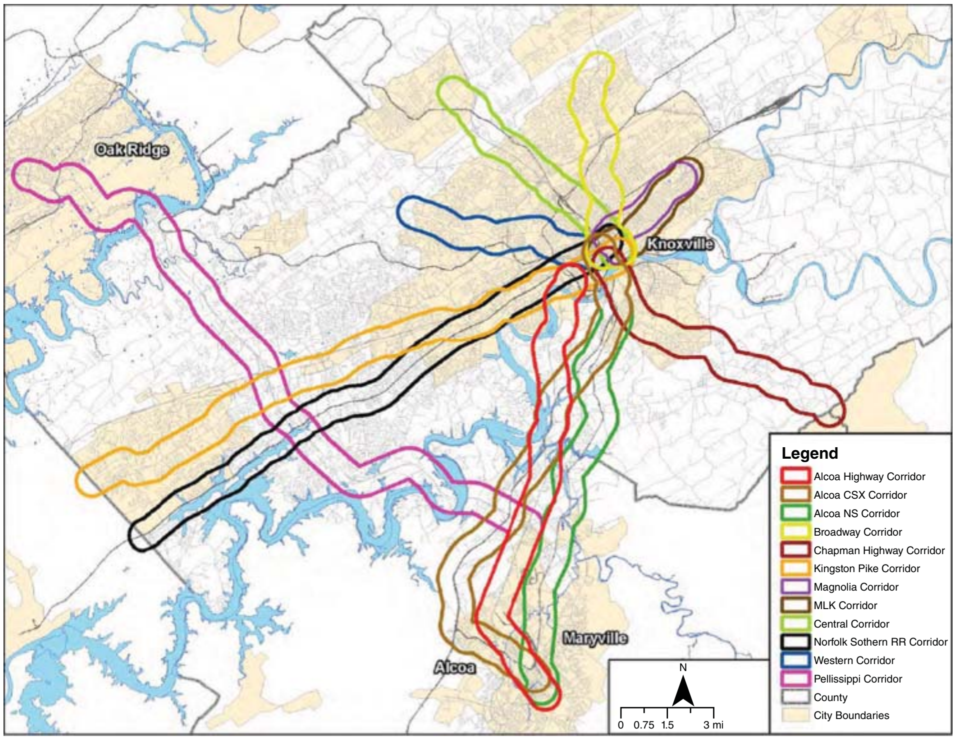
- Enhance Knoxville's image as a world-class city and help the region compete with other metropolitan areas, which are completing and/or already have rapid transit systems.
- Explore the role of transit technologies in creating an efficient transportation system and a more sustainable community.
- Develop and recommend transit supportive land use guidelines, policies, and tools to support transit-oriented development (TOD) and corridor development.

Figure 17-5. Philadelphia Metropolitan Area Corridor-Based Planning



Source: DVRPC, 2015

Figure 17-6. Transit Corridor Plan, Knoxville, Tennessee



Source: Knoxville TPO, 2013

D. Statewide Transportation Plans

Statewide transportation plans (STPs) provide a blueprint for state transportation programs and investments. These plans typically cover all modes of transportation: roadways, ferries, public transportation, aviation, freight rail, passenger rail, marine ports and navigation, bicycles, and walking. The STP can provide a framework within which major intercity or statewide corridor plans are developed.

Similar to metropolitan transportation plans, in some cases, STPs can be based on the results of corridor studies. For example, the 2003 STP for Pennsylvania was based on 26 travel corridors that defined the major travel flows within the state. These corridors became the focus of additional analysis and provided more detailed input into subsequent investment decisions. Many states are now taking a strategic statewide approach to corridor development to better prioritize subsequent corridor planning studies. Statewide planning is addressed further in chapter 15.

E. Relationship to Land Use/Urban Design

Table 17-1 indicated that corridor studies at the local and/or metropolitan levels often have land-use and urban design components. Corridor studies with much broader applications, that is, state or multistate studies, most often do not. Especially in an urban environment, a corridor investment strategy must take into account expected or desired land uses and urban design principles. One of the trends in local and metropolitan-level corridor studies over the past 20 years has been a much more comprehensive approach toward integrating transportation solutions and land-use/urban design strategies.

Figure 17-7 illustrates this integration with an example from the state of Washington. In this case, an environmental impact statement prepared under the state environmental law developed a preferred alternative that combined both transportation and land-use components. [City of Bellevue, 2007] The study examined the following alternatives:

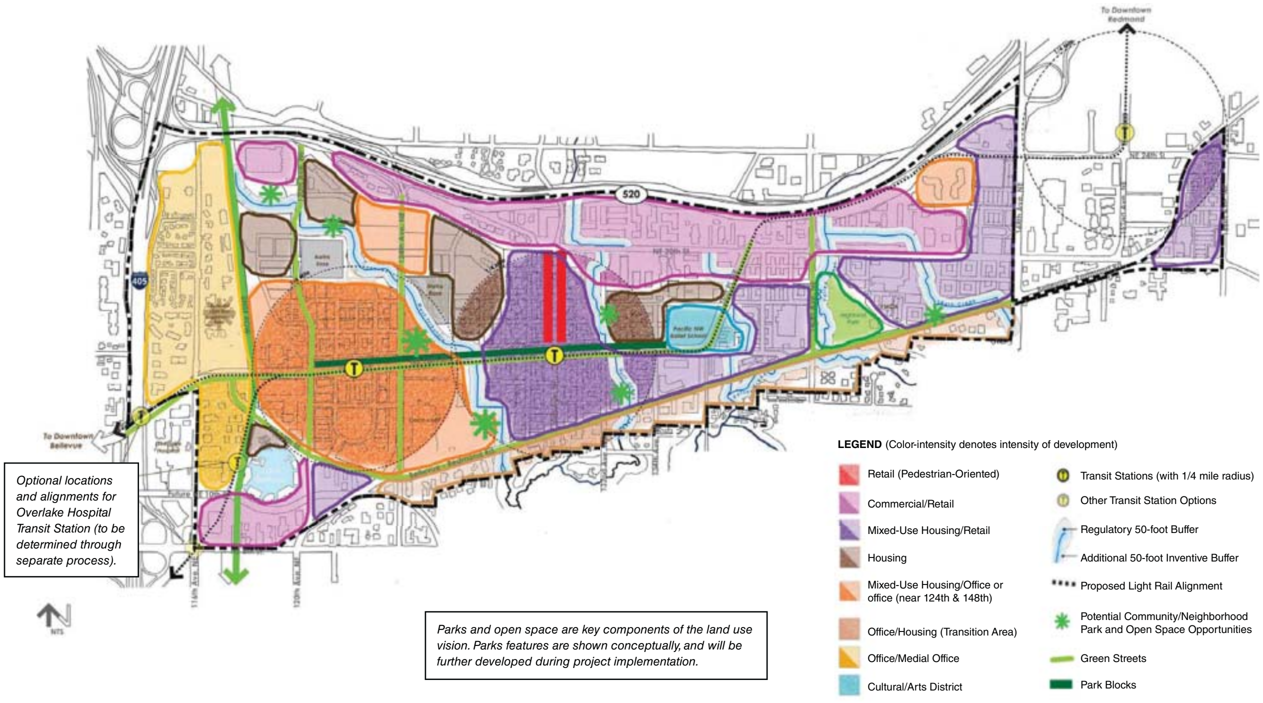
No-Action Alternative: The No-Action Alternative assumed no major changes in land use or transportation other than those already programmed as part of existing plans or proposed by other agencies. Based on existing trends, it was estimated that 1.03 million additional square feet of nonresidential space would be developed in the corridor by 2030.

Alternative 1: Mid-Range Employment and Mid-Range Housing: This alternative assumed a net increase of 3.5 million square feet of new commercial (office and retail) space and roughly 3,500 new housing units. Two light-rail transit (LRT) stations were recommended.

Alternative 2: Low Employment and High Housing: This alternative assumed roughly 2.5 million square feet of new commercial space and 5,000 new housing units. Three LRT stations and associated development nodes were recommended.

Alternative 3: High Employment and High Housing: This alternative assumed approximately 4.5 million square feet of new commercial space, along with 5,000 new housing units. Three LRT stations and associated development nodes were recommended.

Figure 17-7. Land-Use and Transportation Corridor Strategies, Bellevue, Washington



Source: City of Bellevue, 2007

The final environmental study chose a preferred alternative including four light rail stations, with increased development density in the western half of the corridor by including closely spaced development nodes. These nodes would alternatively include office and medical; office and housing; office, housing, and retail; and mixed-use housing.

Another example of the combination of land use/urban design and transportation issues, only in a different and more limited context, is found in Scottsdale, Arizona. In this case, the city of Scottsdale established design guidelines for scenic corridors that traversed the Sonora Desert. The city designated scenic corridors for several purposes, which included, (1) preserve or encourage the preservation of the natural setting along the roadway, (2) provide views of nearby natural landforms, (3) allow for connectivity of nonvehicle travel buffered safely from motor vehicle traffic, (4) visually link corridors to open space, and (5) buffer adjacent land uses from the adverse effects of traffic along a roadway. Given the sensitivity of the desert environment to disturbance, the city provided both recommended guidelines for roadway design as well as development strategies to minimize the impact on the desert. A desired right-of-way cross section was defined that included width and access requirements; median treatments; provision of bicycle, pedestrian, and multi-use paths; utility easements; landscaping; and drainage structures. A development setback requirement was established to minimize the impact of development immediately surrounding the scenic highway, and development guidelines were established for land uses immediately beyond this setback.

III. CORRIDOR SELECTION

In some instances, state DOTs or MPOs have adopted a corridor approach as a major strategy for developing their transportation plan. [Carr, Dixon, and Meyer, 2010] In essence, this means they have identified a number of corridors that are important from a transportation perspective and that are candidates for investment. The question then becomes which corridors should receive attention first? There are several examples of how this can be done.

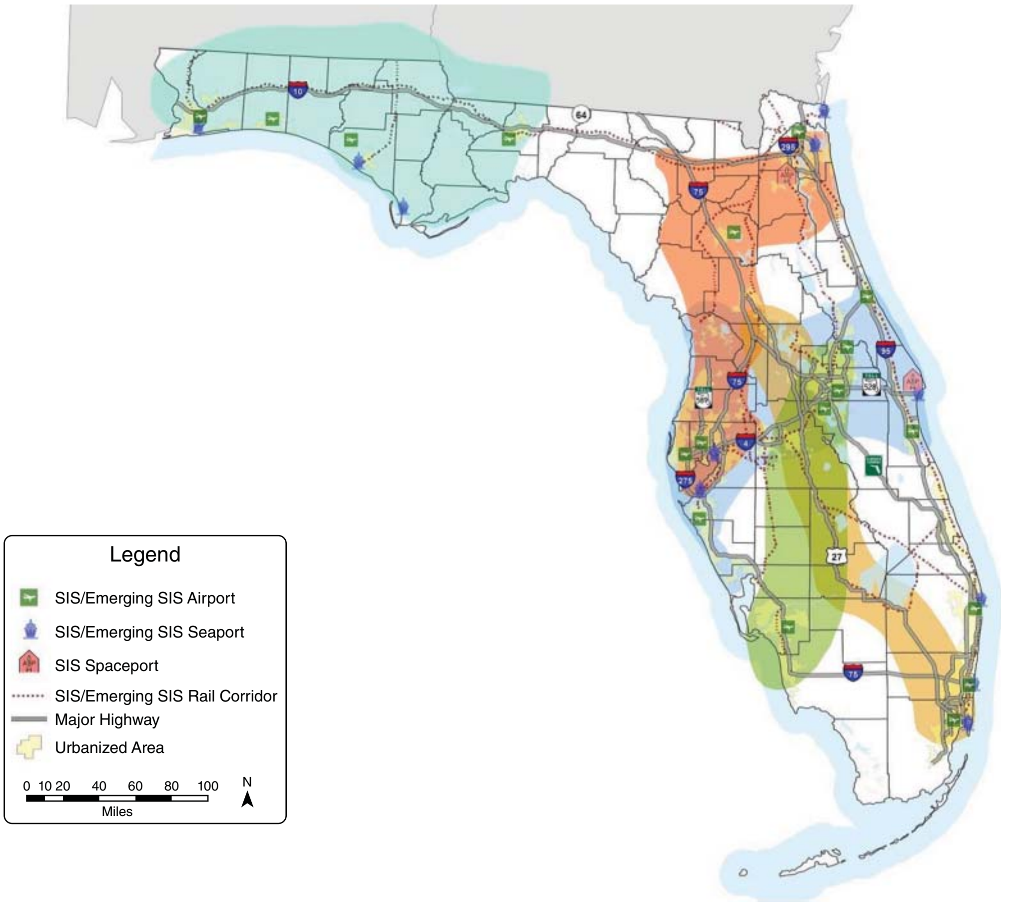
Guiding Principles for Florida's Future Transportation Corridors Planning Process [Florida DOT, 2015]. Realizing the importance of long-distance travel to the economy of the state, the state of Florida has identified a corridor investment strategy to support economic development. Figure 17-8 shows the corridors that will be subject to analysis. The selection of which corridors to proceed with first is based on the following characteristics of each corridor.

- *Be consistent with statewide and regional visions and plans:* Make decisions about statewide transportation corridors consistent with:
    - The goals and objectives of 2060 Florida Transportation Plan and other statewide plans.
    - Long-range visions about the future growth and development of Florida's regions and, in the future, the state as a whole.
- *Structure planning process:* Develop a structured planning process that:
    - Involves partners early and continuously.
    - Coordinates transportation corridor decisions with land use, economic development, environmental stewardship, water management, and other public and private decisions and identifies opportunities to accomplish multiple objectives.
    - Provides clear decision making points and ensures that issues and recommendations carry forward into future stages.

The corridor needs and strategies identification process is predicated on:

- *Identifying long-term transportation needs:* Define a statewide mobility or transportation connectivity need based on data, consensus forecasts, and statewide, regional, and community visions and plans.
- *Maximizing existing facilities:* Make optimal use of existing transportation facilities.
- *Considering alternatives to highways:* Promote greater use of existing rail, water, and air corridors to move both people and freight.
- *Considering new facilities if needed:* Develop new facilities if existing facilities cannot meet mobility or connectivity needs.

Figure 17-8. Prospective Corridors for Analysis, Florida



Source: FDOT, 2015

Corridor locations were determined based on:

- *Enhancing economic development:* Improve transportation connectivity for people and freight to established and emerging regional employment centers and economically productive rural lands.
- *Supporting growth in appropriate areas:* Locate major transportation corridor improvements and, if needed, new facilities in appropriate and environmentally acceptable areas, consistent with adopted visions and growth plans, local government comprehensive plans, and adopted agency plans.
- *Protecting and restoring the natural environment:* Plan and develop transportation corridors in a manner that protects and, where feasible, restores the function and character of the natural environment and avoids or minimizes adverse environmental impacts.

The corridor planning approach should be:

- *Including multiple modes and uses:* Plan enhanced or new transportation corridors, where appropriate, to:
  - Accommodate multiple modes of transportation for moving people and freight.
  - Coordinate locations with existing and new utility infrastructure.
- *Preserving the function of the corridor:* Maximize the use of statewide transportation corridors for interregional and interstate travel and transport though operational strategies, demand management, access management, coordination with surrounding land uses, and development of effective regional and local transportation networks.

Figure 17-9. Evaluation of Different Transit Corridors in Knoxville, Tennessee

Alternative	Consistant with Local Plans	System Integration	Financial Criteria	Preliminary Environmental Screen	Transportation /Engineering	Community Benefits	Land Use/(Re) Development Opportunities	Recommended Corridors
Cumberland/Kingston Pike	Consistant with local plans	High level of integration opportunities	Low financial cost	Moderate environmental issues	Low engineering issues	High amount of benefits	High level of (re)development opportunities	✓
Rating	●	●	●	◓	●	●	●	
Magnolia Avenue	Consistant with local plans	High level of integration opportunities	Low financial cost	Low environmental issues	Low engineering issues	Low amount of benefits	High level of (re)development opportunities	✓
Rating	●	●	●	●	●	○	●	
Western Avenue	Consistant with local plans	Moderate level of integration opportunities	High financial cost	Low environmental issues	High engineering issues	Moderate amount of benefits	Moderate level of (re)development opportunities	
Rating	●	◓	○	●	○	◓	◓	
Central Avenue	Not consistant with local plans	Moderate level of integration opportunities	Moderate financial cost	Moderate environmental issues	High engineering issues	Low amount of benefits	Moderate level of (re)development opportunities	
Rating	○	◓	◓	◓	○	○	◓	
North Broadway NE	Consistant with local plans	High level of integration opportunities	Low financial cost	High environmental issues	Low engineering issues	High amount of benefits	High level of (re)development opportunities	✓
Rating	●	●	●	○	●	●	●	
Pellissippi Parkway	Not consistant with local plans	Low level of integration opportunities	Moderate financial cost	Moderate environmental issues	Moderate engineering issues	High amount of benefits	Low level of (re)development opportunities	
Rating	○	○	◓	◓	◓	●	○	
Alcoa NS Rail Line	Consistant with local plans	Low level of integration opportunities	High financial cost	High environmental issues	High engineering issues	Moderate amount of benefits	Low level of (re)development opportunities	
Rating	●	○	○	○	○	◓	○	
Legend	High ●	Medium ◓		Low ○				

Source: Knoxville Transportation Planning Organization, 2013

- *Designing modal infrastructure and access carefully:* Plan highway elements of future transportation corridors to be limited access, with interchange locations identified to provide access to economic development activities dependent on long-distance transportation, and to support land uses as identified in local plans. Plan rail and transit elements of future transportation corridors to support compact development locations and to encourage public transportation ridership.
- *Using context sensitive design:* Plan, develop, and implement transportation corridors using context sensitive design practices to the fullest extent possible.
- *Using advanced and energy efficient approaches:* Use state-of-the-art and energy-efficient infrastructure, vehicles, materials, technologies, and methodologies to develop and operate transportation corridors.

Knoxville Transit Corridors for Potential Investment [Knoxville Transportation Planning Organization, 2013]. Figure 17-9 shows a typical assessment based on evaluation criteria for each corridor. In this case, the study was examining different transit corridors in Knoxville, Tennessee, to determine which ones showed the most potential with respect to a range of criteria shown in the matrix. [Knoxville Transportation Planning Organization, 2013] An evaluation matrix allowed decision makers to examine the results of the study in a consistent manner among the potential corridors. As shown in the figure, three corridors were identified as having the most potential in terms of satisfying transit goals. These three corridors were selected for more detailed corridor planning.

IV. CORRIDOR PLANNING APPROACH

Several guides have been developed to help transportation planners conduct an effective corridor study (see, for example, [Vermont Agency of Transportation, 2005b; WSDOT, 2007; City of Ottawa, 2009; Center for Transit Oriented Development, 2010; and City of Waterloo, 2013]). Besides the technical analysis process, public engagement occurs throughout the planning process, providing opportunities for input from a variety of interests and stakeholder groups. However, unlike public engagement programs for developing a metropolitan transportation plan, which often includes abstract concepts and undefined projects, corridor-level public outreach efforts should be more focused and targeted on specific problems.

Figure 17-10. Typical Contents of a Corridor Study, Washington State

Sample Table of Contents for a Transportation Corridor Planning Study

Executive Summary

- Primary function of the corridor.
- The 20-year vision for the corridor.
- The goals for the corridor.
- The study process and public involvement.
- Prioritized recommendations.
- Summary of the next steps.

1) Introduction

- Purpose of study.
- Study area or corridor, including function, classification, and distinguishing characteristics.
- History of the corridor.
- Corridor location, including base map of the corridor.
- Stakeholders.
- The 20-year vision for the corridor.
- Plan contents.
- Goals of the study.

2) Basic Information—Existing Conditions

- Current issues present in the corridor.
- Preservation.
- Safety.
- Mobility.
- Environment.
- Stewardship.

3) Data Analysis for the 20-year Planning Horizon

- How will the existing conditions change?
- Modeling.
- Forecasting.

4) Fiscal Constraints—List of Financial Assumptions

5) Recommendations

- Preliminary recommendations based on goals.
- Screening criteria.
- The Action Plan—Implementation Action Matrix.
- Next Steps for Monitoring Implementation.

A good example of the content of a corridor plan is shown in Figure 17-10, which was offered by the Washington State DOT (WSDOT) as a typical table of contents for a corridor plan. As used by WSDOT, a corridor study focuses on identifying problems and proposing solutions on state highway corridors. These plans are intended to support local and regional planning requirements to implement the state's Growth Management Act. They typically focus on key topics such as route continuity, access management, and future capacity needs.

The content follows a traditional approach of fully documenting existing and future conditions, identifying alternative solutions, and evaluating the alternatives using a set of agreed-upon criteria. A public engagement process is used throughout the study. The end product is a recommendation on a strategy to improve corridor performance.

The following sections describe in more detail some of the important steps that constitute a corridor planning study.

A. Identify Vision, Goals, Objectives, and Evaluation Criteria (Related to Performance Measures)

Similar to the transportation planning process for statewide plans (see chapter 15) and for metropolitan areas (see chapter 16), corridor planning should begin with some sense of a vision of what the community wants with respect to the corridor transportation system. A vision should then be followed by goals and objectives, which provide more specificity in terms of system characteristics, which in turn lead to evaluation criteria for the assessment of different actions and strategies. The evaluation criteria should reflect the overall performance measures established for the jurisdiction. Thus, for example, if a region has established the number of fatalities or injuries on the transportation system as a key performance measure, a corridor study would want to know how the different strategies help this particular performance measure (or help attain the target values that have been established).

Goal statements are general statements that identify desired outcomes of corridor investment. Corridor goals need to be related to regional goals as articulated within the metropolitan transportation plan and to appropriate statewide planning goals. Articulating goals and objectives must be a collaborative process among the corridor stakeholders and should serve as a constant reminder of the purpose of the corridor study. Objectives, which are derived directly from goals, provide more specific direction in terms of the technical process and the type of community outreach that is appropriate. It is important that the objectives be specific enough to be measured either quantitatively or qualitatively.

Some examples from corridor studies are provided below.

San Diego—Imperial County Interstate 8 Corridor Strategic Plan [Imperial Valley Association of Governments, 2009]

Goal 1: Improve interregional collaboration.

- Objective: Establish partnerships or a structural framework for addressing interregional concerns.
- Objective: Establish a collaborative process between I-8 stakeholders, including: Caltrans, SANDAG, IVAG, Tribal Nations, Imperial and San Diego County, and other local governments to address issues of common concern.

Goal 2: Maintain and improve mobility for people and goods.

- Objective: Provide adequate levels of service on the I-8 over the next 20 years and beyond.
- Objective: Improve travel times along the I-8 corridor.
- Objective: Reduce dependency on single occupant vehicles.
- Objective: Implement strategies that reduce the growth in congestion, while improving air quality.
- Objective: Implement strategies that incorporate the management and operations of the transportation system with the overall planning process.

Goal 3: Enhance the quality of life in the Imperial Valley and San Diego County.

- Objective: Improve jobs and housing balance in the Imperial Valley and San Diego County (by developing more efficient land use patterns that accommodate a sufficient housing supply to match population increases and workforce needs for the full spectrum of the population).
- Objective: Implement neighborhood and project designs that promote more walking and biking for healthier communities.
- Objective: Implement smart growth principles such as transit-oriented development around major transit hubs and minimizing of growth in areas that are disconnected from adequate local or regional transportation options.
- Objective: Implement strategies that address transportation safety and security through improved integration of these issues into the transportation planning process.
- Objective: Implement strategies that preserve the unique rural character and viability of communities along the I-8 corridor.

Goal 4: Improve the economic vitality of Imperial Valley and San Diego County.

- Objective: Increase number and diversity of employment opportunities in the Imperial Valley and San Diego County.
- Objective: Increase supply of workforce housing to support a diversified job market.
- Objective: Increase collaborative economic strategies that build on the assets of the two regions.

Goal 5: Minimize negative impacts of growth and transportation improvements on the environment.

- Objective: Improve strategies that protect habitat and environmentally sensitive lands.
- Objective: Implement climate action strategies that reduce the carbon footprint of growth and traffic from the Imperial Valley and greater San Diego region.
- Objective: Improve mitigation of environmentally sensitive lands along the I-8 corridor.
- Objective: Implement strategies that preserve the scenic value of the I-8 corridor.

Route 29 Corridor Study, Virginia [Virginia, 2009]. The vision for this corridor resulted from numerous meetings with stakeholders and the general public. Seven themes were developed from public input and were viewed as a vision for the corridor.

- Control access points to the corridor.
- Influence the type of access/connection type.
- Enhance overall mobility and reduce congestion.
- Expand travel mode choices.
- Encourage corridor planning for land use and transportation.
- Enhance stewardship role for VDOT to preserve transportation investment.
- Preserve the integrity of corridor as a statewide scenic resource.

Goal statements that related to this vision included:

- Keep people and goods moving smoothly and efficiently within and through the corridor.
- Reduce accidents and enhance travel safety.

- Expand transportation choices.
- Expand the market reach of existing and prospective companies in the corridor and relying on corridor businesses.
- Expand the area from which a skilled labor pool can be drawn.
- Help steer growth to desired areas.
- Preserve and enhance the attractiveness of the region to tourists and residents.
- Provide better traveler information and services.
- Ensure that Route 29, as a viable part of the National Highway System, helps the nation compete in the global economy and move people and goods in an energy-efficient manner.

University Avenue Corridor Study [Champaign County Regional Planning Commission, 2010]. The vision for this transportation and land use corridor study was stated as:

> *"The University Avenue corridor will support an intensified and diverse mix of commercial, office, institutional, and residential uses at an appropriate density that serves to connect the two downtowns, University of Illinois and medical campuses to sustain adjacent neighborhoods. The corridor will be served by a multi-modal transportation system that facilitates its status as the communities' main east-west thoroughfare, while supporting other modes of transportation. Enhanced building design and streetscape features will help to unify and breathe new life into this urban corridor."*

The following seven goals reflected the most important principles to be addressed through the corridor study recommendations.

- Promote orderly and attractive redevelopment along University Avenue.
- Develop higher density, multimodal nodes at selected intersections.
- Maximize the safety and efficiency of the current transportation network throughout the corridor.
- Provide bicycle connections from the corridor to the rest of the community.
- Improve pedestrian facilities, safety, and access along the corridor.
- Provide more direct transit service and additional transit facilities throughout the corridor.
- Create an enhanced streetscape with unifying elements along the corridor.

When a corridor study is part of an environmental impact process, the goals and objectives become (either implicitly or explicitly) part of the purpose and needs statement (see chapter 4 on environmental analysis). The I-70E corridor study and environmental analysis in Colorado is a good example of this, with the following identified needs.

- *Transportation infrastructure deficiencies:* I-70 was constructed in the early 1960s with bridge and drainage structures designed to last for 30 years. Nine structures on the corridor are now past their anticipated lifespan and are classified as either structurally deficient or functionally obsolete and in need of replacement, rehabilitation, or repair.
- *Increased transportation demand:* The project area is experiencing rapid growth and development. This includes both areas of new development and redevelopment, with substantial residential populations and business activity. The land-use and development trends within the corridor will result in additional demands on the transportation system. Providing access and maximizing the ability to travel through and within the corridor are critical to maintaining the economy. This includes maintaining and enhancing connections between major activity centers near the corridor.
- *Limited transportation capacity:* I-70 serves a growing number of users, ranging from travelers and tourists from outlying areas and DIA to regional trucking to commuters or local traffic. The demand from these users is exceeding the existing design capacity of I-70 and associated interchanges. Within the project area, I-70 is

currently near or over capacity. Between 47,000 and 205,000 vehicles per day (average daily traffic) travel over the project area, depending on the location in the corridor. Forecasted traffic for the year 2035 shows that traffic on I-70 will increase substantially, carrying from 117,000 to 285,000 vehicles per day. This increase in traffic will result in more hours of congestion, longer delays, and increased potential for crashes.

- *Safety concerns:* In the project area, I-70 generally experiences more traffic crashes than the state average for urban freeways. These crashes cause unpredictable and unavoidable traffic congestion, which adds to or worsens the already existing congestion from travel demand that exceeds the normal roadway capacity. The unpredictable nature of traffic congestion on I-70 increases safety concerns for freight carriers, employers, manufacturers, and business interests in the region, as well as commuters and residents who depend on reliability for their daily travel. [CDOT, 2014]

Establishing criteria for evaluating alternatives is one of the most important steps in the corridor planning process. Evaluation criteria, also known as measures of effectiveness, define the information to be developed and presented to decision makers and the public; thus, they should be directly related to the problems being investigated. The criteria should also be meaningful and easily understood to a wide variety of stakeholders. The evaluation criteria will determine the scope and complexity of the technical analysis process, affect the study schedule and budget, and ultimately, drive the decision process. Therefore, it is important for corridor planners to think about how the criteria are to be used as part of the decision-making process.

Evaluation criteria typically relate to one or more of the following system performance categories, depending on the study goals and objectives:

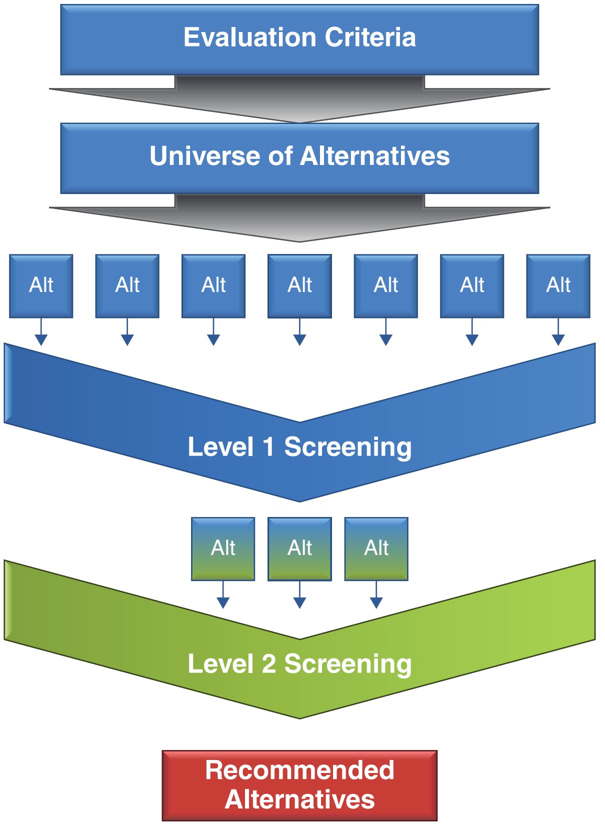
- Transportation performance
- Environmental impacts (natural and built environment)
- Economic impacts
- Cost
- Cost-effectiveness or benefit/cost

The specific criteria to be considered in each category would reflect the goals, objectives, and system performance measures adopted for the study. For example, the criteria used in a corridor study in the state of Washington included: safety benefits, mobility benefits, transit benefits, nonmotorized benefits, environmental impacts, land use and policy consistency, costs, and public support. [WSDOT, 2009]

Evaluation criteria will likely be identified from a number of sources within the planning study area itself. However, maintaining consistency in criteria among similar corridor studies is an important factor in selecting such criteria. Common sources of evaluation criteria include statewide plans, regional and local plans, project selection criteria (for example, those used for prioritization with transportation improvement programs), and funding eligibility criteria (state and federal).

The I-11 and Intermountain West Corridor Study provides another example of the evaluation criteria that can be used in a corridor study. In this case, the corridor spanned two states, with the expectation that the corridor could be expanded to Canada. Figure 17-11 shows the general concept of how the evaluation criteria could be used to screen alternatives to identify the most feasible set for further evaluation. Table 17-4 lists the criteria that were used in the screening process. [i11study, 2013, 2014]

Figure 17-11. Evaluation Process for the Intermountain West Corridor Study



Source: i11study, 2013

Table 17-4. Evaluation Criteria for Screening Alternatives, Intermountain West Corridor Study	
Evaluation Category	**Proposed Criteria**
Legislation	How well does the alternative meet the intent of legislative actions, including MAP-21 and the 1995 National Highway Systems Designation Act?
System Linkage	How well does the alternative connect major national and international activity centers from Mexico to Canada through the Intermountain West?
	How well does this alternative most directly close gaps and/or develop missing linkages in the regional and national transportation network?
	How well does this alternative connect with adjacent segments/sections?
Trade Corridor	How well does this alternative connect major freight hubs and high-capacity transportation corridors?
Modal Interrelationships	How well does this alternative maximize opportunities for intermodal connectivity (highway, rail/transit, and aviation)?
	How well does this alternative accommodate multiple modes in a shared alignment footprint (highway and rail)?
Capacity/Congestion	How well does this alternative align with existing conditions or proposed improvements at land ports of entry (as appropriate)?
	How well does this alternative relieve existing and projected congestion between and within the major activity centers in Nevada and Arizona?
Economic Vitality	How well does this alternative support regional, state, and national economic development goals?
Project Status/Transportation Policy	How well does this alternative comply with corridor-related actions taken to date?
	How well does this alternative conform to locally adopted transportation plans?
Environmental Sustainability	How compatible is this alternative with regional open space, conservation, and land management agency planning?
	How well does this alternative minimize environmental impacts (such as drainage, topography, species, and biological connectivity?
Land Use and Ownership	How consistent is this alternative with regional land use and growth strategies?
	How compatible is this alternative with major land ownership patterns?
Community Acceptance	How well is this alternative accepted by the local communities?
Cost	What is the overall relative cost of this alternative, where 1 is the highest relative cost and 5 is the lowest?

Source: i11study, 2013

Tips on Setting Evaluation Criteria

- Focus the criteria on the key problems being studied.
- Keep the number of criteria small enough to be manageable in the technical analysis.
- Define criteria that are measurable. Do not go beyond the ability of the analysis tools to generate the information.
- Use criteria that can address multiple functions.
- Avoid duplication of overlapping criteria. They should be independent of each other.
- Select criteria that are meaningful for the modes being studied.
- Select criteria that are consistent within a region.

Corridor studies should use criteria that are most meaningful for the study goals and objectives. For example, economic development impacts may be paramount for projects located in rural areas, while transportation performance may be most important in an urban area. Importantly, if a corridor study is serving as part of an environmental analysis that leads to required documentation (such as an environmental impact statement), the criteria should reflect those required by environmental regulations. For example, Table 17-5 shows the criteria used as part of a transit tier 1 evaluation

Table 17-5. Criteria Used for a Tier 1 Corridor Evaluation Mode Criteria
Mode Criteria • Travel time competitiveness • Capital costs • Cost effectiveness • Ease of implementation • Mobility • Consistency with local plans • Compatibility with Central Phoenix/East Valley LRT project • Alternative eliminated in previous studies
Alignment Criteria • Travel time competitiveness • Directness of travel • New rider potential • Proximity and ease of access to activity centers • Proximity and ease of access to zero-car households and low-income households • Potential of transit-oriented development • Economic development potential • Ease of implementation • Large business commercial driveways losing full access • Small business commercial driveways losing full access • Single family residential driveways losing full access • Multi-family residential driveways losing full access • Additional 1/4 mile street traffic signals required • Additional 1/2 mile street traffic signals required • Lane miles of parking lanes removed along arterials • Lane miles of parking lanes removed along collectors • 15-mph school zones along alignment • Right-of-way impacts • Capital costs • Consistency with local plans • Consistency with LRT project • Compatibility with connections to Deer Valley Core and Glendale • Alternative eliminated in previous studies • Possible impacts on potential historic resources or sites • Possible impacts on potential prehistoric resources • Possible impacts on parks • Impacts on floodplains, riparian areas, critical habitat • Possible impacts on major utilities

Source: Valley Metro Rail, 2004

of alternatives, where the evaluation criteria had to satisfy Federal Transit Administration (FTA) requirements. It is interesting to note the difference in specificity between the mode criteria used to select a preferred mode and the criteria used to determine alignment options. The set of alternatives must also include the necessary baseline options (including a "no-build" alternative).

Decision makers will use the results of the evaluation process to decide on the appropriate strategies and actions. In so doing, each decision maker implicitly weighs or applies a degree of importance to the criteria. To aid in this process, some studies explicitly weight the criteria. For example, some studies use points that apply different scores or ratings to each project based on the total number of points assigned. This is discussed later in the chapter and other examples of weighting criteria are found in chapter 7 on evaluation.

B. Collecting and Analyzing System Performance and Condition Data

A corridor study is usually initiated in response to problems or issues identified by the periodic monitoring of transportation conditions, regional or local plans that identify future needs, the media, public complaints, and the concerns of local officials and others. The problem identification step systematically examines these problems in a manner that helps articulate the types of solutions for solving them. The analysis of these problems is called the *needs analysis* portion of the corridor study. Through needs analysis, the transportation professional examines the current situation and presents a case to proceed with the study or defer the process to another time or situation.

Realistically, both the technical assessment and the public perception of the problem are considered when stating the needs for the study. For example, if the public perceives congestion as being a critical issue in the corridor even though planning officials do not consider it as bad as in other corridors, the study should examine in more detail the potential causes of the public's perception and tailor the analysis accordingly. It is important to focus on factors that can play a meaningful role in defining the problem and shaping the corridor alternatives. Most corridor planning processes emphasize the need for a comprehensive and multimodal approach. However, corridor studies often have limited resources, so it is important to define the most cost-effective ways to solve the problems impacting the corridor during the problem identification stage.

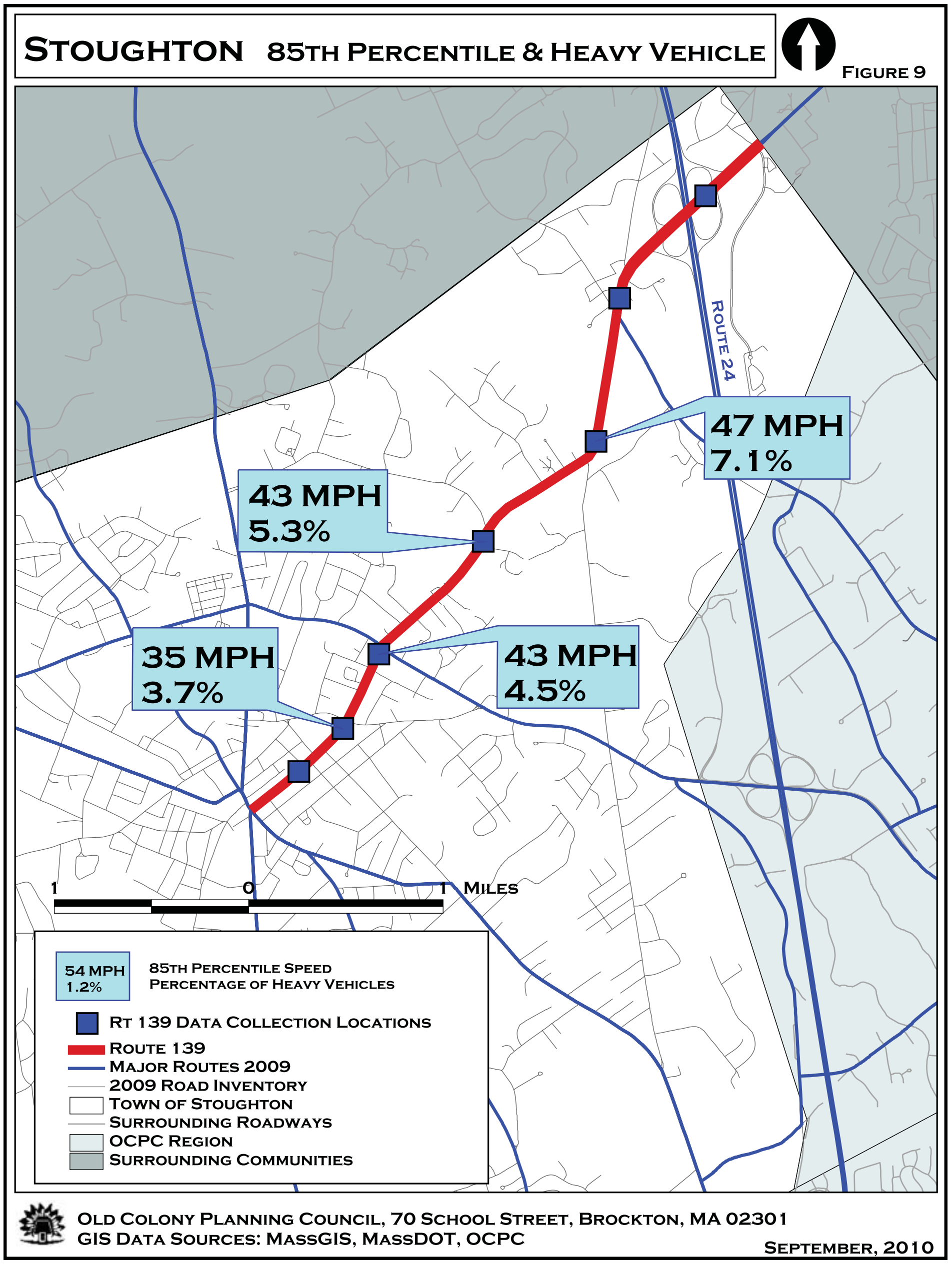
Problem Identification Process in Corridor Planning Studies

- Include existing, known problems, as well as anticipated future problems.
- Do NOT frame the problems in terms of a solution—let the problems define the appropriate solution.
- State the problems in an easy-to-understand manner.
- Describe the problems sufficiently to identify the alternatives.
- Seek agreement on the problems from all affected agencies.
- Document the problems in a way that can be integrated with NEPA.

Geographic information systems (GIS) are important tools for identifying problem areas. GIS can provide important information on the conditions and performance of the corridor transportation system in an easy-to-understand manner. GIS-based identification of high-crash locations have been used for many years to illustrate both the magnitude and type of crashes that occur in a corridor. Another advantage of GIS tools is that they are readily used by local planning agencies in identifying local land uses, zoning characteristics, and environmentally or community-sensitive areas. Thus, to the extent that land-use strategies are to be considered part of the corridor study, GIS provides useful information. As alternatives are assessed and evaluated, it is important to have an inventory of wetlands, historic properties, noise-sensitive land uses (for example, hospitals), and other impact areas. A GIS system is a useful means of providing this information and using it for assessing relative impacts of potential corridor strategies.

The first step in analyzing system performance is to examine existing conditions, especially as they relate to the evaluation criteria established at the beginning of the study. Depending on the focus of the corridor study and the types of strategies to be considered as part of the study, the range in data collected on performance and asset condition could be quite large. The following examples come from a corridor study in Massachusetts whose focus was on identifying traffic flow and circulation problems and safety deficiencies. [Old Colony Planning Council, 2010] Existing condition data was collected on roadway characteristics, land use, main route traffic flow characteristics, traffic speed, heavy

Figure 17-12a. 85th Percentile Speed and Percent Heavy Vehicles, Stoughton, Massachusetts



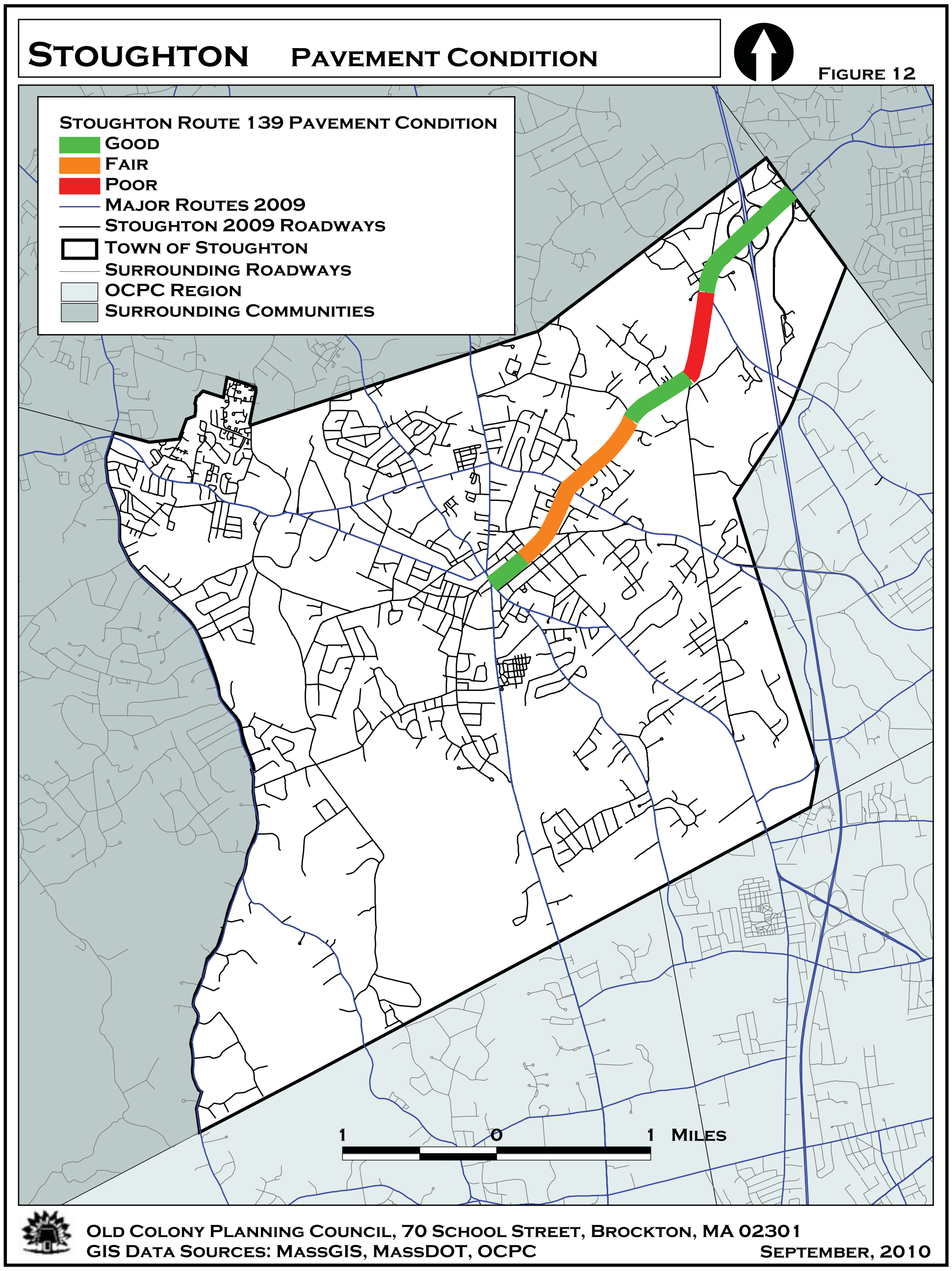
vehicle data, pavement conditions, crashes, existing peak hour operations, pedestrian/bicycle accommodations, and level of service. Figure 17-12a to d shows typical figures that might be found in an analysis of existing conditions.

According to the Washington State DOT's corridor planning guidelines, the following steps should be taken in analyzing existing conditions. [WSDOT, 2007]

Gather information about each of the transportation system components in the study area including:

- Highways and streets (public, private, state, and local streets and highways).
- Railroads (freight and passenger).
- Airports (freight and passenger).
- Transit services (public, private, general citizen, and special needs).

Figure 17-12b. Pavement Condition, Stoughton, Massachusetts

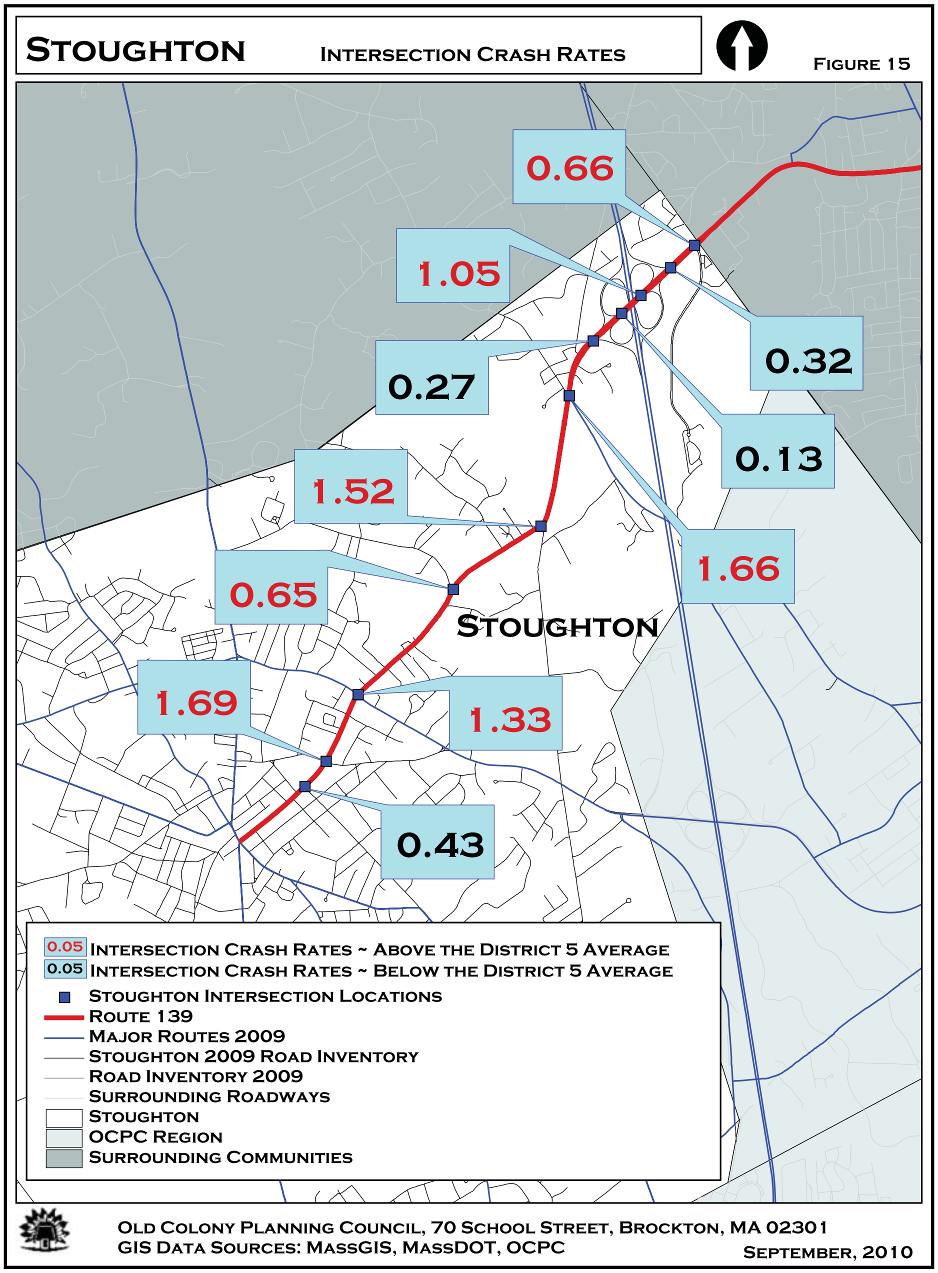


- Bicycle facilities (locations and routes).
- Pedestrian facilities (locations, signalized, and nonsignalized).
- Intermodal connection facilities and stations (park-and-ride lots, railroad and port truck transfer stations, bicycle, pedestrian, and airport transfer facilities).
- Utilities

Define the role of the corridor by asking the following questions:

- Is this a Highway of Statewide Significance, Freight Corridor, Scenic Byway, NAFTA Corridor, etc.?
- Does tourism have a central role in the area economy?
- Is there a need for quick farm-to-market trucking?
- Is this a heavy commuter route or a key freight route?

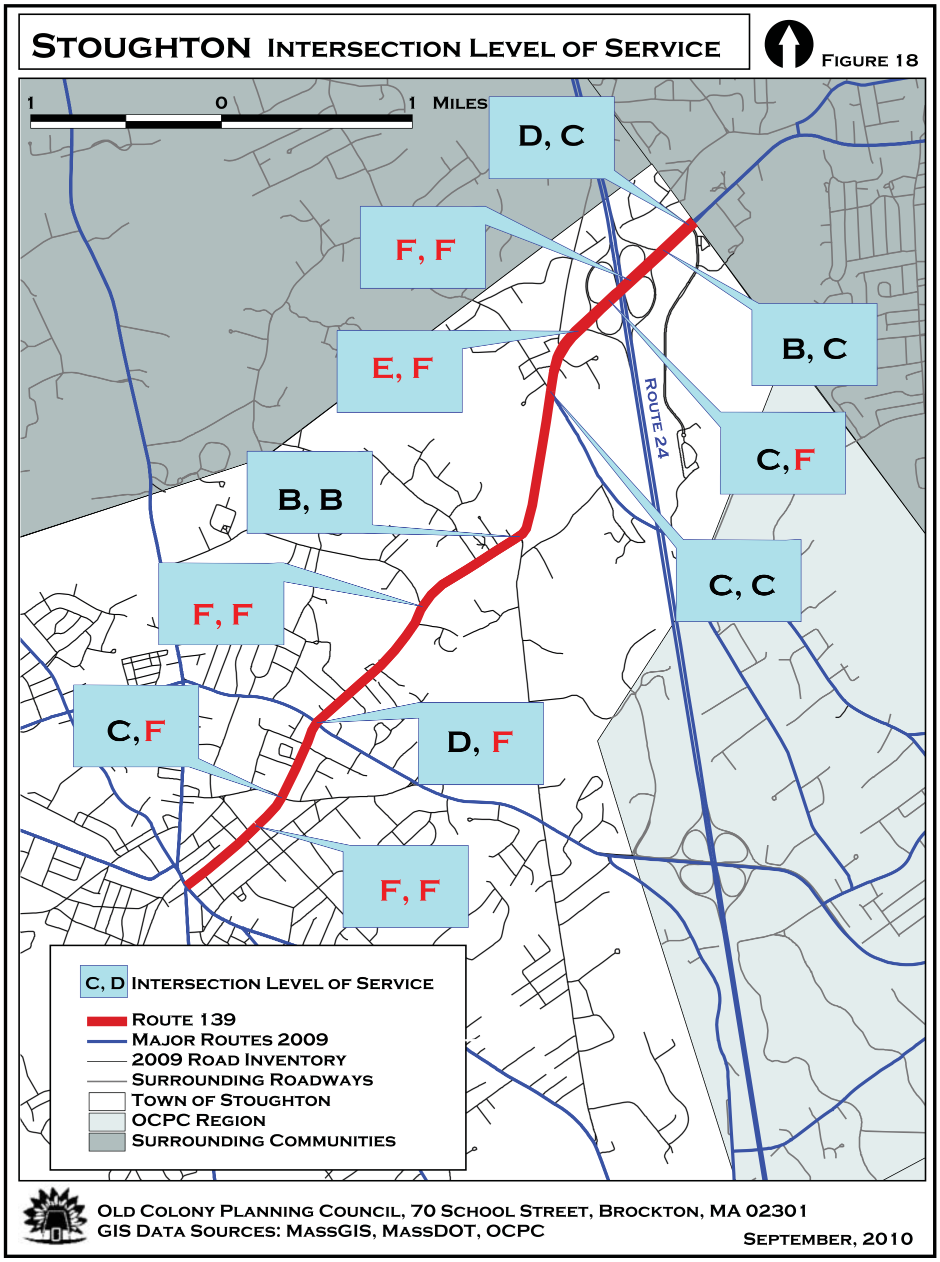
Figure 17-12c. Intersection Crash Rate, Stoughton, Massachusetts



Research land uses and other characteristics of the region:

- Census data and the state's population statistics agency.
- Population projections.
- Location of low income or minority populations.
- Employment characteristics, such as journey-to-work reports, commuting pattern studies, labor force data, and employment by industry statistics.
- Land-use assumptions from city and county comprehensive plans.
- Zoning classifications and planned developments for the corridor area.
- Pipeline and large utility locations.

Figure 17-12d. Intersection Level of Service, Stoughton, Massachusetts



Source: Old Colony Planning Council, 2010

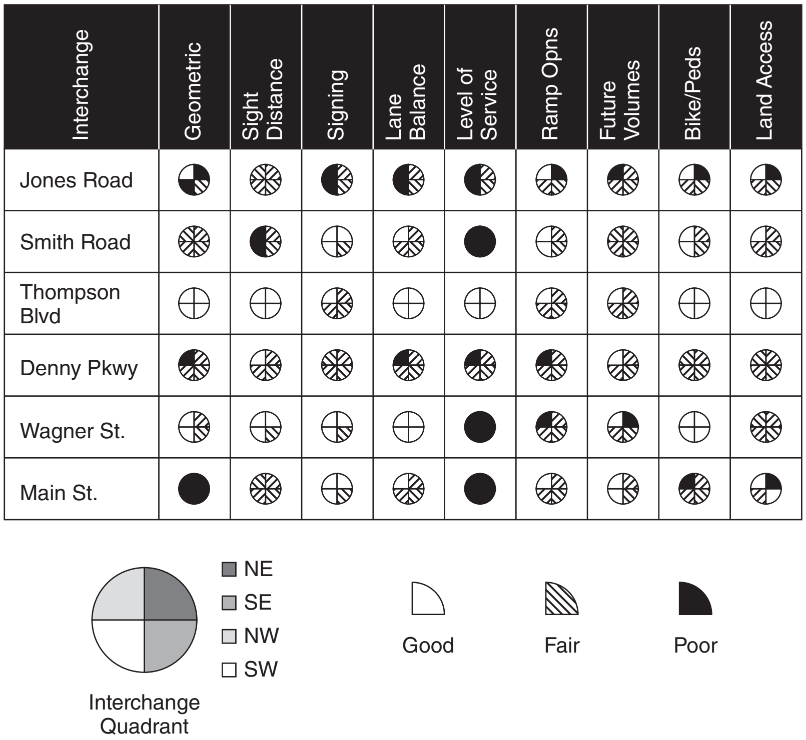
- Human and neighborhood characteristics.
- Lists of historical buildings and sites and cultural resources.

Identify critical environmental factors in the corridor area:

- Applicable federal, state, and local environmental laws, regulations, and policies.
- Existing environmental studies that include geotechnical, hydrological, and soil types.
- Major geologic and general terrain features.
- Environmental and socioeconomic resources and issues.
- Maps of environmental resources, listed environmental issues, and identified areas that require further analysis.

Figure 17-13 shows another example of how problem areas can be identified, in this case for a hypothetical corridor study. The magnitude of the problems faced at each interchange is indicated by the degree to which the evaluation circle is darkened for each quadrant of the interchange.

Figure 17-13. Evaluation of Freeway Interchanges



C. Identifying and Analyzing Alternatives

1. Identifying Alternatives

Identifying alternatives is an important step in the planning process because ultimately the breadth and depth of alternatives shape the range of options available to decision makers. It is also very important in satisfying federal or state environmental requirements to address a full set of reasonable alternatives.

Although the following guidelines for specifying alternatives had been suggested by the FTA in the past for transit projects, they are still valid for virtually all types of corridor alternatives:

- The set of alternatives must address the purpose and need for considering a major transportation investment.
- The set of alternatives must include the necessary baseline options.
- The alternatives should include all reasonable modes and alignments.
- Alternatives designed to address differing goals and objectives should be included.
- The set of alternatives should include all options that have a reasonable chance of becoming the locally preferred alternative.
- The alternatives should encompass an appropriate range of options without major gaps in the costs of the alternatives.
- Where questions remain on feasibility of specific alternatives, other alternatives should provide related fallback options.
- The number of alternatives should be manageable so that decision makers can realistically be expected to understand the implications of each and make an informed choice. [FTA, undated]

While every effort should be made to limit the number of alternatives to a manageable level, the study team should take care to include as wide a range of alternatives as necessary to examine the problems in the corridor and to meet the information needs of decision makers. For simple projects, alternatives identification can be a one-step process and may consist of "No-Action" and "Action" alternatives. In more complex studies, identifying alternatives typically evolves over several steps. Frequently, there is at least a two-step process in defining alternatives—screening the initial alternatives, followed by detailed identification and evaluation of the alternatives chosen for more detailed study. The initial screening process may include a larger number of ideas or concepts that will undergo a simple evaluation, often involving only a few criteria. This process is followed by the development of more detailed alternatives and in-depth evaluation.

Another approach for developing alternatives is called the *incremental approach*. In this process, the study team initially defines a small number of alternatives. Insights gained from this analysis are then used to refine the existing alternatives or to create new ones. This process would be repeated as needed until a consensus is formed over a preferred alternative.

It is important that the stakeholders agree up front on the process for developing and evaluating alternatives. The study team, however, should be sensitive to the changing nature of these studies and be flexible in accommodating change. Corridor studies have also been known to add alternatives relatively late in the process to deal with new information or changing public and/or political attitudes.

The breadth of alternatives considered in a corridor study will vary considerably based on the study goals and objectives. At one extreme, local corridor plans typically involve the examination of specific roadway connections or locations, such as intersections. In these studies, the alternatives may involve variations of roadway improvement or intersection designs, while modal strategy options could be limited. In urban settings, corridor studies often include transit services, pedestrian and bicycle movements, urban design strategies, and system operations. Because of the possible wide range of strategies, actions, and alternatives that are possible in many studies, transportation planners often conduct a prescreening to determine which of the alternatives are feasible and which have fatal flaws. According to the Washington State DOT, such screening criteria should consider:

- How well each option meets the vision and goals established for the study area.
- The costs of each alternative. While planning level estimates will be adjusted in the scoping process, they are important at this step. Identify low-, medium-, and high-cost options.
- The effects of each option on the study area features, such as environmental resources, and its feasibility regarding environmental issues and regulations.
- The feasibility of each option regarding compatibility and consistency with local and regional transportation plan goals and priorities.
- How each option provides improved access to important educational, medical, major employment, or recreational facilities. [WSDOT, 2007]

Metropolitan, nonmetropolitan, regional, and statewide corridor plans could involve many different modal strategies, often defined by the purpose of the corridor study. For example, a corridor study focusing on transit investments will not likely examine highway capacity expansion options (unless transit is included). The Denver Regional Council of Governments (DRCOG) has implemented a regional corridors program whereby corridors important to the region's transportation system are examined for targeted investments to improve performance. [DRCOG, 2011] Given the large number of corridors that are part of this program, DRCOG has identified the types of strategies listed below that may be considered in nearly every corridor.

Overall

- Coordinate land use and transportation decisions and implementation.
- Support urban centers and transit-oriented developments (TODs).
- Complete projects in an environmentally-responsible manner.
- Maintain the existing infrastructure including pavement, subsurface, bridges, traffic management devices and facilities, communications networks, park-n-ride lots, stations, rail lines, multipurpose trails (bike paths), and sidewalks.
- Implement safety improvements as stand-alone projects or within larger projects.
- Conduct a regional vulnerability assessment to identify critical transportation system infrastructure; determine/deploy critical infrastructure protection as required.

Transit Facilities and Services

- Implement security and safety features at transit stations, park-n-ride lots, and on vehicles.
- Make modifications to bus routes per changing ridership demands.
- Implement timed-transfer points throughout the system.

- Provide pedestrian and bicycle connections between transit facilities and adjacent neighborhoods and developments.
- Provide bicycle accommodations at transit facilities and on transit vehicles.
- Construct transit-oriented developments (TODs) around appropriate stations and park-n-ride lots.
- Increase Regional Transportation District (RTD) access-a-ride ADA transit service as the fixed-route service expands.
- Increase other specialized transit services to elderly, disabled, low-income, and rural residents.

Travel Demand Management

Baseline assumption: A regional program will facilitate and promote use of alternative travel modes, carpooling, teleworking, alternative work schedules, and efficient site development designs in all corridors.

Physical Improvements as Part of Roadway Projects

- Construct improvements to current design standards.
- Improve ramp terminal and arterial intersections to serve future volumes (turn lanes).
- Provide acceleration/deceleration lanes in appropriate locations.
- Construct standard paved shoulders on freeways and non-urban arterials.
- Provide appropriate curb/gutter/sidewalk section on urban arterials.
- Provide appropriate space and/or treatments for on-street bicyclists.
- Provide applicable crosswalk markings and devices at locations with pedestrian activity.
- Provide bus lanes and pull-outs in appropriate locations.
- Install traffic signals as warranted.
- Control arterial access per assigned state highway access category.

System Management Strategies for Relevant Corridor Baseline Assumptions:

- Link together all traffic and transit operations centers and emergency management centers to support employment of an advanced transportation management system (ATMS) that includes incident management, regional traffic control, and multimodal coordination. Implement/use effective, reliable, and cost-efficient communications infrastructure to support both connectivity between operations centers and connectivity to field equipment from operations centers.
- Operate and maintain (CDOT) a regional advanced traveler information system (ATIS)/51 service. Implement/use effective, reliable, and cost-efficient technology to both collect traveler information data and support traveler information dissemination to drivers in vehicles and travelers on transit.
- Develop, implement, and maintain a unified regional incident management plan.

Freeways

- Meter on-ramps to congested freeways; integrate ramp meters with adjacent arterial signals.
- Implement/operate full network surveillance; feed to regional ATIS.
- Operate incident detection where surveillance is deployed.
- Implement/use dynamic message signs (DMSs) to disseminate real-time traffic information, including real-time park-n-ride parking occupancy and transit parking alternatives; from regional ATIS.
- Prepare, implement, and maintain corridor incident management plans consistent with the unified regional incident management plan; operate traffic-responsive signal control along key incident diversion routes.

Tollways

- Maintain/upgrade electronic toll collection.
- Implement/operate probe surveillance using toll tags; feed to regional ATIS.
- Implement/operate select (not full) surveillance; feed to regional ATIS.
- Implement/use DMSs to disseminate real-time traffic information, including real-time park-n-ride parking occupancy and transit parking alternatives from regional ATIS.
- Prepare, implement, and maintain corridor incident management plan consistent with unified regional incident management plans; operate traffic-responsive signal control along key incident diversion routes.
- Operate tollway service patrol.

Arterials

- Install signals as warrants are met, consistent with CDOT or city/county access management requirements or access management plans.
- Operate existing and new traffic signals using signal system(s) for surface street control.
- Update traffic signal timing/coordination plans on a regular basis.
- Consider application of advanced signal control strategies where needed.
- Implement/operate transit signal priority selectively at signalized intersections adjacent to park-n-ride lots/stations, to favor key bus transfer points, and along heavily used bus transit corridors.

Transit

- Implement/operate transit security features at park-n-ride lots/stations and on transit vehicles.
- Disseminate real-time transit vehicle arrival/departure information to transit patrons at park-n-ride lots/stations and key transfer points and feed to regional ATIS and other available means.
- Compile real-time parking space occupancy at park-n-rides; feed to regional ATIS.

Some examples of strategies and actions considered in corridor studies are described below. Table 17-6 shows the types of actions and strategies that are being considered for a state-level corridor study of I-75 in Florida. [Florida DOT,

Table 17-6. Strategies Considered by Florida DOT in I-75 Corridor Study

Strategy Category	Specific Actions
Add Capacity to Parallel Corridors and Develop New Parallel Corridors	Add lanes on arterials, improve local intersections, operational improvements, new roadways, and new separated crossings for local connectivity.
Transportation System Management and Operations (TSM&O)	Virtual Freight Network, Intelligent Transportation Systems (ITS).
Managed Lanes	High-occupancy vehicle (HOV) lanes, truck-only lanes, reversible lanes, express lanes, vehicle-restricted lanes, dedicated bus lanes.
Intermodal Logistics Center (ILC)	Intermodal Logistics Centers (ILCs) that may be known as Inland Ports, Freight Activity Centers (FAC), freight terminals or a freight village.
Marine Highways	Marine highways and short sea shipping.
Parallel Freight Rail Corridors	CSX, Norfolk Southern, Florida Northern, Seminole Gulf Railway.
Passenger Rail Services	High speed rail, commuter rail, light rail, Amtrak.
Intra-Regional Transit Services	Cross county bus services, express bus services, bus rapid transit (BRT).
Transportation Demand Management Programs	Carpool, vanpool, express, bus services, ridesharing, park and ride, telecommuting.
Add Capacity to I-75	Add full lanes, add interchanges, add auxiliary lanes, operational improvements.

Source: FDOT, undated

undated] Note the wide range of strategies, ranging from adding lanes to the interstate to managing transportation demand to investing in parallel rail routes for freight traffic.

Table 17-7 illustrates the range of roadway, transit, intelligent transportation system (ITS), and demand management strategies to address current and future projected congestion in a multimodal corridor plan in Santa Barbara County, California. [Santa Barbara County Association of Governments. 2006]

Freight movement is also an important consideration in selecting alternatives within major highway corridors. Freight mobility relates to both roadway (trucking) and rail considerations. While truck movements will benefit from strategies focused on general traffic flow improvements, there are both technical and institutional issues that should be addressed within the corridor plan. Rail-oriented strategies typically follow a similar, but separate, study process; however, there are many situations where rail and highway strategies must interface to provide full corridor mobility. National Cooperative Highway Research Program (NCHRP) Report 594, *Integrating Freight into Transportation Planning and Project-Selection Processes*, developed a framework for incorporating freight needs into transportation

Table 17-7. Multimodal Strategies for U.S. 101 Corridor Study, Santa Barbara, California

- Add a carpool/HOV lane both directions south of Milpas to County Line—*Major Highway Improvement.*
- Add commuter rail, Camarillo/Oxnard to Goleta—*Major Alternative Transportation Element.*
- Designate new lanes as carpool/HOV—*Encourage Transportation Demand Management.*
- Increase express bus and shuttles with rail and regional transit—*Alternate Transportation Element—possible early action item.*
- Connect local bus and shuttles with rail and regional transit—*Alternate Transportation Element—possible early action item.*
- Bus priority on selected streets through signal priority, queue jumps, bulb-outs at bus stops, etc.—*Alternate Transportation Element—possible early action item*.
- Provide vanpool/carpool/trip reduction incentives—*TDM Element—possible early action item.*
- Encourage telecommuting and flexwork/flextime—*TDM Element—possible early action item.*
- Vary parking rates as feasible by jurisdiction—*TDM Element—possible early action item.*
- Individualize marketing—*TDM Element—possible early action item*.
- Add capacity and install meters at selected ramps—*Operational Management.*
- Use the following ITS technology to inform the traveling public and smooth operations:
  - Freeway service patrol—*Operational Management—early action item*.
  - 511 phone and Internet traffic and transit reports—*Operational Management.*
  - Variable message signs—*Operation Management—early action item.*
  - GPS real-time of arrival information at bus stops—*Operational Management*
  - Phase Improvements north of Milpas
- Implement operational improvements required to address current congestion hot spots—*Major Highway Improvement.*
- Proactively work to reduce peak period traffic through aggressive demand management and rideshare programs—*TDM Element.*
- Monitor need for additional 101 improvements following implementation of operational improvements, commuter rail, TDM and rideshare, ITS, and General Plan updates.
- Add auxiliary lanes and/or additional if needed, funds are available, and there is community support.

Source: Santa Barbara County Association of Governments, 2006 planning, with a major emphasis on corridor plans (see chapter 22 on freight planning). [Cambridge Systematics et al., 2007] As noted in the report,

> *"One way to more effectively link long-range goals with nearer term actions is to define key freight corridors and facilities that contribute to statewide or regional economic competitiveness, mobility, or quality of life. Identifying key freight corridors and facilities within a long-range planning document can have several important benefits. First, it can provide structure and focus to a freight planning program, particularly at a statewide level, by allowing states and MPOs to focus potential investments on those corridors and facilities that have the greatest effect on economic competitiveness, mobility, or quality of life. While specific projects need not be identified, defining key freight corridors and outlining specific objectives for those corridors (e.g., improve access to port/intermodal facilities, implement ITS technologies to improve flow, and improve access to highway facilities to spur economic development) can improve the ability of states and MPOs to identify freight-specific projects and help ensure that those projects are consistent with statewide or regional goals."*

It is important to recognize that a strategy does not equate to an alternative. For example, a study might consider a transit strategy or a strategy that focuses on better land development policies. Such strategies, however, are not specific alternatives. Most major corridor programs consist of combinations of strategies, with each addressing a portion of the corridor needs. Often in high-profile studies, various interest groups promote strategies that need to be considered seriously, if not given a full evaluation. The challenge to the study team is to assemble the best mix of strategies into a set of alternatives that represent reasonable contrasts worthy of evaluation.

Base Alternative. All evaluations, not just those for corridor studies, require a basis for comparison. Most studies choose a "No-Action," "Do-Nothing," or "Base Condition" alternative as a frame of reference. The "No-Action" alternative, on first glance, is relatively straightforward; it defines a condition under which no improvements are made. In reality, defining the "No-Action" alternative requires considerable thought and interaction with the study stakeholders.

Table 17-8 presents various options for identifying projects in a base condition. Most base conditions include those projects for which full funding has been secured. The challenge tends to be whether projects are really fully funded or merely *committed* for funding. Committed projects are those likely to occur, but may not have full funding currently available.

Table 17-8. Selection of a Base Condition

Base Condition Option	Advantages	Disadvantages
Use projects in the applicable metropolitan transportation plan (MTP).	Most logical for most situations. Represents a set of conditions that has been reviewed and approved on a regional basis.	May not be the best choice if the MTP projects do not represent what is reasonable under financial constraint in the vicinity of the corridor being analyzed.
Use only projects in the TIP.	Provides greater assurance that projects will actually be in place in horizon year.	Conditions would appear worse and benefits of certain alternatives may look better than they actually would be if more projects were assumed.
Use a set of fundable projects that is viewed to be reasonable by the stakeholders.	Can solve dilemma of a MTP that is believed to be unrealistic.	Takes more time to identify base condition. Could be challenged if broad agreement is not reached.
Where there is uncertainty as to future major improvements in corridor, use dual base conditions, testing sensitivity of alternatives against each condition.	May remove uncertainty from a decision that could be contingent on other future projects. This approach is particularly advantageous where a potential improvement in the corridor is one part of a larger potential improvement.	Increases resource requirement in analysis of alternatives (but sensitivity analysis may not be needed for all alternatives).

Source: Smith, S. 1999, Reproduced with permission of the Transportation Research Board.

Typically, two or more base conditions are defined—a short-term or *year of opening*, and a long-term design or *horizon year* (typically 20 to 30 years in the future). The short-term definition is easier because this period typically coincides with known and adopted 6- to 10-year funding cycles. The longer-term "No-Action" alternative is more difficult to define. Many agencies use a conservative point of comparison with only the funded or committed definition. Other agencies use the projects in the statewide and metropolitan transportation plans as the preferred choice for base conditions in that fiscally constrained plans are by definition supposed to contain only those projects for which there is funding. However, in reality, project priorities change and estimated revenues for future years are often uncertain. The important determination is what represents the most reasonable set of conditions to frame a reference for the various "Action" alternatives.

Choosing a base condition for a major high-capacity transit (for example, rail or bus rapid transit) alternatives study can be challenging. The potential for success of a high-capacity transit alternative depends in part on the level of other transit investment assumed in the base regional transit system. It is difficult to evaluate a high-capacity transit corridor without assuming the existence of other regional transit improvements. These improvements may vary depending upon the corridor or transit strategy being examined.

Another challenge in selecting a base condition relates to strategies such as ITS or toll roads. For example, a toll corridor project might be examined in conjunction with the addition of lanes on an adjacent freeway. While the proper base condition for evaluating the freeway lane expansion would be a "No-Action" freeway without the added lanes, the proper base condition for the tolling alternative would be the freeway with the added lanes. This creates the possibility of having multiple base conditions within a single corridor plan and is quite challenging to explain.

Assumptions concerning future land uses can be yet another challenge in defining a base condition. Generally, the base condition should include the regionally adopted land-use forecasts for the given study year. Consistent land-use assumptions should be used in the base year alternative. If land use changes are to be considered in the study, they typically are introduced into the build alternatives.

Finally, it is not unusual for the base condition to change during the course of the study—or after the study—due to changes in land-use forecasts or the inclusion or exclusion of a major transportation facility in the transportation plan for the region. In this situation, the agency should address the issue in a straightforward manner to determine, (1) what impact such a change will have on study conclusions, and (2) whether such an impact will likely occur. In the latter case, sensitivity tests can be conducted to identify the range of likely impacts on the results. At that point, a decision can be made whether to document the results of the sensitivity tests or conduct more detailed analyses.

Transportation System Management (TSM) Alternative. For many years in the United States, any alternatives analysis for capital transit investment seeking federal support had to include a transportation system management (TSM) alternative. The TSM alternative was considered a low-cost approach to solving the problems in the corridor. In the federal alternatives analysis process, the TSM alternative was considered a baseline for comparison with all other investment alternatives. Technical guidance from FTA defined the TSM alternative as "the best that can be done for mobility without constructing a new transit guideway. Generally, the TSM alternative emphasizes upgrades in transit service through operational and small physical improvements, plus selected highway upgrades through intersection improvements, minor widenings, and other focused traffic engineering actions."

MAP-21 and subsequent regulations removed the requirement for a specified TSM alternative and defined the point of comparison for incremental changes as the existing system or "No-Build" alternative. The "No-Build" alternative consisted of those transportation investments committed to in the TIP if the project adopted a 10-year horizon or the existing system plus the projects included in the fiscally constrained long-range transportation plan if the time horizon was 20 years. [FTA, 2013]

2. Analyzing Alternatives

The tools used to analyze corridor alternatives vary widely, depending on the scope and breadth of the studies, the common practices within jurisdictions, and the study scope/budgets. The analysis approach should closely relate to the evaluation criteria established earlier in the study. This linkage is one that should be made by the study team early in the corridor planning process. The study team should focus the analysis resources on the most important issues and avoid data overkill for those topics that are of lesser importance. Since many corridor studies involve two or more phases with differing levels of detail, the analysis methods should be tailored to the appropriate decisions being made.

Screening-level analyses are often conducted using the results of generalized travel model output to establish the relative performance of a wide range of alternatives. At this level, it may not be reasonable to spend considerable resources refining the travel model results. However, once the number of alternatives is reduced to a smaller set, there is often a need for refined data to examine the detailed performance of each alternative.

The analysis approach and types of analysis tools used in corridor studies are similar to those found in other transportation studies, including data collection, travel demand models, sketch planning models, and traffic operations models. In fact, many of the same models and tools are used only at a smaller scale than what would occur at a regional level. Looking at the Washington State DOT list of corridor planning steps described earlier, one could expect that each of the questions asked would require some form of analysis. WSDOT also identified some of the tools that transportation planners could use to analyze corridor performance or some elements thereof, including:

- Micro-simulation model used to analyze roundabout operations.
- Traffic data analysis and reporting spreadsheet.
- Travel demand model.
- Highway capacity software.
- Route optimization model.
- Simulation tool for signalized intersections.
- Signalized intersection optimization and level of service analysis tools.
- Traffic data management program.
- Multimodal microsimulation model to analyze freeways, intersections, arterial, and transit operations in particular transit signal priority.
- Model to identify and evaluate potential carbon monoxide air quality concerns. [WSDOT, 2007]

In addition, the guide noted that travel demand surveys and origin-destination surveys are often used in corridor studies as well.

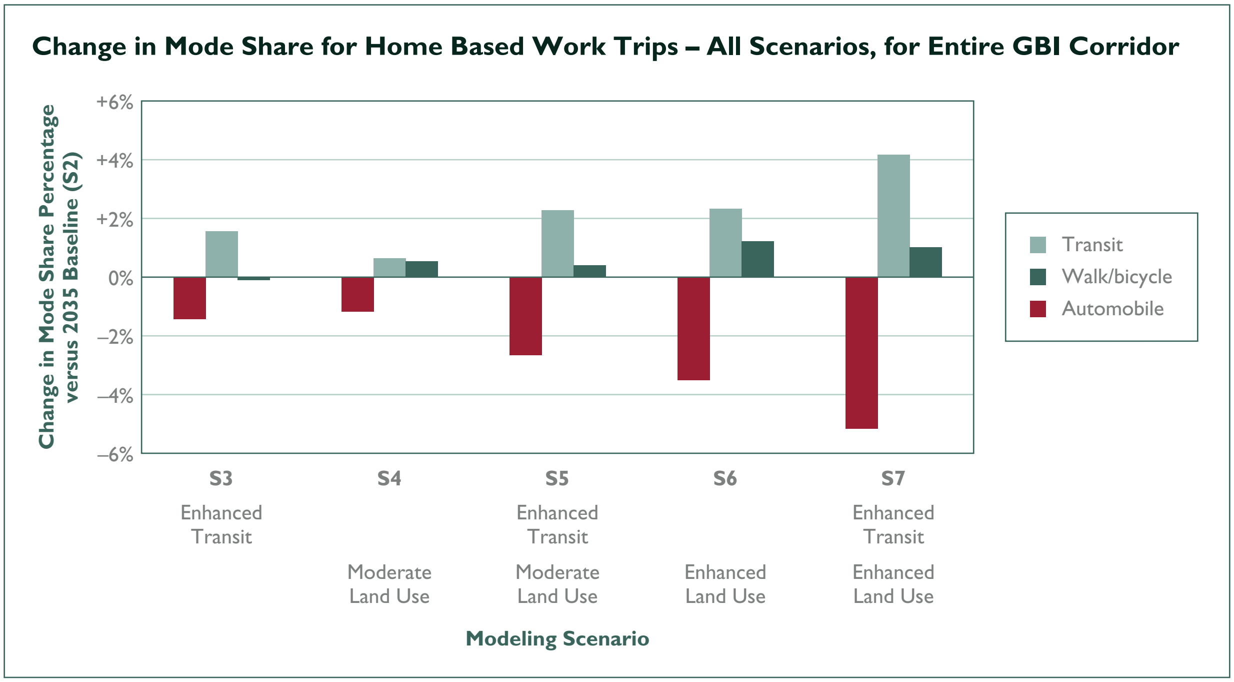
The reader is referred to chapters 2 (data), 3 (land use and urban design), 4 (environmental analysis), 6 (travel demand modeling), 9 (road and highway planning), 10 (network and facility operations planning), 12 (transit planning), 13 (pedestrian and bicycle planning), 14 (travel demand management), 22 (freight planning), and 23 (safety planning) for further description of the analysis tools that can be used to examine different types of transportation and land-use strategies.

D. Evaluating Alternatives

Good planning practice as well as federal and state environmental regulations require a consistent and valid comparison of the impacts of the alternatives. Evaluation is the process of comparing the analysis results for each alternative with the evaluation criteria defining the major dimensions of comparison. Each alternative is also compared against a common frame of reference, usually the base condition. It is important to be internally consistent with the evaluation criteria with respect to the identified goals and objectives of the study and the performance measures that have been identified for the region's transportation system. The following examples illustrate many different ways that the evaluation process has been conducted in corridor studies. In some cases, planners have used quantitative measures to assess relative worth of the alternative; the assessment is fully subjective in others; and in still others it is a combination of the two.

Figure 17-14 illustrates the concept of land-use and transportation scenarios in the Grand Boulevard corridor study in San Mateo and San Clara Counties in California. The study focused on both land use/urban design and transportation strategies that jointly affected travel behavior. The study used a travel demand model to determine the impact on travel characteristics of the different scenarios.

Figure 17-14. Evaluation of Different Alternative Scenarios, Champaign, Illinois



Source: Grand Boulevard Initiative, 2010

Table 17-9 shows a typical presentation of alternatives evaluation. Called an impact matrix (see chapter 7 on evaluation), this table presents the quantitative and subject assessment of the impacts that are important to the study. Decision makers use this type of information to choose an alternative based on all of the information presented to them.

Figure 17-15 shows a subjective approach to corridor assessment. In this example, the Florida DOT was examining different strategies for improving performance of I-75. The relative impact of each strategy, for example, adding capacity to parallel corridors, managed lanes, passenger rail service, and the like, is indicated by the number of symbols in each column relating to corridor goals, for example, enhancing mobility, providing for emergency response, encouraging economic development, and the like. The assessment was conducted by FDOT staff.

In many cases, alternatives evaluation also includes a benefit-cost analysis or some form of cost-effectiveness assessment. In such instances, the results are usually incorporated into the evaluation matrix, similar to the impacts shown in Table 17-9, simply as another impact category to consider when choosing a preferred alternative. One of the key considerations in doing so, at least in the benefit-cost approach, is that project benefits need to be defined in monetary terms. For many types of impacts, this is a significant challenge. See chapter 7 for a discussion of different approaches to evaluation that could be used in a corridor planning study.

Another aspect of evaluation found in many corridor studies is assigning points or using some other way of establishing priorities. There are several ways of doing this, as explained in chapter 7 on evaluation. Table 17-10 illustrates the approach of assigning weights to different evaluation criteria as used in a corridor study in Ft. Collins, Colorado. The corridor team rated each criterion from 1 (low) to 10 (high) in terms of importance. An average weighting was then achieved for each criterion. Once the weight was established, each of the alternatives was evaluated and rated on a 0 to 1 scale. Final scores were calculated as the product of the rating times the weight.

Many evaluation techniques also include "weighting" certain criteria higher than others. This can be done by prioritizing goals up front (for example, if safety is more important of a goal than keeping costs down, an alternative that costs more but produces fewer anticipated accidents will likely rank higher). It may be useful to determine the weighting of goals and criteria during the initial goals identification step.

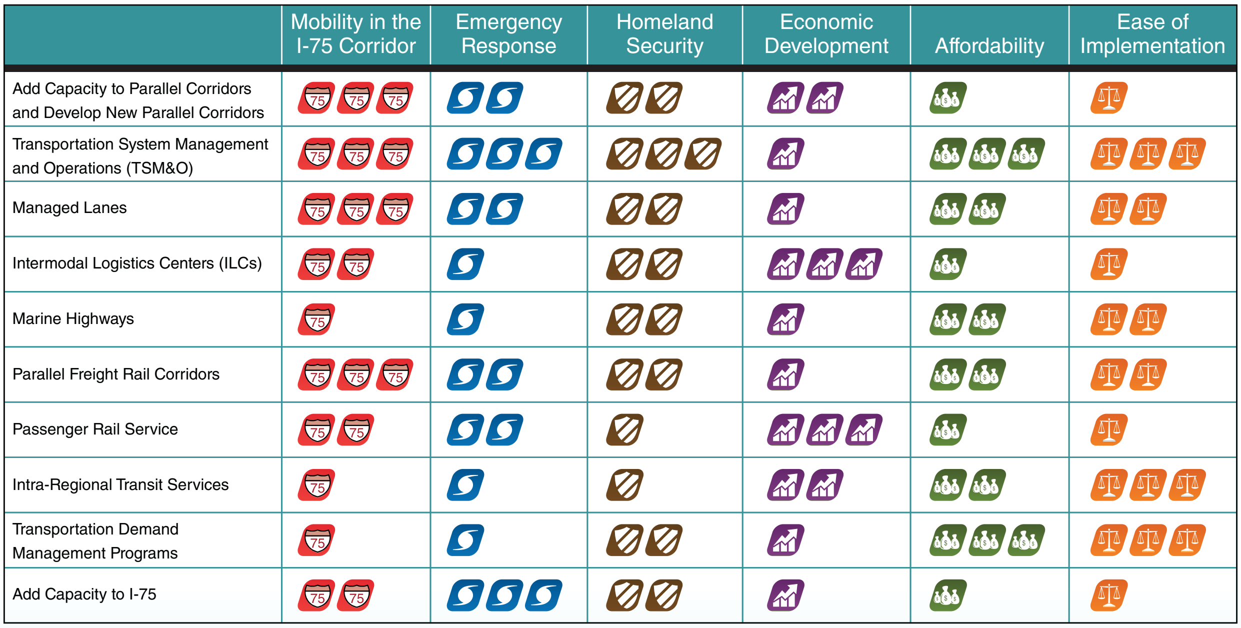
A more involved process for assigning scores to corridor alternatives comes from Queensland, Australia, where the state transport department conducted a corridor study in southeast Queensland to improve the performance of transit

Table 17-9. Example Impact Evaluation Matrix, Interstates 39/90 Environ7ental Assessment, Wisconsin

Environmental Issue	Unit Measure	Alternatives/Sections			
		No-Build	Build Inside Lanes	Build Outside Lanes	Reconstruct
Cost$					
Construction	Million $	$0.00	$410.40	$445.80	$415.20
Real Estate	Million $	$0.00	$6.20	$7.50	$6.70
Land Conversions					
Total Area Converted to Right of Way (ROW)	Acres Hectares	0	126.6 52.3	418.0 160.3	228.8 92.7
Wetland Area Converted to ROW	Acres Hectares	0	12.1 4.9	16.8 6.7	14.2 5.8
Upland Area Converted to ROW	Acres Hectares	0	18.6 7.6	31.0	12.622.8 9.2
Other Area Converted to ROW	Acres Hectares	0	23 9	59 24	57 23
Real Estate					
Number of Farms Affected	Number	0	25	212	128
Total Area From Farm Operations Required	Acres Hectares	0	75 30	311 126	135 55
AIS Required	Yes/No	No	No	Yes	Yes
Farmland Rating	Score	N/A	N/A	N/A	N/A
Total Buildings Required	Number	0	0	0	0
Housing Units Required	Number	0	0	0	0
Commercial Units Required	Number	0	0	0	0
Other Buildings or Structures Required	Number	0	0	0	0
Environmental Issues					
Flood Plain	Yes/No	No	No	No	No
Stream Crossings	Number	10	10	10	10
Endangered Species	Yes/No	No	No	No	No
Historic Properties	Number	0	0	1	0
Archaeological Sites	Number	0	0	0	0
106 MOA Required	Yes/No	No	No	No	No
4(f) Evaluation Required	Yes/No	No	No	No	No
Environ.Justice at Issue	Yes/No	No	No	No	No
Air Quality Permit	Yes/No	No	No	No	No
Design Year Noise Sensitive Receptors	Number	941	1776	1776	1776
No Impact	Number	19	36	36	36
Impacted	Number	922	1740	1740	1740
Exceed dBA Levels	Number	922	1740	1740	1740
Contaminated Sites	Number	0	5	5	5

Source: Wisconsin DOT, 2005

Figure 17-15. Subjective Assessment of Strategy Effectiveness, I-75 Corridor, Florida DOT



Source: [FDOT, undated]

Table 17-10. Example Weighting for Establishing Priorities, Ft. Collins, Colorado

Categories	Criterion Weight		
Performance	**Minimum**	**Maximum**	**Average**
Person-carrying capacity	4	10	7.1
Transit ridership	4	10	6.8
Mobility	4	9	7.4
Vehicle miles traveled	4	9	6.5
East/west arterial time	3	10	6.4
Automotive/transit corridor travel time	5	10	7.9
Cost Effectiveness	**Minimum**	**Maximum**	**Average**
Capital cost	3	10	7.7
Total annualized cost	4	10	8.2
Annualized cost per transit user	4	10	7.8
Environmental Impacts	**Minimum**	**Maximum**	**Average**
Air quality	3	10	7.6
Residential and business displacements	2	10	6.3
Noise	3	10	6.9
Visual/aesthetics	6	10	7.9
Lighting	3	9	5.8

Source: City of Ft. Collins, 2001

service and the location of prospective stations. [PB and Queensland Department of Transport and Main Roads, 2009] Twenty-one (21) criteria were used to assess different alternatives including:

Transport integration

- Patronage potential (station location delivers patronage).
- Network efficiency (bus and rail network operational efficiency).
- Modal integration/bus interchange (bus, rail, and road integration and interchanging).
- Traffic/network permeability (how well the road network functions, for example, severance and grid structure).

Engineering costs

- Construction cost (rail and road impact).
- Operating and maintenance cost.
- Engineering compliance, constructability.

Economics

- Promotes new retail (how well can the option deliver these gross floor areas (GFAs), catalyze investment, job creation and timing?)
- Creating residential density (how well can the option deliver these GFAs, catalyze investment, job creation and timing?)
- Development sequencing of rail and land uses. Timing for delivery of the various development components and the options ability to support this, for example, pre-Caboolture to Maroochydore Corridor Study).

Urban placemaking

- Quality of built form measured at street level and streetscape, and investment in built form and timing.
- Compact city core.
- Safety.

Natural environment

- Impact on Cornmeal Creek/other waterbodies.
- Other natural impact (e.g., significant vegetation).
- Flood risks and climate change.
- Soils and geology.

Social environment

- Construction noise and vibration.
- Operation noise and vibration.
- Visual amenity.
- Impact on existing property owners (area of impact and number of owners and owner type—consider acceptance by owner).

Interestingly, the number of criteria was deliberately chosen to "provide a balance between the number of the "harder" transport cost and engineering criteria and the "softer" natural and social environment criteria."

A pair-wise comparison was made between each criterion pair, for example, criterion A was compared to B, then to C, then to D and so on. A "value" was assigned to the preference of one criterion over another, with 3 points representing a major preference; 2 points representing a medium preference, and 1 point representing a minor preference. A value of "0" was used if the two were considered to be of equal value. Table 17-11 shows the aggregated scores for each criterion and the relative weight in terms of the individual score compared to the total number of points.

Table 17-11. Evaluation Criteria Weighting, Queensland, Australia

Goals, Desired Criteria, Functions, Features	Raw Score	Weight
Transport Integration		17%
Patronage potential	43	7%
Network efficiency	26	4%
Modal integration/bus interchange	21	3%
Traffic/network permeability	17	3%
Accessibility*	0	0%
Engineering Costs		20%
Construction cost	28	4%
Operating and maintenance cost	23	4%
Land resumption costs*	0	0%
Engineering compliance, constructability	75	12%
Benefit/cost ratio*	0	0%
Economics		7%
Promotes new retail	26.5	4%
Creates residential density	16.5	3%
Identifiable office node*	0	0%
Benefit cost to community*	0	0%
Development sequencing of rail and land uses	18	3%
Urban Place-making		12%
Quality open space*	0	0%
Quality built form	16	2%
Civil space*	0	0%
Compact city core	22	3%
Safety	42	7%
Natural Environment		31%
Impact on Commeal Creek/other water bodies	46	7%
Other natural impact (e.g., significant vegetation)	48	7%
Air quality*	0	0%
Flood risks and climate change	53.5	8%
Soils and geology	54	8%
Social Environment		10%
Construction noise and vibration	3	0%
Operation noise and vibration	11	2%
Visual amenity	8	1%
Disruption to traffic during construction*	0	0%
Impact on existing property owners	44	7%
Total	641.5	100%

*The criteria shaded are those part of the formal evaluation process, but did not receive any points in the evaluation process

Source: PB and Queensland Department of Transport and Main Roads, 2009

The different options were then rated on a scale of 1 (poor) to 5 (excellent), and aggregate scores for four options were estimated as shown in Table 17-12.

A sensitivity analysis was conducted by changing each of the weightings at the category level, keeping the individual weightings within each category at the same ratio. This weighting was increased in each category in turn until the preferred option changed according to the total score. Table 17-13 shows the preferred alternative for each criterion when the weights were changed.

According to the study, the sensitivity analysis showed that:

- Carnaby Street elevated is the preferred option from an economic and natural environment point of view, as well as under the balanced approach.
- Carnaby at-grade becomes the preferred solution if engineering costs become the main criterion, to the exclusion of nearly all other criteria.
- Carnaby subgrade becomes the preferred solution if socioeconomic criteria become dominant. A moderate increase in the importance of the social environment is necessary to make the change.
- At no stage is the existing Caboolture to Maroochydore Corridor Study alignment the preferred option.

E. Corridor Study Outcomes

Most corridor studies recommend one or more projects and/or alternatives to carry to the next level of implementation. For example, some corridor plans might recommend that the MPO include a project in the metropolitan transportation plan or transportation improvement plan. In other cases, corridor studies could recommend urban design and land-use policies consistent with and supporting the transportation recommendations. In some instances, a corridor study could recommend policies on how to better manage a corridor, such as improved access to surrounding land uses, called access management.

Table 17-12. Ranking of Options, Queensland, Australia

Description	Score
Carnaby Street Alignment, elevated	426
Carnaby Street Alignment, elevated, at-grade	391
Carnaby Street Alignment, elevated, sub-grade	384
Existing Caboolutre to Maroochydore Corridor Study Alignment	320

Source: PB and Queensland Department of Transport and Main Roads, 2009

Table 17-13. Sensitivity Analysis on Corridor Results, Queensland, Australia

	Transport Integration	Engineering Costs	Economics	Urban Place-making	Natural Environment	Social Environment
Existing Alignment	315.1	307.0	302.5	316.7	401.3	263.8
Carnaby sub-grade	407.5	403.6	356.6	383.9	348.9	**357.3**
Carnaby elevated	**438.4**	444.3	**472.8**	**424.3**	**428.5**	356.8
Carnaby at-grade	408.5	**444.9**	327.2	388.7	356.6	353.9

Source: PB and Queensland Department of Transport and Main Roads, 2009

The types of decisions resulting from a corridor study include the following:

Type of Decision	Comments
Pick a preferred alternative—not an environmental process	Document the selection process leading to a recommendation of a preferred alternative. Forward decision to appropriate implementing agency(ies).
Pick a preferred alternative—leading to an environmental decision	Same as above, plus include process to clear the project through NEPA/state EPA.
Designate a range of reasonable alternatives to be studied further	Forward a short-list of alternatives to appropriate agency(ies) for follow-on evaluation and selection.
Identify projects for programming—leading to inclusion in the STIP or TIP	Projects could be defined in enough detail that they could be included in the investment programs.

Once the decision is made regarding a preferred alternative, the challenge becomes how to actually implement this decision. This challenge will vary, depending on whether the implementation period is short, medium, or long.

1. Short Term

Decisions to implement an alternative in the short term (up to 5 years) are typically associated with projects that are reasonably well-defined and have design and environmental features fully analyzed. These projects are usually defined in enough detail that they can be included as part of the TIP. In this situation, the following actions should be considered:

- Prepare project description and cost estimates sufficient to include in local/regional TIP.
- Prepare a timeline of actions leading to implementation.
- Identify specific implementation responsibilities among agencies.
- Identify specific funding sources and actions needed to secure funding.
- Prepare a plan to acquire needed right-of-way or other corridor facility needs.
- Utility relocation can take just as long if not longer to coordinate, fund, and execute than right-of-way. A utility relocation/adjustment plan is also helpful.

2. Medium Term

Decisions for medium-term alternatives (6 to 10 years) are those either still in the planning and environmental process, where the project scope is not yet defined in sufficient detail to allow engineering to occur. However, the alternatives have usually been identified as part of a transportation plan, which usually entails general project descriptions and cost estimates. In this situation, the following actions should be considered:

- Prepare general project descriptions and cost estimates sufficient to include in a transportation plan.
- Prepare a schedule for plan and project implementation.
- Identify responsibilities among agencies.
- Identify general funding categories and project-specific funding options.

3. Long Term

Decisions that identify long-term solutions (usually 10 or more years) will likely have fewer design details, costs, and funding arrangements identified. In order to move the corridor plan forward, the following actions should be undertaken:

- Identify all project elements, including physical and policy-related features.
- Prepare programmatic cost estimates sufficient to include within local and regional TIPs.
- Prepare a recommended schedule for implementation.
- Define agency responsibilities and secure interagency agreements supporting the recommendations.
- Evaluate options for funding sources.
- Begin pursuing funding opportunities.

Many longer-term decisions may have somewhat vague project descriptions and may even consist of multiple alternatives that should be further analyzed. It is very important to further detail the project elements to develop a consensus on which elements are most important and to fully explain the project to the public.

Tables 17-14 and 17-15 provide examples of implementation recommendations for transportation and land-use strategies from the *Vermont 15 Corridor Management Plan*. [Vermont Agency of Transportation, 2005a] The transportation results produced short-, medium-, and long-term recommendations focused on specific areas within the corridor. The land-use recommendations focused more on policy and design elements that could be implemented in concert with the transportation improvements.

The Delaware *Route 40 Corridor Plan* established triggering thresholds that would result in actions being taken to implement the plan. [Delaware DOT, 2000] Table 17-16 shows the various plan elements that are regularly monitored to identify whether specific triggers have been met. The monitoring activities trigger an evaluation of whether to continue with a plan project on the originally proposed schedule or to move it forward or back as conditions dictate. The monitoring and triggering activities are documented in a periodic corridor monitoring and triggering report, which provides all interested stakeholders with the status of the monitoring efforts and any triggering activities that are initiated. This ongoing process will help ensure that the plan is actively managed over time.

F. Access Management

This corridor-level strategy, which has received increasing attention during the past two decades, provides more control of access to land parcels adjacent to corridor roads and reduces the potential for vehicle conflicts on major highways (see Figure 17-16). Transportation agencies most often adopt standards for road access. For corridor planning, access management and the associated standards are important considerations for safeguarding the capacity of a roadway. Such standards are often very specific with respect to what will be allowed with respect to road access. For example, Table 17-17 shows the access management standards for the Florida DOT with respect to the state highway system. Such standards often become the focus of development plans where developers want the most access possible ("build us a new interchange") and transportation agencies are trying to preserve the safe operation of the road.

The types of techniques and strategies applied in access management vary according to the types of problems encountered along the corridor. According to the FHWA, access management strategies can include the following types of techniques:

- Increased spacing between signals and interchanges.
- Driveway location, spacing, and design.
- Use of exclusive turning lanes.
- Median treatments, including two-way left turn lanes (TWLTL) that allow turn movements in multiple directions from a center lane and raised medians that prevent movements across a roadway.

- Use of service and frontage roads.
- Land use and driveway access policies that limit right-of-way access to highways. [FHWA, 2015a]

NCHRP Report 548, *A Guidebook for Including Access Management into Transportation Planning*, provides useful recommendations on how access management can be better integrated into the transportation planning process. [Rose et al., 2005] Specifically, this guidebook recommends the following steps for an effective access management program:

- Developing and applying an access classification system that assigns access management standards to roadways in accordance with their level of importance to mobility. This system generally parallels the roadway functional classification system.

Table 17-14. Sample Implementation Recommendations, Vermont 15 Corridor Study

Sample Implementation Recommendations				
Area	**Purpose**	**Need**	**Recommendations**	**Comments/Next**
Jericho Village	Improve safety for pedestrians and cyclists Connect village residential and commercial origins and destinations Enhance community character	Traffic volumes expected to increase 10,900 to between 15,000 and 20,000 vehicles per day; will have negative impact on pedestrian travel and quality of life	***Short-term*** New sidewalk in front of Keith Agency and Village Cup, extending from new VT 15 crosswalk from bridge ***Medium-term*** Traffic calming devices along VT 15 Signage indicating historic district Extensions of historic light policies Bury utility lines Improved access management ***Long-term*** Sidewalks and bike lanes on both sides of VT 15 Additional crosswalks	Endorsed by Jericho Transportation Subcommittee Evaluate possibility of reducing posted speed to 25 mph when measures implemented Conduct feasibility study of extending sidewalks; identify appropriate crosswalk locations
Jericho, Intersection VT 15/Lee River Road	Improve intersection safety and efficiency for pedestrians, bicyclists, and motorists	LOS F currently exists on Lee River Road; will worsen as traffic on VT 15 increases. Future conditions satisfy warrants for left- and right-turn lane on VT15 and traffic signal.	***Short-term*** Reconfigure intersection to include one-way exit along north side of Flat Iron with a simple T intersection on south side ***Medium-term*** Evaluate right and left turns and/or traffic signal. Incorporate proposed streetcar designs	Conduct scoping study to evaluate long-term intersection design alternatives
Jericho, rural-suburban road segment (Cilley Hill to River Road)	Maintain a reasonable level of mobility for through traffic and improve local circulation options.	Projected traffic will approach 11,500–15,000 vehicles per day. Existing entrances from side streets and driveways will become more difficult. Vehicles turning from VT 15 will reduce speeds on VT 15.	***Short-term*** Manage access for parcels directly adjacent to VT 15 by following VTrans guidelines. ***Medium-term*** Provide new street connections between adjacent subdivisions to create a local network accommodating vehicles, pedestrians, and bicyclists.	Include access management guidelines in Jericho zoning and subdivision regulations consistent with VTrans Access Management Category 6. Town of Jericho should map easements to explore possible connections. Evaluate traffic impacts of providing connections.

Source: Vermont Agency of Transportation, 2005a

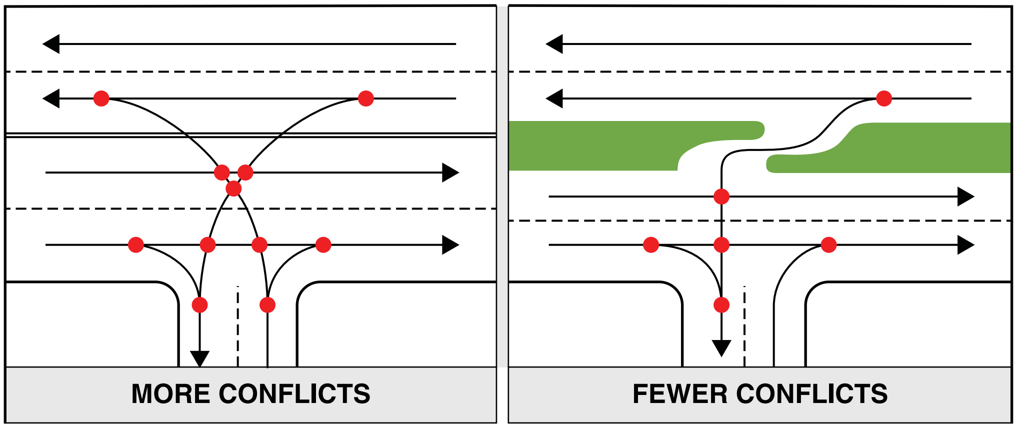
Table 17-15. Example Corridor Land-Use Recommendations, Vermont	
Sample Land-Use Recommendations	
Town	**Recommendations**
Jericho	• Consider site plan review as a requirement for all developed along VT 15 corridor; and • Include provisions for shared access and driveways in subdivision regulations.
Westford	• Consider establishing an overlay district along VT 15 to establish zoning guidelines to implement existing town plan objectives of protecting scenic, historic, and natural resources.
Johnson Town/ Village	• Adopt regulatory documents (such as zoning) to implement and enforce town/village Master Plan goals, or delineate VT 15 as a specific planning area and include development guidelines in the Master Plan.
Morristown/ Morrisville	• Establish minimum distance between curb cuts, consistent with VTrans Access Management standards; and • Establish design guidelines and/or a landscape plan for the commercial district.
Wolcott	• Delineate areas of compact, mixed-use development at major intersections, and minimize development between these areas; • Establish other zoning districts (e.g., residential, agricultural, and commercial) and lot requirement/densities; • Encourage sharing of access and parking for commercial developments; and • Allow Planned Residential Developments to promote concentrated development.

Source: Vermont Agency of Transportation, 2005b

Table 17-16. Monitoring and Triggering Elements, Delaware Route 40 Corridor Plan		
Monitoring Element	**Trigger**	**Resulting Actions**
Land development	Major land development activity	Review transportation needs for level of service implications and strategy.
Traffic	Deteriorating level of service ("D" or worse)	Implement strategies to: stabilize/reduce demand; or increase capacity.
Highway safety	Safety improvements recommended by the Highway Safety Improvements Program review team	Evaluate the compatibility of the proposed improvements with the plan and the need to make adjustments to the plan.
Transit service	Transit service changes proposed by Delaware Transit Corp.	Evaluate any ancillary improvements needed to complement the service changes, such as sidewalks or shelters that should be advanced to the plan.
Status of projects in design, implemented, or other projects in the region	Transportation improvements not part of the plan but affect the corridor and are proposed for implementation.	Evaluate the compatibility of the proposed improvements with the plan and the need to make adjustments to the plan.
Any of the above		Assessment of potential changes may trigger one of the following options to best respond to the new conditions: Continue project(s) as currently scheduled, move project(s) forward, or move project(s) back.

Source: Delaware DOT, 2000

Figure 17-16. Reducing Vehicle Conflicts through Access Management, Florida DOT



Source: FDOT, 2014

Table 17-17. Access Management Standards for the Florida State Highway System

Access Class	Segment Location				Applicable Interchange Spacing Standard	
1	Area Type 1: CBD and CBD fringe for cities in urbanized areas				1 mile	
	Area Type 2: Existing urbanized areas other than Area Type 1				2 miles	
	Area Type 3: Transitioning urbanized areas other than Area Types 1 or 2				3 miles	
	Area Type 4: Rural areas				6 miles	
	Medians	**Median Openings**		**Signal**	**Connection**	
		Full	**Directional**		**>45 mph posted speed**	**≤ 45 mph posted speed**
2	Restrictive w/service roads	2,640′	1,320′	2,640′	1,320′	660′
3	Restrictive	2,640′	1,320′	2,640′	660′	440′
4	Nonrestrictive			2,640′	660′	440′
5	Restrictive	2,640′ for > 45 mph posted speed	660′	2,640′ for > 45 mph posted speed	440′	245′
		1,320′ ≤ 45 mph posted speed		1,320′ ≤ 45 mph posted speed		
6	Nonrestrictive			1,320′	440′	245′
7	Both median types	660′	330′	1,320′	125′	125′

Source: FDOT, 2014, 2015

- Planning, designing, and maintaining road systems based on this access classification system and related road geometry.
- Defining the level of access permitted to each classification, which includes the following:
  - Permitting or prohibiting direct property access.
  - Allowing for full movement, limited turns, and median.
  - Designating the type of traffic control required such as signal, raised median, or roundabout.
- Establishing criteria for the spacing of signalized and nonsignalized access, as well as access setback distances from intersections (corner clearance) and interchanges.

- Applying agreed-upon engineering standards that include appropriate geometric design criteria and traffic engineering measures to each allowable access point or system of access points.
- Establishing policies, regulations, and permitting procedures to implement the listed components.
- Ensuring coordination with and supportive actions by local jurisdictions exercising their land-use planning authority as well as their development permitting and review authority.

In addition, many state DOTs have adopted their own access management program or plan on their respective websites. See chapter 3 on land use and chapter 9 on road and highway planning for further discussion on access management.

G. Environmental Process

Corridor studies might or might not follow a formal environmental process. The plans following a NEPA or state-based environmental process will result in a programmatic or project-level decision leading to a categorical exclusion, a finding of no significant impact, or a record of decision or the state/provincial equivalent. These more detailed plans must make sure all of the key decision milestones are reached to ensure that the project can be cleared environmentally.

In cases where further study is needed, a process should be established to follow the project through subsequent environmental studies sufficient to clear the selected project. This process may proceed for a period of months or years until a preferred alternative is fully defined, evaluated, and approved by the respective agencies. During this time, the alternatives may change and the results may be revised based on new information available to the project team. The important action is to keep the process sufficiently alive to avoid repeating the entire corridor analysis process. The reader is referred to chapter 4 on environmental analysis.

H. Public Engagement

Because of the local nature of many corridor studies, corridor planning requires a thoughtful approach on how to involve the public. Public engagement complements technical analysis in providing information to decision makers. Decision makers will weigh the results of both the technical analysis and public input and make a decision that is in the best interests of the community and/or region. Most studies include the important role of partner agencies in the overall public outreach effort. Involving the public in goal setting and the identification of purpose and need can be helpful in determining evaluation criteria. Taking back to the public a list of alternatives to choose from (developed as a result of their input) is much preferred over a set of alternatives developed solely outside of a public participation process.

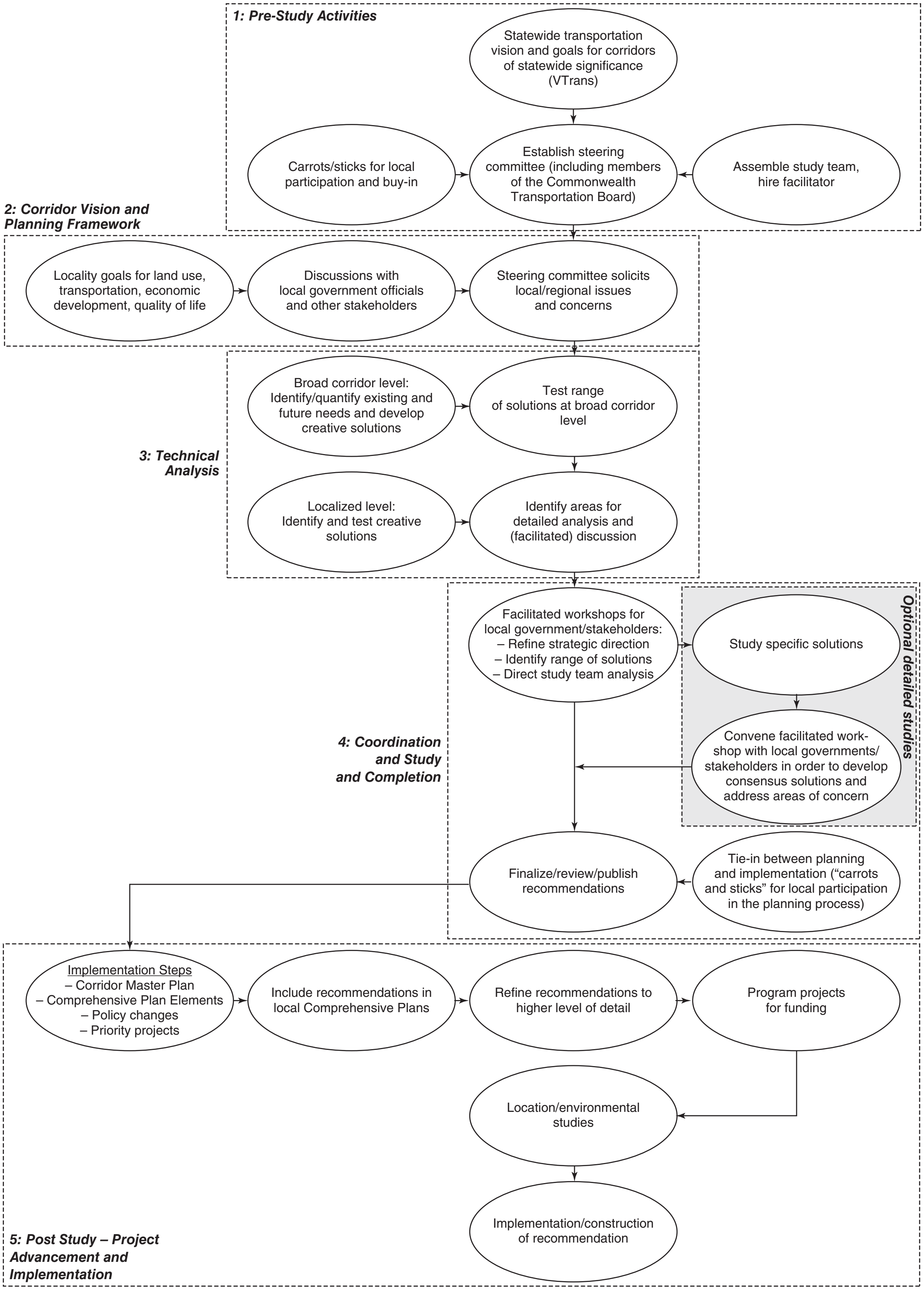
From a public engagement perspective, corridor planning is not that different from other types of transportation planning activities. However, what sets many corridor studies apart is the local familiarity with the corridor and the potential controversies that could begin at the very start of the study. Such controversy occurs particularly when corridor strategies involve new facilities or expansion of existing facilities. Many corridor studies also often begin with public disagreements over the identification of the corridor problems and what should be done about them. The public engagement program should clearly articulate the issues in a way that leads people to understand them and to develop informed opinions.

Many corridor studies could benefit from the participation of a public participation specialist. A public affairs specialist deals with questions and public policy issues, most often having a political dimension. A specialist in community outreach helps agencies and communities improve their decision-making process by involving the people most likely to be affected.

Chapter 24 discusses public engagement in much greater detail. Interested readers are referred to that chapter.

Figure 17-17 shows the overall process for corridor planning sponsored by the Virginia DOT. As shown, this process includes all of the steps presented in this section, as well as linking the corridor plan recommendations to other plans and implementation strategies at the end of the study. [VDOT, 2015]

Figure 17-17. Corridor Planning Process, Virginia DOT



Source: VDOT, 2015

V. CORRIDOR MANAGEMENT PLANS

Corridor management plan is a term that is used to describe two different transportation planning efforts. The first reflects the natural progression from a corridor planning process to efforts to manage corridor system operations, land-use decisions, and future investments. The second is a term that is used as part of the U.S. scenic highway program and is intended to highlight the steps necessary to enhance the historic and scenic nature of an area bisected by a scenic highway or byway.

A. Managing Corridor System Performance

Corridor management refers to the "management of land development and the transportation facility within an existing corridor to ensure that they develop in accordance with adopted land use plans, roadway improvement plans, access management, future ROW needs, or any specially adopted plans or objectives for the corridor." [Williams, 2000; Hard et al., 2008] A corridor management study "evaluates roadway design and access characteristics, and proposes changes that maintain reasonable access to property, while improving the safety and operation of the highway." Such changes may involve:

- Medians or median opening closures.
- Signal location and spacing.
- Auxiliary lanes.
- Right-of-way needs and requirements.
- Site access and circulation design.
- Land use and activity center concepts.
- Improvements to the supporting roadway network.
- Improvements involving access for other transportation modes (for example, bus pullouts, transitions for special use transit lanes or bus rapid transit, pedestrian crossing treatments).

Corridor management is distinguished from another concept, corridor preservation, which is the practice of acquiring, preserving, or protecting right-of-way needed for a future transportation corridor. Corridor preservation relies on several different land use regulatory and DOT financial options in order to preserve the DOT's ability to use the right-of-way in the future for system expansion.

A study by the Texas Transportation Institute noted the "connected" nature of road operations and land use in many of today's transportation corridors (especially those in urban areas). [Hard et al., 2008] The report concluded that the solutions to the problems lie in coordinated corridor management and preservation activities that help bring together land use and transportation planning decision making among the affected jurisdictions and agencies. Different types of system management and preservation strategies and actions were described in the report. Table 17-18 shows the variety of ways that DOTs could implement both types of corridor efforts. Table 17-19 from the same study shows the institutional authority for using different strategies in Texas. This table shows the important role that cities (or local jurisdictions) have in implementing any plan that has land use as part of the strategy. The reader is referred to chapter 3 on land use and urban design strategies.

B. Enhancing Scenic and Historic Characteristics of Scenic Corridors

Corridor management plans (CMPs) are also developed for those interested in enhancing the condition and performance of scenic byways. [FHWA 2015b] A CMP specifies "the actions, procedures, controls, operational practices, and strategies to maintain the archaeological, cultural, historic, natural, recreational, and scenic qualities that support the byway's designation." The Brandywine Valley Scenic Byway Corridor Management Plan is a good example of such a CMP. [Brandywine Valley Scenic Byway Commission, 2014] The Brandywine Valley, located between Delaware and Pennsylvania, was the site of one of the most important battles during the American Revolution. Many other events of

Table 17-18. Types of Corridor Management and Preservation Actions, Plans, and Implementation Tools, Texas

	Plans			Implementation Tools				
	Comprehensive	Thoroughfare	Statewide or Regional	Design Standards or Policies	Corridor Specific Plans	Access Management Regulations	Subdivision/Planning Regulations	Zoning Ordinances
Corridor Management								
Connectivity	P	•	P	•	•		•	•
Access roads	P	•	P	•	•	•	•	•
Median openings	P	P	P	•	•	•	•	•
Driveway spacing	•	•	•	•	•	•	•	•
Signal spacing, location	P	•	P	•	•	•		
Access easements	•	•	•	•	•	•	•	•
Acquisition of access rights	•	•	•	•	•	•	•	•
Access management plans	P	P	P	•	•			
Clustering development	P			•	•		•	•
Traffic impact analyses	P	P	P		•	•	•	•
ITS/Operations strategies	P	•	P		•			
Setback requirements	P	P	P		•			•
Site plan review	P	P	P	I		•	•	•
Access permits	P	P	P	•	•	•		
Corridor Preservation								
Dedication (via plat)	P	P	P	•			I	
Reservation (via plat)	P	P	P	•			I	
Impact fee credit	P		P					•
Purchase development rights	P				P		•	•
Transfer development rights	P				P		•	•
Transfer of density rights	P				P		•	•
Fee simple purchase	P	P	P		I		•	•
Option to purchase	P	P	P		I		•	•
Protective purchase	P	P	P		I		•	•
Hardship acquisition	P	P	P		I		•	•
Early acquisition	P	P	P		I		•	•
Property exchange	P	P	P		I		•	•

P = Policy I = Implementation • = Specific part of plan or action

Source: Hard et al., 2008

major historical significance have occurred within the corridor, making it an excellent candidate for a historic byway. The CMP is organized into several chapters related to the vision for the corridor, identifying the intrinsic qualities of the corridor, describing the byway itself, recommending strategies for enhancing the historic and scenic nature of the corridor, and implementing the plan.

Similar to a regular corridor transportation planning process, the CMP for the Brandywine Byway conducted extensive outreach with key stakeholders and the public, developed a vision that could guide the planning effort, established

Table 17-19. Comparison of Corridor Management and Planning Authority among Cities, Counties, and Extra-Territorial Jurisdictions, Texas				
Tool	**CM, CP, or Both**	**Cities**	**Extra-territorial Jurisdictions**	**Counties**
Comprehensive (land-use) plan	Both	√		
Transportation plan	Both	√	√	limited
Zoning	CM	√		
Regulate land use/density	Both	√		
Overlay zones	CM	√		
Building setbacks	CM	√		
Parking setbacks	CM	√		
Landscaping requirements	CM	√		
Aesthetic controls (signs, architectural,lighting)	CM	√		
Clustering	Both	√		
Subdivision regulations	Both	√	√	√
ROW dedications via platting	Both	√	limited	limited
ROW reservation via platting	Both	√	limited	limited
Street size via functional class	Both	√	limited	limited
Street layout/connectivity	Both	√	limited	limited
Access easements	CM	√	limited	limited
Lot size/Dimension requirements	Both	√	limited	limited
ROW acquisitions/preservations	Both	√	√	√
Fee simple purchase	Both	√	√	√
Negotiated purchase	Both	√	√	√
Advanced acquisition (hardship, protective options)	CP	√	√	√
Condemnation	Both	√	√	√
Temporary use agreements	CP	√	√	√
Property leaseback	CP	√	√	√
Access management	CM	√	√	limited
Driveway spacing requirements	CM	√	√	limited
Driveway design criteria	CM	√	limited	limited
Purchase access rights	Both	√	√	√
Signal spacing	CM	√	√	√
Medians/facility design	CM	√	√	√
Miscellaneous tools/methods	Both	√	√	
Development agreements	CM	√	√	
Purchase of development rights	CP	√	√	
Transfer of development rights	CP	√	√	
Traffic impact analyses	CP	√	limited	
Density transfers	CM	√	limited	
Operational measures—signal timing, ITS	CM	√	√	

CM = corridor management CP = corridor preservation √ = Tool can be used

Source: Hard et al., 2008

goals, and developed strategies and actions to preserve and enhance the historic and scenic nature of the corridor. The transportation goal and corresponding objectives for the CMP were:

Transportation and Traffic Safety Goal: To provide for a multimodal Byway corridor that accommodates all users, ensures safe travel, and provides connectivity and access to facilities, services, and destinations in an attractive setting.

Objectives

- Work with PennDOT, DVRPC, Chester and Delaware Counties, and all municipalities located in the corridor to accommodate and balance the needs of all roadway users including residents, visitors, businesses, public facilities, and institutions by utilizing context sensitive design and multimodal approaches to solving transportation challenges.
- Adopt traffic calming measures, in coordination with PennDOT and the affected municipalities, as a means of self-enforcing posted speed limits, improving pedestrian safety, and encouraging pedestrian and bicycle use of the Byway corridor.
- Plan for both safe access as well as intermodal access to recreational facilities in consultation with PennDOT and pertinent recreational facility providers.

Table 17-20. Example of an Historic Byway Corridor Management Plan

Description	Strategy	Lead Stakeholder	Support Stakeholders
Roadway Functional Classification and Typology	Establish consistent roadway functional classification and typology designations.	Commission, Byway municipalities	PennDOT, Chester, and Delaware County's Planning Commissions (CCPC and DCPC), Delaware Valley Regional Planning Commission (DVRPC)
Context Sensitive Solutions	Provide input to context sensitive design treatments for all transportation improvement projects.	Commission	PennDOT, CCPC/DCPC, Byway municipalities
Safety	Implement safety enhancements along the Byway and at critical conflict areas.	Commission; State and municipal police forces	PennDOT, DVRPC, CCPC/DCPD, Byway municipalities
Traffic Calming	Design and implement traffic calming at key locations.		Commission, PennDOT, Byway municipalities
Roadway Maintenance	Regularly clear debris and overgrowth along roadway edges, particularly along bicycle and pedestrian routes.	PennDOT, Byway municipalities	
Bicycle and Pedestrian Routes	Implement safe, continuous, and well-connected bicycle and pedestrian routes.	Commission, Byway municipalities	PennDOT, DVRPC, CCPC/DCPC
Existing Bus Service	Enhance SCCOOT Bus Service with improved signage, amenities, and pedestrian crossings.	PennDOT, Transportation Management Association of Chester County (TMACC), Byway municipalities	DVRPC
Future Bus Service	Provide connecting bus service to key Byway attractions.	PennDOT, DART, Southeast Pennsylvania Transit Authority (SEPTA)	TMACC, CCPC/DCPC, DVRPC
Regional Rail Access	Support improvements for multimodal accessibility at nearby rail stations.	SEPTA, Amtrak, PennDOT	TMACC, CCPC, DCPC, Byway municipalities

Source: Brandywine Valley Scenic Byway Commission, 2014

The CMP identified the opportunities in the corridor that reinforced the vision, including:

- Planned bicycle and trail improvements in support of the CMP transportation goal provides for a multimodal corridor, which suggests that a comprehensive approach to accomplish this opportunity is through a Bicycle and Pedestrian Master Plan for the Byway corridor.
- In order to meet the transportation goals, consistent roadway classifications and design parameters for the Byway segments among the Byway municipalities and other agencies responsible for the road segments should be provided.
- The Byway corridor has limited public transportation services to serve current and future regional and Byway destinations, to address the goal for a multimodal corridor. It will be important to identify opportunities for expansion of alternative transportation means, notably through private-sector enterprise.
- To accomplish a fully integrated multimodal system for the Byway corridor, off-road trails, paths and sidewalks also can serve as linkages to Byways destinations as well as between missing links of on-road facilities.

Table 17-20 shows the types of strategies and actions that were recommended by the study. As can be seen, the recommendations are much in line with the types of values and goals outlined by the corridor stakeholders. In many ways, this concept of a CMP is an excellent example of context sensitive solutions (see chapters 3 and 9).

VI. SUMMARY

Although transportation planning can occur at many different levels, one of the most important is the corridor level. Corridor planning can be part of a four-step process consisting of: (1) planning, (2) project development, (3) design, and (4) construction. The purpose of corridor planning is to vet potential projects for inclusion in this four-step process. Through each step, the parameters of the corridor improvement, first identified in the planning stage, get refined and more detailed, with the overall process perhaps taking over 10 years. Corridor planning allows planners to focus on specific transportation problems that affect mobility and accessibility, thus allowing the identification of problem-specific solutions. In addition, while regional transportation planning often deals with general land-use and development policy issues, corridor plans can be very specific about the land-use policies needed in a corridor to complement transportation investment.

Many metropolitan planning organizations use corridor plans as a way to identify projects for their transportation plan. State departments of transportation often use corridor studies as a way to identify multimodal capacity and operations improvements at the regional or statewide level. Many transit agencies also conduct corridor studies to identify the most cost-effective set of transit investments for the corridor's contribution to regional transit system productivity and effectiveness.

Corridor studies provide many advantages in assessing transportation needs and identifying strategies for improvement. Because a corridor study focuses on specific travel corridors, the study team can identify problems associated with specific strategies to improve the corridor transportation system. Engaging stakeholders and the public in a public involvement process for a corridor study tends to be easier than regional efforts, because participants can relate to the locations being discussed and can personalize the potential benefits of the improvements. The land use/urban design component of corridor studies provides important insights into how the transportation decisions affect future land-use patterns and how careful land use planning and urban design can influence the transportation solutions. Finally, the types of improvement strategies identified in a corridor study can focus either on specific-site improvements (for example, improve this interchange) or more regional strategies (for example, expand transit services in the corridor). Thus, the priorities and next steps for implementing the corridor study recommendations can be clearly determined.

It is important to note that corridor planning studies require professional competencies in a variety of disciplines. NCHRP Report 435, *Guidebook for Transportation Corridor Studies: A Process for Effective Decision-making,* recommends training in the following core competencies important to corridor planning: modeling, public involvement and consensus building, economic and financial analysis. [Smith, 1999]

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Local and Activity Center Planning[1]

I. INTRODUCTION

As noted in chapter 2, the majority of the U.S. population lives in urban areas, which is true of most countries of the world (see chapter 2 on data collection and analysis). According to the U.S. census, there were 3,144 counties (and county equivalents) and 19,354 incorporated places in the United States in 2013. Although not all incorporated jurisdictions are of a size to have their own transportation department or agency, most cities and towns have some transportation responsibility, as do all of the counties. For purposes of this chapter, local planning is defined as county and municipal transportation planning. Whether individually or as a part of a larger planning organization such as a metropolitan planning organization (MPO) or regional planning commission, these governments have staff members whose responsibility is to ensure the local transportation system operates effectively and efficiently.

Although state departments of transportation (DOTs) and MPOs are primarily concerned with state and regional transportation flows, the success of a transportation system often lies in the "last mile." That is, city and local streets provide the connectivity to homes, stores, businesses, and recreation sites that are so important to the livelihood of a community's residents. This is especially true when considering goods movement where the delivery of goods relies on an ability to reach grocery stores, retail stores, warehouses, and distribution centers. A municipal and local-level transportation network that provides effective mobility and accessibility is critical to the overall success of a state or regional transportation system, and to the state and regional economy.

In addition, it is the local transportation system that most travelers experience on a daily basis. Local governments provide sidewalks and bicycle paths, control many of a city's traffic signals, review and approve land-use plans (usually having an important transportation component), enforce the laws and regulations on the use of that system, and maintain many of the roads that provide for local trip-making. As an example of the responsibilities of one of the larger municipal transportation agencies in the United States, the San Francisco Municipal Transportation Agency (SFMTA) defines its efforts as follows:

> *"The SFMTA plans, designs, builds, operates, regulates, and maintains one of the most diverse transportation networks in the world. In addition to four modes of transportation (transit, walking, bicycling and driving, which includes private vehicles, taxis, carsharing, and commercial vehicles), the Agency directly oversees five transit modes (bus, trolley bus, light rail, historic streetcar, and cable car), in addition to overseeing paratransit service, which serves individuals unable to use fixed-route transit service. The SFMTA also partners with regional transit operators who connect the city with the region using four additional transit modes (heavy rail (BART), commuter railroad, regional bus, and ferry) … the SFMTA has a robust planning, design, and construction function that includes reviewing all proposed land use developments with our partners; planning, designing, and building the transportation modal networks (transit and paratransit, streets, signals, bicycle, pedestrian, taxi, commercial delivery, and loading); and providing long-range forecast analyses of the fleets, facilities, and right-of-way infrastructure in the city and their relation to the region. The SFMTA also oversees on- and off-street public parking and manages it . . . . Last, but not least, the Agency creates and enforces rules on the city's streets, transit system, and parking. Combined, these efforts make an all-in-one transportation agency that directly impacts the daily life of everyone who moves about the city." [SFMTA, 2012]*

Although SFMTA is not typical of most local transportation agencies (given its size and breadth of responsibilities), one can see that transportation planning at the local level can be an important component of a community's mobility strategy, and an often critical input into the overall transportation planning effort in a state or metropolitan area.

[1]Portions of this chapter were originally written by Herbert S. Levinson, P.E., Transportation Consultant, New Haven, CT, USA and Icon Mentor, Region 2 Transportation University Center, City University, New York, NY. Changes made to this updated chapter are solely the responsibility of the editor.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

Local development strongly influences the magnitude and pattern of transportation flows (see chapter 3 on land use and urban design). One of the more important development trends in metropolitan areas over the past 30 years creating both challenges and opportunities for transportation planning has been the clustering of land uses in what are referred to as "activity centers." Activity centers are an important part of the urban landscape. They take many shapes and sizes and include central business districts (CBDs), suburban business districts, colleges, universities, medical centers, office parks, and large transportation terminals. They attract large numbers of people, generate substantial traffic and transit movements, and require often extensive transportation infrastructure. Where they are located, how well they are designed, and how easy they are to reach have an important bearing on their viability and, in a broader sense, on the livability of communities. Safe and convenient transportation access is essential for their continued success.

Local planning and the planning for activity centers are discussed together in this chapter because the steps in the planning process, the data and tools used, and the types of strategies that come out of the planning process are very similar. Clearly, the governmental and decision-making structure is different between the two in that local planning carries with it the authority of the local jurisdiction as realized in comprehensive plans, zoning codes, and subdivision regulations. Activity centers do not have such governmental powers, although many of the larger activity centers have created organizations called transportation management associations (TMAs) to coordinate the strategies and actions that help provide accessibility to the site and the mobility within.

The first half of this chapter focuses on local planning, while the second half looks at activity centers. The following section describes the substance and form of local transportation planning, including a definition of place-making, a discussion of the typical steps in such planning, and the identification of strategies and projects that usually result. Typical data needs and analysis tools are described. The following section examines the characteristics of activity centers, and follows the same approach as outlined above for local planning. The chapter ends by discussing the importance of developing an implementation plan that lays out the funding sources, the schedule of activities, and identifying those who are responsible for furthering the plan's goals.

Note this chapter focuses on urban communities and activity centers in metropolitan areas; rural communities are addressed in chapter 20 on rural community and tribal planning.

II. LOCAL TRANSPORTATION PLANNING

Transportation planning for local communities and municipalities can either occur as a stand-alone study or as part of a more comprehensive planning effort. A stand-alone effort focuses on the transportation system and the components thereof (such as streets, pedestrian/bicycle paths, and parking). In a more comprehensive planning effort, transportation is usually presented in one chapter of a community's comprehensive plan, which includes chapters on other infrastructure needs, land-use strategies, and related policy initiatives. Transportation planning as part of a comprehensive plan is discussed in chapter 3 and will not be repeated here.

The local transportation planning process follows similar steps as other types of transportation planning. Figure 18-1, which shows the planning process for a subarea study from the city of Houston, lays out the key steps in planning for the study area. This figure will be used to structure the following discussion on local transportation planning, while acknowledging that the process might not be applicable to all county/city/town contexts. In particular, the following sections will discuss identifying issues and opportunities, defining the study area, selecting objectives and performance measures, conducting the technical analysis, and incorporating planning outcomes into the investment and policy programs for the county, city, or town.

A. Challenges, Problems, and Opportunities

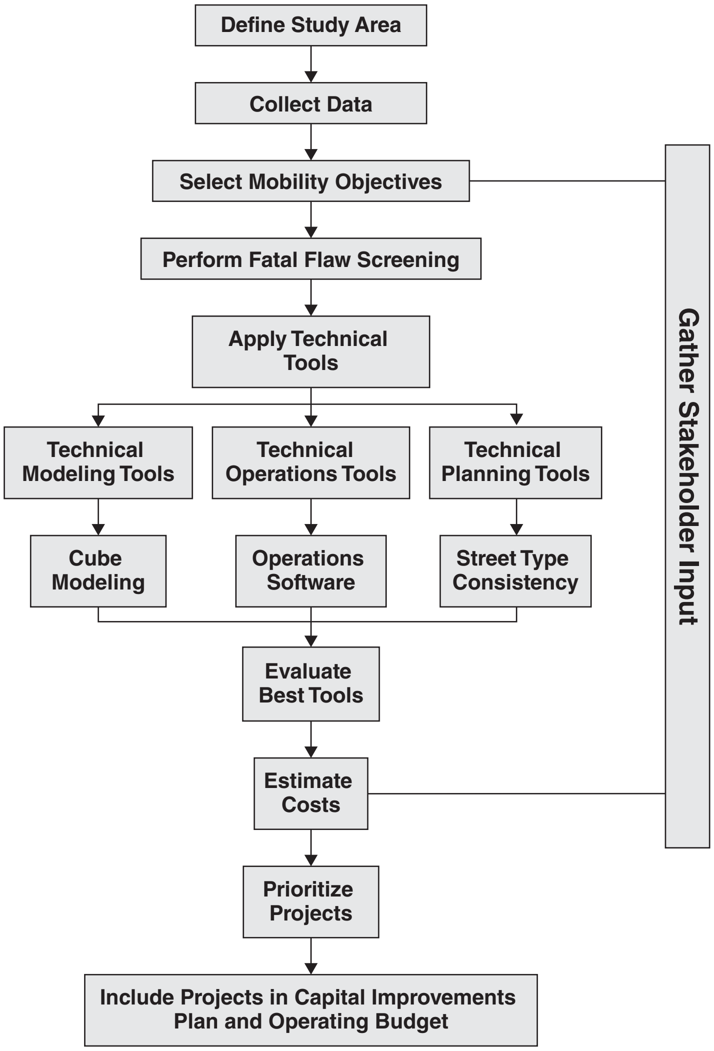
Put in simplest terms, the purpose of transportation planning is to help solve today's transportation problems and to position a community to meet the transportation challenges expected in the future. This means there needs to be some indication of what the problems are today and what they will likely be tomorrow given changes in the economy, population, and technology. As will be discussed later, an initial step in the planning process is analyzing the performance of the transportation system to identify where streets and roads are not performing like they should, where improvements can be made in transit and paratransit services, and how pedestrian and bicyclist movements can be made safer. However, cities also often undertake efforts to better understand the many demographic and economic forces that are affecting the provision of city services, and how such trends might affect these services in the future. Such efforts are undertaken particularly by larger cities and often funded by chambers of commerce or local foundations. Such studies are usually not part of the formal transportation planning process, but when they do occur, they provide important input into the challenges and opportunities facing a community.

An example of this comes from San Francisco where the SFMTA outlined the challenges and opportunities for the city as they relate to transportation planning and investment decisions. Table 18-1 shows how it describes some of the societal trends affecting the use of transportation and the opportunities they present to the agency. This information is presented here simply as an example of how one can think about the broader context within which transportation planning occurs. The list also corresponds to the responsibilities that the agency has for transportation in San Francisco.

Depending on the size of the county, city, or town, transportation planning could focus on the community as a whole, or might be targeted on specific geographic areas, or on topics that are of concern to decision makers. For example, the website of the city of Houston transportation planning group lists the following topics as being part of its planning program: [City of Houston, 2015a]

- Major thoroughfare & freeway plan.
- City mobility planning.
- Complete Streets policy.
- Consolidated transportation planning.
- Urban corridor planning/transit corridor ordinance.
- I-69: Driven by Texans.
- Livable centers studies.
- Planning studies—Reports.
- Heights-Northside subregional study.
- Northwest subregional mobility study.

Figure 18-1. Example Planning Process for a City Subarea, Houston, Texas



Source: City of Houston, 2015b

As can be seen from this list, the city's transportation planning group is not only involved with the city's transportation plan, but it sponsors subarea studies, corridor studies, city-wide transportation plans focused on particular topics (for example, the thoroughfare and freeway plan), and helps implement transportation policy initiatives (for example, Complete Streets). This range of planning involvement usually does not occur in smaller cities and towns because of limited resources, but for larger cities it is not unusual to see a variety of planning efforts undertaken by the planning department.

Another way of identifying typical planning issues is to look at the type of information found in transportation plans. The transportation plan from Salem, Oregon, provides a good range of topics as follows:

Table 18-1. Examples of Issues and Opportunities, San Francisco		
Category of Issue	**Issues**	**Opportunities**
General Context	• Projected 25% increase in jobs and 15% increase in population by 2035; more seniors, fewer families with children • Funding, particularly federal and state, is declining • Local and regional funding becomes more important to finance our capital and operational needs • Insufficient resources to operate and maintain the transportation system and to address state-of-good-repair and expansion needs • Different modes are not integrated, systems are hard to navigate and require separate payment • Mixed traffic, circling, and double parking slows down transit, taxis, and deliveries • Electric vehicle parking demand impacts public garages	• Better linkages between transportation and smart land uses can create efficiencies in future development • New funding sources and new funding partnerships can help meet growing needs • New technology and good planning will allow • Integration of all modes, customer information, and payments • Dedicating lanes and spaces for shared mobility can be effective • City is positioned to have a greater voice in regional, state, and federal forums • Transportation system can benefit from zero- and low-emission vehicles
Walking	• Population aging • Demand for walking is increasing • Most collisions are preventable • Traffic speeds not compatible with land uses in key locations	• Public support to implement best practices in street design and the Mayor's Directive on Pedestrian Safety • Technology applications for speed enforcement and education • Infrastructure support for walking is cost-effective
Transit	• Transit system safety • Transit speeds lowest in the nation; vehicles are operating mostly in mixed traffic • Peak crush loads mean people shifting back to auto, with some switching to bicycle and walking • State-of-good-repair and major maintenance needs • Existing vehicle fleet is difficult for families to use and needs major overhaul • Many stops not fully accessible	• New technology and educational opportunities to improve system safety • Ability to speed transit and increase reliability through cost-effective measures like dedicated transit lanes, all-door boarding, stop spacing, and signal priority tools • Upcoming fleet replacement cycle • Public support to prioritize the funding of mission-critical assets to ensure the preservation of a safe and reliable system • Capital and operations funding through development agreements
Bicycling	• Interest in bicycling is growing; mode share expected to double in next five years • Bicycle network connectivity is fragmented • Limited bicycle parking supply	• Expanding bicycle infrastructure is cost-effective: lanes, parking facilities, signals, and marketing yield high returns • Bike sharing provides cost-effective access for inner-urban trips • Business community is open to bicycle parking as prudent customer strategy

Table 18-1. (*Continued*)		
Category of Issue	**Issues**	**Opportunities**
Parking	• Parking is not efficiently used and creates congestion through double parking and circling; results in slower transit speeds • Residential parking is not consistent across city • Disabled placard abuse is compromising access to parking spaces for the disabled community • Demand for parking for family vehicles is increasing • State Vehicle Code limits best practices in parking management	• New technologies make it easier to find and pay for parking • Demand-responsive parking pricing • Parking maximums and California's Parking Cash-Out • Law provide incentives for Transit First modes • Growing support to amend the State Vehicle Code to allow flexibility in local parking management and better parking management strategies across the state
Taxis/ Rideshare	• Demand for taxis not being met • Improved collaboration is needed for car- and vehicle-share to share growth • Shuttle and ridesharing providers need expanded coordination and partnerships with city	• Public support to identify the number of taxis needed in the city and improve taxi services • Growth of car-share and vehicle-share usage leads to the reduction of single occupant automobile trips • Ridesharing and regional shuttles can mitigate regional traffic coming to the city

Source: SFMTA, 2012

- Street system element
- Transportation system management element
- Neighborhood traffic management element
- Local street connectivity element
- Bicycle system element
- Pedestrian system element
- Transit system element
- Transportation demand management element
- Parking management element
- Intercity passenger travel element
- Freight movement element
- Transportation system maintenance element
- Transportation finance element
- Long-range transportation strategy
- Plan implementation
- Issues requiring future study

This list is not meant to imply that all plans should include these elements; it simply shows the types of topics that planners get involved with. It is interesting to note that the plan includes both a section on finance and implementation, two topics that 20 years ago would not likely have been in the plan (see chapter 5 on transportation finance and funding).

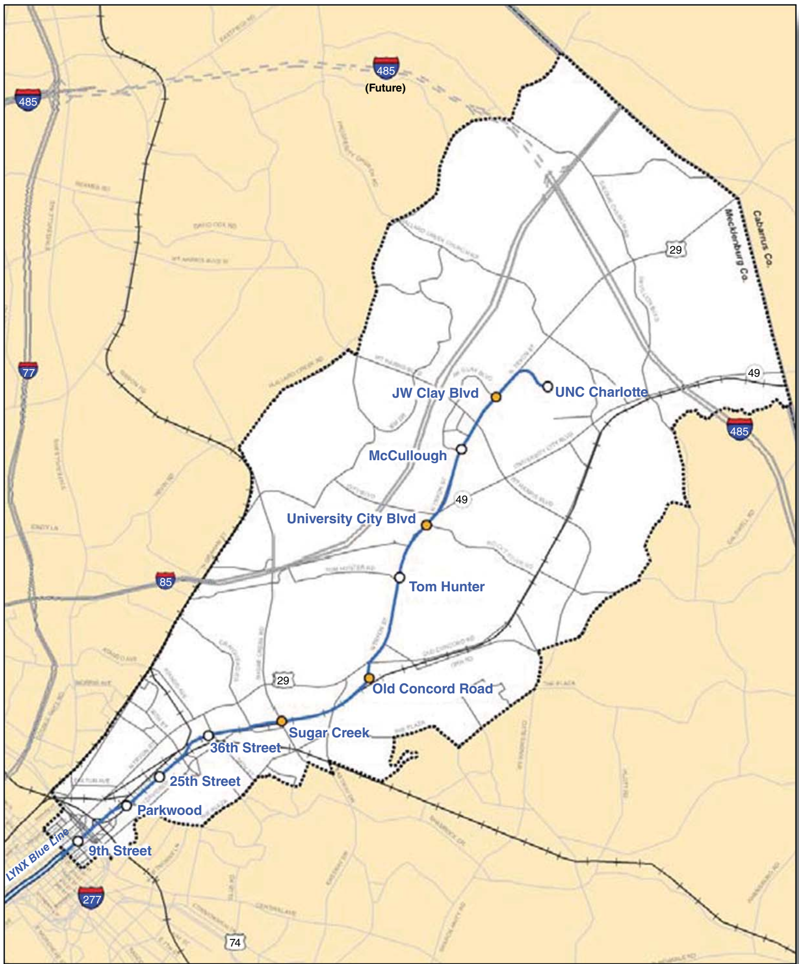
B. Define the Study Area

The study area boundaries for a local comprehensive transportation plan are usually established as the boundaries of the jurisdiction itself. If a travel demand model is used for the study, the study area will include areas beyond the city or town lines simply to account for the external origins and destinations that are part of the modeled network (see chapter 6 on travel demand modeling). The challenge for transportation planners is establishing the boundaries of studies that examine areas smaller than the entire jurisdiction. In this case, judgments must be made on where the study boundaries are. Some of the factors for establishing such boundaries include:

- Major geographic features that separate sections of the community (for example, a river).
- Major transportation facilities.
- Markets for transportation services (for example, walking distance to transit stops).
- Travel sheds that represent the predominant travel flows in the community.
- Neighborhood or other local boundaries.
- Census tracts.
- Other zone systems with aggregated data (for example, traffic analysis zones).

It will save a lot of time in the data collection and interpretation phase of a study if the study area is consistent with typical configurations of the databases to be used in the study. For example, it is quite common to use census

Figure 18-2. Corridor Study Boundaries, Charlotte, North Carolina



Source: City of Charlotte, 2011

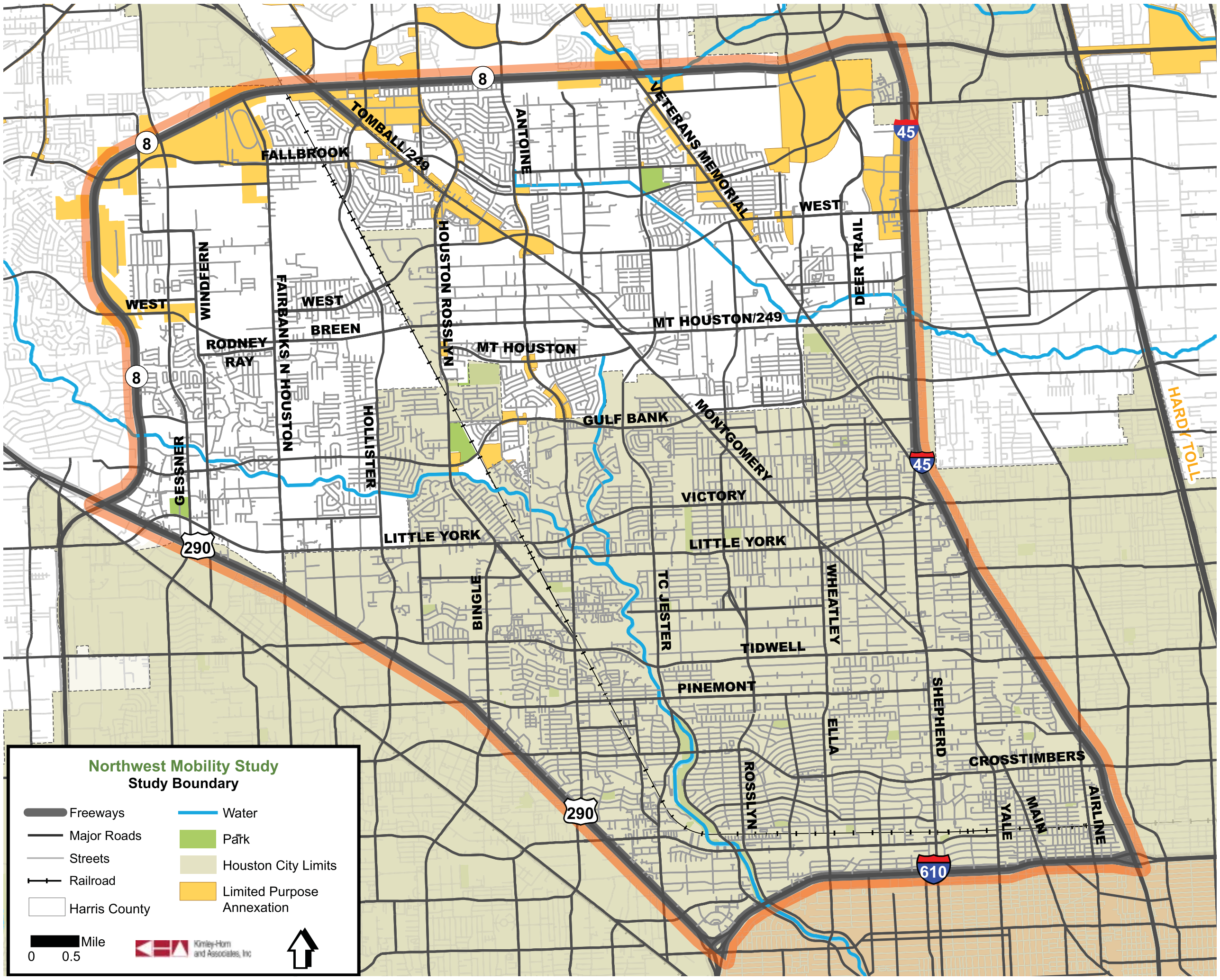
tracts or zones as building blocks for a study area. Otherwise, determining the distribution of data between study boundaries can be quite challenging (unless the data being used are spatially defined and the study is using geographic information systems).

Typically, two types of subarea studies are conducted as part of the transportation planning process—subarea and corridor studies. An example of the latter is shown in Figure 18-2 from Charlotte, North Carolina, where the possible extension of a light rail line through the middle of the corridor helps define the potential travel market that is the focus of the study. The boundaries were defined by jurisdiction lines, railroad lines, and local streets (see chapter 17 on corridor planning).

Figure 18-3 shows an example of a subarea boundary from the Houston study mentioned earlier. The boundary of this study area was defined by a well-established neighborhood boundary and by interstate highways to the east, north, and south. In this case, the study area included two major jurisdictions, the city of Houston and Harris County. This made the study more complicated because, “any recommendations resulting from this study must consider implementation processes and considerations of not only the city of Houston, but Harris County as well.” [City of Houston, 2015b]

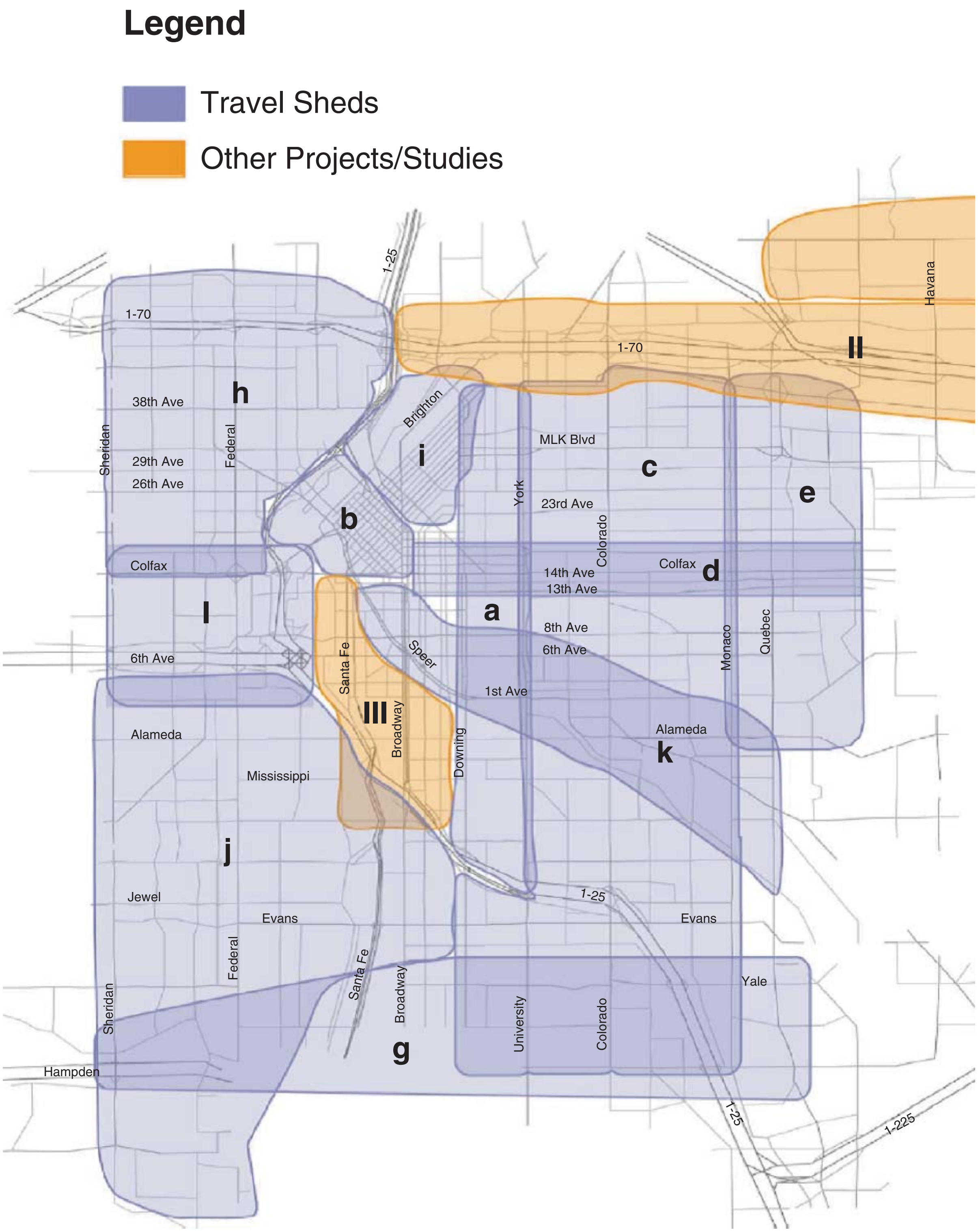
A rather unique approach to defining study boundaries occurred in Denver where the city developed travel sheds as a way of delineating logical boundaries for prospective subarea studies. A travel shed was defined as “a collection of streets and mobility routes that feed into the larger, connected transportation system.” [City of Denver, 2008] Twelve travel sheds were identified that shared similar characteristics, such as trips that start and finish in the same area and geographic features that create barriers to travel movement (see Figure 18-4). These travel sheds became the basis for further studies that examined local transportation needs.

Figure 18-3. Subarea Study Boundaries, Houston, Texas

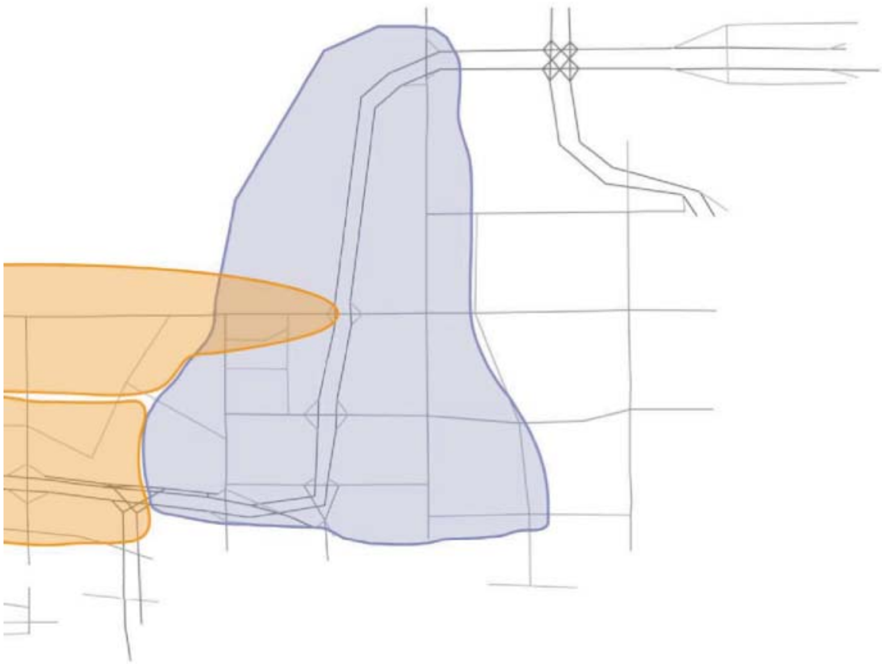


Source: City of Houston, 2015b

Figure 18-4. Travel Sheds Defining Study Boundaries, Denver, Colorado



Source: City of Denver, 2008



Travel Sheds

a) Central Denver

b) Downtown

c) East Central

d) East Colfax

e) East Side

f) Gateway

g) Hampden

h) Northwest

i) River North

j) Southwest

k) Speer/Leetsdale

l) West Side

Other Projects / Studies

The following areas of the city are being specifically analyzed by major studies that are underway or recently completed:

I. 56th Avenue EA

II. I-70 EIS

III. Valley Highway EIS / Broadway NEPA

C. Goals, Objectives, and Performance Metrics

As with other planning processes, articulating goals, objectives, and performance measures is one of the early steps in the local planning process. Because transportation is so engrained in the daily lives of residents, the list of goals and objectives (sometimes referred to as policies) is often quite long. The city of San Diego's Mobility Element of its General Plan had 94 distinct policies as part of its plan. [City of San Diego, 2005] The city of Salem (Oregon) had 27. [City of Salem, 2007] The city of Charlotte, North Carolina, had five goals, 16 objectives, and 105 policies. [City of Charlotte, 2011] Clearly, the more local the study, the more issues arise in the planning process causing planners to develop strategies and actions to deal with the issues. Space does not allow for an enumeration of the long list of transportation goals and objectives to illustrate what a typical plan might include. However, the city of Orlando, Florida, goals give some sense of what these statements look like.

Goal 1: To develop a balanced transportation system that supports building a livable community and improves access and travel choices through enhancement of roads, public transit, bicycle, and pedestrian systems, intermodal facilities, demand management programs, and traffic management techniques.

Goal 2: To sustain the city's long-term land use vision by implementing mobility requirements, within defined mobility areas, which ensure that transportation facilities and services are available for multiple modes of travel for new developments.

Goal 3: To develop a financially feasible transportation system which meets the accessibility needs of the city residents.

Goal 4: To promote coordinated transportation planning efforts across Central Florida's jurisdictions and transportation agencies. [City of Orlando, 2014]

In addition to these goals, the city of Orlando identified performance measures to monitor progress toward goals achievement. Table 18-2 shows the types of metrics that were adopted for doing this. Table 18-3 shows another example of performance metrics used by the SFMTA in its strategic transportation plan. [SFMTA, 2012]

Readers are referred to chapter 2 and chapter 7 for more information regarding the use of performance measures in transportation planning.

Another example of goals comes from the city of Ann Arbor, Michigan, which identified the following eight goals to direct its transportation planning effort.

- Provide effective access and mobility for people and goods, with minimal negative impacts for all.
- Protect and enhance the natural environment and energy resources, and the human and built environment.
- Promote a safe, secure, attractive, and productive transportation system.
- Invest in transportation infrastructure in a manner consistent with other goals, and within the financial constraints of public/private resources.
- Promote cooperation between the city of Ann Arbor and other governmental entities, particularly the surrounding townships and municipalities and the University of Michigan, in support of transportation initiatives in a manner consistent with the other goals.
- Ensure meaningful public involvement will be part of any transportation project in the city of Ann Arbor.
- Promote a transportation system supportive of and integrated with land use decisions.
- Promote green transportation improvements to reduce vehicle emissions. [City of Ann Arbor, 2009]

One can see in this list the local nature of goals statements in the call-out to the major university in the city as a major participant in the study.

Another study that illustrates how transportation can be viewed as part of a larger market is from Chamblee, Georgia, a suburban city just outside of Atlanta. [Kimley-Horn & Assocs., 2014] As part of the Atlanta Regional

Table 18-2. Performance Metrics for Monitoring Plan Progress, Orlando, Florida		
Categories	**Measures**	**Strategies**
Alternative modes of transportation	Sidewalk coverage near transit stops	The percentage of transit stops within the city with direct sidewalk access shall be increased by 5% by the next Environmental Assessment Review (EAR).
	Transit vehicles with bicycle accommodations	All transit rolling stock shall be equipped with bicycle racks.
	Transit shelters	The number of transit shelters shall be increased by at least 3 per year.
	Designated transit corridors having a weighted average headway of 30 min. or less	At least fifty-one percent (51%) of the designated transit corridors shall be maintained with a weighted average headway of 30 minutes or less.
Urban design and land-use mix	Urban design plans and standards	Each year, the number of activity centers and infill areas with pedestrian-oriented design standards and/or design plans shall be increased.
	Land-use mix in activity centers	A mix of land uses shall be increased in activity centers.
Land-use density and intensity	Employee/resident population ratio	An employee/resident ratio between 0.98 and 1.3 shall be maintained citywide.
	Population density	The citywide population density shall be increased by the next EAR (2014). This strategy may also help reduce VMT per dwelling unit.
	Density and intensity of new developments	New development within 1/2 mile of commuter rail stops and in medium or high intensity future land use categories shall be built at a minimum of 12 dwelling units/acre or at a minimum floor area ratio (FAR) of 0.3.
	Active ground floor uses near transit	Each year, the amount of pedestrian-oriented retail space within 1/2 mile of the two downtown commuter rail stops shall be increased.
Transportation network connectivity	Pedestrian connectivity	Each year, at least four (4) miles of new sidewalks shall be built within city limits.
	Bikeway connectivity	At least twenty (20) miles of bikeway facilities shall be built by the next EAR.
	Street connectivity	A connectivity index of 1.4 or greater shall be maintained in new or redeveloped large-scale, single-family subdivisions and planned developments.
	Multimodal transportation facilities	The percentage of major thoroughfare miles within the city with more than two parallel modes (excluding limited access facilities) shall be more than 60% by the next EAR.
Strategic Intermodal System (SIS) and Florida Intrastate Highway System (FIHS) facilities	Traffic counts and queue lengths at SIS and FIHS ramps within the City	The city shall coordinate the monitoring of traffic counts and queue lengths at SIS and FIHS ramps within the City with FDOT on an annual basis.

Source: City of Orlando, 2014

Commission's (ARC's) Livable Communities Initiative (LCI) program, Chamblee undertook a study to enhance the economic attractiveness of its city center, which was served by a subway station. The study goals were articulated as:

- Clarify the vision and future market potential of the Chamblee downtown and the MARTA rail station area.
- Provide additional detail and direction to the city of Chamblee comprehensive plans.
- Offer recommendations to improve local zoning regulations and encourage appropriate future development/redevelopment.
- Prioritize public improvement projects, identify funding sources and move key projects toward implementation by providing a five-year action plan.

Table 18-3. Performance Indicators for a Goal of Making Transit, Walking, Bicycling, Taxi, Ridesharing, and Carsharing the Preferred Means of Travel, San Francisco, California

Key Performance Indicators	Targets		
	FY 2014	**FY 2016**	**FY 2018**
OBJECTIVE 2.1: Customer rating: Overall customer satisfaction; Scale of 1 (low) to 5 (high)	Establish baseline and improve satisfaction rating by 0.5 point each budget cycle		
OBJECTIVE 2.2: Percent of transit trips that have less than a 2-minute spacing between vehicles by line and route on the Rapid Network ("bunches") Percent of transit trips where gaps in service exceed scheduled headway by more than 5 minutes by line and route on the Rapid Network ("gaps")	Eliminate bunches and gaps for 25% of ridership	Eliminate bunches and gaps for 45% of ridership	Eliminate bunches and gaps for 65% of ridership
OBJECTIVE 2.3: Mode Share	FY 2018 mode split goal—private auto: 50%; non-private auto modes: 50%		
OBJECTIVE 2.4: % average occupancy of public metered parking spaces (SFpark areas and SFMTA garages)	Maintain 75%–85% range of occupancy in SFpark areas		

Source: SFMTA, 2012

The recommendations from the plan were thus to describe desired (and achievable) land use; recommend a development framework; and identify priority transportation projects, policies, and strategies.

Goals and objectives statements are most often identified via a comprehensive and inclusive public participation process, where opportunities for engagement in the process are provided throughout the community. Given the local nature of the types of strategies and actions that will surface from the plan, getting local participation is often not as challenging as that for statewide or metropolitan-wide planning. See chapter 24 on public participation and community engagement for a discussion on the methods and approaches that are most effective for transportation planning.

D. Existing Conditions Data

When updating a transportation plan, the planner wants to understand current issues and problems, their magnitude, and the extent to which these problems are widespread. This step in the planning process utilizes existing data and/or collects additional data to identify the current performance of the study area's transportation system. Three studies, from Ann Arbor, Seattle, and Chamblee, illustrate the types of data and data presentations that represent this step in the planning process.

Ann Arbor. Two types of traffic volume data were used to evaluate congestion within the city—average daily traffic (ADT) volumes for roadway segments, and peak hour turning movements at key intersections. Roads were identified where the volume-to-capacity ratio was greater than 1.0 (where the volume of traffic on the roadway is greater than the capacity). The a.m. and p.m. peak traffic counts and current traffic signal timings for the intersections were analyzed with a software package and intersection level of service was estimated during the peak hours. Sixteen intersections were identified as being high crash locations based on a 3-year crash record (both crash frequency and crash rate were estimated). Vehicle crashes involving pedestrians and bicyclists were evaluated by using available crash data, and the intersections with an average of one or more pedestrian/bicycle crashes per year were reviewed as well as any location where a pedestrian/bicycle fatality or serious injury occurred. Transit routes were analyzed both for frequency of service and crowding, and the highest ridership corridors were identified. Both on- and off-street parking occupancies were identified as well as the overall parking supply for the city. Tables 18-4 and 18-5 show how the data on level of service and crashes were summarized.

For land use, data was collected on residential, institutional, recreational, industrial, and commercial properties, including both densities and extent. Future land-use maps for the various areas of the city were compared to current zoning.

Seattle. The city of Seattle conducted a subarea study of southeast Seattle to anticipate the economic benefits of a new light rail line and to improve mobility and safety in the area. [City of Seattle, 2005] The study area was bounded

Table 18-4. Intersection Level of Service Analysis for Existing Conditions, Ann Arbor, Michigan				
	A.M. Peak		**P.M. Peak**	
Intersection	**Delay (s/veh)**	**LOS**	**Delay (s/veh)**	**LOS**
State Street @ Ellsworth Road	56.4	E	84.9	F
State Street @ I-94EB	66.1	E	25.8	C
State Street @ I-94 WB	33.3	C	25.4	C
NB State Street @ Hilton/Victors Way	-	F	-	F
SB State Street @ Hilton/Victors Way	11.8	B	-	F
State Street @ Eisenhower Parkway	26.8	C	50.1	D
Eisenhower Parkway @ Boardwalk Street	10.4	B	20.0	C
Packard Road @ Stone School	8.1	A	8.3	A
Packard Road @ Jewett 6	0.7	A	7.8	A
Ann Arbor-Saline @ Eisenhower Parkway	20.5	C	56.2	E
Ann Arbor-Saline @ I-94 WB	21.5	C	40.6	D
Miller Road @ Seventh Street	19.8	B	14.5	B

Note: LOS E or worse is considered unacceptable

Source: City of Ann Arbor, 2008

Table 18-5. Intersection Crash Analysis for Existing Conditions, Ann Arbor, Michigan											
Intersection	**Total**	**Angle**	**Rear end**	**Head-on**	**Head-on, Left Turn**	**Sideswipe, opposite direction**	**Sideswipe, same direction**	**Single Vehicle**	**Pedestrian**	**Bicycle**	**Other**
First Street @ Huron Street	64	31	11	-	-	1	13	1	4	2	1
Fifth Ave @ William Street	59	30	3	-	-	1	19	-	1	2	3
Church Street @ University Ave	39	9	7	2	1	1	1	-	2	3	3
Eisenhower Pkwy @ Northbrook	21	14	3	-	-	-	2	2	-	-	-
Eisenhower Pkwy @ Plaza Road	24	13	1	-	1	1	7	-	1	-	-
Fletcher Street @ Huron Street	30	14	12	-	1	-	2	1	-	-	-
Huron Street @ Main Street	57	17	17	1	3	-	15	4	3	-	1
Maple Road @ West M-14 Ramp	85	22	33	-	4	3	15	4	-	-	-
Packard Road @ Stadium Blvd	26	12	9	-	-	1	-	4	-	-	-
Ann Arbor-Saline @ Eisenhower	71	21	36	3	2	1	6	1	-	-	1

Source: City of Ann Arbor, 2008

by two interstate highways, Lake Washington to the east, and a major city street. One of the first steps in the study was to inventory the area's road network, with the data collected by functional class of road, including:

- *Interstate Freeways*—Roadways providing the highest capacity and least impeded traffic flow for longer vehicle trips.
- *Principal Arterials*—Roadways serving as primary routes for moving traffic through the city, connecting urban centers and urban villages to one another or to the regional transportation network.
- *Minor Arterials*—Roadways distributing traffic from principal arterials to collector arterials and access streets.
- *Collector Arterials*—Roadways collecting and distributing traffic from principal and minor arterials to local access streets or providing direct access to destinations.

- *Commercial Access Streets (Non-Arterial)*—Streets providing access to commercial and industrial land uses and providing localized traffic circulation.
- *Residential Access Streets (Non-Arterial)*—Streets providing access to residential land uses, higher-level traffic streets and providing localized traffic circulation.
- *Alleys*—Travel ways providing access to the rear of residences and businesses and are not intended for the movement of through trips. In neighborhoods with continuous alleys, utilities (such as garbage collectors) prefer to use alleys rather than residential or commercial streets.
- *Major Truck Streets*—Arterial streets accommodating significant freight movement through the city and connecting to major freight traffic generators.
- *Urban Trails*—A network of on- and off-street trails facilitating walking and bicycling as viable transportation choices, providing recreational opportunities, and linking major parks and open spaces with Seattle neighborhoods.
- *Bicycle Streets*—An on-street bicycle network connecting neighborhoods and urban centers and villages and serving major intermodal connections.

An investigation of Census data and other travel databases showed that, (1) only 9 percent of community members lived and worked in southeast Seattle, (2) over 50 percent of the residents traveled north for employment (downtown Seattle, Capitol Hill, Northgate, and further north), and (3) although major employment areas for southeast Seattle residents are within the city of Seattle, residents travel beyond King County for employment opportunities. Looking at community sites and resident travel patterns, the study concluded that major internal destinations included public schools, libraries, and community centers, which tended to be clustered together. In addition, the study noted that the steep topographical grades in parts of the study area created physical barriers for pedestrians. For bicycle trips, the study observed that the area's bicycle network had very few designated bike lanes, and that several bike routes were on roads with high vehicle speeds, and in some cases on roads with damaged pavement. For transit, most transit trips (40 percent) from southeast Seattle were destined to downtown Seattle. The main transit corridors in southeast Seattle were on major north–south arterials, and few transit circulation routes existed to service the area's residents. With respect to goods movement, there was only one city-designated "Major Truck Street" in the study area, and freight traffic spills onto area streets from a nearby freight area when the interstate highways are congested.

Similar to the Ann Arbor study, the Seattle study identified where most of the pedestrian and bicycle crashes were occurring and noted that many of the crashes occurred at unregulated intersections (no traffic signal or simply a traffic circle) or that did not have marked crosswalks. Traffic counts were taken at all major intersections (see Figure 18-5), and parking utilization data were collected (see Table 18-6).

Chamblee, Georgia. This study gathered data on land use and transportation characteristics similar to Ann Arbor and Seattle. However, the Chamblee study also conducted a market analysis to examine the strengths and weaknesses of the study area's economy and transportation system. This analysis set the context for future economic opportunities and for identifying transportation strategies that could enable these opportunities to occur. The Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis found the following: [Kimley-Horn, 2014]

Strengths

- The Metropolitan Atlanta Regional Transit Authority (MARTA) transit station provides comparatively quick access to regional employment centers.
- MARTA-owned parcels adjacent to transit station are well-positioned for redevelopment and location inside I-285.
- Equidistant to Buckhead and Perimeter Center employment and regional retail.
- Comparative housing affordability for areas inside I-285 and west of I-85.
- Strong local school performance.
- Growing higher-income household base, with 21 percent earning over $100k in 2012, more than double the 10% share in 2000.

Figure 18-5. Intersection Counts as Part of an Existing Conditions Analysis, Seattle, Washington

Source: City of Seattle, 2005

Table 18-6. Summary of Parking Utilization in Southeast Seattle			
Area	**Average Parking Utilization (%)**	**Peak On-Street Parking Utilization**	**Peak-Period Time**
Columbia City (M.L. King Jr. Way)	48	74	12-1 p.m.
Columbia City (Rainier Ave. S.)	43	52	6-7 p.m.
S. Henderson St Station Area	15	20	8-9 a.m.
M.L. King Jr. Way S. at Holly	37	31	4-5 p.m.
North Beacon Hill (S. Atlantic St.)	69	86	11-12 p.m.
North Beacon Hill (S. Lander St.)	36	39	1-2 p.m.
North Rainier	36	39	1-2 p.m.
Rainier Beach	17	18	5-6 p.m.

Source: City of Seattle, 2005

- Large and growing 25–34 age cohort.
- Strong citizen participation in planning efforts and support for growth in the LCI study area.

Weaknesses

- Limited visibility from Peachtree Boulevard.
- MARTA and Norfolk Southern railroad lines bisect the study area, creating a two-sided market.
- Two "competing" nodes of historic downtown and MARTA station along Peachtree Road.
- High share of existing commercial buildings and housing stock are suffering from physical and economic obsolescence.
- Excessive housing vacancy rate of 21 percent in 2012.
- Lack of major private-sector employers.
- Absence of newer hotels owned or operated by major national chains.

Opportunities

- Several large vacant or underutilized parcels available for redevelopment, including those owned by MARTA.
- Rapidly increasing share of one- and two-person households creates demand for smaller housing units.
- Growth of Generation Y and Baby Boom age cohorts and national shift toward rental housing create demand for higher-quality apartments.
- New housing will increase demand for retail, professional services, and restaurants.
- Professional office space will accommodate growth for employers seeking close proximity to MARTA station and a mixed-use environment near I-285.
- Office employment growth will support hotels.

Threats

- General Motors Plant redevelopment in adjacent Doraville could "steal" market share from Chamblee LCI.
- City zoning codes requiring retail uses to occupy the entire first floor of multi-family buildings and steel/concrete construction are not supported by current land/development economics shaping Chamblee LCI.
- Resistance to rental housing could cause Chamblee LCI to get bypassed in current development cycle.

Market studies such as this provide an important context for understanding the current conditions in a study area, and for defining future economic prospects.

The collective data and data analysis for each of these studies was compiled in a technical report and provided input into forecasted future conditions. Several other chapters in this handbook provide much greater detail on data collection and the process of identifying existing system performance and condition. Readers are referred to chapter 2 on travel data, chapter 3 on land use and urban design, chapter 8 on transportation asset management, chapter 9 on road and highway planning, chapter 10 on transportation systems management and operations, chapter 11 on parking, chapter 12 on transit planning, chapter 13 on pedestrian and bicycle planning, chapter 17 on corridor planning, chapter 19 on site planning and impact analysis, chapter 22 on integrating freight into the transportation planning process, chapter 23 on integrating safety into the transportation planning process, and chapter 24 on public participation and engagement.

E. Future System Performance and Condition

Transportation planners are primarily concerned about the future. In the context of local transportation plans, this means predicting future transportation challenges that lead to projects or strategies to solve these problems before they become too serious. Looking into the future means understanding what the population and employment will be like in the plan horizon year, where people will live and work, how they will travel and by what means, and what factors will influence their travel choices. For statewide and metropolitan transportation planning, this usually means a large-scale transportation modeling effort, including updates on socio-demographic data and coding of large transportation networks (see chapter 15 on statewide planning and chapter 16 on metropolitan planning). Such models are also used for local planning, especially for larger cities or large subarea studies. However, in some smaller cities and towns, a less involved approach is used to forecast future conditions. In many cases, the planning study tends to focus on existing conditions and system performance with the assumption that these locations will be the problem locations in the future as well. Or, a slightly more sophisticated approach is to "grow" the population and employment in the traffic analysis zones, apply new trip generation rates, and assign the trips to the network to identify future problems (see chapter 6 for different methods of travel demand forecasting).

When travel demand models are used for local planning, they usually are of two types. The first is a stand-alone model calibrated and validated for the study area. Stand-alone models are usually found in only the largest of cities. The second is to use the MPO's travel demand model, modifying it to local conditions, and making it more appropriate for the scale of analysis. For example, it is not uncommon for additional traffic analysis zones and more links/nodes to be added to the model structure for subarea studies. The modeled network outside of the study area then becomes the "external" inputs into the travel flows into and out of the area. Two advantages of this approach are that the subarea modeling is consistent with the regional model, which is important when seeking funding from MPO programs. The second advantage is that the zonal system and databases are already established (although as noted with some likely modifications needed) so that new data are not necessarily needed to undertake the study.

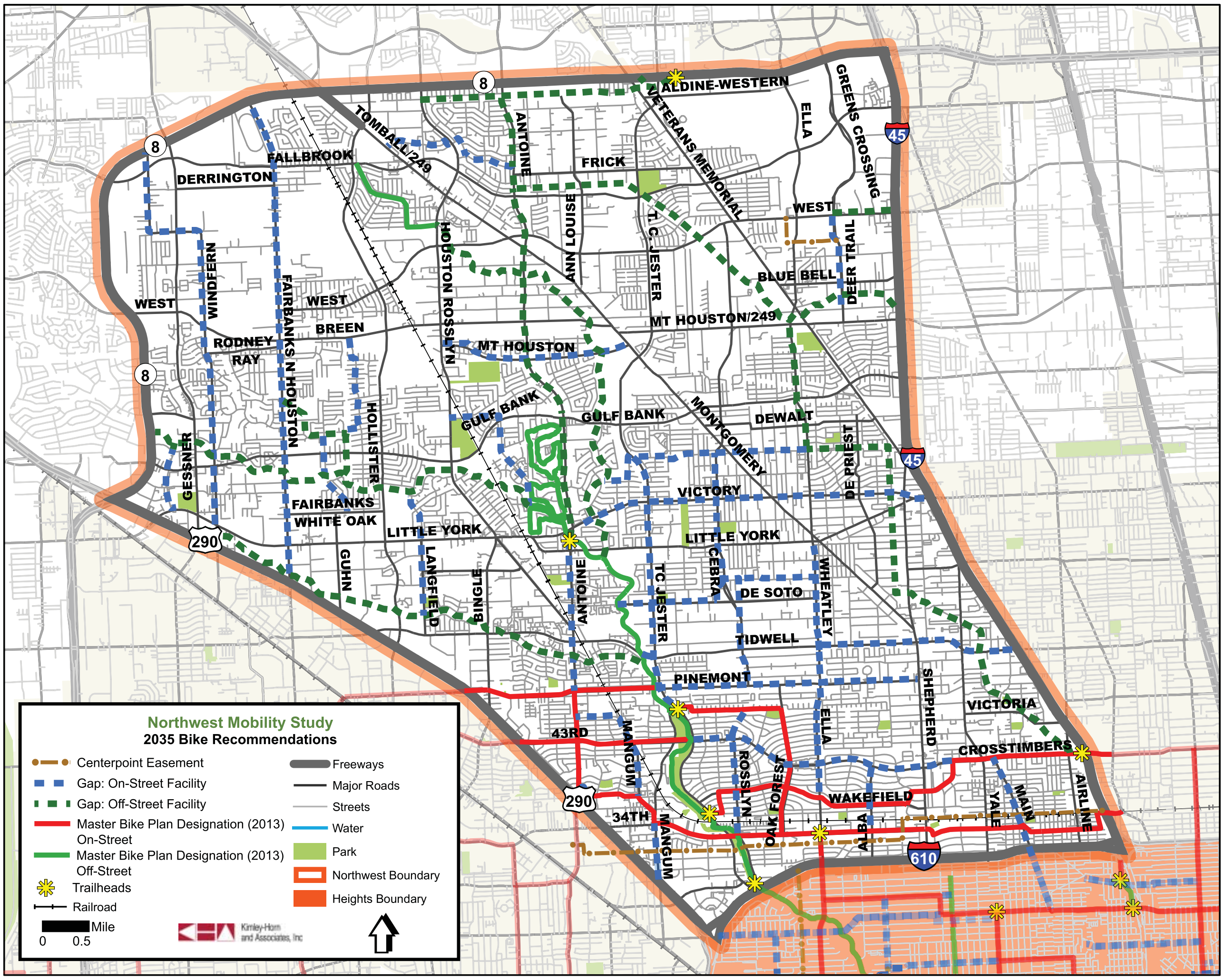
Two examples illustrate the use of a travel demand model at the local level:

Houston Northwest Subarea Study. The City of Houston and the Houston-Galveston Regional Council (H-GAC), the MPO for the region, collaborated on developing a model that could be used for subarea studies in the city. The HGAC regional travel demand model was used, with additional zones and network links added to provide better fidelity in model results for city streets. The study team created four initial scenarios for the Northwest Subarea study that became model runs for testing the impact on system performance. The scenarios were analyzed individually to compare outcomes among different concepts. A combined scenario (Scenario 5) was then developed of the recommended projects and actions. The scenarios were:

- Scenario 1—(Base Build-Out): The Base Model scenario assumes the full development of all major thoroughfares and major collectors as identified in the city's major thoroughfare plan. The effects of such recommendations on traffic volumes and congestion levels were evaluated in this scenario.
- Scenario 2—(Couplets): This scenario was from another study that had been done on some of the areas included in this study. It was included in this study simply for reference purposes only.
- Scenario 3—(Capacity Projects): Scenario 3 combined road expansion (as designated by the major thoroughfare plan) and street reduction projects. The intent was to create a network that safely and reasonably supported a variety of mobility uses. This model was a more financially feasible option than the Base Model.
- Scenario 4—(High-Frequency Transit): This high-frequency transit scenario included transit routes that factored in public input, population growth, job growth, activity centers, and connectivity to other destinations (such as downtown). The increase in service was modeled by doubling the service frequency during the peak hours. Non-peak hour headways were also increased slightly. (The study recognized that it was the regional transit operator what was responsible for the frequency and stop locations of all city bus routes).
- Scenario 5—(Recommendations): The four scenarios were analyzed separately and compared to the 2035 Base Model as provided by H-GAC (with the new future demographics). Scenario results were then taken to stakeholders for feedback. This input and the project team's analysis were combined to create Scenario 5. The result was a network of corridors that needed capacity expansion as well as corridors where existing capacity could in fact be reduced.

For pedestrian and bicycle needs, the city adopted a Complete Streets design approach for those intersections and streets where the analysis suggested there might be problems (see chapter 9 for a discussion of Complete Streets; also discussed in the next section). In addition, the study relied on an already existing Pedestrian and Bicycle Plan to identify specific projects and strategies for the study area. Figure 18-6 shows the recommended bike improvements.

Figure 18-6. Subarea Recommended Bike Improvements, City of Houston, Texas



Source: City of Houston, 2015c

North Fulton County Comprehensive Plan. North Fulton County, one of the fastest growing counties in the United States, is located just north of Atlanta. One of the busiest freeways in the region serves as the backbone of longer-distance travel in the area, and many local streets are notorious for their congested conditions. This study was to be a strategic plan identifying strategies to better manage traffic (such as travel demand management) as well as recommending projects where capacity expansion was needed. [City of Alpharetta, 2010] The study team relied on a variety of information sources and data analyses to identify current and future problem areas, including:

- *Public Involvement* was one of the primary methods used for developing a list of transportation needs, particularly current ones. Residents and stakeholders in the area represent an important source of information for those system needs that currently exist.
- *Existing Studies* were reviewed for areas across North Fulton to build a strong foundation for this plan by giving consideration to work done in previous studies.
- *Geographic Information Systems (GIS)* is a software tool used to relay spatial information in the form of maps. Economic, census, land, and transportation data were displayed using this software.
- *Census Data and American Community Survey* data from the U.S. Census Bureau were obtained for the purposes of understanding population and employment trends. This information was used for identifying area employment centers, areas with greater density, and areas with aging populations, lower incomes, lower auto ownership, or a larger disabled population that may have different transportation needs.

- *Coordination with the Atlanta Regional Commission's (ARC's) On-going Planning Initiatives* was necessary to develop the plan in accordance with region-wide goals and strategies. Coordinating with on-going regional initiatives that are being implemented by ARC ensures that the North Fulton plan will be aligned with those goals that extend beyond its borders.

- *Crash Data* statistics were analyzed in order to identify safety needs and trends within the transportation system. These data provide insight into the nature of vehicular, bicycle, pedestrian, and commercial vehicle crashes. Geospatial data were also obtained from the Georgia Department of Transportation (GDOT) so that locations of these crashes could be identified. [City of Alpharetta, 2010]

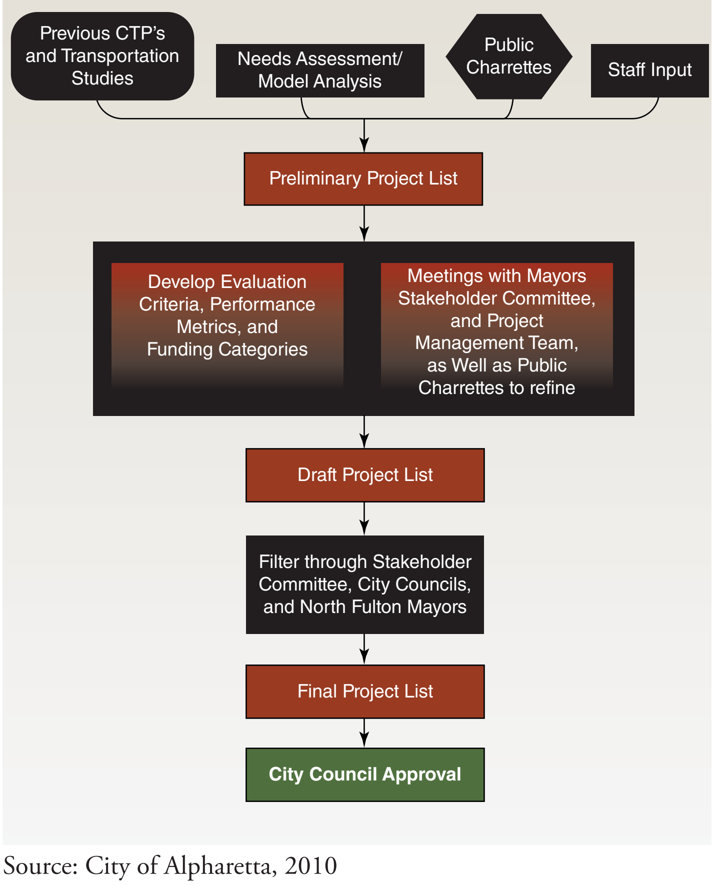
The ARC's travel demand model was used to forecast future traffic on the study area's road network, assuming future land use patterns, demographic forecasts, and existing and planned road projects. The model identified road capacity hotspots and expected ridership on proposed transit services.

With respect to pedestrian movement, a pedestrian LOS metric was used for pedestrian accommodation based on such factors as the presence of sidewalks, sidewalk width, width of any buffer between the sidewalk and the roadway, presence of on-street parking, volume of vehicular traffic, and the like. The network was analyzed for existing pedestrian LOS scores; a study threshold of LOS C was chosen as a trigger point for improvements (LOS B was selected in some areas where large volumes of pedestrians were expected). Roadway characteristics were identified where the threshold LOS was not met, and additional data on the road profile was collected for more detailed analysis. This additional data included characteristics of the shoulder and adjacent grading such as whether the shoulder was flat, sloping, or contained a ditch. These characteristics were used to develop recommended actions. See chapter 11 for further information on pedestrian planning.

A similar approach was used for bicycle LOS, where factors such as width of lanes, roadway lane width, gutters, buffers, and sidewalks, as well as observed roadway characteristics including lane counts, configuration (undivided, divided, or use of a two-way left turn lane), posted speed limit, roadside profile, pavement condition, and cross section type (curbed or open shoulder), were used to calculate a bicycle LOS score. LOS scores were used to identify locations where possible design improvements could be made. Additional data were collected to facilitate the evaluation of potential improvements, including total width of asphalt, presence of a raised median, presence of curb and gutter, and roadside profile (flat, sloping, or ditch). See chapter 11 for further information on bicycle planning. The results of the analysis fed into the evaluation and prioritization process.

Whether coming from a travel demand model or from simple extrapolation of existing population and employment trends, decision makers rely on the type of information produced in these two studies to make informed decisions.

Figure 18-7. Project Selection in the Context of a Subarea Planning Study, North Fulton County, Georgia



Source: City of Alpharetta, 2010

F. Evaluation and Prioritization

Similar to the choice of tools for analyzing current and future system problems, project selection and importantly project prioritization varies from one study to another. As shown in Figure 18-7, which shows the planning process for the North Fulton County study, project prioritization had both a technical and a public/decision-maker component. This is especially found in local planning where every recommended project most likely affects someone who is known by at least one decision-maker, or where feelings are so strong about problem hotspots that individuals will gladly participate in the planning process to "solve" their problem.

Larger planning studies usually adopt a formal process to prioritize projects, relying on some form of scoring or benefit/cost analysis (while still realizing that local decision makers will have their own calculus for determining priorities). For smaller studies where the focus is on selected intersections and key road segments, the prioritization process is fairly straight-forward and is based on the expected intersection/road performance (which reflects the problems being experienced today). In this case, either level of service metrics or delay measures can be used to assign a priority to proposed projects.

The following two examples of project prioritization illustrate different ways of assigning project priorities:

North Fulton Comprehensive Transportation Plan. An evaluation matrix was used to assess the relative priorities of candidate projects. The matrix included factors such as a project's expected reduction in vehicular congestion; the potential in creating new connections; expected improvements to bicycle, pedestrian, and transit modes; and likely environmental/social impacts. Expected costs as well as potential operating and maintenance costs were considered relative to the likely benefits of the project. Monetary benefits were estimated for road projects. The feasibility of construction was considered as well as whether the project is already part of the Regional Transportation Plan. [City of Alpharetta, 2010]

Southeast Seattle Study. The city of Seattle uses a 100-point scoring system for prioritizing projects in its capital program. The Southeast Seattle study decided to use the same scoring system, which was based on seven criteria, (1) safety, (2) preserving and maintaining infrastructure, (3) cost-effectiveness or cost-avoidance, (4) mobility improvement, (5) economic development, (6) comprehensive plan/urban village and land use strategy, and (7) improving the environment.

The evaluation criteria were applied to the projects in a multistep process. Early in the study, project staff and community members identified more than 500 potential actions based on past studies and new analysis. This list was then narrowed by combining overlapping actions and by eliminating those that had already been completed or were currently underway. Sixty-three projects were ultimately formally submitted to a Core Community Team (CCT) for review and comment. After the CCT review, preliminary cost estimates were prepared for the actions considered to be high priority. The projects were then scored according to the criteria and weights shown in Table 18-7. An overall priority of high, medium, or long-term was assigned to each project, with roughly a third of the projects in each category.

Evaluation and prioritization are critical steps in a study. Planners should give a lot of thought at the beginning of the study on how evaluation will occur. Not only does this get decision makers to think about what is important with respect to study results, but it tells the planner what type of data to be collected, the type of forecasts that need to occur, and what type of tools will have to be used in the study.

The reader is referred to chapter 7 on evaluation and prioritization methods for more detailed discussion on different approaches.

Table 18-7. Evaluation Criteria Used in Seattle Subarea Study

Evaluation Criterion	Score	Weight	Maximum Points
Safety and Security	–5 to +5	4	20
Mobility	–5 to +5	3	15
Infrastructure Preservation/Maintenance	–5 to +5	3	15
Cost-effectiveness and Implementation Feasibility	–5 to +5	3	15
Comprehensive Plan/Urban Village Strategy	–5 to +5	3	15
Environmental Quality	–5 to +5	2	10
Economic Development	–5 to +5	2	10
Total Points			100

Source: City of Seattle, 2005

G. Other Actions and Strategies

The previous section discussed approaches and methods to identify priority projects. These approaches focus mostly on capital projects or service changes such as intersection improvements, pedestrian/bicycle projects, and transit service improvements. However, many local plans often include other types of strategies aimed at reducing single-occupant vehicle trip-making to and from a locale, such as travel demand management (TDM) strategies. As an example, in addition to a list of highway, transit, and pedestrian/bicycle projects recommended for construction, the North Fulton Comprehensive Plan included the following (copied from the report):

Transportation Demand Management (TDM)

- *Flextime and Teleworking*—Teleworking (that is, working from home) and flextime (working alternate hours) both reduce trip-making during the peak hours, which can have a significant effect on reducing congestion and air pollution.
- *Transit and Shuttle Services*—There is significant opportunity to increase the use of both transit and shuttle services in North Fulton.
- *Education and Cultural Awareness*—Education and cultural awareness can have a big impact on the choices people make. Many communities routinely sponsor events to raise awareness and educate people about using transit or bicycle travel.
- *Variable Road Pricing and Managed Lanes*—With the planned addition of managed lanes to the GA 400 corridor, variable pricing will likely be used on that corridor to discourage travel during the traditional peak periods. Also, these managed lanes will encourage carpooling and transit ridership.
- *Development Codes*—several specific requirements or limits within each city's development codes have a direct impact on travel. For example, some communities require facilities for bicycle parking and showers/changing facilities at all commercial and large office uses. Preferential parking for carpools and vanpools can also be required.
- *School-Related TDM Strategies*—School-related TDM strategies are an important consideration to any community. Such strategies could include: (1) reducing barriers to non-motorized transportation by improving sidewalks, crosswalks, bicycle lanes, and bicycle parking; (2) implementing parking management at high schools by reconsidering free parking—parking proceeds could then be used to improve facilities for walking and biking to school; (3) organizing school pool programs; and (4) planning over the long term for new school locations to allow a greater percent of students to walk and bike to school.

Access Management

Three regionally significant corridors were identified as the primary non-freeway roadways facilitating regional trips through North Fulton, particularly east–west movements. Because of their regional significance, the implementation of a consistent access management strategy along these roadways was recommended. Additionally, strong access management policies should be considered in order to improve arterial traffic flow without the need for traditional widening (see chapter 9 on road/highway planning).

Advanced Traffic Management Systems (ATMS)

Advanced traffic management systems (ATMS) allow government agencies to better manage the traffic on the roadway and to disseminate traffic information to drivers. ATMS components include; traffic signal controllers, closed circuit television (CCTV) cameras, dynamic message signs, communication equipment, and control center monitoring equipment and software. The study recommended that North Fulton should, (1) expand the reach (communication) of the existing signal systems, (2) coordinate signals and sync clocks across jurisdictional boundaries, (3) expand CCTV coverage, (4) evaluate the need and potential locations for dynamic message sign deployments, (5) provide center-to-center communication, (6) establish protocols for sharing information and managing traffic across municipalities, (7) identify other potential ATMS strategies (such as transit priority, reversible lanes, etc.) that may be applicable within north Fulton, (8) develop a strategy that is flexible and expandable that allows for future growth as development continues to occur, and (9) develop a system that minimizes recurring costs. [City of Alpharetta, 2010]

The types of strategies included in a plan will vary by community. Some will focus more on land-use strategies, while others will emphasize physical infrastructure improvements. It seems likely that larger cities or smaller communities within larger metropolitan areas will develop a study design that includes both. As infrastructure dollars become more limited, finding ways to reduce trip generation and the associated impacts means that noninfrastructure strategies and better management of community-oriented mobility options will be the norm for transportation planning.

The Chamblee, Georgia, study included a very wide range of recommendations. [Kimley-Horn & Assocs., 2014] In addition to recommendations on pedestrian, bicycle, corridor, gateway, parking, and transit recommendations, the study recommended action on the comprehensive plan update and land-use policy, urban design priorities, historic resources, market/economic development strategies, lifelong community strategies, and zoning considerations. For example, to take advantage of the proximity of a subway station, the plan recommended:

- Continue to work with developers to ensure that development around the existing MARTA rail station is walkable.
- Seek high-quality development immediately adjacent to the MARTA rail station.
- Develop a regional detention area and community space on the MARTA owned property located at a targeted parcel of land.
- Provide safe and convenient access to future Chamblee Rail Trail extensions.
- Adopt a long-range maintenance plan for parks and green space.
- Seek opportunities for alternative fuel source stations in public or semi-public places.
- Develop brownfield evaluation and designation criteria.

Figure 18-8 shows the recommended transportation actions that came out of the study.

Figure 18-8. Recommended Transportation Projects, Chamblee, Georgia

Source: Kimley-Horn & Assocs., 2014

Other chapters in this handbook are particularly relevant to the options that might be considered in local planning. Readers are referred to chapter 3 on land use and urban design, chapter 9 on road and highway planning, chapter 11 on parking, chapter 12 on transit planning, chapter 13 on pedestrian and bicycle planning, chapter 14 on travel demand management, and chapter 22 on freight planning.

III. ACTIVITY CENTERS

The locations and forms of activity centers have evolved during the past century in response to changing transportation services and population patterns. Central Business Districts (CBDs) grew as main office, retail, and governmental centers during the first half of the twentieth century. Due to a variety of reasons, not the least of which was the construction of large-scale highway networks, the focus on downtowns has declined over the years. Today, most metropolitan areas consist of major activity centers, where the downtown is just one of many. In the Atlanta region, for example, the Atlanta Regional Commission (ARC) has identified 14 distinct activity centers having their own development patterns and transportation flows. [ARC, 2012] In many of these activity centers, organizations have been created to deal with the mobility challenges facing the residents and employees. Called transportation management organizations (TMOs) or associations (TMAs), these organizations are a new participant in the transportation planning process (see chapter 19 on site planning and impact analysis).

A. Characteristics and Concepts

The term *activity center* refers to a large concentration of development usually containing a mix of land uses, especially office and retail. Activity centers may also include institutional complexes, such as government centers, colleges and universities, and medical centers. Activity centers range in size from a few hundred acres to as much as 6 to 8 square miles. Larger activity centers typically have more jobs than residents; include major amounts of retail space; exhibit mixed office, retail, hotel, residential, or other commercial uses; have higher development densities than surrounding areas; and are recognized as a focal point for activity within the community. Most of the larger centers have also been subject to master planning.

Activity centers usually occur in one or more of the following forms:

- Central business district (CBD).
- Office park of several hundred or more acres.
- Retail center of 100 or more acres.
- Mixed-use center of several hundred to thousands of acres.
- Large office corridor stretching a mile or more.
- Major outlying or suburban office concentrations.
- University, medical center, or other institutional complexes and campuses.
- Major recreational facility with ancillary uses.
- Large retail, dining, and entertainment centers.

Activity centers are usually located where businesses can tap into a large consumer or labor market that is accessible in a reasonable travel time. Historically, they developed at focal points of convenient transit and highway access, such as the CBD, outlying business districts, and large town centers along suburban railroad lines. However, the dispersion of population with the development of urban freeway systems over the past 50 years has dramatically changed where activity centers locate. Freeway interchanges and major arterial roadway junctions have today become primary locations for many activity centers.

The emergence and successful developments of clustered economic activity in areas such as the Silicon Valley (California), Research Triangle Park (North Carolina), and Route 128 in Massachusetts have served as case studies for other regions as they develop similar business agglomerations. These agglomerations—or "clusters"—represent groups of

Table 18-8. Employment Clusters, Metropolitan Divisions, and Edge Cities in the 20 Most Populous Metropolitan Statistical Areas, 2000

Metro Area	2000 Population	# of Employment Clusters 1970	1980	1990	2000	# of Edge Cities CBDs	Edge Cities	Emerging Edge
New York-Northern NJ-Long Island, NY-NJ-PA	18,323,002	6	12	18	26	4	17	4
Los Angeles-Long Beach-Santa Ana, CA	12,365,627	6	23	27	25	2	15	6
Chicago-Naperville-Joliet, IL-IN-WI	9,098,316	2	7	11	11	1	4	0
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	5,687,147	2	3	8	9	1	3	0
Dallas-Fort Worth-Arlington, TX	5,161,544	2	5	8	8	2	4	3
Miami-Fort Lauderdale-Miami Beach, FL	5,007,564	2	1	16	7	2	1	2
Washington-Arlington-Alexandria, DC-VA-MD-WV	4,796,183	1	3	10	14	1	16	7
Houston-Baytown-Sugar Land, TX	4,715,407	1	7	8	9	1	9	2
Detroit-Warren-Livonia, MI	4,452,557	3	10	8	9	1	5	3
Boston-Cambridge-Quincy, MA-NH	4,391,344	2	7	8	8	1	5	5
Atlanta-Sandy Springs-Marietta, GA	4,247,981	1	4	8	10	1	4	3
San Francisco-Oakland-Fremont, CA	4,123,740	2	6	10	12	2	5	5
Riverside-San Bernardino-Ontario, CA	3,254,821	1	3	2	3	0	1	2
Phoenix-Mesa-Scottsdale, AZ	3,251,876	0	2	7	10	1	3	4
Seattle-Tacoma-Bellevue, WA	3,043,878	2	4	6	2	2	1	3
Minneapolis-St. Paul-Bloomington, MN-WI	2,968,806	2	6	8	10	2	1	1
San Diego-Carlsbad-San Marcos, CA	2,813,833	1	3	4	4	1	3	2
St. Louis, MO-IL	2,698,687	1	4	5	7	1	2	1
Baltimore-Towson, MD	2,552,994	1	2	6	6	1	3	4
Pittsburgh, PA	2,431,087	1	3	3	1	1	1	0

Source: Marlay and Gardner, 2010

interrelated businesses that choose to co-locate for one reason or another. [ARC, 2012] A study by the U.S. Census that examined the change in metropolitan employment between 1970 and 2000 showed the rapid movement of employment into employment clusters in U.S. metropolitan areas. [Marlay and Gardner, 2010] Table 18-8 shows the change in employment for the 20 largest U.S. metropolitan areas. As can be seen, the number of new employment clusters increased significantly between 1970 and 2000. The study also observed that for larger metropolitan areas (population > 4 million), 37 percent of the employment was located in employment clusters; for medium size metropolitan areas (1 to 3 million), the proportion was roughly 34 percent; and for smaller metropolitan areas (<1 million) the proportion was 25 percent.

B. Central Business Districts (CBDs)

CBDs are the largest and oldest urban activity center with many dating from a time when most businesses were located in one central area and travel distances were limited. Over the years, downtown areas grew as street railways, rapid transit lines, commuter rail lines, and then buses and automobiles expanded their reach and market areas. Decentralization of urban activity, however, has resulted in accompanying changes in the strength, vitality, and functions of downtown areas. Although the CBD generally has declined in relative concentration to the rest of the metropolitan area, it still represents a major economic activity for a typical metropolitan region and still attracts the highest transit ridership in most major cities in the world.

1. *Characteristics*

Downtowns are typically located near the population center of the urban region, except where constrained by topography. They generally occupy one to two square miles of area and represent one of the highest concentrations of office floor space and employment density within most urban areas. However, the total number of employees as compared to the region as a whole is small—the average is 7 percent in metropolitan areas over 1,000,000, with New York City the highest at 22 percent (second in the world to Tokyo). [Demographia, 2014] The number of employees per acre ranges from 100 to more than 400 in large cities.

The concentration of employment and mixed land uses results in a large number and variety of CBD trips. The CBD is usually the area with the highest transportation accessibility within the urban area, showing the highest transit utilization (77 percent of commuters into New York City; between 50 and 60 percent for Boston, Chicago, and San Francisco; and around 40 percent for the Denver and Seattle downtowns). CBDs also devote a high percentage of land to transportation purposes—approximately half of all downtown land is devoted to streets, sidewalks, alleys and parking. It generally has less off-street service and loading facilities than developments in suburban areas. Peak period travel is more widely spread than that for outlying business districts.

Some downtowns have expanded beyond their original limits into surrounding areas. Chicago's original CBD was about 1.20 square miles; however, the expanded central area that includes the near north and west sides contains more than 4 square miles and increases the central area employment by about 50 percent.

Good transportation to and from the CBD has been and remains an essential element of a downtown's success. Rapid transit and commuter rail service have supported large office developments in major U.S. cities such as New York City, Chicago, Boston, Philadelphia, and more recently in Atlanta, Baltimore, Los Angeles, San Francisco, and Washington, DC. Other cities have implemented light rail or busway systems to both improve mobility and encourage downtown development. And, in most cases, the downtown area has a very high level of access to the region's freeway system, given that the original purpose of the interstate system was to connect major cities.

2. *Travel Characteristics*

Travel characteristics for downtowns vary by size of CBD, densities in employment, parking availability and costs, transit availability and fares, relative accessibility by available travel modes, and local transportation policies that encourage non-automobile use in the downtown area. Small downtowns may generate their peak period travel demand over concentrated periods as short as 15 or 20 minutes. Larger and more diverse downtowns generate their peaks over 2 hours or more. The range in characteristics requires that transportation planning efforts be based on careful studies and accurate data for the specific downtown being considered.

Reported characteristics for CBD travel include:

- Except for the very largest downtowns in terms of employment, peak-hour, one-way cordon volumes are generally less than 100,000 persons. This implies corridor movements by all modes that are less than 25,000 persons per hour.
- Per capita trip attractions to the CBD generally decrease with increasing travel time and distance.
- In most cities, CBD trips have grown at a slower rate than the overall growth in the region's total trips. Trips between established neighborhoods and the city center have generally decreased, and trips between suburban areas and the city center have generally increased. As a consequence, average trip lengths have increased and public transport use has decreased in many areas.
- The proportion of work trips to the CBD increases with urbanized area population. In most large areas (population of more than 1 million) more than half of all downtown person destinations are for work trips.
- Pedestrian and parker walking distances vary according to city. They reflect the locations of transit stops/stations and parking facilities in relation to major retail and office concentrations. Median walking distances are approximately 500 to 600 feet, and 80 percent of pedestrians walk less than one-quarter mile, except in very large cities.
- Workers usually park for 6 to 8 hours, while parking for shoppers and personal business trips usually lasts about 2 hours.

3. Challenges

The challenges facing CBDs will vary by city. In some downtowns that are experiencing new growth, for example, Denver, Portland (Oregon), San Diego, and Seattle, the challenge is providing mobility options to serve both the residents and commuters. In others where such growth has not occurred, the challenge is combining transportation strategies with development and urban design strategies to encourage growth to occur. Generally, transportation problems are often found on both access gateways to the city center and within the center itself. However, in many CBDs, peak-hour congestion is more serious on the access facilities than it is in within the CBD. Commonly encountered problems include:

- Inadequate access to regional rapid transit service.
- Congested freeways and access roads to and from freeways.
- Poor freeway operations close to the city center that also may cut off access from surrounding areas.
- Offset, discontinuous, and irregular street patterns.
- Dispersed developments and long blocks that make walking difficult.
- Narrow and obstructed sidewalks that make pedestrian circulation difficult.
- Poorly located parking facilities in relation to the activities they serve and/or that make walking difficult and unattractive.
- Limited off-street facilities in buildings for handling and delivering freight, mail, parcels, and supplies.

4. Planning Steps

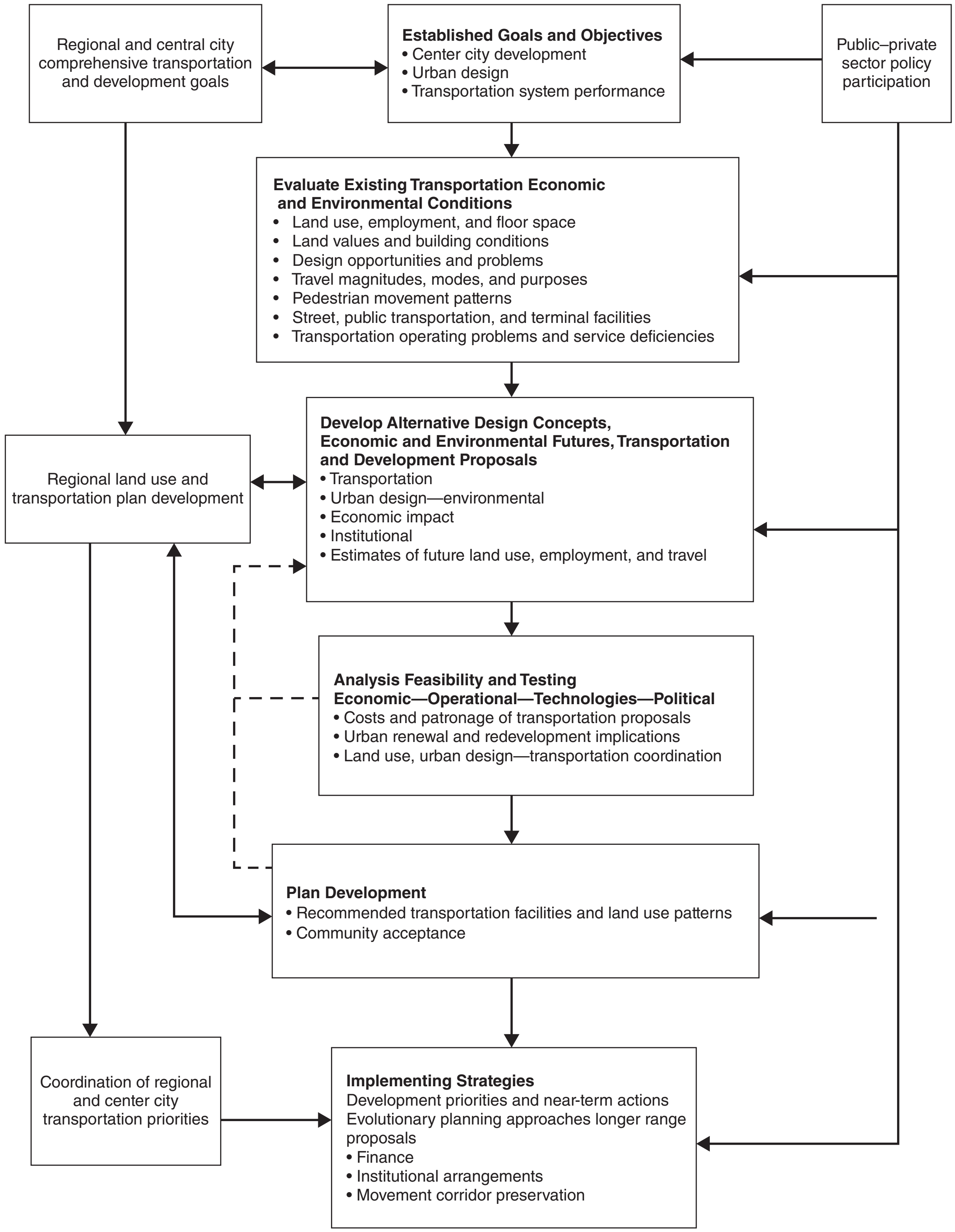
Transportation planning for the city center should be done as a cooperative process with the CBD community. Such planning usually includes transportation planners and engineers, urban planners, landscape architects, land economists and developers. The steps in this process depend upon the type and scale of the planned improvements. Thus, a traffic improvement plan would likely include a different focus and time horizon than a major public transport investment plan that is keyed to downtown development.

Figure 18-9 provides an overview of the city center transportation planning process. Transportation planning decisions and improvement strategies should reinforce CBD economic and environmental objectives. They should be coordinated to improve the accessibility, character, amenities, and economy of the CBD; foster orderly and compact developments; encourage residential areas in the downtown and its environs; and preserve necessary corridors for transportation. Travel by public transit should be encouraged, especially in larger cities. This means not only providing reliable, high-capacity transit services, but also applying parking management and TDM strategies to encourage such use (see chapter 14 on travel demand management and chapter 19 on site planning and impact analysis).

As shown in Figure 18-9, the downtown planning process begins with an articulation of goals, objectives, and/or guiding principles. An example of this comes from Bellevue, Washington, where the city council adopted the following guiding principles to focus the planning effort.

1) *Plan for multiple modes of travel within and to and from Downtown Bellevue:* Develop an innovative multimodal transportation strategy for Downtown Bellevue that updates the existing Downtown Subarea Plan project list.
2) *Accommodate the anticipated travel demands from the 2030 land use forecast:* Ensure that the planned transportation system will accommodate the 2030 forecast for Downtown residential and employment growth.
3) *Advance the adopted vision for Downtown Bellevue:* Ensure that the Downtown transportation system advances and supports the land-use and urban design vision for Downtown Bellevue—articulated in the Downtown Subarea Plan as a vibrant, livable, accessible, and memorable mixed-use Urban Center.
4) *Recognize changes in the regional and local transportation and land-use environment:* Incorporate local and regional transportation projects and plans that have been approved and/or implemented since the Downtown Subarea Plan was adopted.
5) *Integrate City Council direction:* As potential Downtown transportation projects are identified, incorporate City Council direction on regional transportation facilities.

Figure 18-9. Downtown Transportation Planning Process



6) *Provide for comprehensive public involvement:* Ensure that the process to update the Downtown Transportation Plan invites broad and inclusive public involvement that engages the diverse Downtown commercial and residential communities, nearby residential neighborhoods, and other community stakeholders.

7) *Minimize traffic impacts on neighborhoods:* Consider measures as needed to protect Downtown residents and nearby residential neighborhoods from significant adverse impacts from traffic and commuter parking.

8) *Involve regional transportation and planning partners:* Coordinate planning for the Downtown Bellevue transportation system with regional transportation and planning partners.

9) *Leverage funding from outside sources to implement projects:* Identify transportation system projects that effectively leverage grant funding opportunities.

10) *Utilize measures of effectiveness to evaluate potential projects:* Use both quantitative and qualitative measures of effectiveness to evaluate project ideas relative to each other and to community objectives. Consider the cost of a project relative to its benefit to mobility as an important metric, in addition to measures such as improved safety for pedestrians and bicyclists, management of traffic congestion, and the efficient use of the available right-of-way. [City of Bellevue, 2012]

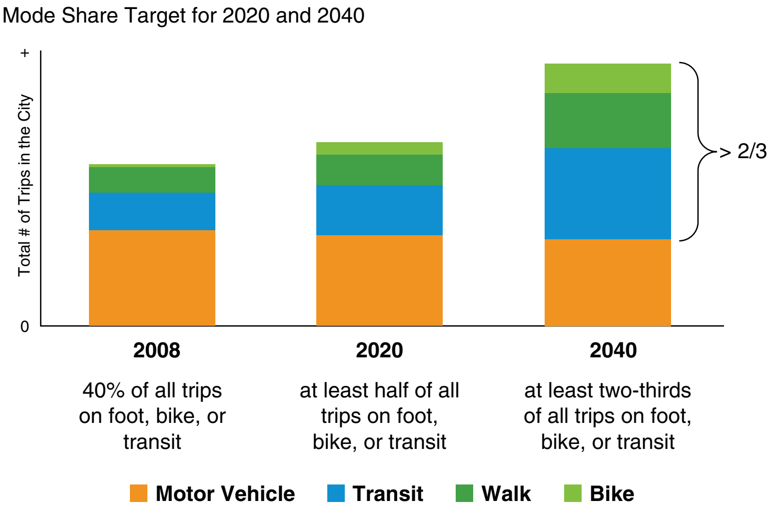
Another way of laying out direction for a plan is to ask key questions that the plan should answer. In Minneapolis, for example, the Downtown Action Plan began with the following questions.

- Which streets need to be modified to encourage more biking?
- Which streets need to be modified to encourage more walking?
- Which pattern of transit service works best for the downtown and which streets need to emphasize the movement of transit?
- Which streets are critical for moving traffic in and out of downtown and which are important for circulating traffic within downtown?
- Where is better freeway connectivity needed?
- What curbside changes or management strategies are needed to address property access needs, such as access to parking ramps, deliveries, drop-off/pick-up, valet, and on-street parking? [City of Minneapolis, 2007]

Along with these questions, the plan was linked to broader downtown objectives of sustaining continued growth, maintaining and improving the quality of life and the character of downtown; and using limited space efficiently, and effectively by moving more people using existing infrastructure. This makes it practical to live without a car if desired, and making downtown attractive and easy to navigate for visitors, customers, residents, and workers.

In a few cases, most notably cities outside the United States, some municipalities have adopted plan targets. In Vancouver, British Columbia, for example, the city has adopted a mode share target for 2040 as shown in Figure 18-10. The transportation plan for the city and the downtown is structured around meeting this target.

Figure 18-10. City of Vancouver's Mode Share 2040 Target



Source: City of Vancouver, undated

For larger cities, or for those that want to invest in models, the analysis process for assessing today's transportation system performance and forecasting future values is very similar to the process and tools used for regional transportation planning. Thus, in the Bellevue case, for example, travel demand models were used similar to those used by metropolitan planning organizations (MPOs) (see chapter 6 on travel demand models). Data had to be collected to update the socioeconomic database, and the network coding had to be checked to reflect changes to the network since the model had been last used. As noted in the section on local planning, in many cases, the regional travel demand model used by the MPO is the basis for the models used for city planning, only modified to be more reflective of the planning needs of the city.

Good CBD pedestrian access and circulation are an essential component of an effective downtown transportation system. This may entail providing ample sidewalk space along streets lined with ground floor commercial spaces, good pedestrian linkages to transit stations, clearly visible traffic controls and signage, and attractive pedestrian focal points or plazas. Sometimes it may be desirable to separate pedestrian movements vertically through grade separation from transit vehicles and cars. The degree of preference given to transit and pedestrians as compared to motor vehicles varies among downtowns. Some cities have limited parking space and vehicle access with the aim of creating a more walkable city and fostering transit use. Examples include the supply caps put on downtown parking in Boston and Portland (Oregon), and the deconstruction of freeway segments in Boston, Milwaukee (Wisconsin), and San Francisco.

Table 18-9 shows transportation planning principles for typical downtowns. As will be seen, some of these access concepts and principles differ from those for suburban activity centers. Principles that are especially applicable in downtown settings include the following:

- Major access and circulation routes should be concentrated on or near the periphery of the area.
- The core area should be devoted to high-intensity uses, with major reliance placed on transit, pedestrian, and bicyclist circulation in large downtowns.
- Transit service, where available, should be provided to major concentrations of employment and patron- or visitor-oriented businesses; transit utilization should be encouraged, especially where roadway level of service, air quality, or other conditions would significantly benefit, or where downtown employment densities are very high.
- Transit priorities and amenities should be provided where transit usage is encouraged.
- Continuity of pedestrian circulation in plan and elevation should be provided.
- Parking should be separated for long-term (employee), short-term (visitor or patron) and errand or service purposes. The most convenient parking, on- or off-street, should be reserved for short-term and errand parking.
- Curb-loading zones should be provided in accordance with actual loading activity and should be located to minimize conflicts with pedestrians and vehicles.
- Parking should be utilized on a shared basis rather than restricted to individual businesses; parking garages serving the public should be encouraged.
- Employee parking should be located away from the immediate downtown core area to the extent practical to reduce traffic circulation in the congested downtown.
- In larger downtowns, free intra-CBD transit service, local bus circulator service, and closer spacing of rail transit stations can enhance circulation.
- Total unit parking demand rates will be lower than for suburban locations. In large areas, the ratio may be as low as one-half of that for suburban developments. In a few of the largest downtowns, it is a small fraction of typical demand rates due to high mode splits and vehicle occupancies.
- Access to downtown developments should be linked directly to parking or transit facilities where possible to facilitate access.
- Pedestrian facilities should be provided with adequate capacity and minimum conflicts with other modes. Grade-separated pedestrian system segments may be appropriate in some larger downtowns.
- Secure and convenient bicycle parking facilities should be provided at major downtown destinations and at transit stations or other multimodal transportation stations.

Typical downtown transportation plans recommend a wide range of projects and policies to improve the performance of the downtown's transportation system. For example, Figure 18-11 shows the pavement and bridge needs in the downtown Minneapolis area. Plans can also recommend physical designs and treatments on downtown streets, as the Minneapolis plan did for street transit lanes (see Figure 18-12). Finally, Figure 18-13 shows the recommended improvements in the downtown area.

In addition to physical improvements to the transportation network, downtown transportation plans can make recommendations on parking policies, movement of trucks and delivery hours, the relationship between land use/urban

Table 18-9. Transportation Planning Principles for Typical Downtowns

Traffic Circulation Principles

- A hierarchy of downtown streets should be established (for example, major arterials, minor arterials, collector and distributor streets, and local streets) that defines the relative importance of moving through traffic and providing access to property. This hierarchy should be implemented through the use of street design techniques, traffic control measures, and parking regulations.
- Freeways should be sufficiently removed from the city center and should not isolate one side from another. An "inner loop" of one-way streets is preferable to a tight freeway loop with inadequate weaving space.[9]
- Major access and circulation routes should be concentrated at or near the periphery of the area.
- The CBD street system should have sufficient traffic capacity to minimize congestion and handle peak-hour traffic loads during the planning period.
- Non-CBD traffic should be directed away from the core area utilizing alternative or bypass routes.
- The CBD street system should provide adequate access and circulation for CBD traffic.
- The central area street system should provide direct access for emergency and service vehicles.
- The CBD circulation system should connect with both existing and proposed major thoroughfares beyond the CBD (for example, radial freeways and principal arterial streets).
- The CBD street system should provide more than one opportunity to reach a destination.
- The CBD circulation pattern should be easily comprehended by the average driver and provide relatively direct routings without circuitous travel.
- The circulation plan should be designed for incremental implementation with individual elements available for use as they are completed.
- Streets should be designed to provide continuous routings and continuity of capacity.
- The CBD circulation plan should allow drivers to circulate around the blocks or areas that generate high traffic volumes.
- Major downtown streets should be free from conflicts with major at-grade railroad crossings.
- The CBD street network should be regularized by street extensions and closures.
- Complex intersections and multiphase signals should be avoided.
- Streets and land development should not be so large as to make circulation difficult; the street pattern should not cut land areas into parcels too small to permit sound development.

Parking Principles

- CBD parking should be accessible from the primary CBD approach routes and located with direct connections to major vehicle entry points.
- CBD parking facilities should be distributed in relation to the directional distribution of vehicular approach to the area.
- The parking system should provide space for explicit use of long-term, short-term, visitor, and errand parking.
- CBD parking system should have sufficient capacity to accommodate present and future peak parking demands, but should not undercut transit ridership. (The degree of preference to transit and pedestrians compared to motor vehicles varies greatly for different downtowns.)
- CBD parking, where possible, should facilitate dual or shared usage of facilities.
- Shuttle buses should connect peripheral commuter parking facilities with ultimate CBD destinations.
- Facilities must be provided to accommodate the needs of regular delivery vehicles, quick-stop service (such as mail and newspaper trucks), and special-purpose vehicles such as construction and maintenance trucks.
- Employee parking should be located away from the downtown core to the extent practicable.

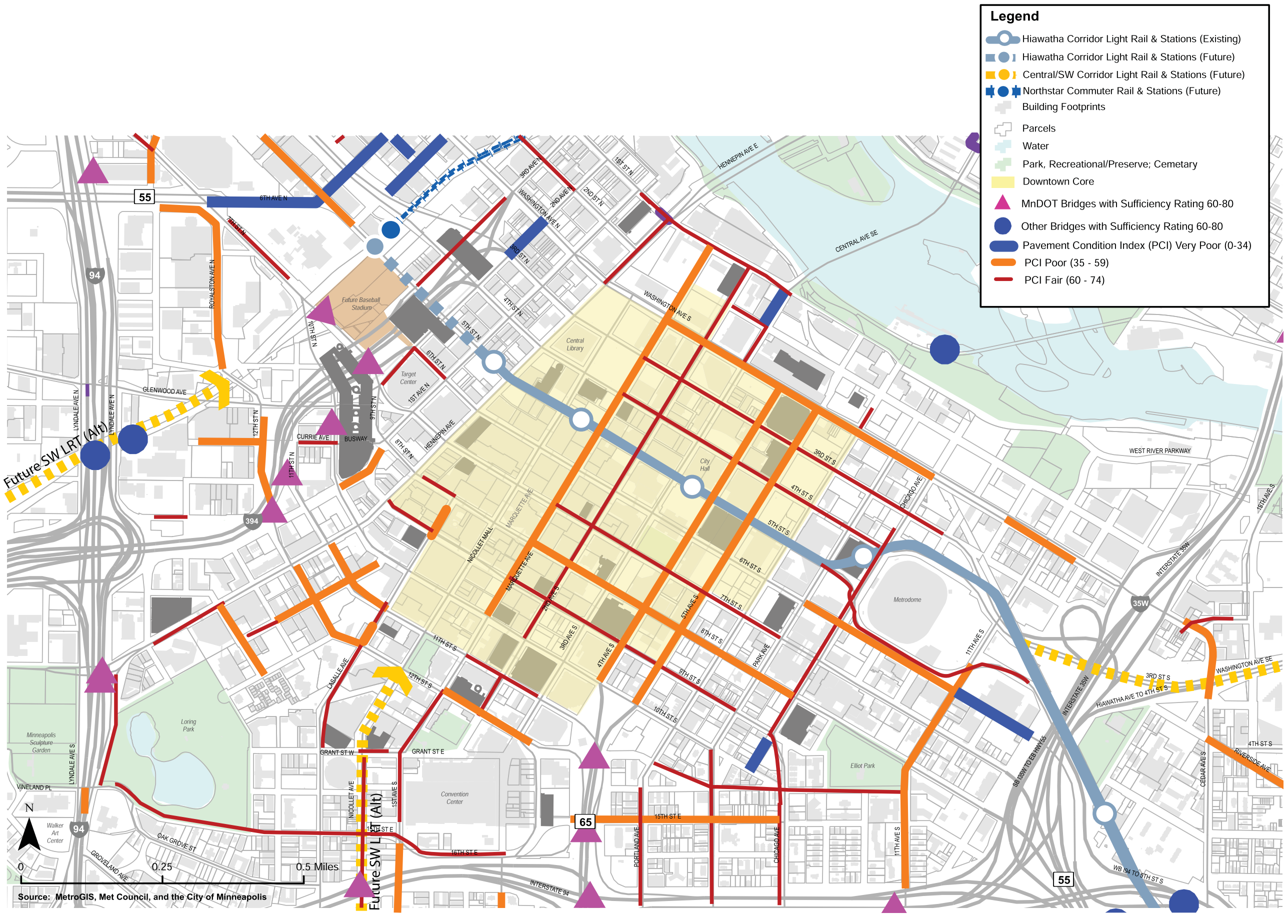
Table 18-9. (*Continued*)
• Curb loading zones should be provided in accordance with actual loading activity and located to minimize conflicts. • Outlying park-and-ride lots along express bus/bus rapid transit, rapid transit, and commuter rail lines should intercept motorists, especially commuters. • On-street parking should be discouraged along main shopping streets. • Ground floor retail use of parking garages should be encouraged. • Open-lot parking should be screened and landscaped.
Pedestrian/Bicyclist Circulation Principles • Continuity of pedestrian and bicyclist circulation between downtown destinations should be a priority. • A suitable environment for pedestrians should be created. This should include, in addition to other amenities, protection from weather, especially in high pedestrian volume areas. Safe environments should be created for bicyclists as well, especially avoiding conflicts with motor vehicles. • Pedestrian and bicyclist access from major CBD parking facilities and transit stops or stations to CBD land use should be located to avoid traffic conflicts and enhance safety. • Major pedestrian and bicyclist ways should be properly defined and identified by landscaping and lighting. • To maintain safe and convenient pedestrian crossings, streets should have no more than four moving lanes, unless medians with suitable pedestrian refuges are provided. • Sidewalks and bike lanes should be kept clear of clutter and obstructions. • Suitable provisions should be made for the mobility impaired.
Transit Principles • Surface transit should be given priority to use street facilities. • Direct transit access should be provided to primary CBD destinations areas for the convenience of passengers. • Land uses should be located to capitalize on transit facilities as well as to maximize the market for transit. • To the extent possible, the principle of through-routing should be applied to all CBD transit facilities to avoid looping and artificial doubling of transit vehicle loads. • Off-street transit service facilities for transit that passes through CBD should be fostered in CBDs with high employment concentrations. • Transit stops and stations should have a strong identity.

Source: Adapted from Edwards, J. (ed.). 1999. *Transportation Planning Handbook*, 2nd Edition. Washington, DC: Institute of Transportation Engineers.

design and transportation projects, and institutional relationships among key agencies and downtown stakeholders. For example, the Minneapolis plan made the following recommendations regarding downtown parking:

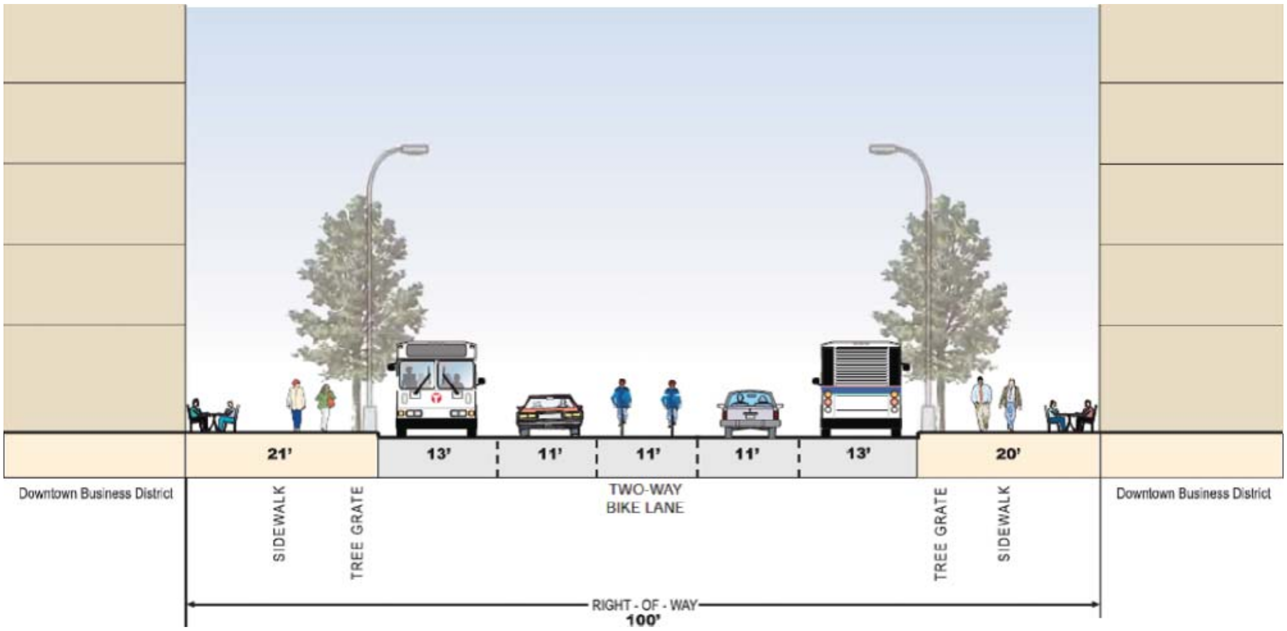
- The city will encourage private property owners to locate parking facilities, particularly those for employees, outside the core area along one-way streets that provide direct access to/from freeway ramps. New parking facilities will be discouraged along transit spines and primary pedestrian corridors.
- The city will implement pricing practices that encourage parking outside the core, particularly for long-term commuter parking.
- The city will continue to expand the use of electronic message signs to provide direction to available parking facilities to minimize the amount of “search and park” circulating traffic.
- The city will continue to encourage the use of motorcycles and scooters by designating free parking spaces in municipal parking ramps. [City of Minneapolis, 2007]

Figure 18-11. Pavement and Bridge Needs, Downtown Minneapolis, Minnesota



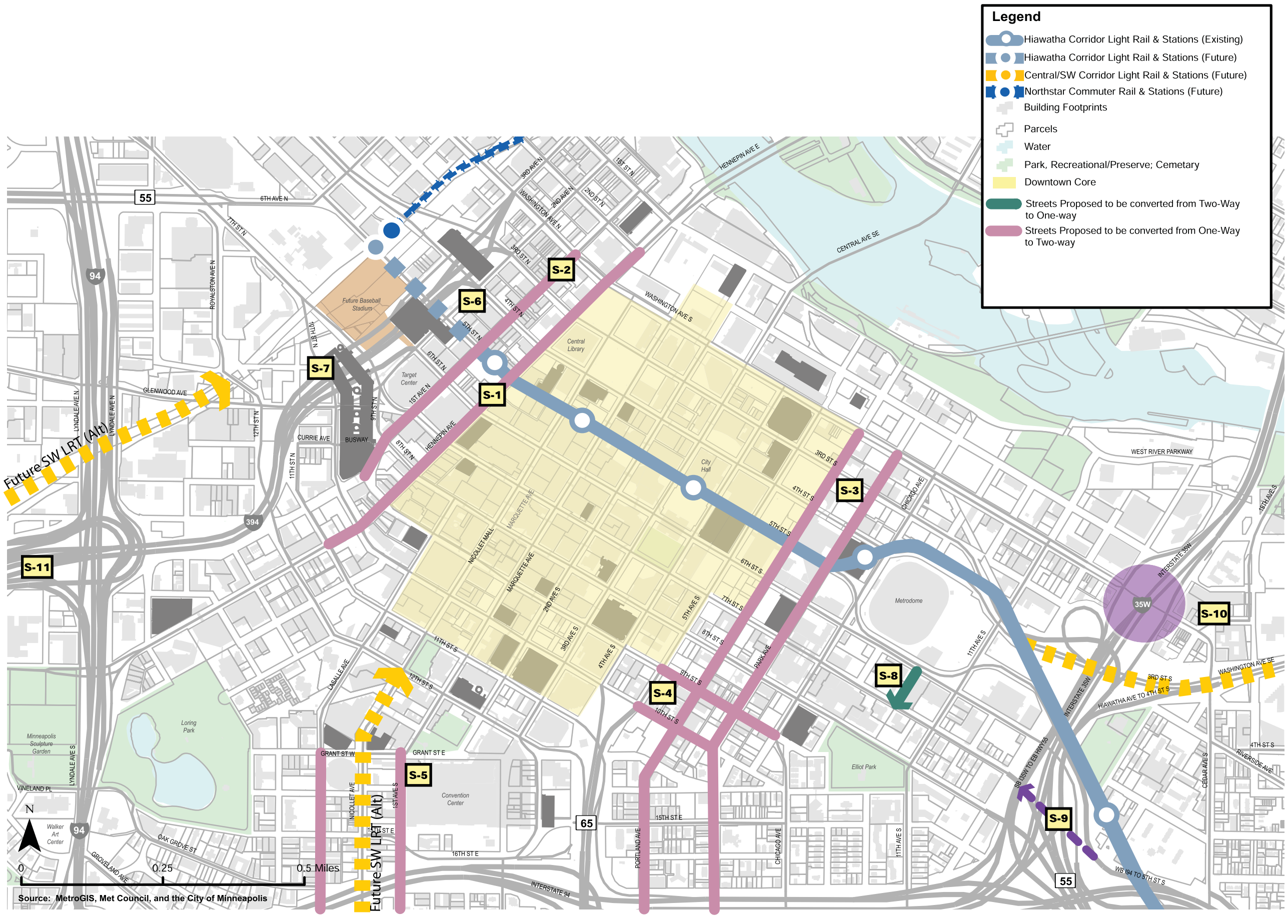
Source: City of Minneapolis, 2007

Figure 18-12. Transit Service Option on Downtown Street, Minneapolis, Minnesota



Source: City of Minneapolis, 2007

Figure 18-13. Improvement Recommendations for Downtown Minneapolis, Minnesota



Source: City of Minneapolis, 2007

C. Suburban Activity Centers (SACs)

Suburban activity centers are a response to the decentralization of the urban United States and many other Western cities since World War II. As such, they have been established for many of the same reasons as downtowns—high automobile accessibility, convenience to a major proportion of a region's population, and a need for commercial development to support a significant portion of the area's economy. They have joined traditional downtowns as major nodes of economic activity, and therefore as major attractors and generators of trips. These centers have been variously termed *suburban subcenters*, *megacenters*, *suburban activity centers* (SACs), or simply *suburban business districts*.

1. Characteristics

The Urban Land Institute (ULI) has identified four overlapping periods of suburban business district development that has occurred in the United States. [ULI, 2001] This history is important because it places suburban activity centers and their transportation challenges in context. The first wave (1960s) started when retail and then office uses followed resident relocation to the suburbs. The second wave (1970s) continued the development of office and retail clusters at somewhat lower densities, close to executive housing. The third (1980s) and fourth (1990 to today) waves developed even farther from the city center, often in campus-like settings. In many instances, the fourth wave activity centers located along freeways to take advantage of the accessibility afforded by road access.

Suburban activity centers normally contain most or all of the following features:

- Critical mass of floor space—usually more than 5 million total square feet.
- Land-use mix of predominantly office and retail uses (and some entertainment), although not usually within the same building.
- Many more jobs than residents, although the balance in many cases is shifting toward more residential uses.

- Heavy reliance on automobile access, and in some cases located outside of a transit agency's service area.
- Predominantly free parking, and even when there is a parking cost, the first few hours are often free.

Suburban activity centers have been classified in many ways—by age, land use, building form and layout, major transportation mode, and distance from downtown. The ULI suggests classifying them as compact, fragmented, or dispersed (see Table 18-10). Compact suburban business districts are generally the oldest of the three types of suburban business districts, and they have the greatest similarity to a CBD. They are characterized by fairly high densities, a grid street layout, transit availability, and a pedestrian environment that is serviceable or even friendly. Leading examples of compact suburban business districts in the United States that have established a strong sense of place and a pedestrian-friendly environment include Bethesda, Maryland; Bellevue, Washington; Buckhead in Atlanta; and Arlington Heights, Illinois near Chicago (see Figure 18-14).

Fragmented suburban districts are perhaps the most problematic to transform into attractive and lively pedestrian-friendly areas. They are characterized by medium densities, superblock configurations, and relatively

Table 18-10. Categories of Suburban Business Districts

	Compact	Fragmented	Dispersed
Floor/area ratio	2.5 and above	0.5 to 2.5	Up to 0.5
Building coverage	0.5 or more of lot area	0.25 to 0.5 of lot area	Up to 0.25 of lot area
Lot area (acres)	< 1 acre	> 1 acre	Generally exceeds 10
Street layout	Grid	Superblock	Superblock
Land value	High	Medium	Low
Buildings dominate space	Yes, buildings built to street alignment.	No, buildings set back from road and separated from surface parking lots.	No, buildings set back from road; often one to two stories in height in campus/park setting.
Parking	Structured; managed.	Surface; managed.	Surface; unmanaged.
Transportation choice	Wide, frequently includes light and heavy rail transit.	Limited, usually car and bus.	Very limited, usually car with infrequent transit, if any.
Pedestrian linkages and interconnection of development	Extensive, encourages pedestrian activity.	Limited, often no linkages; layout encourages patrons to drive to adjoining location.	Very limited, developments far apart and not within walking distance.

Source: ULI, 2001, Reproduced with permission of the Urban Land Institute.

Figure 18-14. An Example of an Activity Center, Buckhead, Atlanta, Georgia

Photo courtesy of Buckhead Coalition

hostile pedestrian environments. They generally do not contain large parcels of vacant or unused land, although they do contain underused land devoted to parking and other low-intensity uses. Their transportation and land-use patterns are often well established and difficult to alter. To transform these patterns usually requires strong public intervention, new infrastructure investment, both public and private redevelopment initiatives, and creative infill development. The most robust of these fragmented U.S. suburban business districts, such as Tysons Corner, Virginia, near Washington, DC, are experiencing strong growth in demand and pressure to redevelop underused land.

Dispersed suburban business districts, the least mature of the three types, are characterized by low densities, superblock configurations, hostile or nonexistent pedestrian environments, and a substantial amount of undeveloped or underused land. Modest intervention by the public and private sectors can be effective in making them more pedestrian-friendly.

2. Travel Characteristics

Travel characteristics and demands associate with suburban activity centers reflect the location, size, uses, density, and auto dependency of each center. The transit share of some major employment clusters outside of CBDs is shown in Table 18-11. As can be seen, the transit share varies widely. Most of the employment centers that have a fairly high transit share are served by a subway station.

Retail centers are often the core of suburban centers just as major department stores were (and sometimes are) located at prime downtown locations. The ability of retail activities to draw from offices and nearby residential areas within the suburban center lowers the average trip generation rates for the activity center itself. Retail center origins and destinations also show differences between large and small activity centers, especially during the midday peak. This reflects the large numbers of office employees who patronize the shops (see chapter 19 on site planning and traffic impact analysis).

A study of suburban activity centers in the mid-1990s showed that hotels in large activity centers draw about one-third of all peak-hour trips from the activity centers themselves; they are more self-contained than offices in the same activity center. Hotels in smaller activity centers had less, but still significant, synergy with the corresponding activity centers; about 20 percent of the a.m. peak hour internal trips were to and from the activity center, and 27 percent of the p.m. trips were internal. [Hooper, 1996]

Parking demands at suburban activity centers are less than those for isolated developments of the same magnitude. This is because certain activities can share spaces when demands occur throughout the day and a sizable portion of retail customers come from offices within the center. (Thus, if 25 to 35 percent of the shoppers come from offices, it is reasonable to assume a comparable reduction in shopper parking generation.)

3. Challenges

The transportation challenges facing many suburban activity centers relate to the dominance of the automobile for access. [Dunham-Jones, 2011] Depending on where the activity center is located, the mode share will be heavily oriented to auto use (note that those employment centers in Table 18-11 with a high transit mode share are served by a subway station). Given the location of many of these activity centers along freeways and at major freeway interchanges, major congestion often does not occur in the activity center itself, but on the major access roads. This has led to the reconstruction of many freeway interchanges whose original design did not intend to handle as much traffic as has occurred. Many of these freeways and major arterial roads are under the control of state and local transportation agencies, and thus the activity center owners do not have direct say on how these roads are managed. This congestion has often been exacerbated with the redevelopment and density increase of new buildings in the activity center, in some cases to compete better with other centers in the region.

Managing an activity center's parking resources is another challenge. This has often led to shared parking strategies (when the tenants were agreeable to such a strategy), construction of parking structures when surface lot capacity was becoming inadequate, and in more urban areas the participation in TDM programs designed to lower the demand for parking.

Typical planning issues for suburban activity centers are listed in Table 18-12. Perhaps the most serious and challenging issue is the ability of larger activity centers to accommodate transportation demand as they grow and intensify. It may be difficult or impractical to provide enough road capacity, and in many cases, parking may be converted to commercial or residential use. This leads to a longer term focus on public transportation in siting and designing

Table 18-11. Transit Shares of Major Employment Centers Outside CBDs	
Metro Area	**Transit Mode Share**
Atlanta	
Atlanta Airport Area	4.4%
Buckhead	12.4%
Fulton Industrial & I-285 Corridor	2.7%
Perimeter Center	8.5%
Chicago	
O'Hare Airport/Elk Grove Village	4.6%
Schaumberg	2.5%
Dallas-Ft. Worth	
Dallas North Tollway	1.2%
Love Field & I-35 North Corridor	2.2%
Las Colinas-Irving Corridor	0.4%
Houston	
Energy Corridor (I-10 West)	0.7%
Texas Medical Center	7.6%
Uptown (Galleria)	3.3%
Los Angeles	
Anaheim-Orange	3.7%
Burbank-Glendale I-5 Corridor	5.6%
Century City	6.9%
I-110/I-405 Corridor (South Bay) Corridor	3.7%
Santa Clarita I-5 Corridor	4.2%
Warner Center	6.8%
Portland	
Lloyd Center & Inner East Side	11.6%
Portland Airport & Columbia River South Corridor	4.3%
Wilsonville	1.6%
St. Louis	
St. Louis Airport Area	1.3%
Westport Plaza–Mid-County Corridor	1.5%
Washington	
Arlington-Ballston Corridor	19.8%
Silver Spring	23.0%

Source: Demographia, 2010, selected employment centers, Reproduced with permission of Demographia.

centers, improved efforts to manage the transportation system more effectively, or implementing TDM programs to reduce peak demands on the transportation system.

4. Planning Steps

Activity center transportation planning can occur as part of regional, sub-regional, or sub-area planning efforts; as a stand-alone activity center plan; a corridor plan; plans for anticipated development in an approval pipeline, and/or comprehensive land use or zoning plan revisions. Table 18-13 shows transportation planning principles that should guide planning for suburban activity centers. These principles can be adapted to fit specific activity centers.

A general outline of the analysis process is shown in Table 18-14. The type and level of analysis is governed by the study's specific objectives, which should reflect local policies and needs. The steps and procedures include:

- Evaluate existing traffic, transit, parking, bicyclist, and pedestrian systems.
- Evaluate the effects of potential land use changes.

Table 18-12. Typical Suburban Activity Center (SAC) Transportation-related Concerns and Issues

Projected activity center size and character • Degree of concentration or sprawl (mixed-use vs. multi-use). • Densities and square footage by use (actual vs. zoned, announced or planned). • Rate of development.	**Property access** • Access on major arterials. • Priority trade-offs between access and mobility. • Use of turn prohibitions and access management. • Protection of roadway and intersection capacity. • Road, signal, and access spacing. • Access between properties. • Access connection design and storage access.
Site conditions • Size, shape, terrain, and visibility. • Frontal area (opportunities for access connections).	**Service** • Special service needs. • Separation of heavy truck traffic.
Travel demand projections • Trip generation internal trip-making. • Ridesharing. • Vehicle occupancies. • Transit use. • Travel demand management potential (and commitment).	**Parking** • Parking ratios/synergy with adjacent developments. • Convenience. • Fees and impacts on both marketability and demand. • Conflicts with transit incentives. • Surface vs. structured supply. • Use of fringe parking. • Shared parking/design features.
Regional access to the activity center • Expressway (overall capacity and number and capacity of interchanges). • Arterial (capacity, directness of service connectivity, and penetration of center). • Other modes. **Through traffic** • Conflicts with access and internal circulation. • Priority given to through versus local movements. • Bypasses or grade separations for through traffic. **Internal circulation** • Roadway system—capacity, continuity. • Pedestrian system needs, potential, and priority. • Transit functions, productivity, and cost factors. • Transit priority treatments/separate rights of way. • Conflicts with through and regional access traffic.	**Transportation improvements** • Freeway and arterial designs. • Expressway interchanges (more, redesigned). • Ramp improvements. • Additional streets or improved continuity/connectivity. • Transit routes and circulators. • Rapid transit routes and station connections. • Travel demand management strategies. • Parking ratio reductions. • Provision of amenities to encourage transit use and walking for internal trips. • Improvement priorities. • Costs. • Source of financing for improvements. • Environmental impacts.
General roadway system characteristics • Capacity to accommodate further density increases. • Spacing of expressway interchanges, arterials, collectors, local streets, and signalized intersections. • Continuity in roadway design. • Special treatments (for example, grade separations, ramps, one-way streets). • Potential for operational improvements.	

Table 18-13. Typical Transportation Planning Principles for Suburban Activity Centers
General • Planning for activity center transportation systems should encourage coordination and most effective use of all appropriate modes and forms of transportation. • Transportation and land-use plans should be mutually supportive. • Activity center transportation and land use should be arranged so that the highest trip generating land uses are located nearest high accessibility transportation facilities, particularly transit routes and stations. • The transportation facilities should be aesthetically attractive and, to the extent possible, blend in with or highlight the surroundings and the topographic features through which they pass. • The transportation system should be comprehensible and easy to use for both frequent users and unfamiliar visitors. • Adequate system capacity, continuity and connectivity should be ensured by defining and protecting sufficient future transportation right of way early, consistent with local policies on accommodating traffic and potential build-out of development. • All elements of the transportation plan should be consistent with political and financial realities. • The plan should be able to be staged with individual elements to be usable as they are completed.
Roadway System and Traffic Circulation • The street system should provide adequate access and circulation for activity center traffic. • The activity center circulation system should connect with both existing and proposed major thoroughfares beyond the activity center (for example, radial freeways and principal arterial streets). • The activity center street system should provide more than one opportunity to reach a destination. • Through traffic should be directed away from the core area utilizing alternative or bypass routes. • The activity center circulation pattern should be easily comprehended by the average driver and provide relatively direct routing. • The circulation plan should be designed for incremental implementation with individual elements available for use as they are completed. • Streets should be designed to provide continuous routing and continuity of capacity. • The activity center circulation plan should allow drivers to circulate around blocks or areas that generate high traffic volumes. • Emergency vehicles must be able to reach any portion of the activity center in a reasonably direct manner. • Given streets should perform specific functions (for example, major arterials, minor arterials collector/distributor streets, and local streets) to the extent that a hierarchy can be identified. This hierarchy should be implemented through the use street design techniques, traffic control measures, and parking regulations. Streets should have an appearance consistent with their function. Major streets should have wider pavements, right of way, and building setback than minor streets to give the appearance of a more important street. Minor streets should encourage slower speeds and pedestrian movement. • One-way streets should have balance convenience to through-trips with inconvenience to local destinations. • One-way streets facilitate signal progression, simplify intersections, increase capacity, and reduce crashes, but they may be inconvenient in certain situations. • Complex intersections and multiphase signals should be avoided. • Streets and land development should be designed to complement each other. Arterial streets should border rather than sever activity center land-use activity areas. Land parcels should not be so large as to make circulation difficult. The street pattern should not cut land areas into parcels too small to permit sound development. • Adequate spacing of arterial streets should be provided to meet both capacity and circulation needs.

Table 18-13. (*Continued*)

- Efficient use of existing facilities should be considered in addition to physical improvement or construction of new facilities.
- Major roadways should be improved or constructed to appropriate geometric and safety standards; however, needed improvements should not be discarded only because all design standards cannot fully be met due to right-of-way or other constraints. Sometimes reduced standards may be desirable.
- The activity center freeway system should recognize basic principles of route capacity and continuity.
- Care must be exercised to ensure that there is sufficient capacity at interchanges. Collector-distributor facilities may be required to distribute the traffic from the freeway onto several arterial streets. Special ramp configurations, including direct connector ramps, may be desirable.
- Direct connections to the activity center by transit and high-occupancy vehicles (HOVs) via transitways and HOV lanes should be considered during the planning stage.

Parking Principles

- Activity center parking should be accessible from the primary activity center approach routes and located at major vehicle entry points.
- Activity center parking facilities should be distributed in relation to the direction of vehicles entering the area of development.
- Parking should provide explicit space for long-term, short-term, visitor, and errand parking.
- The activity center should have sufficient parking capacity to accommodate peak parking demands, consistent with adopted parking policies and the effectiveness of programs to reduce peak vehicle use.
- Activity center parking should facilitate dual or shared usage of facilities by the development and operation of facilities.
- Parking should not be permitted on major thoroughfares.
- Adequate off-street facilities should be provided to accommodate the needs of regular delivery vehicles, quick-stop service (such as mail and newspaper trucks), and special-purpose vehicles such as construction and maintenance trucks.

Pedestrian/Bicyclist Circulation Principles

- Continuity of pedestrian and bicyclist circulation among key buildings in the center should be a priority.
- Similar to the CBD, a suitable environment for pedestrians should be established. This should include, in addition to other amenities, protection from weather, especially in high pedestrian volume areas. Safe environments should be created for bicyclists as well, especially avoiding conflicts with motor vehicles.
- Major pedestrian and bicyclist ways should be properly defined and identified by landscaping and lighting.
- To maintain safe and convenient pedestrian crossings, streets should have no more than four moving lanes, unless medians with suitable pedestrian refuges are provided.
- Sidewalks and bike lanes should be kept clear of clutter and obstructions.
- Suitable provisions should be made for the mobility impaired.

Transit Principles

- Service should be directly oriented to major destinations in the activity center.
- The most direct possible routing should be used.
- Routes should be designed to be comprehensible to those who are not familiar with the transit system.
- Transfers for activity center trips should be minimized.
- Conflicts of buses with traffic and pedestrians (heavy right turns, garage access, curb parking and loading, crosswalk conflicts, etc.) should be minimized.
- Bus turns and mileage should be minimized.

(*continued*)

Table 18-13. (*Continued*)

• Service design should avoid overcrowding. • Adequate passenger amenities, such as information systems and transit stop signs, adequate seating, queuing space at bus stops, and shelters should be provided where needed. • Compatibility of the transit system with the activity center environment should be enhanced. • Transit access to primary activity center destination areas should be provided for convenience and to encourage patronage of retail activities. • Land uses should be located to capitalize on transit facilities as well as to maximize the market for transit. • To the extent possible, the principle of through-routing should be applied to all activity center transit facilities to avoid looping and artificial doubling of transit vehicle loads. • Surface transit should be given priority use of street facilities. • Activity center transit service should facilitate people movement within the activity center and between any major off-site parking facilities and trip destinations (generally applicable to CBDs). • Internal transit service should generally be provided only for movements for which transit service is faster than walking. • Most service should be concentrated on a limited number of streets that serve major generators to provide the highest possible level of service (headway) to all users. • From the standpoint of activity center development, the most important transit patron is the employee. • Maximum accommodation of employee loads on transit will most effectively reduce peak-hour vehicular requirements. • Off-street rail or bus transit may be desirable on approaches to and within activity centers. Stations and stops should be close to principal passenger destinations.
Pedestrian and Bicycle Circulation • Walking and bicycling should be made feasible and desirable by placing related land uses near one another. • Continuous pedestrian ways and bicycle paths should link all activity center nodes, where appropriate. • Pedestrian and bicycle access from major activity center parking facilities to activity center land uses should be located to avoid traffic conflicts and enhance safety. • Major pedestrian ways and bicycle paths should be properly defined and identified by landscaping and lighting. • To maintain safe and convenient pedestrian crossings, streets should have no more than four moving lanes, unless medians with suitable pedestrian refuges are provided. • A suitable environment for pedestrians and bicyclists should be established. This should include, in addition to other amenities, protection from adverse weather and secure bicycle storage. • Just as there should be continuity in the plan of pedestrian circulation, there should similarly be a continuity of elevation. For example, concentrations of pedestrians alighting from buses should be reconciled with possible second-level pedestrian bridges and linkages. • Provisions for handicapped persons should be made when designing or modifying pedestrian ways.

- Estimate the potential build-out based on the current or proposed transportation system.
- Evaluate the spacing and structure of activity center transportation facilities.
- Determine the size of the various transportation network facilities.
- Modify (usually intensify) an existing transportation plan.
- Evaluate roadway or transit system options and improvements.
- Evaluate potentials for public transport.

Table 18-14. A General Outline of the Analysis Process	
Purpose/Type	**Analysis Method**
Activity center comprehensive land use and/or transportation plan formulation or revision	Forecast travel needs using anticipated land uses by parcel, parcel group, or zone (depending on level of detail needed); apply regional travel model on a subregional focus or window basis using microcomputer software; analyze needs on corridor or link basis using daily or peak-hour volumes. Test other alternatives (facilities, land use, and/or policies) in similar fashion.
Assess needs for specific transportation facilities within an activity center	Focus analysis detail on subarea or corridor(s) within activity center, with zone and network detail increasing closer to area/corridor; proceed as for comprehensive plan. In some cases where question of need is quite basic, a manual analysis may be sufficient to determine if a facility should be included in the plan.
Develop revised zoning strategy or plan	May be similar to activity center comprehensive plan process; must have land-use assumptions at sufficient level of detail to show sensitivity to zoning changes at freeway, arterial, and at least collector street level as well as transit; in some cases an assessment of ultimate transportation system capacity to determine how much land-use density can be accommodated.
Analyze potential transportation policies	May be similar to comprehensive plan process; level of detail must be sufficient to show sensitivity to policy variations—may need to use parcel-level analysis of trip generation for some policies. Many variations can be evaluated using detailed trip generation analysis followed by activity center network analysis.
Assess cumulative effects of several proposed developments	Modify travel model inputs for trip generation by zone and return travel projections; assess changes in traffic assignments by link and resulting transportation facility levels of service and/or improvements requirements.
Assess transportation impacts of individual developments	Estimate site traffic manually or using computer-assisted method; analyze site plus non-site traffic needs, including off-site changes for horizon year.

- Develop a revised zoning strategy or plan.
- Analyze the potential of transportation management policies (for example, pricing, parking ratio limits).
- Assess the cumulative effects of proposed developments of several sites within the activity center's environs.
- Assess the effects of a major new development within an established activity center.
- Prepare a staged improvement plan.

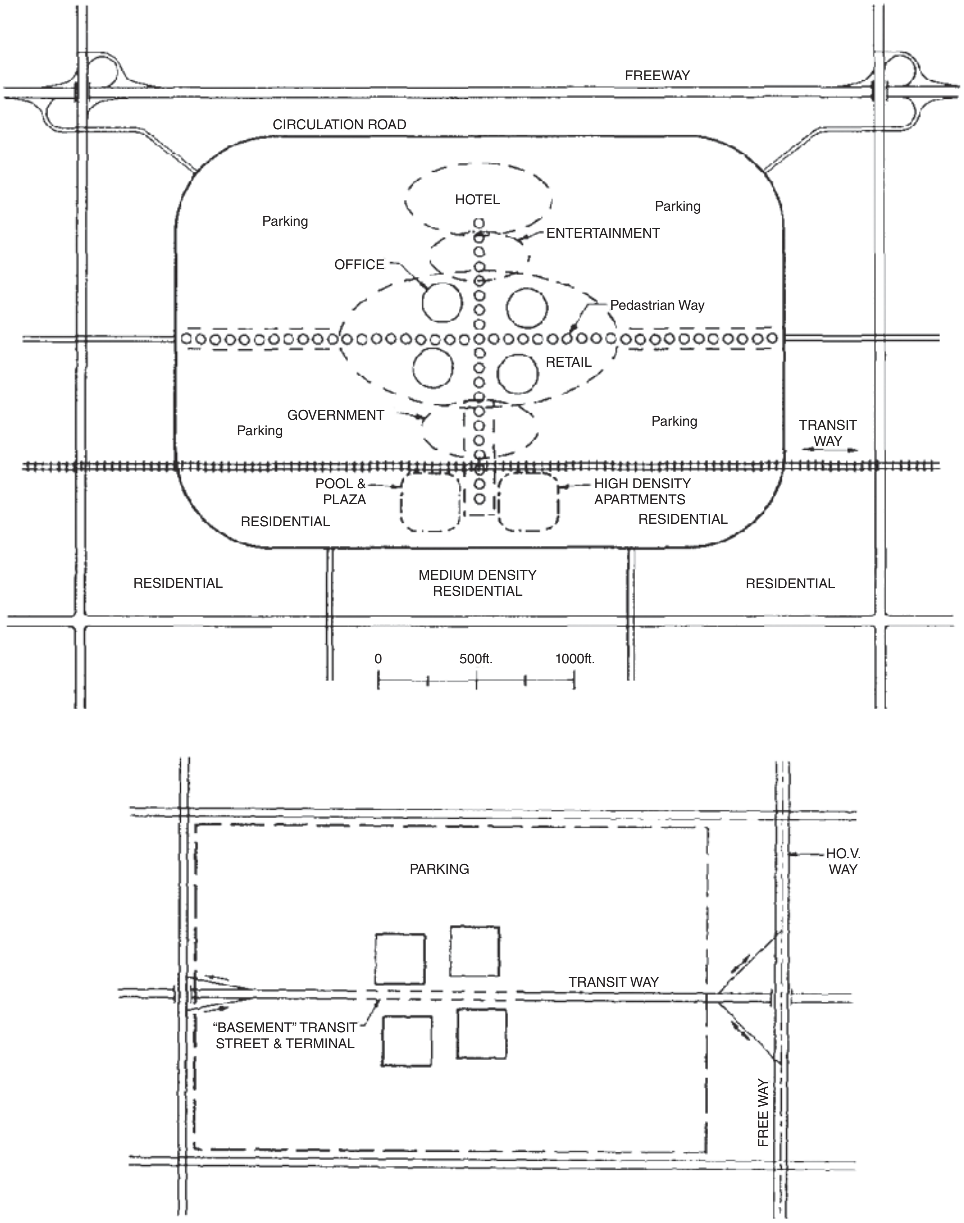
The analysis tools and methods used for analyzing the transportation needs of a suburban activity center are very similar to those used for local planning described earlier and site planning and traffic impact studies, which are described in chapter 19.

5. Transportation and Site Planning Strategies

Providing mobility options to those working or living in a suburban activity center really starts at the site planning stage, where decisions are made concerning the layout of buildings and support infrastructure. Multiuse or mixed-use activity centers can provide several benefits to both the center's patrons and to the surrounding community. The integration of retail, office, residential, and recreational activities, especially in large activity centers, re-creates the traditional city center in suburban settings and reduces the need to travel because many people do not have to go elsewhere to work or shop. Clustering offices, stores, restaurants, and entertainment activities facilitates walking trips and enables each activity to reinforce the others. Intermingling residential and commercial areas or locating medium- to high-density residential areas near the main business centers can increase interaction and reduce vehicle travel. A pedestrian- and transit-friendly design helps achieve these benefits.

Planning should create a sense of place by providing a unique physical form, distinctive open space, mixed land uses, a well-landscaped environment, and an interior pedestrian scale with connectivity to adjoining neighborhoods. Density, diversity, proper design, and good accessibility and circulation are essential. Figure 18-15 shows how various activities can be integrated within a center and its environs to maximize pedestrian flows and facilitate transit use while maintaining good highway access. Pedestrian ways and zones serve as the heart of the development where the major retail, office, and government activities are provided. Residential and parking areas surround the commercial core.

Figure 18-15. Suburban Activity Center Integrated Vision



Source: Koepke and Levinson, 1992, Reproduced with permission of the Transportation Research Board.

A grade-separated transit way passes through the center with a station near the commercial core and apartments. A perimeter road provides the framework for internal circulation and connects with approach roads. Direct connections are provided to the center from the parallel freeway.

Transportation strategies include those relating to streets/highways, transit, pedestrians, bicyclists, parking, and TDM.

Streets and Highways—Most trips to activity centers in the United States and Canada are made as auto drivers or passengers. (The exceptions are the peak-hour commuter trips to the CBDs of large cities with high employment densities.) Freeway spacing at 4- to 6-mile intervals is desirable in urban areas where environmental conditions permit. Arterial street spacing at one-half-mile to 1-mile intervals should be provided where terrain permits. The high density of activities usually requires closer roadway spacing within the center. Arterial spacing should be one-quarter to one-half mile in activity centers (and no more than three to four blocks apart in CBDs). Spacing decisions are best made as part of an overall development plan that makes it possible to ensure route continuity and adequate rights of way. As new districts within an activity center are developed, it is possible to stage the expansion of roads to serve them.

In some cases, developers may contribute rights of way or fund road improvements through impact fees or other conditions of approval. Such combinations of private, local, and state improvements make an organized staging plan even more important.

Cross sections of boundary and approach roads should provide sufficient rights of way to meet anticipated demands. They should include medians with protected turn lanes, sidewalks, bicycle lanes and buffer areas, management of access and in some cases grade separations at key junctions. Integration of activity center access points and freeway interchanges is desirable. Access points into activity centers should be located where they allow efficient signal coordination along the surrounding roads.

The scale and design of roadways within suburban centers should reflect their function and future usage. Sufficient right-of-way should be reserved for *ultimate* needs, including special provisions for property access. This means that likely access provisions should be included in the analysis process, as should provisions for pedestrian and transit facilities. Urban design and other amenities should also be incorporated in the right-of-way. If needed and appropriate, building setbacks may also be specified to help meet the expected needs.

Cross sections should be sufficient to provide sidewalks, buffer access, turning lanes, and in some cases medians. However, excessive road widths should be avoided to make pedestrian crossings easier and to minimize barrier effects. Intersection capacity and needs should be based on estimated peak-hour intersection approach volumes; they should consider both a.m. and p.m. peaks as well as any other peaks that may result from specific land uses. Because some intersections will need extra turn lanes, attempts should be made to identify these locations early in the process. Heavy turn locations are best identified from the current turning volume patterns, appropriately expanded to account for planned development. Lane requirements for arterials and other major streets should be sufficient to accommodate projected traffic at the desired level of service in the horizon year.

Transit—Good public transportation—essential for city centers—is desirable for activity centers as they grow and intensify. Transit service is more effective when parking is limited and/or parking costs are high. It is desirable (where travel demands warrant) to provide transit service between the activity center and the areas where employees and visitors live and park, typically up to about 10 miles for employees.

Bus service to and from activity centers can be supported where there are at least 10 million square feet within less than a square mile and the tributary area has a density of at least seven dwellings per acre. Lesser activity center densities can be supported where the activity center is located along a bus line. A combination of high-density housing in a corridor, a short walk at both ends of the trip and competitive service with the auto on a time and cost basis is the best way to encourage transit use to and from activity centers (such as Bethesda). However, in many centers and their environs, free parking and low densities are the norm resulting in low transit ridership. Standard or customized modal split models can be used to estimate potential transit use (see chapter 6 on travel demand modeling, chapter 12 on transit planning, chapter 14 on travel demand management, and chapter 19 on site planning and traffic impact analysis provide more detailed examples of the type of transit strategies that might be appropriate in a suburban activity center.

Pedestrians and Bicyclists—Good pedestrian and bicycle circulation contributes to the amenity, livability, and vitality of activity centers. Many businesses, developers and designers seek to create walkable centers that differentiate their developments as unique, attractive destination environments, rather than simple suburban office locations or malls. Since all trips begin on foot, whether they are from a parking lot, transit stop, or a nearby home or commercial building, pedestrian considerations are an essential component of planning for activity centers. Moreover, they are a critical pre-condition for successful transit. As noted by a nationally recognized firm in urban design, "a healthy walking environment can succeed without transit, but a transit system cannot exist without the pedestrian." [Calthorpe & Assocs., 1997]

Developing a system of effective pedestrian and bicycle circulation requires a fine-grained, interconnected pattern of streets. The superblock pattern that is found in newer suburban developments requires long, circuitous walking routes, even to reach buildings that are nominally adjacent. A block pattern scaled to pedestrians, with buildings oriented to the street, can go a long way toward creating attractive walking opportunities. Pedestrian and bicyclist linkages should directly connect trip generators, provide shelter, or other appropriate amenities, are interesting to walk along and have a minimum of conflicts with vehicles. Readers are referred to chapter 13 on pedestrian and bicycle planning for further information.

Some examples of strategies that have been recommended from subarea studies include:

Downtown Minneapolis Downtown Action Plan [City of Minneapolis, 2007]

- Pedestrian network, including primary pedestrian corridors, and skyways.
- Bicycle network.
- Transit network, including:
  - Corridor transit facilities and services.
  - Intra-downtown circulation service.
  - Near downtown neighborhood service.
  - Layover facilities.
  - Auto/street network, including:
    - One-way network.
    - Two-way network.
    - Traffic operations.
    - Management of curbside uses.
  - Travel Demand Management
    - Carsharing.
    - Carpooling.
    - Telecommuting and flextime.
    - Incentives.
    - Parking.
    - Design guidelines.
    - Agency coordination.

Salt Lake City Downtown Plan [Salt Lake City, 2008]

- Pedestrian and Bicycle Recommendations
  - Enhanced walkability of downtown sidewalks along all city streets.
  - A network of walkways throughout downtown that will include an integrated system of midblock walkways and a completed network of midblock street crosswalks.
  - Infrastructure for bicyclists that will accommodate all skill levels of cycling:
    - Continuation of designated bike lanes on streets.
    - New markings and signage indicating bicycle/automobile shared use of the right-hand lane on streets without designated bike lanes.
    - Separate bike paths between the sidewalk and streets in some areas of downtown.
    - Legalize responsible bicycle riding on sidewalks in Downtown under specific conditions.
  - Augmentation of the downtown way finding system.
  - New urban design features, monuments, and gateways throughout downtown.
  - Additional bicycle racks and lockers on street and inside buildings.

- Light Rail Recommendations
  - Completion of two loops of TRAX to provide a backbone of rail transit circulation in downtown.
  - Construction of TRAX along 400 South from Main Street to 600 West and the Intermodal Hub—completing an inner loop of rail circulation in downtown.
  - Construction of TRAX along 700 South from 200 West to 400 West, and then continuing north on 400 West connecting to the existing system near Gateway, completing an outer loop that serves downtown and the emerging southwest quadrant of downtown.
  - Further study of streetcar access to Downtown from surrounding neighborhoods not served directly by TRAX.
- Automobile Recommendations
  - More frequent updating of traffic signal timing plans Downtown to support traffic progression.
  - A network of streets that are classified and designed according to a hierarchy of traffic needs allows operational improvements for improved flow into and out of downtown as well as within the core of downtown.
  - Coupled with parking programs and way finding, more efficient access to downtown parking spaces.
  - An expanded network of midblock streets.
  - New urban design elements incorporated into downtown streets.
- Bus Recommendations
  - Revised bus routes downtown.
  - A new bus passenger facility to be located at 200 South and State Street.
  - More attractive and comfortable bus stops downtown, including better information about bus service.
  - Branded bus corridors for circulation within downtown.
- Parking Recommendations
  - Immediate formation of a parking management group to coordinate operating policies of public parking downtown.
  - Way finding enhancements for off-street parking spaces.
  - New zoning policies that foster the development of convenient off-street parking for visitors.
  - New parking meters with more payment options.
  - An enhanced parking validation system for downtown.
- Circulator/Shuttle Recommendations
  - Continuation and expansion of the Free Fare Zone to include the Library light rail station, the Intermodal Hub, and the hotels on 600 South.
  - Improved transit circulation downtown with a combination of more frequent light rail service, branded bus corridors, and a downtown shuttle service.
  - Further study of additional streetcar access to downtown from surrounding neighborhoods not served directly by light rail.
  - Until completion of the light rail Airport Extension, shuttle bus service at 15-minute headways linking the airport, the Intermodal Hub, and the hotels along 500 South and 600 South Streets.

Both of these plans had phased implementation schedules built into the plans, one for 6 years and the other for 10 years. These schedules identified when certain actions would be taken and agency responsibility.

IV. IMPLEMENTATION OF TRANSPORTATION PLANS

Transportation plans for activity centers and local communities require a cooperative effort among private- and public-sector entities. The cooperation starts during planning, but extends into funding, construction, operation, and other areas. For this reason, implementation priorities, strategies, and responsibilities for implementation should be agreed to by all parties during the planning process. It is seldom possible to make binding financial commitments far into the future because of the many uncertainties surrounding both public- and private-sector funding. Nevertheless, each entity should agree to the responsibilities for rights of way, funding, construction, operation, and maintenance of each plan component. In many cases, joint responsibility may be appropriate. Priorities should be set using criteria consistent with overall participant and activity center objectives with the understanding that the activity center systems must function with each increment of improvement.

In Houston, for example, property owners supported by local businesses in the region's largest suburban center established an improvement district, allowing property owners to pay for improvements and to finance bonds. In Georgia, state law allows the formation of community investment districts (CIDs) that with a required vote of commercial property owners collects a certain percentage of property taxes each year to fund transportation improvements in their area. The CIDs have become an important source of funds for investing in transportation strategies in the region.

The Atlanta Regional Commission's LCI program described earlier led to a variety of institutional arrangements and policy changes in implementing the results of the LCI planning studies. For example, from 2000 to 2014, the following strategies/actions were adopted to implement study recommendations (the number of instances shown in parentheses): historic preservation districts (16), form-based zoning code (16), special zoning districts (20), master streets plan or code (21), street design standards or guidelines (46), architectural design standards (55), overlay districts (56), sign ordinances (57), and zoning ordinance changes to allow mixed use developments (67). [ARC, 2015] In addition, the program has seen the participation of many different types of organizations in making the studies a reality, including downtown development authorities, community or neighborhood organizations, main street programs, community improvement districts, and transportation management associations.

Institutional arrangements should be established to implement the plan's recommendations. Some actions might require legal and political efforts, while others may already be available. Actions that have been used to generate the dollars to invest in transportation include:

- Zoning overlay districts (area with special zoning provisions) or special districts with special provisions to facilitate or ensure plan implementation.
- Special assessment or improvement districts.
- Model joint access agreements.
- Development agreements between developers and local governments to guide long-term, multiphase projects.
- Revised subdivision platting or access policy components or powers.
- Special public authority for district.
- Transportation or thoroughfare plan amendments.
- Urban design guidelines.
- Special transportation system standards or design criteria.
- Additional development review or approval stages.
- Special district association.

Beginning in the 1970s, many downtowns such as Toronto and New Orleans were faced with deteriorating municipal finances. The result was the creation of business improvement districts (BIDs), which allowed property owners to tax themselves to provide the kind of services that could no longer be provided by the city. Originally these programs emphasized trash collection and security, the most visible services to the public. Recently, some have recognized the need for broader involvement in longer-term planning and economic development. Such an institution, with official sanction, may present an excellent means of bringing businesses, developers, and city officials together to address critical needs for downtowns.

The creation of transportation management associations (TMAs) has served a similar purpose in the suburbs to that of the BIDs downtown. While most of the early focus has been placed on operating or promoting commuter assistance programs, today most take an active role in addressing longer-term transportation needs. The proliferation of such TMAs creates a built-in institution in many suburban growth centers that cannot only help identify needs, but also advocate for the implementation of plans. Where there is no formal institution such as a BID or a TMA, it may be useful to create an informal group that can help establish a vision and bring pressure on the appropriate parties to implement their plans when initial enthusiasm has waned.

The reader is referred to chapter 5 on transportation finance and funding for further discussion on alternative mechanisms for providing the dollars necessary to implement a plan's recommendations.

V. SUMMARY

This chapter has focused on a planning context that is becoming more important over time. Many of the metropolitan areas in the world are following a development pattern in which clusters of land uses, mostly complementary, are becoming centers of economic activity. Traditionally, this was the purpose of the downtown, but beginning in the 1960s with the dispersal of population and employment to the suburbs, more of these activity centers began to sprout up in both suburban and exurban areas. The initial transportation concern with these centers focused on physical infrastructure, how to provide the highway access, and in some cases transit access for employees and visitors. But as these centers have evolved, and with growth have become more congested, many of the transportation planning effort focuses on how to reduce single-occupant vehicle trips. Most of the plans today for activity centers include both physical improvements to the road, transit, and pedestrian/bicycle networks, as well as a consideration for transportation demand management strategies, access management, and parking management.

The planning process for local communities and activity centers is similar in form to that which occurs in state DOTs and MPOs. There should be data collection and analysis to determine existing conditions and performance of the transportation system; goals, objectives, and performance measures need to be articulated; future performance needs to be predicted based on some sense of future population, employment, and land use levels; and projects/actions/strategies need to be prioritized based on their cost effectiveness. The only real difference between local and activity center planning and that which occurs at the state or metropolitan level is the scale of application. For example, although many larger cities and communities in large metropolitan areas use travel demand models for their transportation planning, many of the smaller cities and activity centers do not. Although many local governments examine the range of strategies for reducing congestion (including TDM, parking, and access management), many simply look at the key road segments and intersections. It is important, therefore, for the planner at the very outset of a study to lay out the type of information that will be needed to make decisions at the end of the process, and work backward to determine what type of data will be necessary and what types of tools will be appropriate.

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Site Planning and Impact Analysis[1]

I. INTRODUCTION

This chapter covers two topics. *Site planning* is the process of placing a proposed development on a parcel of land and assessing different aspects of how it will be built and its compliance with a community's zoning code and comprehensive plan. *Transportation access and impact studies* analyze the likely changes and effects on the transportation system resulting from this new development site. Impact studies recommend on- and off-site transportation improvements to improve access to the site as well as mitigate expected impacts. They identify public safety requirements and the transportation needs of the site and the surrounding road system. Impact studies are often part of a state environmental impact review process, or for major developments, they could be subject to what is called the Development of Regional Impact (DRI) review process. [FHWA, 1992] Both site planning and impact studies are concerned with site trip generation, how these trips arrive and depart, and the paths taken through the transportation network to reach the site, although impact studies focus on these issues at a much finer level of detail.

Site planning and impact studies are an essential part of the development review process in that they assist private developers in the proposal preparation and public agencies in proposal review. They address a wide range of issues and concerns including defining preliminary site and development characteristics, obtaining access (driveway) permits, determining necessary transportation improvements, and preparing overall access management plans. Studies can help developers and permitting agencies to:

- Establish the basic characteristics of the development footprint.
- Assess the number, location, and design of access points.
- Forecast the transportation (traffic) impacts created by proposed development based on accepted practices.
- Determine needed transport improvements to accommodate proposed developments.
- Identify travel demand management strategies.
- Allocate funds in a cost-effective manner.
- Provide a basis for determining the developers' responsibility for on- and off-site improvements.

Site plan reviews provide the community with a means of linking proposed developments to desired development characteristics as defined in zoning codes and ordinances. They also provide critical input when determining the desirability and/or conditions on which variances to these ordinances will be granted. Transportation access and impact studies ensure that safe and convenient access is provided to development sites while maintaining mobility and safety on public roads and other surface transportation facilities. In addition, impact studies provide nearby property owners with a way of making sure that new development does not negatively affect access to their property, and thus downgrade their property values.

Methods for conducting impact studies have been well-defined for many years. However, current experience in many communities suggests that their scope should be broadened to ensure that, (1) adequate access is provided for transit riders and pedestrians/bicyclists, (2) access to a development site does not adversely affect the performance of the surrounding street system, and (3) site design and access do not add to visual blight of the surrounding street environment. In addition, in many communities, such studies not only lay out the physical changes needed to

[1]Portions of this chapter were originally written by Herbert S. Levinson, P.E., Transportation Consultant, New Haven, CT, USA and Icon Mentor, Region 2 Transportation University Center, City University, New York, NY. Changes made to this updated chapter are solely the responsibility of the editor.

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provide better and safer access to the site (for example, building a turn lane at the site entrance), but they also identify travel demand management (TDM) strategies to reduce the number of automobile-related trips generated by the site.

Given these concerns, the key questions in an impact analysis include:

- Can people reach the site safely and conveniently as pedestrians, bicyclists, transit riders, automobile drivers, and passengers?
- Do the site access design, internal circulation system, parking, and building arrangements allow safe and effective vehicle and people circulation and movement?
- Can access be provided without adversely affecting the performance of the surrounding roadways?
- Do planned improvements ameliorate present and future problems?
- Are there ways of reducing the demand for trips to the site?

An example of such concerns comes from the Virginia Department of Transportation (VDOT), which states that a traffic impact statement for a rezoning request should,

> *(1) assess the impact of a proposed development on the transportation system and recommend improvements to lessen or negate those impacts, (2) identify any traffic issues associated with access from the site to the existing transportation network, (3) outline solutions to potential problems, (4) address the sufficiency of the future transportation network, and (5) present improvements to be incorporated into the proposed development. [VDOT, 2014, 2015]*

Some transportation agencies have placed the transportation impact review process within a much broader policy context. Addressing these questions often requires a multimodal perspective, as well as a serious look at access management issues and other policy/sustainability opportunities. The Massachusetts Department of Transportation (MassDOT), for example, notes that its intent in impact reviews is to:

> *Ensure that the transportation impact review process reflects and advances the Commonwealth of Massachusetts' policy goals, in particular those that promote MassDOT's* Project Development and Design Guide Standards on Complete Streets, *the Global Warming Solutions Act, the Massachusetts GreenDOT Policy Initiative, the Mode Shift Initiative, the Healthy Transportation Compact, the Healthy Transportation Policy Directive, the Massachusetts Ridesharing Regulation, and Safe Routes to School policies. [MassDOT, 2012]*

California is another state that has adopted statewide policies relating to sustainability, energy conservation, and greenhouse gas emission reductions (see https://www.wildlife.ca.gov/Conservation/CEQA/Purpose).

The following section describes the administrative requirements for site planning and impact analysis. These requirements dictate the type of information that must be part of a study, and often establish the thresholds of when such a study is necessary. The next section offers definitions of key terms used in both site plan reviews and traffic impact studies. The next two sections discuss the specifics of site plan review and traffic impact analyses. More attention is given to traffic impact studies in that this is where most of the site-related transportation planning efforts occur. This section discusses key issues like the identification of analysis horizon years and performance measures; travel demand models and tools; and the analysis approaches for site-specific, corridor, and network impacts. The next section focuses on on-site transportation design options and strategies, including internal circulation networks and parking management. This is followed by a discussion of access management and the many different types of mitigation strategies that can be considered as part of an impact study. The final section presents a sample table of contents for a traffic impact study.

The Institute of Transportation Engineers (ITE) published a transportation impact analysis *Recommended Practice* in 2010 that provides a detailed, step-by-step description of the analysis process. It is not the intent to replicate the *Recommended Practice* in this chapter. Some key tables and figures from that reference will be used simply to illustrate the important characteristics of the impact analysis process. Interested readers should read this more detailed guide. [ITE, 2010] In addition, many of the mitigation strategies usually considered in a traffic impact study are described in more detail in other chapters of this handbook. Readers are referred to chapter 3 on land use and urban design, chapter 4 on environment and the community, chapter 6 on travel demand modeling, chapter 9 on road and highway planning, chapter 11 on parking, chapter 12 on transit planning, chapter 13 on pedestrian and bicycle planning, chapter 14 on travel demand management, and chapter 23 on transportation safety.

II. ADMINISTRATIVE REQUIREMENTS

Administrative rules and requirements established by governments provide the basic requirements for both a site plan review and a traffic impact study process. These vary by jurisdiction, depending on the community definition of what constitutes an impact. Importantly, site planning requirements are part of the zoning process and occur when a development of a certain size is proposed (see chapter 3 on land use and urban design).

ITE [2012] notes that traffic impact studies, as specified in rules and procedures, can be required when:

- The development will generate a specified number of daily trips.
- The development will generate a specified number of peak-hour trips.
- A specified amount of acreage is being rezoned.
- The development contains a specified number of dwelling units or amount of square footage.
- Financial assessments are required and the extent of impact must be determined.
- The development will require a significant amount of transportation improvements.
- A previous transportation impact analysis for a site has been deemed out of date.
- Development will occur in a sensitive area.
- The judgment or discretion of staff can be applied based on previous experience.

Some examples of thresholds that might trigger an impact study include:

Iowa Department of Transportation (IDOT). Two types of impact reports are possible. A *traffic impact letter* is required if the average annual daily traffic (AADT) is less than or equal to 500 vehicles, and the peak-hour volume is less than or equal to 100 trips. Volumes over these thresholds require a *traffic impact study*. [Iowa DOT, 2013]

California Department of Transportation (Caltrans). The following criteria are considered starting points for determining when a traffic impact study is needed for a state highway in California. [Caltrans, 2002] Such a study is needed when a project:

1) Generates over 100 peak-hour trips assigned to a state highway facility.
2) Generates 50 to 100 peak-hour trips assigned to a state highway facility, and affected state highway facilities are experiencing noticeable delay, approaching unstable traffic flow conditions (levels of service (LOS) “C” or “D”).
3) Generates 1 to 49 peak-hour trips assigned to a state highway facility and where:
    a. Affected state highway facilities experience significant delay or unstable or forced traffic flow conditions (LOS “E” or “F”), or
    b. The potential risk for a traffic incident is significantly increased (that is, congestion-related collisions, nonstandard sight distance considerations, increase in traffic conflict points, and so forth), or
    c. There is a change in local circulation networks that impact a state highway facility (that is, direct access to state highway facility, a non-standard highway geometric design, and so forth).

Oregon Department of Transportation (ODOT). ODOT will likely request an impact study when, (1) the proposed development is within a quarter mile of the terminal of an interchange ramp, (2) the local development code requires that there be “adequate facilities” to serve the proposed development (often applies to “change of use” applications), (3) an ODOT preliminary review identifies operational or safety issues related to increased traffic or highway access at the development site, and/or (4) an approach to the state highway will be the development's only or primary access to the roadway network. [ODOT, 2014]

City of San Francisco, California. The city of San Francisco requires an impact study when a project:

1) Potentially adds at least 50 p.m. peak-hour person trips.
2) Potentially increases existing traffic volumes on streets in its vicinity by at least 5 percent.
3) Potentially impacts nearby intersections and/or arterials, which are believed to presently operate at level of service (LOS) "D" or worse.
4) Provides parking that would appear likely to be deficient relative to both the anticipated project demand and code requirements by at least 20 percent.
5) Has elements that have a potential to adversely impact transit operations or the carrying capacity of nearby transit services.
6) Has elements that have the potential to adversely affect pedestrian or bicycle safety or the adequacy of nearby pedestrian or bicycle facilities.
7) Would not fully satisfy truck loading demand on-site for an anticipated number of deliveries and service calls exceeding 10 daily trips. [City of San Francisco, 2015]

City of Tampa, Florida. The city of Tampa requires an analysis and mitigation of *critical links and intersections* adjacent to a development's major roadway network access point(s) when:

1) The average annual daily traffic (AADT) on the adjacent major roadway link(s) is less than 95 percent of the LOS "D" daily service capacity of the link and the subject development consumes more than 2 percent of the LOS "D" daily service capacity of the adjacent major roadway link(s), and capacity is available.
   or
2) The AADT of the adjacent major roadway link(s) is greater than or equal to 95 percent of the LOS "D" daily service capacity of the link and the subject development consumes more than 1 percent of the LOS "D" daily service capacity of the adjacent major roadway link(s), and capacity is not available.

An analysis of *roadway network impacts* is required when:

1) The AADT of the adjacent major roadway link(s) is less than 95 percent of the LOS "D" daily service capacity of the link and the subject development consumes more than 5 percent of the LOS "D" daily service capacity of the adjacent major roadway link(s).
   or
2) The AADT of the adjacent major roadway link[s] is greater than or equal to 95 percent of the LOS "D" daily service capacity of the link and the subject development consumes more than 2 percent of the LOS "D" daily service capacity of the adjacent major roadway link(s).

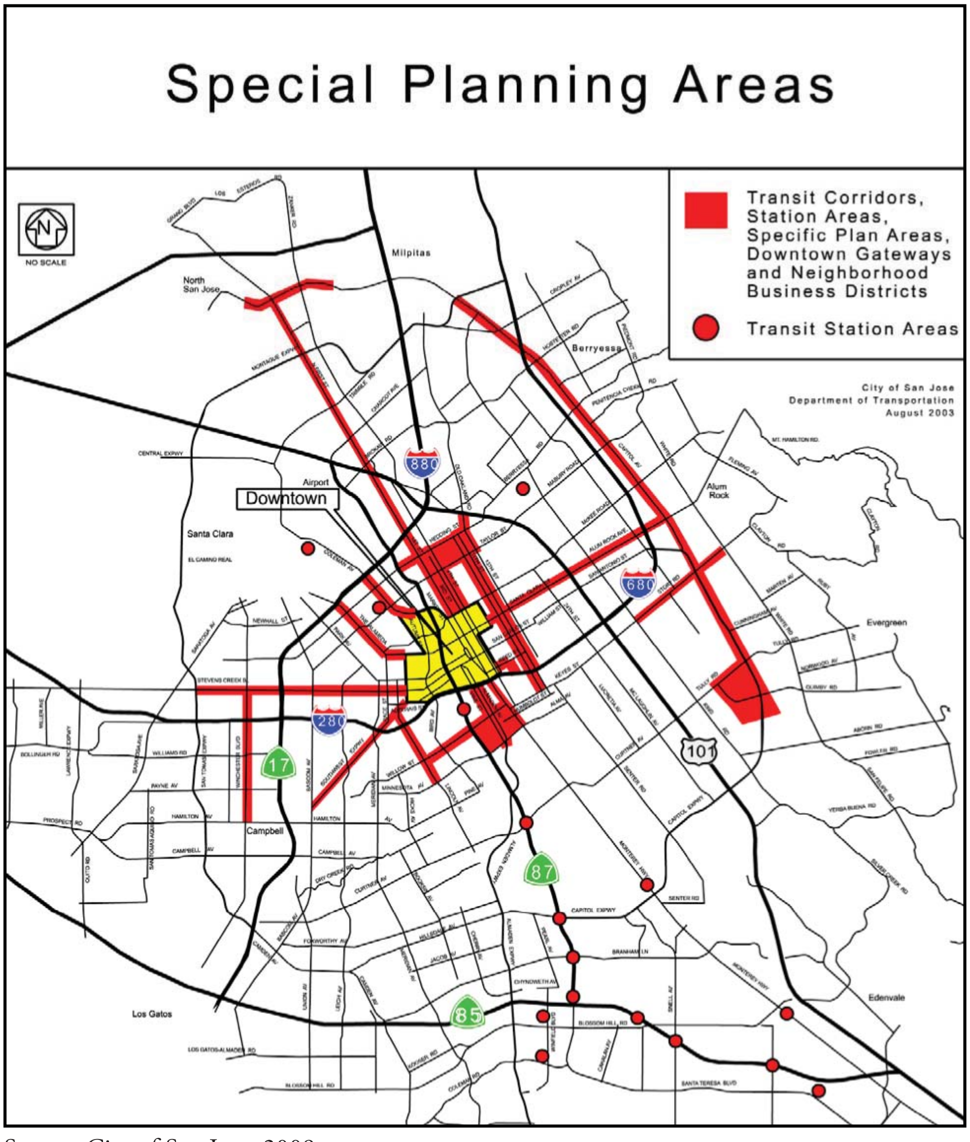
Enhanced network impact analyses are required when the AADT of a significantly impacted link (as identified in a network impact analysis) operates at greater than 120 percent of the LOS "D" daily service capacity of the link and the subject development traffic consumes more than 5 percent of the LOS "D" daily service capacity of the link. [City of Tampa, 2011]

Another way of defining impact analysis thresholds is for communities to identify when a traffic impact study is *not* required due to the nature of the development itself or because of local conditions (for example, developments designed to encourage transit use). A good example of this comes from Tampa where the following exclusions of the traffic impact study requirement are part of the planning rules. In Tampa, generally, any development that generates more than 100 net daily trip ends per day will likely have to undergo a traffic impact study unless the development is located in the Downtown Revitalization District, Urban Redevelopment District, or Urban Infill District, in which case the developer must pay the city's transportation impact fee (but does not have to commit to any specific action). If the project is in an approved Transportation Master Plan Area (for example, Tampa International Airport, Port of Tampa, or the University of South Florida), the developer must mitigate site impacts and otherwise conform to the city's land development code and comprehensive plan. Similarly, developments that are serviced by one or more "Primary Transit Facility" service areas must mitigate on-site impacts. Service areas are defined as within a one-fourth mile (0.4 km) of high-frequency bus transit routes, within one-third mile (0.54 km) of a bus rapid transit station, within one-half mile (0.8 km) of a rail transit station, and within one-third mile (0.54 km) of a transit center/transfer center.

Figure 19-1 shows a similar concept from San Jose, California, where areas near transit facilities and neighborhood business districts are identified for special treatment in the traffic impact study process. In planning terms, these are often called overlay districts as defined in zoning codes (see chapter 3 on land use and urban design).

Although one often sees different community threshold criteria for initiating a traffic impact study, ITE [2012] recommends a study be done for any project that generates at least 100 peak-hour vehicle trips per day. As noted, however, the context of such development is a critical consideration—small developments generating fewer trips than this may still require a site access and circulation review to ensure that access connections are located safely.

Figure 19-1. Special Districts for Traffic Impact Study Requirements, San Jose, California



Source: City of San Jose, 2009

III. DEFINITION OF KEY TERMS

Some key terms used in site planning and traffic impact analysis include:

- *Access management:* Strategies to manage the access to streets, roads, and highways from public roads and private driveways. Requires balancing access to developed land while ensuring movement of traffic in a safe and efficient manner.
- *Analysis hour:* A single hour for which a capacity analysis is performed on a system element.
- *Critical density:* The traffic density at which capacity occurs for a given facility.
- *Critical headway:* The minimum headway in the major traffic stream that will allow the entry of one minor-street vehicle.
- *Critical lane groups:* The lane groups having the highest flow ratio for a given signal phase.
- *Critical speed:* The speed at which capacity occurs for a segment.
- *Cycle failure:* A condition where one or more queued vehicles are not able to depart a signalized intersection.
- *Demand-to-capacity ratio:* The ratio of demand volume to capacity for a system element.
- *Design hour:* An hour with a traffic volume that represents a reasonable value for designing the geometric and control elements of a facility.
- *Design year:* A target year (usually 20 years) following the year the project is open to traffic.
- *Development traffic:* Traffic volumes generated by a development.
- *Directional distribution:* The directional split of traffic during the peak or design hour, commonly expressed as a percentage in the peak- and off-peak flow directions.
- *Fair share:* A strategy of sharing the mitigation costs of the impacts of development on transportation facilities through the cooperative efforts of public agencies and private developers or land owners.
- *Floor area ratio:* The ratio of the total floor area of a building or buildings on a parcel to the size of the parcel where the building or buildings are located.
- *Fully actuated control:* A signal operation in which vehicle detectors at each approach to the intersection control the occurrence and length of every phase.
- *Internal capture:* Trips internal to a development site that otherwise would have left the site.
- *Level of service (LOS):* A qualitative measure describing operational conditions in a traffic stream based on service measures such as speed and travel time, freedom to maneuver, traffic interruptions, comfort, and convenience.
- *Mitigation:* Measures to reduce adverse impacts on the environment, in the following order of preference:
  - Avoid the impact altogether by not taking a certain action or part of an action.
  - Minimize the impact by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts.
  - Rectify the impact by repairing, rehabilitating, or restoring the affected environment.
  - Reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action.
  - Compensate for the impact by replacing, enhancing, or providing substitute resources or environments.
- *Opening year:* The year the project is scheduled to be open to traffic.
- *Pass-by trips:* Trips made by traffic already using adjacent roadways and enter the site as an intermediate stop on the way to another destination.

- *Peak hour:* The hour during the day when the maximum volume is using a facility. Used in determining directional distributions. Note that the peak hour of the adjacent street may not be the peak hour of the development.
- *Planning horizon year:* The target year for estimating traffic impacts.
- *Redevelopment site:* Any existing use that generates traffic and is intended to be developed at a different land-use density.
- *Service flow rate:* The maximum directional rate of flow that can be sustained on a given segment under prevailing roadway, traffic, and control conditions without violating the criteria for a specified level of service.
- *Sight distance:* The distance visible to the driver of a passenger vehicle measured along the normal travel path of a roadway from a designated location to a specified height above the roadway when the view is unobstructed by traffic.
- *Stopping sight distance:* The distance required by a driver of a vehicle, traveling at a given speed, to bring the vehicle to a stop after an object on the roadway becomes visible. It includes the distance traveled during driver perception and reaction times and the vehicle braking distance.
- *Traffic impact statement:* A document prepared in accordance with best professional practice and standards assessing the impact of a proposed development on the transportation system and recommending improvements to lessen or negate those impacts.
- *Transit-oriented development:* An area of commercial and residential development at moderate to high densities within 1/2 mile (0.8 km) of a station for heavy rail, light rail, commuter rail, or bus rapid transit transportation and includes the following: (a) densities of at least four residential units per acre and at least a floor area ratio of 0.4 or some proportional combination thereof; (b) mixed-use neighborhoods, including mixed housing types and integration of residential, office, and retail development; (c) reduction of front and side yard building setbacks; and (d) pedestrian-friendly road design and connectivity of road and pedestrian networks (see chapter 3 on land use and urban design).
- *Travel (or Transportation) demand management (TDM):* A combination of measures that reduce vehicle trip generation and improve transportation system efficiency by altering travel demand, including but not limited to the following: expanded transit service, employer-provided transit benefits, bicycle and pedestrian investments, ridesharing, staggered work hours, telecommuting, and parking management including parking pricing (see chapter 14 on parking).
- *Vehicle miles traveled (VMT):* Number of vehicles using a site times the average trip distance estimated from a network model. Used as a measure of impact on the road network, as well as input to air quality and energy impact analysis.

IV. SITE PLAN REVIEW DATA

The type of information accompanying a site plan review examines many different nontransportation items, such as legal ownership, a legal description of the property, preliminary dimensions of the development footprint, and the zoning and planning requirements for the site. With respect to the transportation components of a site plan review, and thus transportation-related data needs, the following guidelines from Seattle show typical inputs into a site plan submittal.

- Dimensions and right-of-way limits in addition to roadway widths of adjacent streets (by name), alleys, or other adjacent public property.
- Curbs, sidewalks, and street trees—type, location, and dimensions.
- Street and alley improvement type and dimensions (asphalt, concrete, gravel, and so forth).
- Location of the pedestrian path to each dwelling unit and the primary entrance to each building.

- Location and dimensions of all driveways, parking areas, and other paved areas (existing and proposed).
- Center elevation and developed roadway at 25 feet intervals if a change to access or parking is proposed. Identify existing and finished grade elevation of driveway at property line, and at garage entry, if a change to access or parking is proposed.
- Curb cut width and distance from adjacent property lines (label curb cuts as "existing" or "proposed").
- Identify all physical restrictions to site access (utility poles, rockeries, street trees, Metro bus stops, and so forth) if a change to access is proposed. [City of Seattle, 2013]

In addition to these requirements, the city of Austin, Texas, requires more detail on the following site-related aspects.

- All driveway dimensions and design specifications, such as: driveway widths, driveway curb return radii, and profiles of finished grades; label on site plan when there are several proposed driveway approaches.
- Proposed operation of driveways on site plan (that is, one-way or two-way operation); identifying and labeling all physical barriers to vehicular access.
- On undivided roadways, show existing driveways on opposite side of street within 120 feet of site driveways, or indicate in a note if there are none.
- Physical obstructions (utility poles, trees, storm sewer inlets, and so forth) in the right-of-way, which could affect sidewalk/driveway locations.
- Dimensions of vertical clearance within fire lanes, including tree limbs, for all driveways and internal circulation areas on-site, where overhead clearance is restricted.
- All off-street and on-street parking; number of required and provided parking spaces including location, number and type (standard, compact, handicapped) of actual parking spaces; dimension parking stall depth and width, stall angle, aisle width, and width on internal driveways. Plan should number each parking space, show structural supports, turning radii, traffic circulation, ramp grades in parking garages, and the numbering and location of compact spaces.
- Reduction in on-site parking requirements assumed and the number of spaces credited.
- Handicapped parking spaces meeting state standards.
- Route of travel connecting all accessible elements and spaces on the site that can be negotiated by a person using a wheelchair and usable by persons with other disabilities (indicated by dotted lines, a shading pattern or other identifiable legend).
- Internal circulation system showing vehicular, bicycle, pedestrian paths, and connections to off-site access.
- Note on the plan indicating that each compact parking space must be identified by a sign stating "small car only" and signs posted on-site directing motorists to such spaces.
- Offstreet loading spaces, if required.
- Location and type of bicycle parking.
- Queue spaces or queuing areas for drive-through uses.
- Location and width of sidewalks on site plan, if required by the city of Austin.
- The location and design of all pedestrian sidewalk ramps related to the construction of this site. [City of Austin, 2014]

As can be seen by these two lists, the transportation-related data requirements for site plan review will vary from one community to another. Transportation planners involved with site plans need to be very familiar with the requirements as set forth by the community zoning and/or planning commission. Other examples of site plan review guidelines can be found at. [City of Alexandria, 2013; County of Fairfax, undated]

V. TRANSPORTATION ACCESS AND IMPACT ANALYSIS

An impact analysis should always begin by establishing the basic terms of reference with relevant public agencies and the developer or owner. These will include, at a minimum, defining the transportation need, identifying impact analysis thresholds as established in requirements, agreeing to a scope of analysis, defining study area limits, establishing the forecast hours (and days) to be analyzed, and defining the study horizon years. The set of feasible travel modes and acceptable methods of determining capacity and level of service should also be established.

The scope of traffic impact studies depends on the type, location, timing, and size of the proposed development. Where walk, bicycle, and transit trips are common (or have potential), both total person trips and vehicular trips should be analyzed. This involves estimates of mode split and vehicle occupancy. In addition, most site impact studies examine the access and movement of commercial vehicles delivering goods to a site. The types of information needed to reach appropriate traffic and development decisions normally include:

- Characteristics of the existing roadway and public transport systems.
- Characteristics of current and proposed nearby developments.
- Estimated future development traffic and access strategies.
- Combined traffic volumes on surrounding and approach roads.
- Traffic growth rates.
- Road system adequacy.
- System needs.
- Access plans.

With respect to access management, site access should maintain the operational integrity of the surrounding road system. This can be best achieved by applying access management principles and designs (see chapter 3 on land use and urban design and chapter 9 road and highway planning). Access management provides (or manages) access to land development while simultaneously preserving the flow of traffic on the surrounding road system in terms of safety, capacity, and speed. It consists of the systematic control of the location, spacing, design, and operation of driveways; median openings; interchanges; and street connections to a roadway. It also includes applications such as median treatments, auxiliary lanes, and the appropriate spacing of traffic signals. [Koepke and Levinson, 1992] An important access management objective is to ensure that the cumulative effects of a series of closely spaced developments do not deteriorate the safety and mobility associated with the surrounding road system.

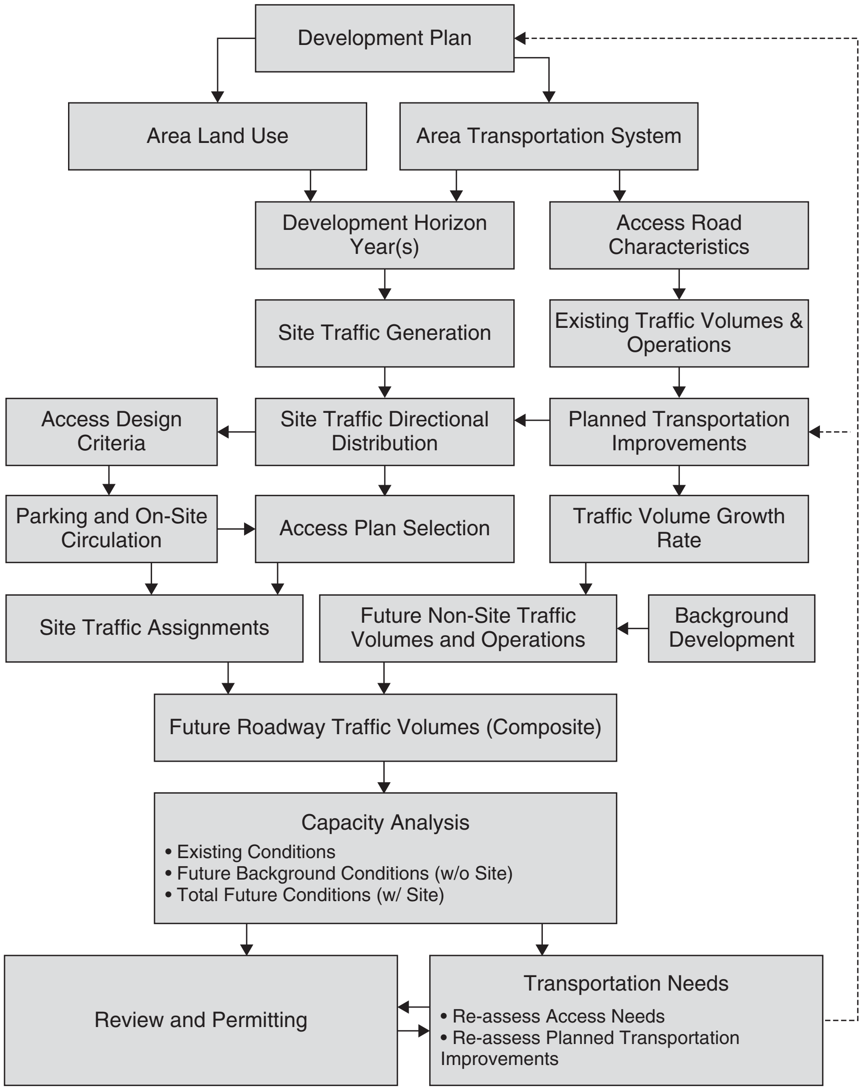
A. Traffic Impact Analysis Process

Figure 19-2 shows the major steps in a traffic impact analysis. [ITE, 2012] Each of these steps uses data and analysis tools that are discussed in other chapters (see, for example, chapter 2 on data analysis and chapter 6 on travel demand modeling). The key outcomes of this process, from the property owner's perspective, are the permits and other permissions granted by public agencies to build the development. Several of the key components of this analysis process are discussed in the following sections.

B. Study Area Boundaries

Study area boundaries should be based on the type of land use, size of development, street system patterns, and terrain. A frequently used method is to carry the analysis boundaries to locations where site-generated traffic will represent five percent or more of the roadway's peak-hour approach capacity. The study area should include critical (or congested) intersections on the adjacent road network. Table 19-1 gives guidelines for determining study area limits based on the size, type, and trip-generating characteristics of typical land uses. Note that the study area limits for a traffic impact study as shown in Table 19-1 would generally not account for the larger study area needed for a concurrency analysis, where a developer would pay a proportionate share for roadway/intersection improvements

Figure 19-2. Transportation Impact Analysis Process



Source: ITE, 2012

needed as a result of the proposed development. Also, traffic impact studies are usually done under the jurisdiction of local governments, but given that development impacts can extend beyond the local roadway network to the state highway system, it is important that local and state authorities coordinate in addressing study impacts and mitigation measures.

The criteria shown in Table 19-1 can sometimes be superseded at the discretion of the jurisdiction's transportation agency. In Massachusetts, for example, intersections or road segments meeting an impact statement threshold of five percent increase in traffic volume may be exempted from study if in the Massachusetts DOT's (MassDOT's) judgment:

- The intersection or segment operates acceptably today and the site development impact will not cause a capacity or safety mitigation need.

  or

- A mitigation for the intersection or segment has been previously identified and no further analysis is warranted (note that site-generated trip assignment may still be required for tracking or mitigation assessment purposes).

  or

- Other reasons are deemed appropriate by MassDOT. [MassDOT, 2014]

Table 19-1. Suggested Study Area Limits for Transportation Impact Analysis	
Development	**Study Area**
Fast-food restaurant	Adjacent intersection if corner location.
Service station, with or without fast-food counter	Adjacent intersection if corner location.
Mini-mart or convenience grocery with or without gas pumps	660 ft from access drive.
Other development with fewer than 200 trips during any peak hour	1,000 ft from access drive.
Shopping center less than 70,000 sq. ft. or Development w/peak-hour trips between 200 and 500 during peak hour	All signalized intersections and access drives within 0.5 mile from a property line of the site and all major unsignalized intersections and access drives within 0.25 mile.
Shopping center between 70,000 sq. ft. and 100,000 sq. ft. GLA or Office or industrial park with between 300 and 500 employees or Well-balanced, mixed-use development with more than 500 peak-hour trips	All signalized and major unsignalized intersections and freeway ramps within 1 mile of a property line of the site.
Shopping center greater than 100,000 sq. ft. GLA or Office or industrial park with more than 500 employees or All other development with more than 500 peak-hour trips	All signalized intersections and freeway ramps within 2 miles of a property line and all major unsignalized access (streets and driveways) within 1 mile of a property line of the site.
Transit station	0.5-mile radius.

Source: ITE, 2012

Alternatively, intersections or road segments that do not meet the five percent threshold might be included in the study area if in MassDOT's judgment:

- The intersection is highly congested, near or over capacity, and prone to significant operational deterioration from even a small increment in traffic.

  or

- The location is expected to have a significant impact to the state highway system.

  or

- There are local municipality requirements that call for an impact study.

  or

- There are special circumstances related to the location that merit review. [MassDOT, 2014]

In addition, for those studies conducted in urban areas, the study area description should discuss not only potentially affected major highways and roadways, intersections, and interchanges, but also pedestrian and bicycle facilities, and the public transit network that are part of (or could be part of) the study area's transportation system. For example, MassDOT's definition of an urban study area includes:

- Walking, bicycling, and public transit networks, with specific attention to connectivity, desire lines, and gap analysis in order to maximize travel choices and promote these modes. Consideration should be given to the appropriate level of analysis for transit, walking, and bicycling study areas. [MassDOT, 2012]

C. Horizon Years

The planning horizon year, that is, the future year for estimating traffic impacts, should be consistent with the size and build-out schedule of the planned developments and any anticipated major transportation system changes. Suggested horizon years are given in Table 19-2. A general guide is to set the planning horizon year for when proposed developments will be fully operational and meeting their market goals, usually three to five years after opening day.

Table 19-2. Suggested Study Horizons	
Development Characteristic	**Suggested Horizon Year(s)**
Small development (<500 peak-hour trips)	• Anticipated opening year, assuming full build-out and occupancy.
Moderate, single-phase development (500 to 1,000 peak-hour trips)	• Anticipated opening year, assuming full build-out and occupancy. • Five years after opening date.
Large, single-phase development (>1,000 peak-hour trips)	• Anticipated opening year, assuming full build-out and occupancy. • Five years after full build-out and occupancy. • Adopted transportation plan horizon year, if the development is significantly larger than that included in the adopted plan or travel forecasts for the area.
Moderate or large multiple-phase development	• Anticipated opening year of each major phase, assuming full build-out and occupancy of each phase. • Anticipated year of complete build-out and occupancy. • Adopted transportation plan horizon year, if the development is significantly larger than that included in the adopted plan or travel forecasts for the area. • Five years after opening date if completed by then and there is no significant increase (less than 15 percent) in trip generation from adopted plan or area transportation forecasts.

Source: ITE, 2012

D. Data on Existing (Background) Conditions

Existing transportation and land-use conditions near a proposed development are important inputs into a traffic impact study. Analyses should provide a clear picture of the market influence area of the proposed development and show how well roadways, transit facilities, and pedestrian/bicycle networks function currently. Key steps in conducting the existing conditions analysis include:

- Hold background meetings with relevant public agencies.
- Assemble and collate existing traffic, transportation, and land-use information.
- Conduct a field reconnaissance of physical and environmental features, transportation facilities, services, and conditions in the site environs.
- Conduct a travel time study to help define the “reach” and market for the proposed development.
- Obtain information on transit routes, coverage, frequencies, and ridership.
- Obtain data on pedestrian and bicycle routes and access information.
- Obtain existing roadway characteristics, such as width, travel lanes, traffic controls, and geometric features such as gradients, alignments, and signal lanes.
- Review traffic volume studies at key intersections during peak and off-peak periods for weekdays and weekends (daily and hourly).
- Assess existing service levels and transportation conditions (including volume-to-capacity comparison).
- Determine crash experience for at least a three-year period.

The existing conditions analysis and results should be presented in a clearly understandable manner, with the use of parcel location and land-use maps desirable. Bus routes and service coverage should be mapped. Daily traffic volumes are also useful in defining the exposure of a site to passing traffic. Peak-hour traffic flow maps showing intersection turning movements are essential. Travel lanes, traffic controls, and service levels should be mapped as well. Table 19-3 shows the data that should be collected as part of the background analysis.

Table 19-3. Suggested Background Data for Impact Analysis

Category	Data
Traffic Volumes	• Current and (if needed for analysis) historic daily and hourly volume counts, including peak period counts (site and street peaks). • Recent intersection turning movement counts, including right-turns-on-red. • Seasonal variations. • Vehicle classification counts. • Peak period queue lengths. • Projected volumes from previous studies or regional plans. • Relationship of count day to both average and design days. • Posted speed limits. • Prevailing operating speeds. • Travel times.
Land Use	• Current land use, densities, and occupancy in vicinity of site. • Approved development projects and planned completion dates, densities, and land use types. • Anticipated development on other underdeveloped parcels. • Zoning in vicinity. • Absorption rates by type of development.
Demo-graphics	• Current and future population and employment within the study area by census tract or transportation analysis zone (as needed for use in site traffic distribution).
Transportation System	• Current street system characteristics, including direction of flow, number and types of lanes, right-of-way width, type of access control, and traffic control including signal timings, sight distances. • Roadway functional classification. • Route governmental justification. • Adopted local and regional plans. • Planned thoroughfares in the study area and local streets in vicinity of site, including improvements. • Transit service, usage, and stops. • Pedestrian and bicycle linkage, usage, and facilities (for example, sidewalks and bike paths). • Available curb and off-site parking facilities, and parking regulations. • Safety hazards. • Implementation timing, funding source and certainty of funding for study area transportation improvements (whether funded in current capital improvement program).
Other Transportation Data	• Origin-destination or trip distribution data. • Crash history (3 years, if available) adjacent to site and at nearby major intersections if hazardous condition has been identified.

Source: ITE, 2012 as edited

The credibility of a traffic impact study to a large extent will depend on the quality of the data collected. Generally, data on traffic volumes and turning movements should not be out-of-date by more than one year, which often requires the agency or a consultant to collect new data (see chapter 2 on data collection). The peaking behavior of adjacent streets, nearby major highways, and parking facilities is of particular interest.

Not only is it important to collect data that focuses on a site's potential impact (for example, turning movements), but it is also important to collect data on non-site traffic that provide a sense of how background traffic will change over time. In particular, through traffic with no origin or destination in the study area as well as traffic generated by all other developments in the study area should be estimated. Methods to do this are discussed later.

E. Performance Measures

The site impact-related performance measures of most concern to transportation planners are those required by administrative regulations, as well as those desired by local decision makers. Some examples are presented below.

City of Cambridge, Massachusetts. The city of Cambridge, Massachusetts, defines "substantial adverse impact on city traffic" and thus the data that must be provided, as: [City of Cambridge, 2014]

Project vehicle trip generation weekdays and weekends for a 24-hour period and a.m. and p.m. peak vehicle trips.

The definition of an impact consists of project-based trip generation in excess of:

- 2,000 weekday or weekend (24-hour) trips; or
- 240 peak hour (a.m., p.m., or Saturday midday) trips.

Change in level of service at identified signalized intersections.

An impact occurs with the following changes in vehicle level of service (VLOS) at intersections:

Existing Vehicle LOS	LOS with Project
VLOS A	VLOS C
VLOS B, C	VLOS D
VLOS D	VLOS D or 7% roadway volume increase
VLOS E	7% roadway volume increase
VLOS F	5% roadway volume increase

Increased volume of trips on residential streets.

An impact is defined based on two parameters. The first is the increase in project-induced traffic volume on any two-block residential street segment in the study area, in excess of:

Parameter[1]: Amount of Residential[1]	Parameter[2]: Current Peak-hour Street Volume (two-way vehicles)		
	<150 Vehicles per Hour (VPH)	150–400 VPH	>400 VPH
1/2 or more	20 VPH[2]	30 VPH[2]	40 VPH[2]
>1/3 but <1/2	30 VPH[2]	45 VPH[2]	60 VPH[2]
1/3 or less	(No max.)	(No max.)	(No max.)

Notes:

[1]Amount of residential for a two block segment as determined by first floor frontage.

[2]Additional project vehicle trip generation in vehicles per lane, both directions.

The second is the *increase of length of vehicle queues at identified signalized intersections*. A project-induced lane queue or increase in lane queue in excess of the amount allowed in the following table constitutes an impact:

Existing Queue	Queue With Project
Under 15 vehicles	Under 15 vehicles, or 15+ vehicles with an increase of 6 vehicles
15 or more vehicles	Increase of 6 vehicles

Lack of sufficient pedestrian and bicycle facilities.

Project impact was defined using three criteria:

Criterion 1: A project-induced increase in pedestrian delay at any study area crosswalk in excess of the amount allowed in the following table:

Existing Pedestrian Level of Service (PLOS)	With Project Must Have:
PLOS A	PLOS A
PLOS B	PLOS B
PLOS C	PLOS C
PLOS D	PLOS D or increase of 3 seconds
PLOS E, F	PLOS D

Safe Pedestrian Facilities are sidewalks, crosswalks or walkways on any publicly accessible street or right-of-way (ROW) which meet City design standards, including handicap treatments

Criterion 2: Safe pedestrian facilities must exist on any adjacent publicly accessible street or right-of-way (ROW); and they must connect to site entrances, interior walkways, and adjoining pedestrian facilities.

Safe bicycle facilities are on-street bicycle lanes or off-road paths along a publicly accessible street or right-of-way which meet city design standards.

Criterion 3: Where sufficient ROW currently exists, safe bicycle facilities must be in place or sufficient ROW must be preserved on any adjacent publicly accessible street or ROW, and they must connect to site entrances, interior pathways, and adjoining bicycle facilities.

Some examples of how other jurisdictions define "impact" are presented below.

Virginia DOT. The Virginia DOT focuses on three impact areas:

1) Development-generated forecast daily and peak-hour traffic volumes on the highway network in the study area, site entrances, and internal roadways, tabulated and presented on diagrams.
2) Delay and LOS (tabulated and presented on diagrams for each lane group).
3) If there is a significant potential for walking, bike, or transit trips either on- or off-site, analyses should be undertaken of pedestrian and bicycle facilities, and bus route or routes and segment(s) (tabulated and presented on diagrams, if facilities exist or are planned). [VDOT, 2015]

Atlanta Regional Commission, Atlanta, Georgia. The Atlanta Regional Commission (ARC) looks at a wide range of criteria when examining developments of regional impact (DRIs). The transportation elements of this review include:

- Traffic generated by the development.
- Capacity of the existing and proposed roads.
- Demand management strategies proposed by the developer.

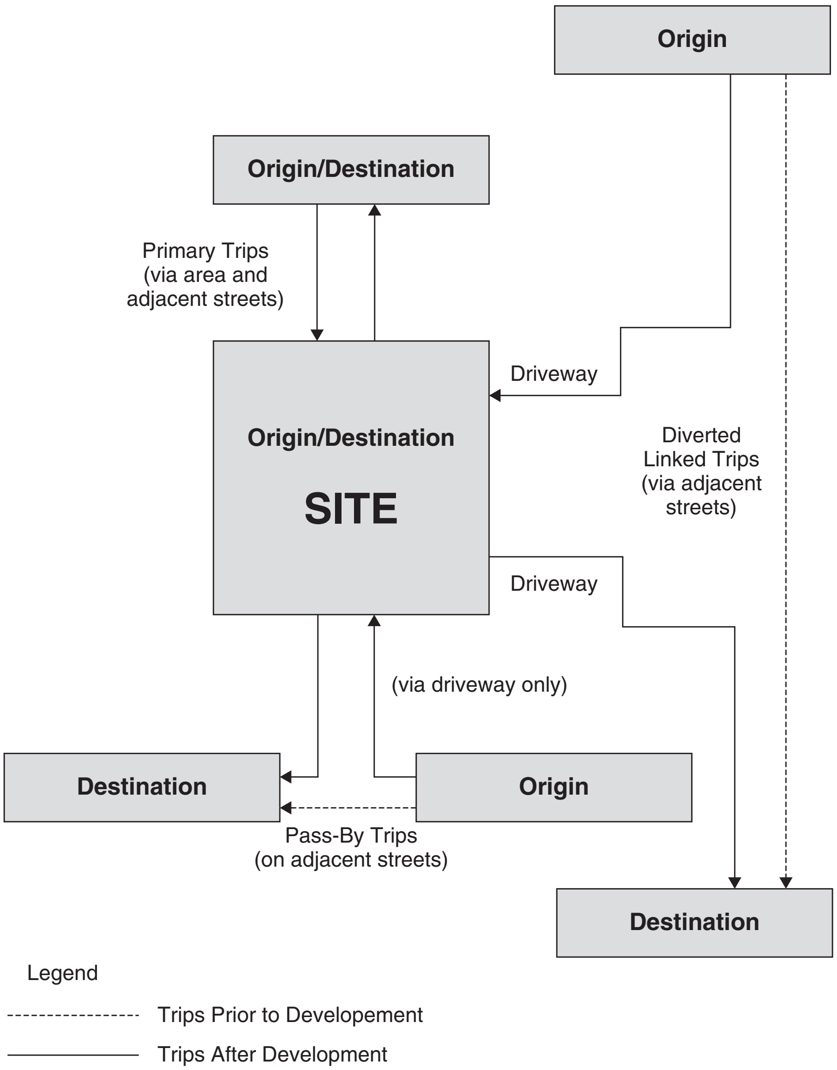
- Air-quality impacts of the DRI-generated traffic.
- Whether the DRI contributes to patterns of development that will reduce average daily miles traveled.
- Rapid transit availability. [ARC, 2013]

As described above, the metrics used for the decision-making process are wide-ranging and emphasize many different issues. Generally, similar direct impacts are measured in almost all cases, such as the number of trips generated, level of service on transportation facilities, and the like. In other cases, these metrics are used as input into further analysis to determine related impacts, such as the amount of motor vehicle-related pollutants generated. The data collected and the tools used for producing this information will clearly depend on information required by the decision-making process.

F. Travel Demand Analysis

Figure 19-3 shows three major kinds of trips that are part of a site demand analysis. The largest predicted volume will be the *primary origin–destination trips* to and from the development site. *Pass-by trips* are trips made to the site using an adjacent road. Vehicle pass-by trips are not new trips to the adjacent road, but do represent new trips to site driveways (and turning movements). *Vehicle-diverted trips* are those that are attracted to the site, but divert from

Figure 19-3. Trip Types for Impact Analysis



Source: ITE, 2012

nearby roads on the road network (not from roads adjacent to the site). Thus, diverted trips are not new to the overall network; they are simply redistributed from their original path.

In addition to these three trip types, there is an "internal capture" of trips for sites that are multiuse and often fairly large. Internal capture reflects those trips that according to the trip generation calculations would be estimated to arrive at the site, but are instead made by a person walking from one part of the site to another (for example, for a cup of coffee or lunch). As such, internal capture trips do not create new trips on the adjacent roads or at the site's driveways.

As an example, assume that a particular land use generates 435 trips as determined by a trip generation equation. Assume that the land use also attracts 40 pass-by trips coming to the site and 25 exiting the site. This means that the 435 driveway trips estimated from the trip generation step would really mean $435 - (40 + 25)$ or 370 new trips on the adjacent roads. Let's assume 10 percent of the trips are internal capture or $0.10 \times 370 = 37$ trips. This means that there will be a final estimated $370 - 37 = 333$ new trips on the adjacent road during the day due to the proposed development.

Anticipated travel demands, traffic volumes, and operating conditions should be developed for each planning horizon year. They should reflect likely growth in background traffic (and transit) volumes during the peak periods; planned changes in the roadways and public transport in the site environs; the type, size, and trip-generating characteristics of the planned development; directions of approach of site traffic volumes and their distribution on the surrounding road system; and combined (site plus background) traffic volumes on roadways and the site environs.

1. Background (Non-Site) Traffic Growth

Several methods can be used for estimating the future volumes of background traffic (see ITE's *Trip Generation Handbook* [ITE, 2012] and the example provided therein on background traffic growth). The simplest approach is to extrapolate from past trends, although this approach is strongly influenced by perturbations in the data (such as the effects of an economic recession). A more detailed approach is to identify major land developments in areas surrounding the proposed development site and assign estimated traffic from these sites to the adjacent road network. The most involved approach is to use a travel demand network model to estimate network link impacts (see chapter 6 for a discussion of travel demand models). Combining the first and second approaches may be desirable in some situations. However, in many major development impact studies, regional and local governments often require the use of computer-based network models to assess likely impacts. No matter which approach is used, the results should be checked for reasonableness. Each method should take into account changes in roadway and transit facilities, such as improving transit service frequency, increasing expressway or arterial roadway capacity, building new roadways, or introducing rail or bus rapid transit lines.

Growth trends. Examining local traffic volume growth trends (usually on an equivalent annual basis) works well for short timeframes (less than five years) especially where there is a good local traffic volume database. This approach is simple to use and can produce reasonable results. It is especially well-suited to small developments that will be open in a relatively short timeframe, such as banks and service stations. Generally, at least five years of data are needed. Estimates can be made more reliable by reviewing and comparing growth trends in population, vehicle registration, daily traffic volumes, and peak-hour traffic volumes. Each factor should be indexed to the base (existing) year.

Build-Up Method. This method is applicable where there are known projects in the planning horizon (usually five years or less). It involves treating each development (or series of contiguous developments) as a new development. The traffic these developments generate is then assigned to the road system for the design hours under consideration. This approach works best where there is good information on proposed developments. Most jurisdictions only consider approved development for the build-up method, specifically those development parameters that have been vetted and approved by a city or county.

Subarea Transportation Plan Volumes. Traffic volumes in transportation plans are usually estimated with the region's travel demand model, which is applied for an assumed transportation network and an assumed land-use pattern. This method is often used for large regional projects that are to be phased in over time. The method is particularly appropriate for use in large population areas and economic growth. Ideally, both daily and peak-hour traffic assignments should be made. With the addition of a new development site, the assumed model inputs might no longer be valid, so using subarea plan volumes needs to occur with caution.

In most cases, and especially for large developments, travel demand models are run with the development site becoming a new traffic analysis zone. This requires the coding of a more refined network. For regional developments, in many instances, the regional travel demand model is only used for trip distribution, that is, determining which direction trips are coming from or going to from the site. The use of the regional model to assign trips to the local roadway network (the so-called trip assignment process) can be done, if it is part of an agreed upon traffic methodology. However, in those instances, it is good practice to make sure that trips generated by the model match the ITE trip generation estimate for the project minus pass-by trips and internal capture.

Readers interested in additional information on travel demand modeling are referred to chapter 6. Some site-specific analysis aspects of the demand modeling process are discussed below.

2. Site Trip Generation

The number of trips to or from an activity center (person-trips) depends on the type and size of land use. The modes of travel will depend on the site location, development density, character of surrounding areas, and the availability and quality of alternative transportation options. The number of automobile driver (hence vehicle) trips depends on both mode split (percentage of travelers using each available mode of travel) and vehicle occupancy. Some of the key considerations in site trip generation include:

Person versus vehicle trips. ITE's multi-volume *Trip Generation* (9th edition) and many trip generation reports prepared by state and local agencies can provide reasonable estimates of the expected number of trips generated. [ITE, 2012] Trip generation rates are available for a variety of settings, although for suburban and exurban settings little or no transit or walk-in traffic is usually estimated. In settings with good transit and pedestrian access, the ITE vehicle trip rates can be adjusted downward to account for the likely percentage of a site's trips that would come as pedestrians or transit riders. Generally, any reduction in vehicle trips to account for pedestrian and transit riders would be agreed to as part of the traffic methodology and require supporting documentation from sites that have similar pedestrian and transit access.

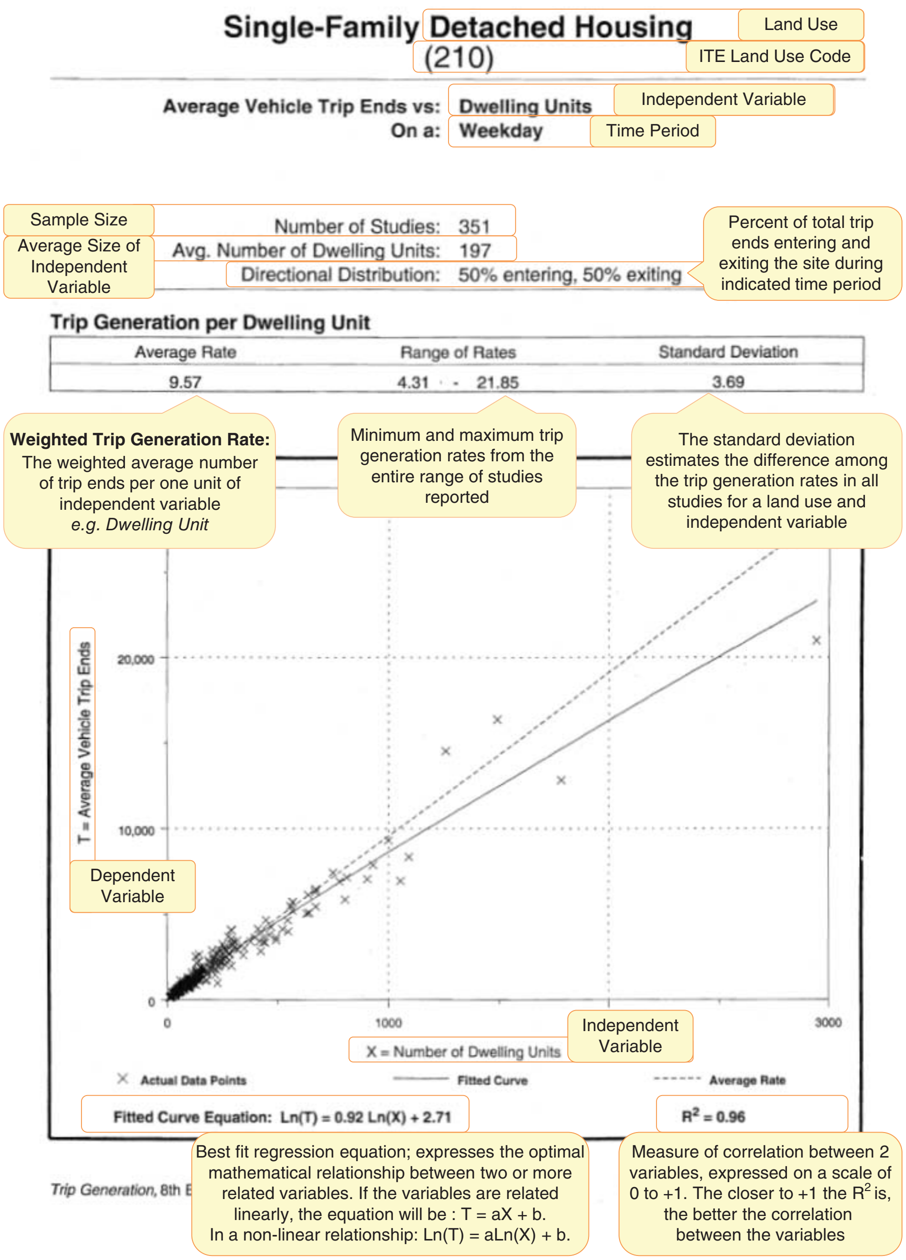
Trip rates. Trip generation estimates should be based on local rates for similar types of development. In some cases, it may be desirable to conduct trip generation studies at sites with similar characteristics. Alternatively, rates for similar development in other parts of a state or region may be used where applicable. The important variables in developing trip rates are the independent variables used to estimate trips generated, for example, number of dwelling units, thousands of retail square feet, and the like. Although such variables are given as part of trip generation handbooks and manuals, if it is desired to estimate jurisdiction-specific equations, the choice of the independent variables will be critical. Other means of estimating trip rates include:

- Regression equations can be used when (1) the independent variable lies within the range of data likely associated with the proposed development, (2) there are at least 20 data points, and (3) $R^2 \geq 0.75$. Equations should be used when the actual trip rates decrease as the development size increases. Examples include office buildings and shopping centers.
- Weighted average rates should be used when (1) there are at least three (preferably six) data points, (2) the independent variable lies within the ranges of the data points, and (3) R^2 is less than 0.75 or no equation is provided.
- Where the standard deviation is more than 110 percent of the weighted average (for example, the coefficient of variation), additional studies may be desirable (see chapter 2 on data analysis).

The trip rates and trip equations set forth in the ITE *Trip Generation* report and the procedures in the ITE *Trip Generation Manual* are often used by transportation agencies. In some instances, these rates are augmented by additional research (see [Daisa et al., 2013], for example). Equations are preferable to rates where they are available and have high statistical relationship among the key variables. Figure 19-4 shows some of the information that can be found in the ITE *Trip Generation Manual*. [ITE, 2012]

Analysis hours. Analyses should be done for the hours of the day when the maximum combined traffic volumes occur on the surrounding road network. They should consider the periods when normal background highway traffic is at a peak as well as when site traffic volumes peak. Given the different activities that occur on individual sites, the study time periods may vary for residential, office, industrial, retail, and recreational developments. Typically, analyses should be done for weekday a.m. and/or p.m. peak hours; however, in some situations, such as major retail developments, Saturday or Sunday peaks should be analyzed. The p.m. peak hour for schools in many instances does not coincide with the surrounding roadway network p.m. peak hour, as the school p.m. peak hour is generally 2–4 p.m. and the surrounding roadway network p.m. peak hour is generally 4–6 p.m. As such, school p.m. peak-hour traffic counts and operational analyses may need to account for this offset from the traditional peak-hour analyses.

Figure 19-4. ITE Trip Generation Manual Example



Source: Florida DOT, 2014

Typical time periods that generate peak traffic flows for selected land uses are shown in Table 19-4. Evening hours from 7:00 p.m. to 10:00 p.m. that sometime generate heavy traffic volumes at regional shopping centers should also be studied.

Multiuse developments: Multiuse or mixed-use developments bring together office, retail, recreational, and/or residential uses in a single project. Six land uses are the most frequent components of multiuse sites: office, retail, restaurant, residential, cinema, and hotel. This mix of land uses fosters internal travel among various activities, either by car or walking, which reduces the number of vehicle trips entering and leaving the development as compared to the sum of the trips generated by the individual land uses. The number of internal trips (that is, internal capture) varies with the type and size of each use. Past experience suggests that about 20 to 30 percent of the trips to and from retail areas come from office buildings, with the percentages differing for the noon time and p.m. peak hours. Smaller amounts of interchange take place between retail and residential and office and residential. Reported internal capture rates for multiuse centers are shown in Tables 19-5 to 19-8 from NCHRP Report 684, *Enhancing Internal Trip Capture Estimation for Mixed-Use Developments*. [Bochner et al., 2011]

Table 19-4. Typical Peak Traffic Flow Hours for Selected Land Uses		
Land Use	**Typical Peak Hours**	**Peak Direction**
Residential	7:00–9:00 a.m. weekdays	Outbound
	4:00–6:00 p.m. weekdays	Inbound
Regional Shopping	5:00–6:00 p.m. weekdays	Total
	1:00–2:00 Saturdays	Inbound
	4:00–5:00 Saturdays	Outbound
Office	7:00–9:00 a.m. weekdays	Inbound
	4:00–6:00 weekdays	Outbound
Industrial	Varies with employee shift schedule	–
Recreational	Varies with type of activity	–

Source: ITE, 2012

Table 19-5. Proposed Unconstrained Values for Distribution of Internal Trip Destinations for Exiting Trips, A.M. Peak Period, %

	Destination Land Use					
Origin Land Use	**Office**	**Retail**	**Restaurant**	**Residential**	**Cinema**	**Hotel**
Office	N/A	28%	63%	1%	N/A	0%
Retail	29%	N/A	13%	14%	N/A	0%
Restaurant	31%	14%	N/A	4%	N/A	3%
Residential	2%	1%	20%	N/A	N/A	0%
Cinema	N/A	N/A	N/A	N/A	N/A	N/A
Hotel	75%	14%	9%	0%	N/A	N/A

Source: Bochner et al., 2011, Reproduced with permission of the Transportation Research Board.

Table 19-6. Proposed Unconstrained Values for Distribution of Internal Trip Destinations for Exiting Trips, P.M. Peak Period, %

	Destination Land Use					
Origin Land Use	**Office**	**Retail**	**Restaurant**	**Residential**	**Cinema**	**Hotel**
Office	N/A	20%	4%	2%	0%	0%
Retail	2%	N/A	29%	26%	4%	5%
Restaurant	3%	41%	N/A	18%	8%	7%
Residential	4%	42%	21%	N/A	0%	3%
Cinema	2%	21%	31%	8%	N/A	2%
Hotel	0%	16%	68%	2%	0%	N/A

Source: Bochner et al., 2011, Reproduced with permission of the Transportation Research Board.

Table 19-7. Proposed Unconstrained Values for Distribution of Internal Trip Origins for Entering Trips, A.M. Peak Period, %

	Destination Land Use					
Origin Land Use	**Office**	**Retail**	**Restaurant**	**Residential**	**Cinema**	**Hotel**
Office	N/A	32%	23%	0%	N/A	0%
Retail	4%	N/A	50%	2%	N/A	0%
Restaurant	14%	8%	N/A	5%	N/A	4%
Residential	3%	17%	20%	N/A	N/A	0%
Cinema	N/A	N/A	N/A	N/A	N/A	N/A
Hotel	3%	4%	6%	0%	N/A	N/A

Source: Bochner et al., 2011, Reproduced with permission of the Transportation Research Board.

Table 19-8. Proposed Unconstrained Values for Distribution of Internal Trip Origins for Entering Trips, P.M. Peak Period, %						
	Destination Land Use					
Origin Land Use	**Office**	**Retail**	**Restaurant**	**Residential**	**Cinema**	**Hotel**
Office	N/A	8%	2%	4%	1%	0%
Retail	31%	N/A	29%	46%	26%	17%
Restaurant	30%	50%	N/A	16%	32%	71%
Residential	57%	10%	14%	N/A	0%	12%
Cinema	6%	4%	3%	4%	N/A	1%
Hotel	0%	2%	5%	0%	0%	N/A

Source: Bochner et al., 2011, Reproduced with permission of the Transportation Research Board.

Activities in central business districts (CBDs) and other densely developed districts usually draw many patrons from nearby origins. In these cases, rather than dealing with internal capture, the primary destinations for each use should be estimated. Retail stores and restaurants, for example, may draw large numbers of patrons from nearby offices and would have vehicle trip generation rates considerably less than those cited in the ITE manuals.

3. Pass-By Trips

As noted earlier, some of the trips generated by new developments will come from currently passing traffic. These pass-by trips have the effect of reducing the anticipated development-generated traffic volumes on the surrounding road system, although the access (driveway) volumes into a site would remain unchanged.

Trips diverted to boundary roads from other roadways to reach a site would not add traffic to the roadways in an area, but may increase traffic on the roads serving a site. These diverted trips are normally treated as part of a site's generated traffic; pass-by trips are deducted from the boundary road traffic.

The proportion of a site's traffic coming from the passing traffic depends on the type and size of development, and whether an activity is a destination in itself or merely a stop along a trip path, for example, an office building versus a gas station. (Up to 50 percent of all trips to a service station have been found to be travelers passing by rather than people who made a special trip to the gas station). Generally, as developments increase in size, there is a corresponding reduction in the proportion of pass-by traffic. This is apparent from the percentages reported for shopping centers as shown below.

Net square feet of floor space for shopping centers	**Percent of pass-by trips**
<100,000	40%
100,000–250,000	30%
250,000–500,000	25%
500,000–750,000	22%
Over 750,000	20%

The percentages of pass-by trips for various land uses are reported in ITE's *Trip Generation* [2012]. Because of limited data and high variability, adjustments should be applied carefully.

Travel demand management (TDM) impacts. The primary purpose of TDM strategies is to influence travel demand, usually targeted at reducing the number of single-occupant vehicles accessing a site during peak periods. They work best in activity centers with a large employment base, often with a single or only a few employers. Employer-based TDM programs normally include preferential parking for vanpools and carpools, company endowment of vans, transit passes, ridesharing coordination at large employers, and flextime. Public sector incentives include free parking at freeway interchanges, financial support of public transport, provision of HOV and high-occupancy toll lanes, and developer agreements to encourage ridesharing (see chapter 14 on travel demand management).

As part of the trip generation analysis, summary tables should list each type of land use, its size, and proposed vehicle trip generation rates for daily, a.m./p.m. peaks, and other peak periods of interest. Deductions may then be necessary for internal trips and multiuse sites, TDM actions, and activities displaced by the development.

In some cases, trip reduction policies have been adopted by transportation agencies and are encouraged as part of the traffic impact study. In Massachusetts, for example, the state's *Mode Shift Initiative* has established a statewide mode shift goal of tripling the share of travel by bicycling, transit, and walking. All elements of the site impact analysis and the project proposal—trip generation, mode split, trip distribution, adjustment factors, parking, siting, and others—must show how the proposed mitigation will help achieve this target.

In Calgary, Alberta, active transportation modes such as walking and bicycling must be considered as part of the impact analysis. Where expected volumes cannot be forecast, default values are to be used, including:

- *Very Low-Impact Areas*: 10 pedestrians/hour and 5 bicycles/hour.
- *Low-Impact Areas*: 25 pedestrians/hour and 10 bicycles/hour.
- *Moderate-Impact Areas:* 50 pedestrians/hour and 20 bicycles/hour. [City of Calgary, 2011]

The review is also to include a qualitative assessment of the connectivity of the proposed development to the region's primary transit and cycling network, and the regional pathway system.

Freight or goods movement. The following questions relating to truck movements in the study area should be considered in the analysis:

- What is the existing percentage of trucks in the study area?
- Are there existing truck safety issues in the study area? Will the proposed development sustain or improve these conditions?
- How will the specific land uses and businesses for the proposed development affect truck trip generation?
- When will the peak hour of truck trip generation occur?
- How will trucks be routed and circulated on-site and off-site?
- How will queuing at driveways and intersections be affected by truck trip generation?
- Will truck trip generation adversely impact site access?
- Will there be sufficient truck turning radii?
- Will a separate truck access point be needed to minimize conflicts between trucks and other vehicles?
- Will deceleration lanes at the site access point be needed to maintain safety?
- How will trucks affect access, circulation, and operations at the proposed development's access points? For the entire study area? [City of Fontana, 2003; McRae et al., 2006]

Freight planning and in particular truck trip generation is discussed in chapter 22 on freight planning.

4. Site Trip Distribution

The direction of approach of vehicle and transit trips should be estimated for the roadways entering the site environs. Trip distribution for proposed developments can be determined from zip code data, census data, market research, travel demand forecasting models, existing travel patterns, and/or the location of complementary land uses. The relative magnitudes of site-generated traffic should be assigned to the boundary roads and access points based on the specific building footprints and the relative square footage of development at various locations at a development site. Trip distribution will depend upon site-specific factors, such as:

- Existing travel patterns.
- Type and size of the proposed development.

- Size of the influence areas.
- Surrounding land uses.
- Locations of competing developments (for example, shopping centers).
- Population and purchasing power distribution.
- Transport system availability, characteristics, and travel times.
- Planned transportation improvements.

Because a combination of these factors will likely be found at any particular site, local codes and ordinances should not require the use of specific traffic distribution techniques. The analyst should be allowed to exercise appropriate judgment, although assumptions and methods of analysis should be clearly stated.

The Oregon DOT identifies three methods that can be used to distribute trips in the study area. [ODOT, 2014]

Analogy Method. The analogy method uses traffic information from a similar development to predict trip distribution for the proposed development. This can be accomplished by various methods including driver surveys, license plate origin-destination studies, and driveway turning movement counts. This method is generally acceptable for small to midsized developments such as:

- Fast-food restaurants where a competing establishment is near the site.
- Service stations where traffic volumes on the adjacent streets are similar to those forecasted at the site.
- Motel sites near an existing motel.
- Residential developments on the fringe of an urban area.
- Sites to be developed for residential use, where the tract is one of the few vacant parcels in a developed area.
- Occupied buildings located in an office complex being developed by phases.

Travel Demand Model. A travel demand model can be effective in estimating traffic distribution patterns, especially for very large developments where a large number of trips is to be generated or attracted. Because travel demand models are typically developed in conjunction with a transportation system plan and comprehensive plan, they can provide a reliable forecast for fast-growing urban areas. The traffic analysis zone (TAZ) containing the proposed development should be investigated closely to ensure land uses, development densities, and trip-making characteristics are modeled consistent with existing conditions (see chapter 6 on travel demand modeling). The steps for using a travel demand model include:

- Interpolate the land-use and socioeconomic data sets to project conditions for the build-out year of the development phase or project.
- Verify that the transportation network includes only existing plus committed facilities.
- Create a new traffic analysis zone for the proposed project. Within this new zone, input the amount of development proposed for the project. Apply the model to determine the project traffic distribution.
- Determine total trips generated by the new zone, so that the percentage of project trips assigned by the model can be determined.
- If there are additional roadways that should be part of the study area network and are not included in the model, then a post-model adjustment can be made to distribute traffic to these facilities.
- Calculate the percentage of trips assigned to each roadway segment in the project vicinity.
- Multiply the percentage of project traffic by the external trips generated. [GRTA, 2013]

Surrogate Data. Surrogate data uses related information other than direct causal variables to represent the influence and impacts of a development on the distribution of trips to and from a site. An example is using the distribution of residential population in the region or study area as a surrogate for the direction of trips approaching office and retail land uses. For example, if 50 percent of the residential population relating to a site location is found southeast of the site, one can assume that 50 percent of the site trips would be coming from this direction. This method can accurately estimate trip distribution when used cautiously and for appropriate land uses. It also requires a database of usable socioeconomic and demographic information for various parts of the city.

In cases where market analyses have been conducted for a property or development, it may be appropriate to use the results of this analysis as a means of developing project traffic distribution. This information can be used at the discretion of the applicant, but should be approved by the reviewing agency prior to proceeding with the study.

A synthesis of traffic impact analysis procedures for the Oregon DOT examined best practices in the different methods and tools used by communities and consultants to do site impact studies. Some of the methods used to distribute traffic volumes included:

- Regional travel demand model.
- Existing street circulation system and a review of the existing traffic volumes, circulation patterns, and intersection turning movements.
- Market analysis provided by the retail store.
- Surveys of those who will be using service to determine residence location (by zip code) and mode of transportation.
- Population density and traffic analysis judgment.
- Percentage of local trips versus regional trips and analysis of the distribution of local traffic of residential areas. [McRae et al., 2006]

The report showed that the trip distribution forecasts for two of the sites were within 20 percent of the actual trip distribution after the development was built. New access control, no infrastructure improvements, and stagnant economic growth in the site vicinity were used to explain why this difference occurred. The report concluded that not including expected or predicted other development in the traffic impact study can have a significant effect on trip distribution estimates, especially if the site is not built as assumed.

The Washington State DOT encourages the use of scenarios, especially for large development sites, to account for possible other development impacts. Scenarios can range from simple "existing conditions with and without project," to more complex analyses where scenarios could include: existing, opening year with and without the project, interim years with and without the project, and design year with and without the project. [Washington State DOT, 2004] The DOT recommends for interim scenario networks that only projects or developments within the forecasting process having the highest probability of occurring within a 10-year horizon be included in the analysis. The city of San Jose recommends a "cumulative conditions" scenario to determine the combined effect of multiple pending projects or foreseeable developments with individually limited impacts on the transportation system. [City of San Jose, 2009]

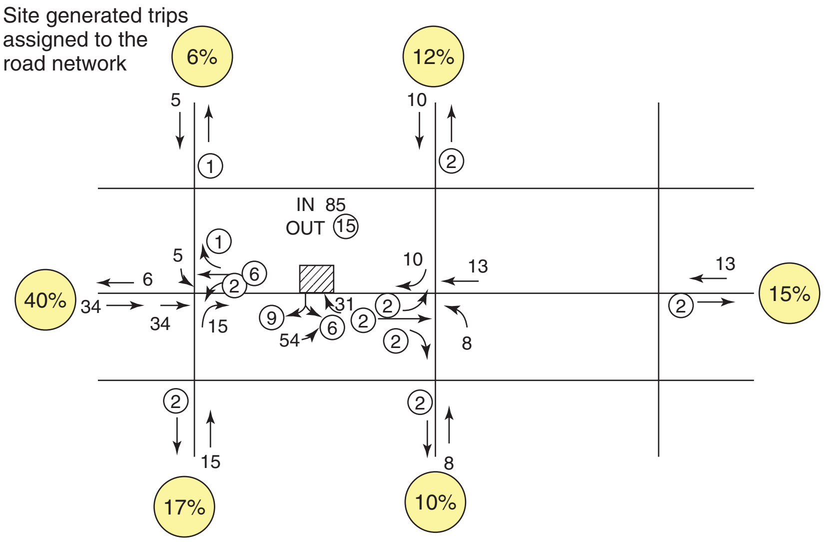
Trip distribution should be expressed as percentages by direction (see Figure 19-5). A table should be prepared showing directions of approach for each community within the trade area. These percentages and their resulting assignment to the road network should then be applied to the anticipated site trip generation to obtain design plans for each part of the road system.

Where transit and walk-in traffic is likely, directions of approach should be estimated for each mode. This requires modal allocations of person trips for each analysis area. The relative origins for each mode can then be assigned to roadways, transit routes, and walkways. In the immediate site environs, transit riders should be assigned to specific bus stops and rail stations, if appropriate. Walk-in trips, which are mainly from nearby areas, should be assigned to the street crossings and walkway system serving the site.

5. Trip Assignment

The combined (composite) traffic volumes for public street and site access roadways should be developed for each future condition analyzed. This involves adding the component of future background traffic and the expected site traffic on each network link and making needed adjustments for pass-by traffic. The traffic volumes should show each

Figure 19-5. Example Trip Distribution for Site Impact Analysis



Source: FHWA, 1985

traffic flow for through, left, and right turns. Anticipated pedestrian flows can be superimposed on these diagrams. They should be plotted on site maps and checked for reasonableness. These resulting combined peak-hour traffic volumes should be compared with the available roadway capacity to assess system adequacy, the need for roadway improvements, and the design of site access points. This comparison is done by assigning trips to the transportation network.

Trip assignment involves determining the amount of traffic that will follow certain paths in a roadway network. The trip assignment will illustrate the project-generated trips, by direction and turning movement, on each roadway segment of the study area. The procedure consists of assigning the project-generated traffic to the roadway network according to the trip distribution for each proposed land use, accounting for any turning movement restrictions (for example, one-way streets, ramps, movement restrictions and raised median islands, and so forth), or other unique roadway characteristics including excessive congestion. If using a travel demand model, this process is simply part of the modeling effort. If assigning trips manually to the network, several factors should be considered:

- Traffic assignment should consider logical routings, available roadway capacities, turning movements, and expected travel times (the basic goal of trip assignment is to follow the least travel time path).
- Multiple paths between origins and destinations should be used to achieve realistic results (assuming multiple paths exist).
- Assignments for future years should consider likely land use and traffic conditions in the target year.
- Assignments should be carried through the external site access points and, in large projects, on the internal roadways.
- When a site has more than one access point, logical routing and multiple paths should be used to obtain realistic driveway volumes. [ITE, 2010]

Readers are referred to [Giaimo, 2001] for a good reference on traffic assignment procedures as applied in site impact analysis.

VI. ANALYSIS PROCEDURES

The type and extent of analysis will depend not only on the characteristics of the development itself, but also on the types of improvements likely to be considered. Typical improvements are shown in Table 19-9 and are described further in ITE [2010].

Table 19-9. Typical Site Transportation Improvements
Roadways
• Install a traffic signal or roundabout. • Coordinate signals on common cycles along boundary and approach roads. • Provide right-and/or left-turn lanes. • Add through lanes. • Expand and/or improve intersections. • Channelization, such as turn lanes or raids. • Frontage improvements. • Install two-way left-turn lanes, where appropriate. • Install physical median (the median may be discontinued to allow only left turns into development of minor streets, or provide all movements at intersection). • Remove shrubbery or otherwise improve sight distance. • Widen access drives. • Consolidate or close driveways (develop shared access driveways). • Limit access drives to right turn exits only. • Establish one-way access drives. • Construct a "backage" road. • Widen and/or locate interchange ramps. • Construct "flyovers" or "flyunders" along artery at major junctions. • Reconfigure freeway interchange. • Construct new freeway interchange.
Transit
• Add bus stops/ shelters. • Install a new bus route. • Improve bus service frequency. • Route buses to stops at heart of development. • Establish a transit center within a development. • Develop a new bus rapid or light rail transit route with good pedestrian access to development.
Pedestrians/Bicyclists
• Provide sidewalks on perimeter road. • Install crosswalks, preferably with a central refuge area. • Accommodations for bicycles such as bike lanes, bike boulevard treatments, bike parking. • Construct walks from surrounding roads to development. • Construct weather-protected skyways that connect developments with express transit way stations, or avoid major highway crossing.
Travel Demand Management
• Create transportation management association (TMA). • Establish rideshare programs, subsidized if possible. • Limit and/or price commuter parking. • Carpool incentives, such as preferred parking. • Consider flex-time and telecommute work programs, where appropriate.

Source: ITE, 2010

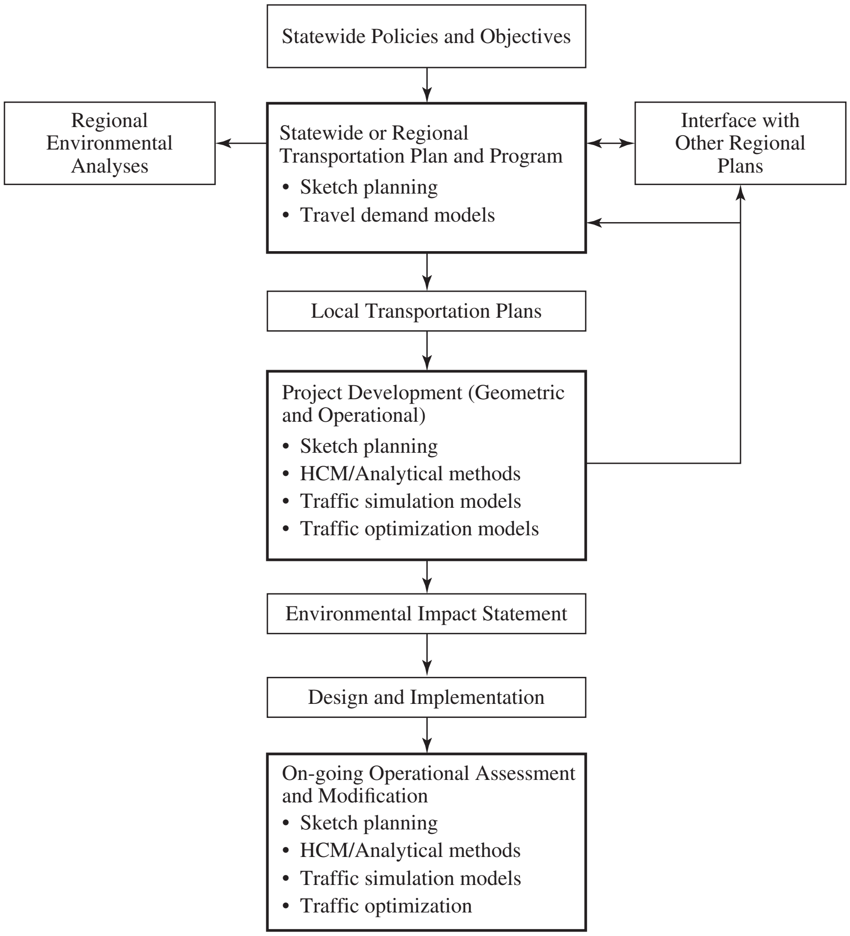
Anticipated traffic, transit, and pedestrian volumes provide the basis for assessing the workability of the existing transportation and recommended improvements. When improvements are added, service-level computations can indicate how well the facilities operate. This is often an iterative process depending on the scale of developments and the amount of background traffic growth. Ideally, needed improvements should be consistent with those planned or programmed by public agencies. Multimodal assessments are essential in densely developed areas and for large mixed-use or commercial developments.

A. Choice of Models or Tools

The selection of analysis tools and methods will depend on the evaluation criteria agreed upon at the beginning of the study. In most cases, some measure of level of service and quality of service is used to estimate system impact. In the United States, this usually means using procedures from the Transportation Research Board's *Highway Capacity Manual* (HCM) [TRB, 2010] and the *Transit Capacity and Quality of Service Manual* (TCQSM). [Kittelson et al., 2013a] In addition, there are specialized methods and approaches for active transportation modes.

The FHWA *Traffic Analysis Toolbox*, Volume 2, provides a methodology for selecting traffic analysis tools. [Jeannotte et al., 2004] Figure 19-6 shows the relationship among the many different traffic analysis tools used by transportation engineers and planners. The different types of tools, as excerpted from the report, were described in the *Toolbox* as:

Figure 19-6. Overview of the Traffic Analysis Process



Note: Boxes outlined by a bold line represent the primary realm of application of traffic analysis tools.

Source: Jeannotte et al., 2004

Sketch-Planning Tools. Sketch-planning methodologies and tools produce general order-of-magnitude estimates of travel demand and traffic operations in response to transportation improvements. They allow for the evaluation of specific projects or alternatives without conducting an in-depth engineering analysis. Sketch-planning tools perform some or all of the functions of other analytical tools using simplified techniques and highly aggregate data.

Travel Demand Models. Travel demand models have specific analysis capabilities, such as the prediction of travel demand and the consideration of destination choice, mode choice, time-of-day travel choice, and route choice in the highway network. These are mathematical models that forecast future travel demand based on current conditions and future projections of household and employment characteristics.

Analytical/Deterministic Tools (HCM-Based). Most analytical/deterministic tools implement the procedures of the HCM. The HCM procedures are closed-form, macroscopic, deterministic, and static analysis procedures that estimate capacity and performance measures to determine level of service (for example, density, speed, and delay). They are closed-form because they are not iterative. The practitioner inputs the data and the parameters and, after a sequence of analysis steps, the HCM procedures produce a single answer. Analysis/deterministic tools are good for analyzing the performance of isolated or small-scale transportation facilities; however, they are limited in their ability to analyze network or system effects.

Traffic Signal Optimization Tools. Similar to the analytical/deterministic tools, traffic optimization tool methodologies are mostly based on the HCM procedures. However, traffic optimization tools are designed to develop optimal signal phasing and timing plans for isolated signal intersections, arterial streets, or signal networks. This may include capacity calculations, signal cycle length, signal split optimization (including turn phasing), and coordination/offset plans.

Table 19-10. Comparison of Analysis Tools and Spatial Application

Analytical Context/ Geographic Scope	Sketch Planning	Travel Demand Models	Analytical/ Deterministic Tools (HCM-based)	Traffic Optimization	Macro Simulation	Meso Simulation	Micro Simulation
Planning							
Isolated Intersection	o	o	●	Ø	o	o	o
Segment	●	o	●[1]	o	Ø	Ø	Ø
Corridor/Small Network	Ø	●	o	Ø	Ø	Ø	Ø
Region	Ø	●	N/A	N/A	N/A	N/A	N/A
Design							
Isolated Location	N/A	N/A	●	●	●	Ø	●
Segment	N/A	o	●	Ø	●	●	●
Corridor/Small Network	N/A	Ø	o	o	●	●	●
Region	N/A	Ø	N/A	N/A	o	o	Ø
Operations/Construction N/A							
Isolated Location	N/A	N/A	●	●	●	Ø	●
Segment	Ø	o	●	●	●	●	●
Corridor/Small Network	N/A	Ø	o	Ø	●	●	●
Region	N/A	Ø	N/A	N/A	Ø	o	Ø

● Specific context is generally addressed by the corresponding analytical tool/methodology

Ø Some of the analytical tools/methodologies address the specific context and some do not.

o The particular analytical tool/methodology does not generally address the specific context.

N/A The particular methodology is not appropriate for use in addressing the specific context.

[1] For linear networks.

Source: Jeannotte et al., 2004

Macroscopic Simulation Models. Macroscopic simulation models are based on the deterministic relationships among flow, speed, and density of the traffic stream. The simulation in a macroscopic model takes place on a section-by-section basis rather than by tracking individual vehicles. Macroscopic simulation models were originally developed to model traffic in transportation subnetworks, such as freeways, corridors (including freeways and parallel arterials), surface-street grid networks, and rural highways.

Mesoscopic Simulation Models. Mesoscopic models combine the properties of both microscopic (discussed below) and macroscopic simulation models. As in microscopic models, the unit of traffic flow for mesoscopic models is the individual vehicle. Similar to microscopic simulation models, mesoscopic tools assign vehicle types and consider driver behavior, as well as their relationships with roadway characteristics. Mesoscopic model travel prediction takes place on an aggregate level and does not consider dynamic speed/volume relationships.

Microscopic Simulation Models. Microscopic simulation models simulate the movement of individual vehicles based on car-following and lane-changing algorithms. Typically, vehicles enter a transportation network using a statistical distribution of arrivals (a stochastic process) and are tracked through the network over brief time intervals (for example, 1 second or a fraction of a second). In many microscopic simulation models, the traffic operational characteristics of each vehicle are based on well-known influences on vehicle dynamics of such things as road grade, horizontal road curvature, and pavement superelevation.

Each tool and method has its own application context. Table 19-10, for example, shows the usefulness of each of the analysis tools with respect to the scale of analysis; Table 19-11 shows the relationship between the tools and type of facility; and Table 19-12 shows similar information for different performance measures.

Table 19-11. Comparison of Analysis Tools and Facility Type

Facility Type	Sketch Planning	Travel Demand Models	Analysis/ Deterministic Tools (HCM-based)	Traffic Optimization	Macro Simulation	Meso Simulation	Micro Simulation
Isolated intersection	o	Ø	●	●	●	●	●
Roundabout	o	o	●	o	Ø	o	Ø
Arterial	●	●	●	●	●	●	●
Highway	●	●	●	Ø	●	●	●
Freeway	Ø	●	●	Ø	●	●	●
HOV lane	Ø	●	Ø	o	●	●	●
HOV bypass lane	o	●	o	Ø	Ø	Ø	●
Ramp	Ø	●	●	●	●	●	●
Auxiliary lane	o	o	Ø	Ø	●	●	●
Reversible lane	o	Ø	●	●	●	●	Ø
Truck lane	o	●	Ø	Ø	Ø	o	●
Bus lane	o	●	o	o	Ø	o	●
Toll plaza	o	Ø	Ø	o	o	o	●
Light rail line	o	●	o	o	o	o	●

● Specific context is generally addressed by the corresponding analytical tool/methodology.

Ø Some of the analytical tools/methodologies address the specific context and some do not.

o The particular analytical tool/methodology does not generally address the specific context.

N/A The particular methodology is not appropriate for use in addressing the specific context.

Source: Jeannotte et al., 2004

Table 19-12. Comparison of Analysis Tools and Performance Measures							
Measure	**Sketch Planning**	**Travel Demand Models**	**Analytical/ Deterministic Tools (HCM-based)**	**Traffic Optimization**	**Macro Simulation**	**Meso Simulation**	**Micro Simulation**
LOS	o	Ø	●	●	Ø	Ø	Ø
Speed	●	●	●	●	●	●	●
Travel time	Ø	Ø	●	●	●	●	●
Volume	●	●	●	●	●	●	●
Travel distance	o	o	o	o	o	●	●
Ridership	o	Ø	o	o	●	Ø	Ø
Average vehicle occupancy	o	●	o	o	o	o	o
V/C ratio	o	●	●	Ø	Ø	Ø	Ø
Density	o	o	●	●	●	●	●
VMT/PMT	Ø	●	Ø	Ø	●	●	●
VHT/PHT	Ø	●	Ø	Ø	●	●	●
Delay	Ø	●	●	●	●	●	●
Queue length	o	o	●	●	●	●	●
# of stops	Ø	o	o	o	o	o	●
Crashes	Ø	o	o	o	o	Ø	Ø
Incident duration	Ø	o	o	o	o	Ø	Ø
Travel time reliability	Ø	o	o	o	o	Ø	Ø
Emissions[1]	Ø	o	o	o	o	Ø	Ø
Fuel consumption[1]	Ø	o	o	o	Ø	Ø	Ø
Noise	Ø	o	o	o	o	o	o
Mode split	o	●	●	Ø	Ø	Ø	Ø
Benefit/cost	Ø	o	o	o	o	o	o

● Specific context is generally addressed by the corresponding analytical tool/methodology.

Ø Some of the analytical tools/methodologies address the specific context and some do not.

o The particular analytical tool/methodology does not generally address the specific context.

N/A The particular methodology is not appropriate for use in addressing the specific context.

[1] Most emissions models are post processing models that use the input from the models in this table to estimate emissions and fuel consumption. In addition, the state-of-the-art of travel demand models has progressed significantly since this table was developed.

Source: Jeannotte et al., 2004

Transportation planners should be aware of the strengths and weaknesses of each type of model and tool that can be used for impact analysis. In some cases, jurisdictions provide guidance on which tools are acceptable. Washington State DOT, for example, provides the following information on acceptable tools for travel impact analysis:

- *Freeway Segments*: Highway Capacity Manual/Software (HCM/S); operational and design analysis—macroscopic, mesoscopic, and microsimulation.
- *Weaving Areas*: Design manual (DM), HCM/S, operational and design analysis, microsimulation.
- *Ramps and Ramp Terminals:* HCM/S, operational and design analysis, DM, microsimulation.
- *Multilane Highways*: HCM/S; operational and design analysis—macroscopic, mesoscopic, and microsimulation.
- *Two-Lane Highways:* HCM/S, operational and design analysis.

- *Intersection, Signalized:* Sidra, Synchro, SimTraffic, HCM/S, Vissim.
- *Intersection, Roundabout:* Sidra, Rodel, HCM, Vissim.
- *Corridors:* Sidra, Synchro, SimTraffic, HCM, Vissim.
- *Stop-Controlled Intersections:* HCM/S for capacity, DM Chapter 1330 and the MUTCD for signal warrants (if a signal is being considered).
- *Transit:* HCM/S, operational and design analysis, *Traffic Manual*.
- *Pedestrians:* HCM/S.
- *Bicycles*: HCM/S.
- *WSDOT Criteria/Warrants:* MUTCD (signals, stop signs), *Traffic Manual* (school crossings), DM Chapter 1040 (freeway lighting, conventional highway lighting).
- *Channelization:* DM. [WSDOT, 2014, 2015]

The following discussion on the analysis of facility performance focuses on three types of facilities: intersections, road segments and corridors, and networks. Many of the models and tools described above can be used for analyzing facility and system performance at different scales of analysis.

B. Intersections

All intersections likely to be significantly impacted by the addition of project-generated traffic, that is, those now likely to experience operational problems or where a traffic signal warrant threshold might be triggered, should be part of the impact analysis. The HCM and accompanying software provides a methodology for assessing the level of service impact on intersections. [TRB, 2010] The reader is directed to this manual for a detailed discussion of the methods and approaches for estimating level of service. For intersection analysis the concept of a "lane group" is important. A lane group is a lane or group of lanes designated for separate analysis, which includes lanes that exclusively serve one movement through the intersection as well as each lane that is shared by one or more movements.

Table 19-13 shows the level of service for signalized intersections as defined in the amount of delay (seconds/vehicle) and the volume-to-capacity ratio of approaching intersection legs. Note that any volume-to-capacity ratio greater than 1.0 is considered LOS F. To give some sense of the type of data that is needed to estimate intersection level of service, Table 19-14 shows required data and the basis upon which the data are input into the calculations.

Level of service impacts should be estimated for transit, bicycles, and pedestrians as well as for automobiles. A variety of methods are used to define the performance of pedestrian and bicycle facilities, including an approach found in the HCM. Transit level of service can be analyzed with the TCQSM. Table 19-15 shows the LOS score and corresponding level of service based on what travelers have defined as being important aspects of walking and bicycling. Based on the perceived desirable characteristics of active transportation options, the HCM software package produces the score shown in the table. Some sense of these characteristics is shown in Table 19-16, which lists the input data for this process.

Table 19-13. Level of Service for Signalized Intersections

Control Delay (s/veh)	LOS by Volume to Capacity Ratio ≤1.0
≤10	A
>10–20	B
>20–35	C
>35–55	D
>55–80	E
>80	F

Source: TRB, 2010, Reproduced with permission of the Transportation Research Board.

Table 19-14. Data Inputs to Estimate Intersection Automobile Level of Service		
Data Category	**Input Data Element**	**Basis**
Traffic characteristics	• Demand flow rate	By movement
	• Right-turn-on-red flow rate	Approach
	• Percent heavy vehicles	Movement group
	• Intersection peak-hour factor	Intersection
	• Platoon ratio	Movement group
	• Upstream filtering adjustment factor	Movement group
	• Initial queue	Movement group
	• Base saturation flow rate	Movement group
	• Lane utilization adjustment factor	Movement group
	• Pedestrian flow rate	Approach
	• Bicycle flow rate	Approach
	• On-street parking maneuver rate	Movement group
	• Local bus stopping rate	Approach
Geometric design	• Number of lanes	Movement group
	• Average lane width	Movement group
	• Number of receiving lanes	Approach
	• Turn bay length	Movement group
	• Presence of on-street parking	Movement group
	• Approach grade	Approach
Signal control	• Type of signal control	Intersection
	• Phase sequence	Intersection
	• Left-turn operational mode	Approach
	• Dallas left-turn phasing option	Approach
	• Passage time (if actuated)	Phase
	• Maximum green (or green duration, if pre-timed)	Phase
	• Minimum green time	Phase
	• Yellow change	Phase
	• Red clearance	Phase
	• Walk	Phase
	• Pedestrian clear	Phase
	• Phase recall	Phase
	• Dual entry (if actuated)	Phase
	• Simultaneous gap-out (if actuated)	Approach
Other	• Analysis period duration	Intersection
	• Speed limit	Approach
	• Stop-line detector length	Movement group
	• Area type	Intersection

Movement: one value for each left-turn, through and right-turn movement.

Approach: one value for the intersection approach.

Leg: one value for the intersection leg (approach plus departure sides).

Intersection: one value for the intersection.

Phase: one value or condition for each signal phase.

Source: TRB, 2010, Reproduced with permission of the Transportation Research Board.

Table 19-15. Intersection Multimodal Level of Service for Walking and Bicycling	
Level of Service	**LOS Score**
A	≤2.00
B	>2.00–2.75
C	>2.75–3.50
D	>3.50–4.25
E	>4.25–5.00
F	>5.00

Source: TRB, 2010, Reproduced with permission of the Transportation Research Board.

Table 19-16. Data Inputs to Estimate Intersection Non-Automobile Level of Service			
Data Category	**Input Data Element**	**Pedestrian**	**Bicycle**
Traffic characteristics	• Demand flow rate of motorized vehicles	Movement	Approach
	• Right-turn-on-red flow rate	Approach	
	• Permitted left-turn flow rate	Movement	
	• Mid-segment 85th percentile speed	Approach	
	• Pedestrian flow rate	Movement	
	• Bicycle flow rate		Approach
	• Proportion of on-street parking occupied		Approach
Geometric design	• Street width		Approach
	• Number of lanes	Leg	Approach
	• Number of right-turn islands	Leg	
	• Width of outside through lane		Approach
	• Width of bicycle lane		Approach
	• Width of paved outside shoulder (or parking lane)		Approach
	• Total walkway width	Approach	
	• Crosswalk width	Leg	
	• Crosswalk length	Leg	
	• Corner radius	Approach	
Signal control	• Walk	Phase	
	• Pedestrian clear	Phase	
	• Rest in walk	Phase	
	• Cycle length	Intersection	Intersection
	• Yellow change	Phase	Phase
	• Red clearance	Phase	Phase
	• Duration of phase serving peds and bikes	Phase	Phase
	• Pedestrian signal head presence	Phase	
Other	• Analysis period duration	Intersection	Intersection

Source: TRB, 2010, Reproduced with permission of the Transportation Research Board.

The city of Cambridge, Massachusetts, provides an example of a pedestrian and bicycle methodology that includes more than just the HCM material. [City of Cambridge, 2014] The city requires an analysis of pedestrian level of service for the a.m. and p.m. peak hour of pedestrian demand at all study area intersections and crosswalks that have project vehicle trips and project pedestrian trips accessing transit. The results are to be reported for each crosswalk. In addition, pedestrian crossing gaps at unprotected crosswalks are to be analyzed (those without signal or stop control) as well as midblock crosswalks. The minimum acceptable gap at each crossing and thus the number of gaps available during the peak hour is computed as:

$$G_{min} = (W/S) + R \tag{19-1}$$

where,

W = crossing distance (ft)
S = walking speed (3.5 ft/sec. unless otherwise approved)
R = pedestrian start-up time (3 sec. unless otherwise approved)

A yielding survey (a survey of number of vehicles yielding right of way to a pedestrian) should be conducted when the number of minimum gaps falls below 60/hour; and an analysis should be done of pedestrian access to/from the site within a one-block radius and along principal access routes (to and from transit, parking, nearby retail, and so forth).

For bicycles, the analysis should:

- Identify conflicting vehicle turning movements at all study area intersections where bicycle facilities are present or peak-hour bicycle volume exceeds 10 on any approach.
- Evaluate bicycle access to the site along streets and at intersections along all paths where vehicle trips are distributed or on likely suitable alternatives including roadway cross sections, presence of bicycle facilities, and ability to install new on- and off-street bike facilities.
- Evaluate available bicycle parking on- and off-site, including access to parking, quality of facilities, and site security.

Readers interested in other methods for assessing the performance of pedestrian and bicycle facilities should see chapter 13.

Transportation safety should be part of every impact study. For example, the Virginia DOT [2014] requires a crash history for roadway segments or intersections that compares the overall crash record for similar locations, with particular attention to severe crash density and rates. For longer segments, corridors should be divided into sections of similar configuration and environments (for example, cross sections, terrain, and adjacent land-use/driveway density). The analysis should be a trial and error refinement of the most important causal factors. Histograms or counts of the total crashes, deaths plus injuries, and collision types (summing to total crashes) should be presented as part of the crash analysis. Readers are referred to chapter 23 for additional ways to assess safety performance.

Some jurisdictions also require a queue analysis as part of the intersection assessment (a queue is a line of vehicles waiting to enter the intersection). In Massachusetts, for example, both a 50th (average) and 95th percentile "Back of Queue" calculation needs to be provided as part of the study, including graphical representations of 50th and 95th percentile queue lengths at select study intersections. Queue analysis can be conducted using Highway Capacity Software or with proprietary software (such as Synchro™).

Table 19-17 shows a typical report on intersection analysis from the Oregon DOT [2014]. Note this illustration is only for automobile level of service and does not include impacts for non-automobile users.

Per Oregon DOT's impact study requirements, if a new signal is being proposed, the traffic impact study should investigate whether the impact:

- Clearly indicates the need for a traffic signal.
- Downgrades the ability of existing, planned, and proposed public roads to accommodate the traffic away from the state facility.
- Affects study area intersections. [ODOT, 2014]

Table 19-17. Example Traffic Operations Impact for Traffic Impact Report, Oregon DOT					
		Weekday PM Peak Hour		Saturday Mid-day Peak Hour	
Interconnection	**Max. Operating Standard**	**LOS**	**V/C**	**LOS**	**V/C**
SW Boones Ferry Rd/SW Tualatin Rd	0.99	B	0.63	Not analyzed	Not analyzed
SW Boones Ferry Rd/ SW Martinazzi Ave.	0.99	D	0.97	B	0.68
I-5 NB Ramp Terminal/SW Nyberg Rd.	0.85	C	0.71	E	0.88
SW Martinazzi Ave/North Site Dr.	E	C	0.24	C	0.19
SW Sagert St./SW Martinazzi Ave.	D	F	N/A	Not analyzed	Not analyzed

Note: LOS and V/C reported for the highest delay of critical movement

Source: ODOT, 2014

In addition, proposed right or left turn lanes at unsignalized intersections and private approach roads must meet the installation criteria in the adopted design manual.

From the perspective of travel safety, most impact guidelines require that adequate intersection sight distance be provided at all study intersections and highway approaches. Intersection sight distance is the standard for the location of approaches to a highway; stopping sight distance is a lower standard that may be used in some cases. Sight distance should meet the jurisdiction's design standards or those adopted from other sources (such as AASHTO's *A Policy on Geometric Design of Highways and Streets*).

The actions proposed for intersection mitigation should be identified and explained in the impact report. Transportation system improvements should be recommended for all locations predicted to fail a performance measure, and should include at least intersection geometry improvements, signal controls and equipment, signal timing, pavement markings, and curb cut locations; pedestrian crossing markings, pedestrian signals, and sidewalks; and bicycle lanes, bicycle signals, off-street bicycle facilities, and the like. Transit-related actions that are oriented to intersection performance should also be included.

C. Corridors

Freeway and arterial corridors could be affected by the additional traffic generated by a new development. The HCM defines three types of highways that could conceivably be part of an affected corridor for the impact study: freeways, uninterrupted flow highways, and interrupted flow roadways. Interrupted flow roadways are those with intersections. As noted by the Florida DOT, "It is widely recognized that signalized intersections are the arterial's primary capacity constraint; it is appropriate to place more emphasis on the intersections' characteristics than midblock characteristics. Generally, midblock segments have capacities far exceeding those of major intersections and it is rare for significant delays to occur midblock. By weighting the effects of intersections more heavily, a more accurate aggregate estimation is possible." [FDOT, 2013]

In San Jose, California, the traffic impact analysis regulations require an assessment of freeway segments if the project is expected to add traffic equal to at least one percent of the freeway segment's capacity. [City of San Jose, 2009] Freeway segments are evaluated using a procedure based on the density of traffic flow found in the HCM. Density is expressed in passenger cars per mile per lane. For calculating the percentage of project-generated traffic based on the freeway segment capacity, the following ideal capacities are used: 2,200 vehicles per hour per lane (vphpl) for four-lane freeway segments and 2,300 vphpl for six-lane or larger freeway segments. For five-lane freeway segments, 2,200 vphpl is used for the two-lane direction and 2,300 vphpl for the three-lane direction.

The Florida DOT has developed planning software for both arterials and freeways that implement many of the concepts in the HCM as well as the TCQSM. [FDOT, 2013] For example, ARTPLAN is FDOT's multimodal conceptual planning software for arterial facilities that is based on the HCM's urban streets methodology. For automobile estimates, it provides a simplified LOS analysis of the through movement on a road segment or at a signalized intersection. ARTPLAN utilizes average travel speed solely as the service measure. For bicycles and pedestrians, ARTPLAN uses the planning application of the bicycle LOS methodology and the pedestrian methodologies in the HCM. For bus, ARTPLAN is the conceptual planning application of the TCQSM methodology applied to bus route segments and roadway facilities. It should be noted that the FDOT ARTPLAN software is a generalized tool for assessing LOS, since there are a large number of default assumptions (that is, peak-hour travel characteristics) used in deriving the LOS. The FDOT software provides a good tool for those interested in looking at both automobile and non-automobile travel flows on a network. For use in traffic impact analysis, however, the user of the tool needs to be aware of the key differences between the tool and the HCM, which the guidance document clearly articulates.

The approaches to highway/roadway capacity and level of service estimation are covered in more detail in chapter 9 on roadway and highway planning. Readers should refer to this material because it provides the analysis foundation for determining the impact of new trips being generated on roadway performance. However, several concepts relating to transit level of service will be discussed here because site-related impacts on transit service will likely occur on a corridor basis, not at the intersection or network level.

Transit-related impacts due to a new development present both positive and potentially negative effects (if not mitigated). The positive effect is the additional riders that will now use transit to and from the site, in the process both reducing expected automobile trips and adding new revenues to the transit system. The negative effect from a corridor perspective is that a new stop (or stops) or a deviation of the route into the development site will add additional time to the bus trip time and possibly reduce the level of service to the other riders in the corridor. Mitigating this effect might require an additional bus added to the route to maintain required headways.

The following discussion focuses on two transit impacts—the need for transit amenities at the new development site to attract transit riders, and the potential impacts on the corridor transit service.

1. On- or Near-Site Transit Service Characteristics

The types of amenities provided at a bus stop (for example, at the new development site) can influence travelers' desires to ride transit. For example, as noted in the TCQSM, the value of time and how it is perceived with respect to transit service is a contributing factor in one's decision to use transit. Table 19-18 shows the relative weight in terms of value of time of different transit amenities. As can be seen, paying attention to the environment within which transit riders travel can be critical to the success of a site impact mitigation strategy.

Figure 19-7 shows a potential transit rider decision-making process that provides a good indication of the desired types of amenities and service characteristics. For example, the second box in the figure suggests that bus stop locations in reference to a new development are key indicators of transit desirability. The third box suggests the same for schedule information. This figure can be used to determine different mitigation strategies that might be part of an overall TDM program for a proposed development site.

Table 19-19 shows the amount of time it takes on average for a person to cross a road of varying number of lanes to reach a transit stop on the other side. Not only does this add to the access time for a person to reach a transit stop, but it also affects the amount of time a traffic signal must provide for safe crossing.

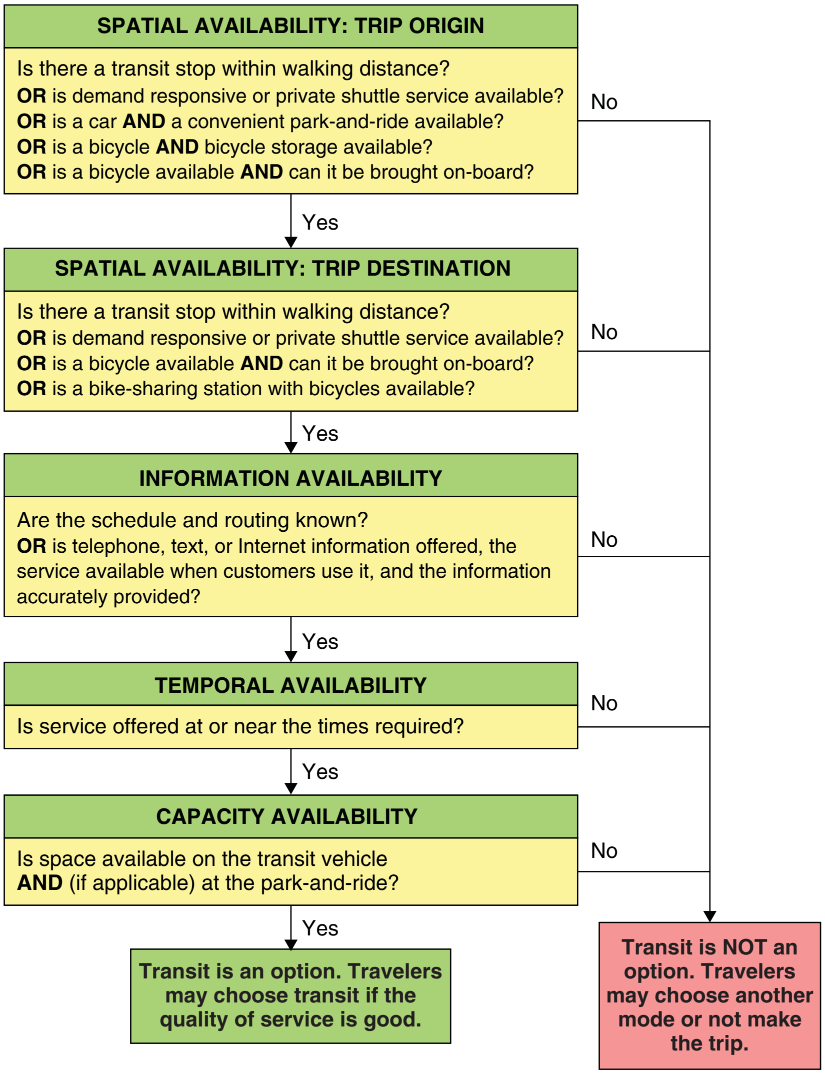
Table 19-18. Relative Weights of Transit Amenities According to Riders

Amenity	In-vehicle Travel Time Equivalent (mins)
Shelter with roof and end panel	1.3
Basic shelter	1.1
Lighting	0.7
Molded seats	0.8
Flip seats	0.5
Bench	0.2
Dirty bus stop	−2.8

Note: Positive values indicate a positive feature

Source: Kittelson et al., 2013b, Reproduced with permission of the Transportation Research Board.

Figure 19-7. Transit Availability Factors



Source: Kittelson et al., 2013b, Reproduced with permission of the Transportation Research Board.

Table 19-19. Average Pedestrian Street Crossing Delay: Signalized Crossings

	Transit Street Crossing Distance							
Lanes	1	2U	2D	3	4U	4D	5	6D
Feet	15	24	28	36	48	54	60	78
Meters	4.6	7.3	8.5	11.0	14.6	16.5	18.3	23.8
Assumed cycle length (s)	60	60	60	90	90	120	140	180
Assumed WALK time (s)	7	7	7	7	7	7	7	9
Delay (s)	20	20	20	35	35	50	59	78
Delay exceeding 30 secs.	0	0	0	5	5	20	29	48

U – undivided D – Divided (with raised median or other pedestrian refuge)

Source: Kittelson et al., 2013b, Reproduced with permission of the Transportation Research Board.

Studies reported in Kittelson et al. [2013b] suggest that most transit riders will walk 0.25 mile (400 m) or less to bus stops, or about five minutes. A 2010 study in Montreal found somewhat longer walking distances; about half of those walking to bus stops walked more than 0.25 mile. For rail stations, one can assume a reasonable walking distance is about 0.5 miles (800 m), although this will vary from one locale to another. As suggested by Table 19-18, an unsafe or poorly maintained pedestrian environment, no matter how close to the stop, will discourage transit ridership.

In addition, those wishing to encourage bicycle transportation should examine ways of incorporating bicycles into transit services. Many bicyclists want to bring their bicycle with them on board transit vehicles (in 2011, about 74 percent of new U.S. buses were equipped with exterior bicycle racks, up from 32 percent in 2001). Bicycle racks allow bicyclists to transfer to a bus and use transit to access a site some distance away. Alternatives to bringing bikes on board transit vehicles include providing bicycle storage at the boarding stop and bike-sharing programs.

2. Off-Site Transit Corridor Performance Characteristics

The TCQSM provides detailed explanations of how transit capacity and service performance can be analyzed. In addition, readers are referred to chapter 12 on transit planning for a similar discussion. The key concepts in the TQCSM as they relate to corridor transit performance include:

- Transit capacity is defined by how many people and buses can move past a given location during a given time period under specified operating conditions; without unreasonable delay, hazard or restriction; and with reasonable certainty.
- Capacity can be determined for both buses and persons, and it can be determined both as a maximum capacity, maximizing throughput without regard for reliability or operational issues, and as a design capacity, the number of buses or persons that can be served at a desired quality of service.
- Vehicle speed represents how quickly people and buses can move from one location to another.
- Reliability deals with how well the transit schedule is adhered to.
- Bus transit corridor capacity is constrained by the ability of bus stops and facilities to serve buses and their passengers, the number and type of buses operated, and the distribution of passenger demand.
- Dwell time, the amount of time a bus stays at a stop to allow riders to board and disembark, can vary significantly from one bus to the next. This is due to variations in passenger demand among the routes serving a given stop, variations in demand from one trip to the next on a given route, and variations in the time required to serve a given number of passengers getting on and off the vehicle.
- Potential sources of time variation include: passengers with mobility challenges, individuals with baby strollers or other large conveyances, people with luggage, and so on. Such individuals take significantly longer to board and alight than the average passenger. In saturation conditions, passenger standing loads on some arriving buses could result in longer passenger boarding and alighting times. Passengers loading and unloading bicycles from bus-mounted bicycle racks; passenger questions to the bus driver; and fare payment issues (for example, defective fare media, passengers looking for change or fare cards in their pockets) can each cause service delays.
- The capacity of a corridor bus route is determined by the capacity of the critical stop along the facility. The critical stop will be the bus stop used by all buses that has the lowest capacity.
- As more vehicle loading areas are added to a bus stop, the greater the likelihood that one or more loading areas will be blocked or will block other loading areas. Therefore, the extra capacity provided by another loading area drops with each additional loading area added to the stop.
- When right turns are allowed from the curb lane, queues of cars waiting to turn right may block bus access to a near-side stop. Queues of cars may also block bus access to a far-side stop, but if another lane is available and traffic permits, buses may be able to change lanes to move around the queue. Or "queue jump lanes" can be constructed to allow buses to bypass the congested location. To the extent that buses are blocked, however, some of the traffic signal green time that would otherwise be available for bus movement into the bus stop is made unavailable, reducing the overall stop capacity.
- Bus stop location influences bus speeds and capacity, particularly when other vehicles can make right turns from the curb lane (which is typical, except for certain kinds of exclusive bus lanes and at intersections with one-way streets where right turns are prohibited). Far-side stops have the least negative impact on speed and

capacity (as long as buses are able to avoid right-turn queues on the approach to the intersection), followed by mid-block stops, and near-side stops.

- A traffic signal located in the vicinity of a bus stop and its loading areas will serve to meter the number of buses that can enter or exit the stop. For example, at a far-side stop (or a midblock stop downstream from a traffic signal), buses can only enter the stop during the portion of the hour when the signal is green for the street that the stop is located on. The lower the green time provided to the street, the lower the capacity, and the longer a bus is likely to wait for the traffic signal to turn green again.
- Similarly, at a near-side stop, a bus may finish loading passengers but have to wait for the signal to turn green before leaving the stop. As a result, the bus occupies the stop longer than if it would have if it could have left immediately, and capacity is lower as a result. Due to the nature of bus operations, shorter traffic signal cycle lengths offer more opportunities for buses to move through a given signal during the course of an hour. In comparison, at unsignalized locations well away from the influence of upstream traffic signals, buses can enter and exit stops immediately, subject to traffic.
- The benefits of providing traffic signal preemption strategies, that is, allowing buses to get a green light upon arrival depends on a complex set of interdependent variables, including whether the signal system along the route was already optimized before application. Documented travel time savings from traffic signal applications in North America and Europe have ranged from 2 percent to 18 percent, depending on the length of route, traffic conditions, bus operations, and the strategy deployed. Travel time savings of 8 percent to 12 percent have been typical. The reduction in bus delay at signals has ranged from 15 percent to 80 percent. [Kittelson et al., 2013c]

The concept of level of service is used in transit planning in two ways. First, transit can be included in the multimodal level of service. If done, Table 19-20 shows the types of factors that can be included in the analysis.

Table 19-20. Transit Factors Included in the Multimodal Level of Service Measure

Item	Potential Sources
Transit Operations Data	
Frequency	• Timetables
Average excess wait time (mins)	• Archived Automatic Vehicle Location (AVL) data, field data
Average passenger load factor	• Archived AVL data, field data, transit agency vehicle data
Average transit travel speed (mph)	• Timetables, HCM methods, TRB Quality Manual, field data
Average passenger trip length (miles)	• Default, National Transit Database (NTD), field data for NTD, archived automatic passenger counter (APC)/smart card
Transit Amenity Data	
Percent stops in segment with shelter	• Field data, transit agency infrastructure database
Percent stops in segment with bench	• Field data, transit agency infrastructure database
Pedestrian Environment Data	
Sidewalk width (ft)	• Field data, aerial photos, infrastructure database
Buffer width from sidewalk to street (ft)	• Field data, aerial photos
Presence of continuous barrier	• Field data, aerial photos
Outside lane, shoulder, and bicycle lane widths	• Field data, aerial photos, infrastructure database
Number of through travel lanes in analysis direction (lanes)	• Field data, aerial photos, infrastructure database
Motorized vehicle flow rate (veh/h)	• Traffic counts
Motorized vehicle running speed (mph)	• Field data, HCM methods, simulation

Source: Kittelson et al., 2013b, Reproduced with permission of the Transportation Research Board.

Table 19-21. Passenger Loads and Quality of Service	
Standing Passenger Space	**Passenger Perspective**
>10.8 sq. ft/passenger >1.0 sq. meters/passenger	• Passengers area able to spread out. • Many/all passengers are able to sit, when vehicles provide a relatively high number of seats.
5.4–5.3 sq. feet/passenger 0.5–1.0 sq. meter/passenger	• Comfortable standing load that retains space between passengers.
4.3–5.3 sq. feet/passenger 0.40–0.49 sq. meter/passenger	• Standing load without body contact. • Standees have similar amount of personal space as seated passengers.
3.2–4.2 sq. feet/passenger 0.30–0.39 sq. meter/passenger	• Occasional body contact. • Standees have less space than seated passengers.
2.2–3.1 sq. feet/passenger 0.20–0.29 sq. meter/passenger	• Approaching uncomfortable conditions for North Americans. • Frequent body contact and inconvenience with packages and briefcases.
<2.2 sq. feet/passenger <0.20 sq. meter/passenger	• Crush loading conditions.

Source: Kittelson et al., 2013b, Reproduced with permission of the Transportation Research Board.

The second measure is illustrated in Table 19-21, which represents a quality of service metric, in this case, the level of comfort for those riding the transit vehicles. Several other measures similar to this are found in the TCQSM.

The analysis of transit service as part of a site impact analysis needs to balance the desire to serve new riders at the development site with the potential impacts on corridor service. In almost all cases, the transit agency will make changes to its service to provide transit access to the site, with possible contributions from the developer.

D. Network/Capacity Analysis

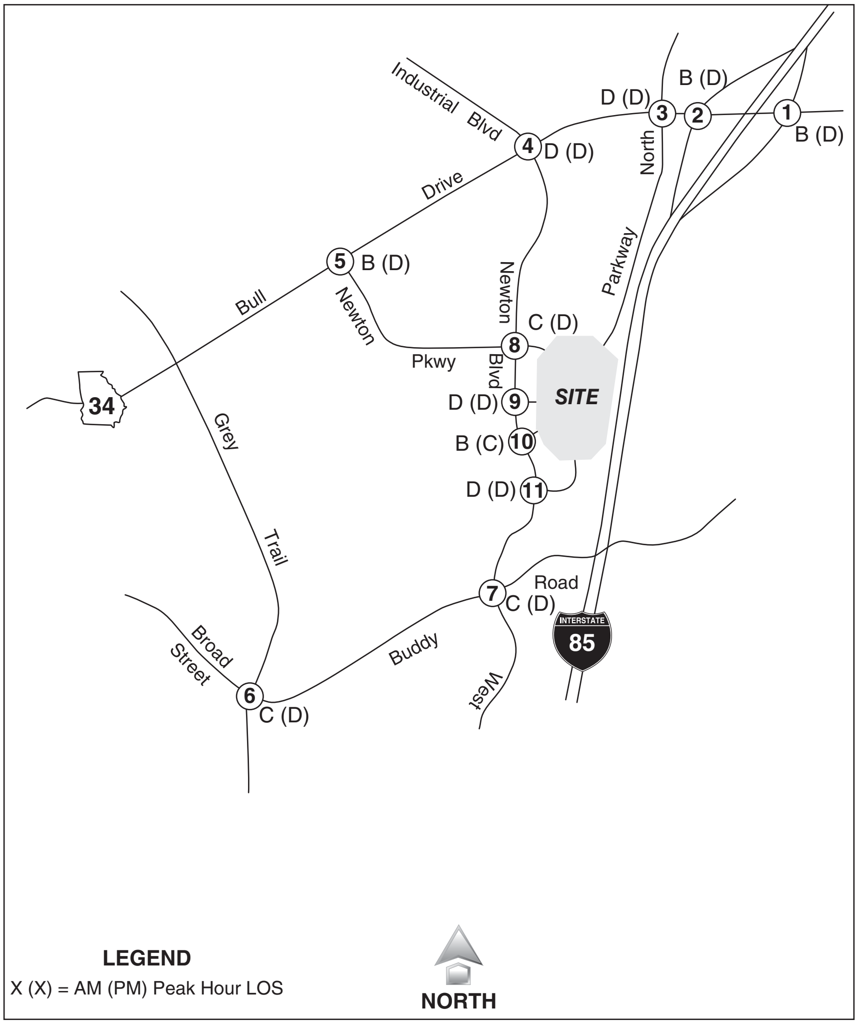
For major developments, in particular, projects will often have off-site road network impacts. These road segments and intersections would have been identified earlier in the process when the study area boundaries were established. For example, as per the development of regional impact (DRI) guidelines from the Georgia Regional Transportation Authority (GRTA), the study network, at a minimum, is to include all access points and/or all accesses on major roads and extend in each direction to the nearest intersection with a major roadway. [GRTA, 2013] All intersections between the development site and these endpoints will be included in the study network.

To determine if additional intersections are required, GRTA recommends a travel demand model be used to assign project-related trips to the network and then compare project traffic assignments to the adjusted two-way generalized roadway service volumes at the appropriate level of service standard. Where the gross number of trips generated by a proposed development exceeds 7 percent of the two-way, daily service volumes at the appropriate level of service standard, the segment will be included in the study network. All signalized intersections and any major unsignalized intersections, which are located within or at either end of roadway segments, are to be included in the study network as well.

Figure 19-8 illustrates how intersections and road segments far from the development site itself might be affected by development-generated traffic.

Once the affected locations have been identified and the traffic volumes assigned, the planner can use any of the tools mentioned above from the Washington State DOT and many others to analyze the impacts of the development traffic. The results of all the analyses discussed above are then summarized and used as the basis for identifying mitigation strategies and other actions that will reduce the impact of the development on the transportation system.

Figure 19-8. Illustration of Network Impacts of Development-Generated Traffic



Source: ITE, 2010

VII. ON-SITE TRANSPORTATION ELEMENTS

As part of the site plan review process and subsequent traffic impact studies, the traffic engineer and planner need to be concerned about transportation-related site design considerations. As noted earlier, this would include such things as the location and design of vehicular and pedestrian/bicycle access points and proposed road improvements, the location and adequacy of parking areas, and the design of traffic circulation and control within the site and with adjoining properties.

The location of buildings on a specific site, also known as the building footprint, is an important urban design issue that can affect many different transportation considerations. For example, clustering buildings within a development encourages walk trips among buildings, reduces walking distances to buildings and transit stops, and reduces the visual clutter associated with strip development. These objectives can sometimes be achieved by inverting the building footprints so buildings lie close to intersecting arterial streets, where transit can more easily be provided. Two other important design considerations are discussed below.

A. Internal Circulation

The effective internal circulation of cars, trucks, pedestrians, and bicyclists is one of the key factors in making the development a success. The planning for this circulation begins with the placement of the building footprints and the provision of sidewalks and bicycle paths. Site planning review often examines the proposed locations of the buildings (for example, is the front of the building close to prospective bus stops? Is parking in front or behind the building? Are buildings close enough together to encourage walking among them?). This along with the overall density of the buildings is often the subject of discussions between the developer and the government agency reviewing the plans.

Once the basic pattern of building footprints has been established, the next step is designing an effective circulation system, one that not only connects the buildings but also connects to the local transportation system. Depending on the jurisdiction, the standards for road, sidewalk, and bike path designs will be established by the planning agency (for example, through subdivision regulations) or be approved by the same agency for application on the site. Design standards relate to such things as lane width, acceptable grades, drainage features, buffer distances between lanes and sidewalks, accepted intersection design controls, and the like.

At a minimum, the site plan review process should include:

- Internal circulation designs that allow all vehicular and non-vehicular circulation to occur on-site rather than spilling over onto adjacent streets.
- Entrance and exit locations, required lanes, and required queuing distances.
- Internal roadway circulation systems to carry motor vehicles, bicycles and pedestrians between access points and parking areas, pick-up/drop-off points, and drive through lanes.
- On-site truck service bays, routes, turning points, and roadway access points (that might be separate from the general access points).
- Appropriate building entrance locations, major parking areas, and pedestrian and bicycle routes.
- On-site landscaping and utility risers to minimize sight distance obstructions. [ITE, 2010]

1. Access Points

One of the most important concerns for those reviewing site plans will be the location and design of the site's access points. It is at these locations where much of the impact on the operations, safety, and efficiency of the local road network will occur. The design of the access points should be based on accepted design standards that reflect such things as the angle of entry (conducive to safe and efficient entry and exit from the site); width (to allow all types of vehicles to operate safely); sight distance (provide for safe operations given local road side conditions); driveway spacing (far enough apart to provide efficient and safe access and exit to local roads); and landscaping elements, utilities, and accessible parking stall space requirements.

ITE [2010] provides the following guidance on access locations:

- Adequate spacing should be maintained from adjacent street and driveway intersections in order to minimize driveway blockage by queues.
- If signalized, the access point should be located to facilitate traffic signal progression past the site.
- Driveways should intercept traffic approaching the site as efficiently as possible.
- Adequate inbound and outbound capacity must be provided in proportion to the distribution of site traffic. A capacity analysis, gap check, or lane adequacy check should be conducted for each access location.
- Two-day driveways should intersect local streets generally at 75- to 90-degree angles.
- The capacity of on-site intersections should be sufficient to prevent traffic backing up onto adjacent streets.
- Traffic safety should be a prime consideration in all access point designs, with special emphasis given to sight distance and stopping sight distance.

2. Complete Streets

Several cities have adopted standards that reflect a Complete Streets or context sensitive solutions (CSS) philosophy toward design (see chapter 9 on road and highway planning). Such an approach recognizes the need to plan and design for all users of the street, and usually adopts a road classification scheme that is different from the traditional functional

Figure 19-9. Differing Desires on Road Design Characteristics, Charlotte, North Carolina

		Pedestrians	Cyclists	Motorists	Transit*	Neighbors
Motorists Want Reduced Delays/Increased Capacity						
The following elements can increase a street's capacity and/or potentially reduce motorists' delay:						
More Travel Lanes	Each additional travel lane increases the street's capacity, especially at intersections; the mix of through and turn lanes can, up to a point, allow an intersection to process more traffic	Negative Impact	Mixed Impact	Positive Impact	Positive Impact	Mixed Impact
Design Consistency	By providing a consistent design (number of travel lanes, e.g.,), motorists don't have to unexpectedly stop or merge; however, this may be difficult to achieve	Mixed Impact	Mixed Impact	Positive Impact	Mixed Impact	Negative Impact
Grade-Separated Intersections	Allows uninterrupted flow; particularly useful for high volume intersections, but destroys urban context for other users	Negative Impact	Mixed Impact	Positive Impact	Mixed Impact	Negative Impact
Unsignalized Intersections	May mean less delay for the higher-volume leg, but more delay for the lower-volume leg; in general, fewer signals means less delay on thoroughfares, but may also mean less connectivity	Mixed Impact	Mixed Impact	Mixed Impact	Positive Impact	Mixed Impact

◆ - Positive Impact ◆ - Negative Impact ◆ - Mixed Impact or Use with Caution ◇ - Neutral

Source: Charlotte Department of Transportation, 2007

classification based on a road hierarchy (see chapter 2 on data analysis). For example, Charlotte, North Carolina, has adopted urban street design guidelines for both public roads and roads/streets that are to be built in large development sites. [Charlotte Department of Transportation, 2007] The design guide is based on five street types: main streets, avenues, boulevards, parkways, and local streets. Figure 19-9 shows the basis for this Complete Streets approach to designing roads in that it recognizes road users often have very different perspectives on what is desirable. The design guide has many more figures like this for all of the characteristics desired by five major participants—pedestrians, cyclists, motorists, transit riders, and neighbors.

Using local streets as an example, the design guide notes there is more than one cross-section option available: a "narrow" cross section and a "wide" cross section, both of which have traffic volumes and speeds that are relatively low. The context for this type of road is a land use that is more commercial or a mixed-use type of environment, having limited off-street parking nearby, where short-term visitors are likely, and thus there could be a high demand for on-street parking. This might not be the case for an office park environment where surface parking is offered off-street.

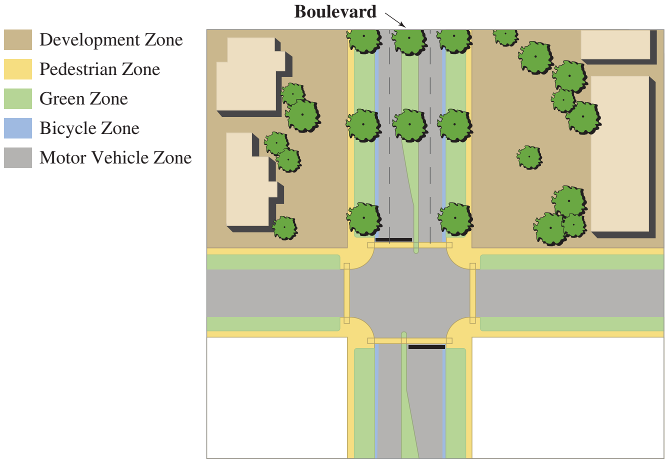
The design guide illustrates different intersection designs based on the desired characteristics of different entering road types. Figure 19-10, for example, shows the intersection characteristics for a boulevard-type road intersecting with other road types, and the desired characteristics relating to development, pedestrians, landscaping, bicycles, and traffic movement. These design concepts are accompanied by a desired level of service for possible combinations of street types and for different road users (see Table 19-22).

Other design guides similar to Charlotte's include: [Boston Transportation Department, 2014; City of New York, 2013; Maricopa Association of Governments (MAG), 2011; National Association of City Transportation Officials (NACTO), undated]. See chapter 9 for more discussion on Complete Streets.

B. Parking Management

The provision of parking is one of the most important decisions that a developer makes and the public review agency reviews. Many critiques of parking supply, especially in the suburbs, have concluded that "free" parking has had a significant effect on the predominance of the single-occupant vehicle for work trips. Many administrative guidelines for site plan review and for traffic impact studies point to parking as one of the key components for the review. As an

Figure 19-10. Example Site Intersection Design Characteristics, Charlotte, North Carolina



Boulevard Intersections
Diagram reflects possible scenarios and intersection may vary slightly in design.
For specific information refer to the guideline on Table 4.3

Boulevards

Development Zone:	Land uses and design will vary, but setbacks will likely be deeper than on Avenues and frontage will not always be directly onto the street; in all cases, good physical connections to the street are still important.
Pedestrian Zone:	Although the balance shifts away from a pedestrian orientation, pedestrians need to be able to travel safely along the Boulevard. This zone should always include sidewalks of adequate width for the adjacent and surrounding land uses.
Green Zone:	Higher speeds and volumes on Boulevards require significant attention to this zone. To serve the important buffer function between pedestrians and vehicles, as well as enhancing the street for other users, this zone should include grass, landscaping, and shade trees in spacious planting strips and medians. Where a parking zone on a parallel access street is used, the Green Zone should also extend to the area between the parking and the pedestrain zones (back of sidewalk).
Parking Zone:	Given the emphasis on traffic flow and development characteristics, this zone should generally be removed from the main vehicle zone; it should either be nonexistent or placed on an access street.
Exclusive Bicycle Zone:	Given the higher speeds and volumes on Boulevards, this zone should get strong consideration for treatment to increase cyclists' safety. Cyclists are generally not comfortable in mixed traffic on these types of streets.
Motor Vehicle Zone:	A very important zone since the Boulevard shifts more toward an auto-orientation; the number of travel lanes will vary by capacity needs, although the impact to other users should be considered in that decision.

Source: Charlotte Department of Transportation, 2007

example, the city of Alexandria, Virginia, has included the following language in its site impact analysis guidelines. The city will look for:

- Measures to reduce the reliance on single-occupancy vehicles by employees and others who will travel to and from the proposed use which may include parking fee structures tailored to discourage single-occupancy vehicles, proscription of tenant-employer subsidy of parking costs for single-occupancy vehicles, time and other access restrictions to parking spaces in on-site parking facilities, and programs to support and encourage the utilization of alternative transportation modes.
- Use and accessory use design options, which reduce reliance on single-occupancy vehicles by employees and others who will travel to and from the proposed site, such as the provision of less parking area than that

Table 19-22. Desired Level of Service for Different Intersection Combinations, Charlotte, North Carolina				
Element	**Main Street Approach to Blvd/ Main Intersection**	**Avenue Approach to Blvd/Avenue Intersection**	**Blvd/Blvd Intersection or Blvd. Approach to Other Intersection Types**	**Parkway Approach to Blvd/Parkway Intersections**
Level of Service (LOS)				
Pedestrian	LOS B for the entire Blvd/Main intersection	LOS B for the entire Blvd/Avenue intersection	LOS C for the entire Blvd/Blvd intersection	LOS D for the entire Blvd/Parkway intersection
Bicycle	LOS B for the entire Blvd/Main intersection, using the average LOS value of only the Blvd approaches	LOS B for the entire Blvd/Avenue intersection	LOS C for the entire Blvd/Blvd intersection	LOS C/D for the entire Blvd/Parkway intersection
Motor Vehicle V/C Threshold	0.95, for two consecutive a.m. or p.m. hours, for the entire Blvd/Main intersection	0.95 for two consecutive a.m. and p.m. hours, for the entire Blvd/Avenue intersection	0.95 for both one a.m. and one p.m. hour, for the entire Blvd/Blvd intersection	0.95 for both one a.m. and p.m. hour, for the entire Blvd/Parkway intersection
Median	Atypical, but allowable under special circumstances	Atypical. When provided, should be a minimum of 6 feet at intersections (8 feet preferred if Avenue approaches have land uses likely to generate heavy pedestrian traffic)	Should be provided with a minimum 6 feet at the intersection; 8 feet minimum at Main Streets and at Avenues if the Avenue approaches have land uses likely to generate pedestrian traffic across the Boulevard.	Yes, preferably 9 feet wide at the intersection; preferably 6 feet minimum (for pedestrian refuge)

Source: Charlotte Department of Transportation, 2007

required under the provisions of this ordinance, shared parking arrangements, the incorporation of residential units (in the case of proposed commercial uses) and other analogous design features.

- Extent to which adjacent neighborhoods may be affected by vehicles associated with the proposed use which park on the public streets, current availability of off-site, off-street parking in the vicinity of the proposed use, and such other design and operational characteristics of the proposed use as the council may determine substantially affect the parking overflow associated with the proposed use. [City of Alexandria, 2013]

Many different strategies have been implemented to manage the supply of parking, ranging from a sharing parking program to variable pricing depending on the time of day and the level of occupancy in the structure or lot. Chapter 11 examines all aspects of parking, including the use of parking strategies as part of a TDM program.

C. Access Management

Key elements of access management include defining allowable access for various types of roadways, establishing spacing of traffic signals and driveway connections, providing a way to grant variances when reasonable access cannot otherwise be provided, and establishing a means of enforcing standards. The degree of access control and management is determined by statute, deed, zoning, and by operational and geometric design standards. Comprehensive statewide access management codes are found in many U.S. states. Access management codes and ordinances specify when, where, and how access can be provided to developments along a roadway. Access classification systems, an integral part of these programs, define the relevant access with spacing guidelines and relate the allowable access to each roadway's purpose, importance, and functional characteristics.

A functional classification system provides the starting point in assigning highways to access categories. Modifying factors include development density, driveway density, and geometric design features, such as the presence or absence of a median. A general framework that relates allowable access to functional roadway classes is based on seven access categories, which include:

1) Full control of access (freeways).
2) Access at public street intersections only (expressways).
3) Right-turn access only.
4) Right and left turns in, and right turns out.
5) Right and left turns in and out with turning lanes.
6) Right and left turns in and out with left-turn lanes optional.
7) Locating and designing access based on safety requirements only.

For each type of access, traffic signal spacing guidelines will often be available from the state or local transportation agency. Additional guidelines are set forth in [Rose et al., 2005; VTrans, 2015; TRB, 2015]. Also, see chapter 3 on land use and urban design, chapter 9 on road and highway planning, and chapter 17 on corridor planning.

The location and design of access points depends on whether there is an active access management program for the surrounding roads. Driveways or connections are an important consideration in reinforcing the functional classification of a roadway. In many instances, this is more important than the spacing of intersections. The circulation plan for a development should coordinate site access with that allowed on surrounding roads, assure safe and efficient access between the site and surrounding roads, distribute traffic to parking areas, and allow convenient pedestrian access between parking places and buildings. If the site has sufficient density and the travel patterns are conducive to public transit, transit services should be provided.

An important access objective is to manage left-turn movements by simplifying intersections where driveways intersect with public highways and internal site roads. Possible strategies include channeling the intersections, installing a median within the driveway, eliminating left turns onto the public highway, and sufficiently separating internal roads from the public highway to reduce conflicts and increase storage distances.

VIII. IMPLEMENTATION ACTIONS/STRATEGIES

A. Applications and Permits

Preparation of applications and access permits is often an important complement to transportation impact studies. Access plans should reflect access spacing and other requirements set forth in access management programs. A permit application procedure usually requires the following information:

1) Access classification of the roadway on which access is requested.
2) Type of access requested relative to the allowable and types of access.
3) Relevant spacing standards.
4) Highway and intersection capacity.
5) Geometric design considerations.
6) Type of proposed traffic control.
7) Need, if required, for any variances to permit criteria.

The procedures should include guidelines for access denial, where alternative access that is better for overall traffic safety and operation is available.

A similar procedure can be followed in determining the type of control for a specific access point. Key considerations include whether the location meets traffic signal warrants and established traffic signal spacing criteria in order to provide efficient arterial roadway signal progression.

B. Transportation Management Associations

The concept of transportation management association (TMA) strategy is important to many communities. TMAs are usually nonprofit groups formed by major employers or developers to provide mobility services to their members. Most existing TMAs are found in areas of high suburban traffic congestion, where there are large activity centers, or in rapidly growing urban office complexes. Typical responsibilities include coordinating a staggered work-hours (or flex-time) program, managing a ridesharing program, managing a shuttle bus system to commuter stations, administering parking management programs, and instituting traffic flow improvement programs.

TMAs generate their revenues through membership dues and individual or voluntary assessments. Some operate their own services, while others contract with professional transportation service consultants. They share a common goal, to improve public mobility, and they provide a forum for cooperative public and private decision-making. See chapter 18 on local and activity center for additional information on TMAs.

C. Transportation Management Plan (TMP)

A TMP is defined as "a site-specific plan of TDM strategies to encourage residents and employees to take public transportation, walk, bike, or share a ride, as opposed to driving alone." [City of Alexandria, 2013] In the city of Alexandria, Virginia, the TMP is required by ordinance through the city's development review process, depending on the size of the development. A TMP is needed for every development exceeding the following thresholds:

- Residential: 20 dwelling units or more.
- Commercial: 10,000 square feet or more.
- Retail: 10,000 square feet or more.
- Hotel: 30 rooms or more.
- Industrial: 30,000 square feet or more.
- Mixed Use: Each use is separately assessed.

Fees are also assigned by development type. For example, for July 1, 2014–June 30, 2015, the standardized city TMP fund rates were:

- Commercial: $0.258 per square foot.
- Residential: $82.418 per dwelling unit.
- Retail: $0.206 per square foot.
- Hotel: $41.209 per room.
- Industrial: $0.103 per square foot.

The funds raised from these fees help pay for the TMP program, including a TMP coordinator. Smaller developments can join a citywide TMP program; medium-sized developments can join the city program or partner with an adjacent TDM program; and larger developments can partner with an adjacent TMP program or create their own.

Importantly, the city requires that annual surveys be done of residents and employees of TMP properties to measure the effectiveness of the transportation strategies carried out by TMP properties. A TMP coordinator is required to spend funds to support the mode share goals stated in the development's TMP. Every TMP includes a combination of program components to mitigate vehicular traffic, including transit subsidies, incentives for carpool/ vanpool/shuttles, car share and bike share memberships, and marketing.

The Alexandria program illustrates an important part of a site mitigation program, that is, following up to make sure required improvements were made and that they are successful.

IX. REPORT ORGANIZATION

The exact table of contents for a site impact statement will vary from one jurisdiction to another and will be found in the administrative rules and regulations for that jurisdiction. As an example, the following outline for a site impact study comes from the Washington State DOT [2014].

Executive Summary

Introduction

- Description of the proposed project with purpose and need.
- "Traffic Impact Analysis Methods and Assumptions" summary.
- Map of project location.
- Site plan, including all access to state highways (site plan, map).
- Circulation network, including all access to state highways (vicinity map).
- Land use and zoning.
- Phasing plan, including proposed dates of project (phase) completion.
- Project sponsor and contact person(s).
- References to other traffic impact studies.
- Other mitigation measures considered.

Traffic Analysis

- Traffic impact analysis methods used.
- Existing and projected conditions of the site: posted speed, traffic counts (to include turning movements), sight distance, channelization, design deviations, pedestrian and bicycle facilities, design vehicle, and traffic controls, including signal phasing and multi-signal progression, where appropriate (exhibit(s)).
- DHV and ADT, project trip generation and distribution map, including references and a detailed description of the process involved in forecasting the projected trips, including tables.
- Project-related transportation mode split, with a detailed description of the process involved in determining transportation mode split.
- Project-generated trip distribution and assignment with a detailed description of the process involved in distributing and assigning the generated traffic, including exhibit(s).
- If intersection control additions are employed and traffic signals are assumed, include functionality and warrant analyses. With roundabouts or signals, include existing conditions, cumulative conditions, and full-build of plan conditions with and without project.
- Safety performance analysis.

Conclusions and Recommendations

- Quantified or qualified LOS, quality of service (QOS), and other appropriate measures of effectiveness of impacted facilities with and without mitigation measures.
- Predicted safety performance with and without mitigation measures.
- Mitigation phasing plan with dates of proposed mitigation measures.

- Defined responsibilities for implementing mitigation measures.
- Cost estimates for mitigation measures and financing plan.

Appendices

- Description of traffic data and how data was collected and manipulated.
- Description of methodologies and assumptions used in analyses.
- Worksheets used in analyses; for example, signal warrants, LOS, QOS, and traffic count information.
- If microsimulation is used, provide a copy of the Confidence and Calibration Report.

An example of a site impact review outline for different development sizes is shown in Table 19-23. This proposed table of contents comes from Alexandria, Virginia, where a great deal of emphasis is placed on mitigating expected traffic impacts through TDM programs.

X. SUMMARY

Site planning for new development is a process used throughout the United States and in many other countries. An important tool in gauging the impacts of this new development is the use of traffic impact studies. The impacts of this new development on the local transportation system and on surrounding communities are of interest not only to transportation agencies, but also to a range of public groups and stakeholders. Site planning and impact studies are designed to give a community the opportunity to examine what is being proposed and to understand the mitigation strategies that are going to be applied. In many ways, site planning and traffic impact analysis are similar to other transportation planning processes. They start with the identification of goals, objectives, and performance measures; and use models and tools to determine trip generation, trip distribution, mode split, and trip assignment. They are also similar to other transportation planning processes in defining or recommending a set of improvements. However, the boundaries of the study area are much smaller than other planning efforts, and the involvement of the local community is often much greater.

This chapter described the major steps in site planning and traffic impact analyses as they relate to transportation. It also discussed the different types of mitigation strategies that can be considered, both on- and off-site. These strategies include both physical engineering changes (such as to a new road access) and actions to encourage non-automobile access to the site.

The transportation system serving a proposed development site should provide the facilities and services that permit safe and efficient travel by various means of travel. Site plan review and traffic impact analysis both emphasize the importance of assessing transportation access and site impacts when examining the potential effects of new development. State and local transportation and planning agencies have established administrative guidelines that direct the type of information that is to be produced as part of the planning process. These guidelines vary across the United States and other countries, depending on the primary issues of concern. All guidelines include some element of road performance, for example, volume-to-capacity ratios, vehicle delay, levels of service, vehicle miles traveled, and road safety. Respective analyses need to be performed on approaches to key roadways, internal roads and impacts on adjacent developments. Transit, pedestrian and bicyclist service levels should also be computed and assessments performed.

Analyses should focus on the following scenarios, at a minimum: (1) existing conditions—base year, (2) future conditions with build-out (site development), and (3) future conditions with site development and proposed access improvements. Depending on the size of the development and the proposed phasing of implementation, intermediate horizon years might be analyzed as well. Many jurisdictions also require future background conditions without the site development, in order to provide a basis for background improvements needed before project traffic volumes are considered.

The extent and level of detail in a site impact analysis will depend on the size and type of development. Roadway analyses should be done for each key intersection along approach and boundary roads, including site access points. Experience has shown that access points usually can be designed to accommodate anticipated demands. However, more critical conditions may arise at public road intersections in the site environs as a result of heavy turning movements, multi-phase traffic signals and the inability to add more travel lanes.

Table 19-23. Example of a Site Impact Report Contents, Alexandria, Virginia			
	Development Size		
	Small	**Medium**	**Large**
Introduction			
Project Description	X	X	X
Project Study Area	X	X	X
Methodology	X	X	X
Existing Conditions			
Existing Transit Facilities	X	X	X
Existing Bicycling and Pedestrian Mobility	X	X	X
Existing Roadway Network	X	X	X
Existing Traffic Volumes	X	X	X
Existing Capacity Analysis	X	X	X
Future Conditions Without Development			
Planned Background Improvements	X	X	X
Future Transit Facilities		X	X
Future Bicycling and Pedestrian Mobility		X	X
Future Roadway Network	X	X	X
Future without Development Traffic Volumes	X	X	X
Future without Development Capacity Analysis	X	X	X
Future Conditions With Development			
Site Access	X	X	X
Site Trip Generation	X	X	X
Site Trip Distribution	X	X	X
Future with Development Traffic Volumes	X	X	X
Future with Development Capacity Analysis	X	X	X
Multimodal Mitigation Summary			
Parking Demand Analysis		X	X
Overview		X	X
Parking Supply		X	X
Parking Demands		X	X
Parking Summary		X	X
Shared Parking-Existing Occupancy		X	X
Shared Parking-Future Peak Demand by Land Use		X	X
Transportation Management Plan			
Conclusion			

Source: City of Alexandria, 2013

The analyses should address questions such as:

- How well does the existing transportation system work?
- What roadway, transit, and pedestrian improvements are necessary to serve the development?
- How well will the transport system work with proposed improvements? What are their service levels?
- Can people reach the development conveniently and safely?
- Are the roadways, access drives, and site circulation system clear and easy to use?
- Are sight distances adequate?
- Are there sufficient gaps in roadway traffic to let vehicles and pedestrians cross roadways safely?
- Is transit service available, and does it enter the development site?
- Are stops conveniently located near major trip generators?
- Do stops and stations provide sufficient amenities for passengers? Can they handle the peak demands?
- Is transit service frequent, and does it reach places that passengers want to reach?
- Are major transit stops conveniently connected to major developments?
- Can pedestrians safely and conveniently reach the development from surrounding areas?
- Are pedestrian crossings protected by traffic control signals?
- Do median islands provide adequate pedestrian refuge?
- Are the parking areas conveniently placed in relation to access points and major buildings?
- Are walking distances from parking areas to buildings and between buildings as short as possible?
- Are there enough parking spaces to meet anticipated needs?
- Are there suitable provisions for service and delivery vehicle access?
- Are neighborhood impacts minimized?
- What are the visual and urban design implications of proposed improvements?

The types of mitigation strategies proposed for a site will include, at a minimum, physical changes to the road network. Increasingly, mitigation strategies also include transit, pedestrian, bicyclist, and transportation demand management actions. Many jurisdictions have adopted access management policies that guide how access to the road network will occur. Any site access designed through the site planning process will need to be consistent with these policies.

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Rural Community and Tribal Nation Planning[1]

I. INTRODUCTION

Rural and tribal nation communities constitute a large portion of the U.S. and Canadian population, as well as a significant portion of the land area of both countries. According to the 2010 U.S. Census, just over 59.5 million people, or 19.3 percent of the U.S. population, lived in rural areas (this was down from 21.0 percent in 2000). The U.S. population also included just over 5 million Native Americans, representing 2 percent of the population. [Bureau of Census, 2015] From a geographic perspective, approximately 56.2 million acres of land are held in trust by the United States for various tribal nations, whereas just over 97 percent of the U.S. land mass is considered rural (or more appropriately, nonmetropolitan).

According to the 2011 Census, more than 6.3 million Canadians were living in rural areas, defined as areas with fewer than 1,000 inhabitants and a population density below 1,000 people per square mile (400 people per square kilometer). The proportion of Canadians who live in rural areas has been dropping and in 2011 was 18.9 percent. Aboriginal people (First Nations, Metis, and Inuit) in Canada make up 4.3 percent of the population. The Assembly of First Nations identifies 634 First Nations communities in Canada. [AFN, 2015]

Even though transportation planning for rural communities and tribal nations occurs within the same regulatory environments as those for more urban jurisdictions (that is, federal laws relating to the planning process), the types of transportation-related issues are different as are the level of resources available for addressing the problems. This results in a number of challenges, including insufficient staffing levels, inadequate funding, and the need for technical tools related to the problems of nonmetropolitan areas. Assessment objectives are often different than those found in urban areas, and are usually more subjective. Rural and tribal nation planners also often face a public and political environment where planning is neither readily understood nor accepted. However, transportation planning for these areas is crucial to their long-term viability, and particularly in the case of transit there may be opportunities to develop unique partnerships and service models that may not be possible in larger centers. In addition, many communities are also actively engaged in developing their economic base and resilience and seek transportation improvements to help foster this.

Although there are differences between urban transportation planning and that for rural and tribal communities, transportation planning for rural and tribal nations are, in many ways, also similar. Both areas often experience inadequate accessibility to economic opportunities and health-care facilities, poor conditions of road infrastructure or roads with poor geometric designs, lack of alternative means of transportation, use of atypical modes of transportation such as farm vehicles and horses, and, in some cases, a peaking of travel demands due to tourism. In addition, where rural communities and tribal nations border larger metropolitan areas, both can face increasing development pressures as growth spreads out from the metropolitan center. This can lead to competing demands and objectives within these communities as some want to take advantage of development opportunities, while others want to preserve their way of life. The main difference between rural and tribal nation transportation planning is that tribes have sovereign nation status, which makes the institutional structure for accepted planning principles and decision making much more complex.

The organization of this chapter reflects both the differences and similarities between rural and tribal nation transportation planning. Both are discussed in separate sections, with each describing the characteristics of the planning

[1] The original chapter in Volume 3 of this handbook was written by Jerry B. Schutz, President, Balanced Transportation Concepts. Changes made to this updated chapter are solely the responsibility of the editor.

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process that are specific to the rural or tribal nation context. However, each section also follows the conceptual framework for planning presented in chapter 1. Thus, each section describes approaches for (1) understanding the problem, (2) identifying a vision, goals, objectives and performance measures, (3) analyzing data that leads to identification of alternatives, and (4) evaluating alternatives, leading to plan recommendations. Each section also describes the public involvement environment for the transportation planning process that presents both opportunities and challenges.

II. RURAL TRANSPORTATION PLANNING

A. Context

Rural communities can be defined in many different ways. In some cases, the term is used to denote a small city, town or village that is outside of a metropolitan area, while in others it represents areas of a state defined as "rural' by the U.S. Bureau of Census. For example, many states have formed rural planning organizations (RPOs) usually consisting of several rural counties with responsibilities for planning transportation, economic development, human resource and social services. In some cases, rural transportation planning organizations (RTPOs) have been created to focus exclusively on transportation issues. No attempt is made here to place a population threshold on what constitutes a rural community. While small community planning differs from rural planning in many ways, there are still many similarities. This chapter uses the term *rural* to denote areas that are apart and distinct from larger metropolitan areas. For the sake of simplicity, this chapter will use the term *local agencies* to mean towns, cities, counties and townships, unless otherwise deemed necessary.

One of the few reports that deals with rural community planning, *Rural Communities, Legacy and Change*, divides local governments into three geographically based categories. [Flora et al., 2008] Strong county governments are found in the western and southern regions of the United States, and they are also common in Canada. They often supply services for small communities (many of which are not incorporated), and in some ways they act as regional governments. The counties and municipalities of the Great Plains states and Canadian provinces often supply similar services, but do not have as many functions as those found in the south and the west of the United States. Townships, which are found in the northeast, are the strongest local governments. Counties in this region of the United States do not have nearly the responsibilities counties in other parts of the country.

This categorization does not account for the importance of metropolitan planning organizations (MPOs) and regional planning organizations (RPOs) where they exist. An MPO is an organization in the United States designated by the governor of a state for urbanized areas with populations greater than 50,000 to act as a forum for transportation planning. An RPO is a generic term for a state-enabled organization that coordinates the planning activities for its jurisdiction and often acts as a recipient for federal and state funds. RPOs provide planning resources to local communities and periodically develop regional transportation plans for a region's capital investment strategy. Where rural areas are included within MPO boundaries, the MPO could be an important planning resource for rural communities. As noted earlier, RTPOs have been formed in many states to focus on rural transportation planning.

Rural Communities, Legacy and Change discusses the many aspects of population mix and demographic change influencing how a rural community views transportation problems. These population characteristics vary by area of the country and between jurisdictions, but one characteristic, in particular, is becoming increasingly important. Most small rural communities are made up primarily of two groups of residents and business owners—those who were born there or in similar environments and those who have moved into the community from an urban area. The latter group can be further divided into three subgroups—those who moved recently and work in the community, those who moved recently and commute to a nearby urban area, and those who relocated to the community some time ago and understand and appreciate the values of those who were born there.

In general, these groups have distinctly different values and will interact with the planner in entirely different ways. Residents who have lived in the community all their lives will more likely consider change to be extensions of past practice and thus will expect solutions to transportation problems to be as they were in the past. This group will want input into decision making and then generally accept the decision if they think it is fair.

The second group will begin with, "I moved here to get away from traffic congestion, air pollution (and other things), and I don't want to see it happen here." This group does not necessarily see change as being simply a continuation of the past; instead they often seek changes, such as land-use restrictions, to prevent unwanted growth (unwanted by them). This group is also a leading voice for increased investment in multimodal solutions to traffic problems. A major concern of this group is the construction of multilane highways, which to them equates to destroying the community character by encouraging more growth. This can set up conflict with the first group, especially landowners, who often plan to subdivide their land and sell it when they are ready to retire or pass it on to their children. Members of this second group may still be working in a nearby urban area and contribute to congestion on the local roads.

The third group is made up of individuals who have lived in the community long enough to appreciate local values, but also understand the significant challenges facing a community associated with growth.

Just as with large urban areas, rural communities have their own identity, resulting in different and often competing transportation needs. Rural economies can be agriculture-based, resource-based (timber and mining), tourist-based, or some combination. The nature of the local economy and the vision of its residents for the future lead to a set of transportation infrastructure and service needs that are tailored to that particular community.

B. Legislative Requirements

As with urban transportation planning, rural transportation planning is often guided by federal transportation legislation. Legislation and ensuing regulations provide direction to rural, metropolitan planning organization (MPO) and state transportation agency planners, and indirectly to local agency planners, whether in metropolitan planning areas or not. An important part of federal legislation affecting statewide transportation planning as it relates to rural areas and small communities is the requirement for consultation during the plan and program development processes. As per federal legislation, "With respect to nonmetropolitan areas, the statewide transportation plan shall be developed in consultation with affected nonmetropolitan officials with responsibility for transportation. The long-range transportation plan shall be developed, as appropriate, in consultation with state, Tribal and local agencies responsible for land use management, natural resources, environmental protection, conservation and historic preservation." [Federal Highway Administration, http://www.fhwa.dot.gov/planning/processes/rural/resources]

States and provinces might also have transportation planning requirements over and above those found in federal legislation and rule making. Where regional transportation planning agencies have been created by state legislation, membership can be either voluntary or local governments might be required to be a member. RPOs often provide planning grants to local communities in return for meeting certain planning requirements, often similar to those of MPOs. State departments of transportation (state DOTs) might also offer technical assistance to these organizations, particularly in obtaining data and developing transportation analysis tools.

Local agency planning requirements, over and above those defined by upper levels of government, provide for the development and support of the local transportation system, coordination with land development projects, identification of projects for the capital improvement program and coordination with the state or provincial highway system and other transportation services. These requirements, when not defined by federal, state, or provincial law, are established by the local governing body.

C. The Job of Rural Transportation Planners

Rural transportation planners usually work either alone or as part of a very small staff. In the smallest agencies, the planner may also take on additional duties such as development review, pavement management, or any variety of added responsibilities. Thus, specialization in a particular discipline or area of responsibility is difficult. Although most rural planners have to be familiar with a broad range of topics, they will often bring some specialized knowledge to the job, or develop it to meet the needs of the community. Transportation specializations applicable to rural areas and small communities include traffic operations, transit planning, traffic calming, recreational traffic issues, main street planning, and travel demand management.

If the community is part of an MPO study area, the MPO can become a resource for community planning. The primary products required of a MPO are a long-range transportation plan, a transportation improvement plan (TIP) and a unified planning work program (UPWP) (see chapter 16). MPOs develop a variety of other plans that support or elaborate on their system plans, including sub-regional, corridor, route-specific, modal, access management, travel demand management, nonmotorized, freight, scenic highway, and other types of transportation plans that might include rural areas. Usually, long-range plans provide the overall context for more detailed studies where specific solutions are recommended. To the extent that rural areas fall under an MPO's jurisdiction, the community's plans and projects could be part of a larger vision of what the region's transportation system should look like.

State or provincial DOT planners can also support rural transportation planning efforts, and, in some cases, even undertake a planning study for the community. These planners will usually be concerned with roads on the state highway system, but can also examine local roads or transit services where there is a common interest. One of the primary contributions of many state DOTs to rural planning is their development and support of analysis tools and traffic models that can be used in rural transportation planning. Many rural agencies do not have the resources to support model development, so state DOTs either provide the funds for developing such a tool, or more often develop a standard modeling approach that is used in rural areas throughout the state. Also, because Census units tend to cover much wider areas in smaller communities, information on population density may not be granular enough for decision making anyway.

D. The Rural Transportation Planning Process

The Federal Highway Administration (FHWA) has identified the following success factors for developing a rural transportation plan. A transportation plan should:

- Set the overall transportation direction for the area and define the transportation future/vision.
- Provide a decision-making structure and incorporate a participatory public involvement process to plan and prioritize improvements to the transportation system.
- Build on existing knowledge, resources, and information to conduct a technical analysis including evaluation of current and future conditions, forecasts, and trends.
- Balance multiple and competing stakeholder objectives and funding expectations.
- Identify and provide a long-range funding program.
- Provide a framework to prioritize expenditures based on policy goals and objectives.
- Focus short-range investments on long-term goals.
- Provide accountability to customers on future direction and actions to get there. [FHWA, 2012]

In addition to the preceding—just as with all transportation planning—it is also crucial that rural plans link to future land use and consider an integrated mix of transportation modes.

Although applied at a different scale, the generic planning process described in chapter 1 (see Figure 1-1) is a useful framework for discussing transportation planning for rural areas. The following sections will focus on the major differences in how several of the planning steps found in Figure 1-1 are applied in a rural context. The reader is referred to other chapters in this handbook for a more extensive discussion of the methods and tools of transportation planning.

1. Understanding the Problems

An articulation of the transportation challenges facing a community depends on whether a study is a systems plan or a project plan. Systems planning usually addresses the broader context of providing basic transportation infrastructure and services. Project planning, such as conducted in a corridor plan, occurs in response to specific or perceived problem(s). Increasingly, it has become common practice to use the National Environmental Policy Act (NEPA) purpose and needs statement format to define the problem when the project and/or program will later be subject to NEPA requirements (see chapter 4 on environmental considerations in transportation planning).

As described earlier, rural communities face unique transportation challenges based on a variety of factors such as geography, lack of public transit options, and longer commuting distances. The National Rural Assembly notes, "rural residents tend to have larger proportions of elderly, young, and low-income people, which also create special transportation needs. And rural residents tend to spend a greater proportion of their incomes on transportation expenses." [National Rural Assembly, undated] Transportation problems facing rural communities can be very similar or very different, depending on the context. For example, depending on location, rural communities might experience road congestion due to encroaching development, a large number of crashes on rural roads, or inadequate access to health facilities for those not able to drive.

One of the first steps in rural transportation planning is understanding the types of transportation problems and challenges facing a study area. This can be done through public outreach such as surveys or public meetings, or by analyzing trend data to determine positive or negative aspects of transportation system performance. Table 20-1 from the Southern Alleghenies Rural Planning Organization's (RPO's) *Long Range Transportation Plan* illustrates the factors it considered as part of the "problem understanding" phase of planning. It is interesting to note that the identified trends not only examined transportation system characteristics, but as well many of the socioeconomic factors in the study area that could affect the use of the transportation system.

In some cases, rural transportation studies focus on particular issues, such as transportation for the elderly, low-income households or those not having access to a car. In such cases, the effort to understand the problems facing the study area is much more focused on particular population groups. For example, the Southern Alleghenies Regional Development Commission conducted a study on coordinated public transit–human services in its jurisdiction. [Southern Alleghenies Regional Development Commission, 2008] As noted in the study, the region is geographically diverse with small urban areas separated by large rural spaces. Travel within the region is typically over long distances via the automobile. The commission identified the following challenges in providing low income persons and welfare recipients with transportation to jobs:

- Automobiles are purchased each month for welfare recipients, because no other means of transportation suits the needs of getting them to work and/or training activities, as well as getting children to child-care facilities.
- In counties providing transportation services, there are still welfare clients in outlying areas … who cannot participate in activities due to inadequate transportation. Also, those seeking jobs on second or third shifts are constrained because the county service does not run late at night.
- A shared ride program is rarely used because clients can only use it if the human service vans are booked with other travelers.
- Costs for van services have greatly increased.
- Van service for welfare clients has been provided in one county through a transportation grant. This service has been successful, but costs to provide service are high in some cases, depending on the location of the client.

In sum, the effort to define the transportation challenges facing a study area not only establishes a context for the analysis that follows, but it also helps the public and other stakeholders understand (in plain English) what the planning process is all about.

2. Developing Vision, Goals, Objectives, and Performance Measures

Establishing a vision, goals, and objectives for a planning process is essential in making sure the results of the planning process relate to community desires. These can come from a variety of sources, ranging from small group discussions to surveys. Most importantly, their definition should reflect public input. Another source is federal and state laws, which often specify goals that should be pursued through the planning process, especially if federal or state funds are being used to support the study and the resulting investment program.

As noted in chapter 7, goals are overall broad statements that express the desired future characteristics of a community and its transportation system. Objectives are very specific, measurable, action-oriented statements that help achieve the goals. Performance measures are indicators of transportation system performance that can be monitored over time

Table 20-1. Trends Affecting Transportation, Southern Alleghenies RPO

Trend/Issue	Implication
Demographics	
Trend/Issue	**Implication**
The region has experienced slight population growth over the past 30 years.	Over that time, the region's population has increased 2.8%. This increase, though not significant enough to impact the region's transportation network, does indicate that the region's transportation needs in terms of total population has remained consistent.
The region's population is aging.	An older population will have greater need for public or human services transportation.
Commuting	
Trend/Issue	**Implication**
Over the past 30 years, more workers are driving to work alone.	The region continues to grow more dependent on the automobile as a primary means for transportation. Carpools have decreased in popularity as a means of transportation.
Over the past 30 years, households have begun to have three or more vehicles available.	
A higher percentage of those workers living in boroughs walk to work than do those living in townships.	The need for safe sidewalks, crossings, and walkways within boroughs and local neighborhoods remains important.
The average worker's travel time to work is 27 minutes, while 62% of workers travel less than 25 minutes to work.	Over the past 30 years, worker's travel times to work have increased slightly. The majority of workers living in the region are commuting within the region, although over the past five years, more workers have become employed outside of the region. Those who do not work within the region are likely to work in either Blair or Cambria Counties. However, there has been a growing increase in workers that are traveling further distances for employment.
Since 1990, the percentage of workers commuting 90 minutes or more to work has doubled.	
Most workers living in the region also work in the region.	
Economic	
Trend/Issue	**Implication**
Over the past decade, the region's economy has switched from a manufacturing economy to a services-based economy.	Over the past 10 years employment in the Manufacturing industry has declined, and is projected to continue to do so. The region's economy is transitioning into more of a health and service based economy, which will require different transportation needs.
Employment projections estimate that employment in the Manufacturing industry will continue to decrease while employment in the Health Care and Social Assistance sector will continue to increase.	
The region's average unemployment rate has consistently remained above the statewide average over the past 10 years.	The region's economy has not experienced significant growth over the past decade. The region has experienced a significant increase in unemployment in 2007.
The percentage of persons below the poverty level has increased since 1999.	
Bridges and Roadways	
Trend/Issue	**Implication**
Travel on the region's roadways has been declining since 2005.	Over the last five years, travel in the region has been negatively impacted by increases in unemployment and gasoline prices. As the economy begins to improve, it is expected that travel will also increase again.
The region has a large network of state-owned, local-owned, and other agency-owned roadways to maintain.	6.57% of all state-owned roadways in Pennsylvania are located within the region, along with over 15% of Pennsylvania Turnpike miles and 10% of miles of roadways owned by other agencies (PA DCNR, PA Game Commission, etc.).

Table 20-1. (*Continued*)	
Bridges and Roadways	
Trend/Issue	**Implication**
Half of all linear miles of roadways in the region are local owned roadways.	The region has a large local roadway network that is the responsibility of local municipalities and counties to maintain.
Roadway conditions are best on primary arterial roadways.	Most conditions on primary arterial roadways are considered to be good or excellent. Only about half of all secondary roadways are considered to be in good or excellent condition.
The region has an extensive bridge system that is growing structurally deficient.	The region's bridge needs to reach condition goals by 2033 exceed the current funding levels available. Just over 18% of all state bridges and 41% of local bridges greater than 20 feet in the region are structurally deficient.
Other Modes of Transportation	
Trend/Issue	**Implication**
The region lacks adequate passenger and rail freight opportunities.	Much of the region is underserved by both passenger rail and rail freight. Limited passenger rail service hinders intercity connectivity and strengthens dependence on the automobile. Limited rail freight opportunities impede economic development and goods movement as well as increase congestion on the road network.
Rail freight traffic is increasing.	An increase in rail freight traffic will impact motorist and pedestrian safety at grade crossings throughout the region.
The region is underserved by public transportation.	The rural nature of the region creates challenges for providing public transportation. As the region's population continues to age, the demand for public transportation will continue to grow.

Source: Southern Alleghenies RPO, 2012

to show progress in achieving plan goals. According to the FHWA, the success factors for the development of policy goals and objectives include:

- Roles should be specified in terms of who will be making the policy decisions and whether those roles are advisory or decision making.
- Development of policy goals and objectives should involve local officials and provide for broad stakeholder and modal involvement.
- Goals and objectives should have sufficient specificity to guide plan development.
- Goals and objectives should be tied to action and be meaningful to stakeholders/customers.
- Decisions should be made for timelines and mechanisms for modifying and updating polices.
- It should be determined how local, county, and regional policies coordinate with the statewide plan. [FHWA, undated]

As an example of goals, Clinton County, Pennsylvania, as part of its comprehensive plan, identified very specific goals and associated strategies designed to achieve the goals. [Clinton County, 2014] Located in north central Pennsylvania, Clinton County is a rural county with a population of 40,000. The comprehensive plan goals built upon a set of goals and objectives that had been identified as part of the 2009 comprehensive plan. The transportation goals and strategies included:

Goal: Address the lack of public transportation options by encouraging the development of alternative mobility systems, including transit and bicycle/pedestrian facilities, where appropriate.

- *Strategy*: Develop a public shuttle bus service.
- *Strategy*: Advocate establishment of bus service for special events and specific destinations.
- *Strategy*: Evaluate the need for park and ride facilities in outlying areas.
- *Strategy*: Increase bicycle and pedestrian facilities and connections.

Goal: Improve access for trucks to Western Clinton County to assist with economic development in the area.

- *Strategy:* Work with local officials and SEDA-Council of Governments (SEDA-COG) to identify specific improvements and to have them added to the Pennsylvania DOT (PennDOT) *Twelve Year Program*.

Goal: Encourage the continuation and expansion of rail service in the County.

- *Strategy*: Continue to work closely with the SEDA-COG Joint Rail Authority to identify opportunities for rail service improvements within Clinton County.
- *Strategy*: Monitor operations of Norfolk-Southern and their future plans.
- *Strategy*: Work with existing and potential new businesses to identify rail needs and issues.
- *Strategy*: Work with the Economic Partnership to promote the County's existing rail services as a potential asset for new business development.
- *Strategy*: Explore opportunities for better connection to other transportation modes, including air, road, and transit.
- *Strategy*: Explore the potential for additional leisure excursion trains.

Goal: Make Piper Airport an integral part of the County's transportation and economic development network.

- *Strategy*: Continue to support needed improvements to the airport facilities as identified in the PennDOT *Twelve Year Program*.
- *Strategy*: Improve connectivity with other modes of transportation.
- *Strategy*: Continue efforts to attract additional charter services at the Airport.
- *Strategy*: Market sport pilot licenses and the light-sport aircraft industry.

Goal: Organize to ensure that US 220 is upgraded to I-99 status.

- *Strategy*: Establish strategic alliances with adjacent counties and SEDA-COG to reinstate projects to continue the upgrade US 220 to Interstate standards and completion of I-99.
- *Strategy*: Develop improvements that are coordinated, improve the visual and safety standards of the PA 150 corridor.

These goals emphasized a range of interests for the county, from ensuring a better environment for pedestrians and bicyclists to promoting an upgrade of a state highway to interstate status (for economic development purposes). For rural communities, the focus on economic development goals and mobility/accessibility needs is not uncommon.

Performance measures should reflect the types of goals identified by the study. The following performance measures were adopted by the Southern Alleghenies RPO for its long range plan. [Southern Alleghenies RPO, 2012]

Maintenance/Preservation

- Number/deck area of structurally deficient bridges
- Percentage of poor international roughness index (IRI) of roadway mileage
- Percentage of funds devoted to system preservation

Economic Vitality

- Unemployment rate
- Estimate of new jobs created

Safety

- Number of fatalities or major injury crashes
- Number of roadway safety projects completed

Environmental/Land Use

- Number of municipal access management ordinances
- Number of Greenways-related projects implemented

Accessibility and Mobility

- Public transportation on-demand ridership
- Passenger rail ridership

Bicycle and Pedestrian

- Number of Enhancement Projects

Education

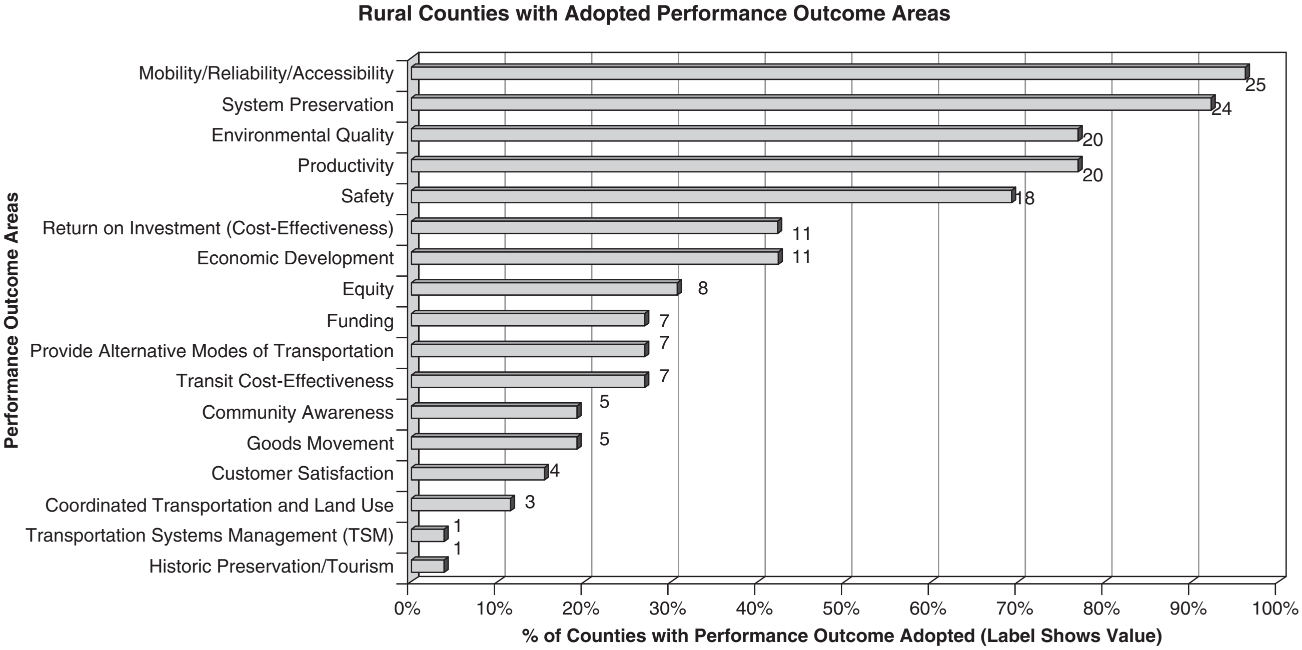
- Number of outreach activities conducted
- RPO newsletter open rate

Maximize Benefits

- Percentage of project let dates on or before projected date

Figure 20-1 shows the range of performance measures that are used by rural county transportation planning agencies in California. [Caltrans, 2006] Unlike major metropolitan areas where numerous system performance measures are fairly common, the types of performance measures often found in rural communities relate to the physical condition of the infrastructure. Thus, for example, pavement and bridge condition measures are used to define the most critical road segments for maintenance or reconstruction. In the context of a transportation plan, however, performance measures should link to and reflect community expectations such as safety, economic development, and accessibility. See chapter 7 for more discussion of goals, objectives, and performance measures.

Figure 20-1. Performance Measures Used in Rural Counties, California



Source: Caltrans, 2006

3. Identifying Needs (through Data Collection) and Analyzing Alternatives

Data collection is an important step in any planning effort. Among the data needs for transportation planning are land-use information, traffic/vehicle and person counts, road geometry data, crash data, traveler preference information, and financial data. Collecting many of these data can be expensive, and many rural communities cannot afford the type of data collection needed for effective transportation planning. Compounding the problem is that data in high-growth areas become outdated quickly.

Data collected on existing systems help identify transportation needs, which then can be analyzed to achieve the most cost-effective program of investments. There are three possible approaches for developing a usable database: (1) using generic data collected from similar communities, (2) applying quick response methodologies that have default values incorporated into the analysis approaches, and (3) pooling resources with other agencies to collect the needed data. One source of generic data for modeling in smaller communities is illustrated by the National Cooperative Highway Research Program (NCHRP) Report 365: *Travel Estimation Techniques for Urban Planning*. [Martin and McGuckin, 1998] This report provides default values for different variables and factors that are used as input in transportation analysis tools.

Caution needs to be exercised when using generic data. Most importantly, the data are usually defined as average values. Averages can hide many of the differences that may be important in a rural context. The usefulness of such data is proportional to the number of samples making up the average value, the relevance of the sample to the study context and the central tendency of the data. A data series that is spread across a wide range will not be useful, whereas a cluster of data points for rural communities within the dataset might be. These types of data should be used only when no other possible source is available or as a check on the validity of local information and on the default values included with model software programs.

For analysis tools, metropolitan transportation planners commonly rely on computer-based travel demand models to forecast future travel demand and then identify corresponding transportation network deficiencies (see chapter 6 for a discussion on the basic steps in travel demand forecasting). Setting up and maintaining a travel demand model is a large investment for a rural community and may not be necessary or relevant to the studies being conducted. In fact, for a community with modest, but steady growth, there is probably little reason to invest in one. Many of the model steps, such as trip generation, trip distribution, mode split and trip assignment, can be done with simple spreadsheets or with manual templates (see, for example, [Perone and Carr 2006; Maciejewski, 2009]). Similarly, in the case of transit planning, manual ridership counts undertaken by drivers and onboard passenger surveys are low cost and simple ways to assess existing service, while community workshops, travel surveys mail dropped to residences (depending on community willingness to participate), and fieldwork to identify community nodes and densities are some basic additional tools to plan for transit to new areas. In other cases, where a rural community is part of a larger study area, such as being within an MPO study boundary, the existing regional travel demand model can be used to analyze travel trends and patterns.

Transportation analysis usually focuses on transportation system performance in at least two target years, the current year and the future build scenario. Additionally, it often includes at least one more, the forecasted year without the proposed transportation investment. One of the biggest obstacles to setting up a model can be getting 20-year land-use forecasts as well as projections for population, employment and travel demands. The 2012 Clay County, North Carolina, *Comprehensive Transportation Plan* illustrates the types of analysis approaches often used in rural communities to forecast these variables. [North Carolina DOT, 2012] The approaches for obtaining population, employment, and traffic volume projections included:

<u>Population</u>

Population trends were estimated using data from the U.S. Census Bureau and data from a survey conducted by the county. Population counts and data were compared between the 2010 and 2000 Census data, and the annual growth rate was assumed to continue over the plan time horizon.

<u>Employment</u>

Future employment conditions within Clay County were obtained from discussions with a steering committee that included representatives from those involved in economic development. This included approximate locations and number of jobs for proposed employment centers.

Future Traffic

Annual Average Daily Traffic (AADT) volumes across the county from 1991 to 2009 were obtained, and growth rates for 1991–2009 and 2000–2009 were analyzed to note any effects of the economy on local growth. Two main methods were used to project this data to 2035. The first method used a linear regression model using all the data from 1991 to 2009. The second method was applying an exponential growth factor to project to 2035. The majority of the projections were made using the linear regression method. In those areas where no growth or a reduction in traffic resulted, the exponential model was used to obtain a conservative estimate.

All of the projections were adopted officially by the respective county boards.

Identifying alternatives is fundamental to transportation analysis. In many cases, the investment alternatives are very straightforward given the problems and eligibility requirements of funding programs. Road improvements and bridge deficiencies can be resolved with a limited number of engineering applications. The more difficult analysis process occurs when decisions focus on major new infrastructure or service provisions. This is where the process of analyzing alternatives becomes important and often more complex.

Depending on preliminary analysis results—and often on public reaction, especially for controversial projects—iterating through different alternatives definitions is now a common step in the planning process. This iteration can result in refined definitions of the alternatives and even produce new alternatives. However, this iterative process can be very lengthy and cause study delay, especially for controversial projects. The best way to avoid such delays is to identify the alternatives using a planning process that is as transparent as possible, provide the community with many opportunities to become involved, and support the process with data-driven analysis.

The discussion so far has assumed that the alternatives being considered are project-specific. Many other types of strategies can be considered as part of a planning study. [Easter Seals, 2006; 2012] For example, access management is one approach to improving road safety and maintaining the ability to handle traffic over time by using road medians, intersection spacing and design, driveway location and design, and control of access to abutting land parcels. Three useful references on access management are the *Access Management Manual* [TRB, 2003], *Guide for the Geometric Design of Driveways* [Gattis et al., 2010] and *A Guidebook for Including Access Management in Planning*. [Rose et al., 2005] The American Association of State Highway and Transportation Officials (AASHTO) manual, *A Policy on Geometric Design of Highways and Streets,* 6th edition, is an industry standard, which incorporates access management techniques throughout. [AASHTO, 2011] Interested readers are also referred to FHWA's website on access management, http://ops.fhwa.dot.gov/access_mgmt/resources.htm.

Intelligent transportation system (ITS) technologies are another emerging transportation strategy for rural communities (see chapter 10 on transportation systems management and operations). FHWA provides helpful information on applying ITS technologies in rural settings on its website. It offers a "rural ITS toolbox," which categorizes the tools into seven areas:

- Emergency services
- Tourism and travel information
- Traffic management
- Rural transit and mobility
- Crash prevention and security
- Operations and maintenance
- Surface transportation and weather

The key step in applying ITS in any community is to develop a *regional architecture* that promotes consistency in applications across the state and community. By determining the types of ITS services needed, the best technology platforms can be identified. To be effective, the development of a regional architecture requires the involvement of

Table 20-2. Linking Transit ITS to Caltrans' Non-Urban and Rural ITS Goals	
Caltrans Goal	**Transit ITS**
Safety Provide the safest transportation system in the nation for users and workers	Transit ITS includes systems such as an on-board security cameras and silent alarms that improve the safety of transit for passengers and drivers. Vehicle tracking allows transit and emergency management to remotely track vehicles and monitor conditions.
Mobility Maximize transportation system performance and accessibility	Transit ITS includes systems to improve fixed-route and demand-response management. They provide transit providers with more accurate information for planning and scheduling, thereby improving on-time performance and increase service.
Delivery Efficiently deliver quality transportation projects and services	Transit ITS can improve efficiency by generating more complete information for planning and scheduling, and by giving rural/non-urban transit providers the ability to respond more quickly to customer needs.
Stewardship Preserve and enhance California's resources and assets	Transit ITS includes many systems, such as real-time transit information, that encourage increased transit ridership, thereby reducing congestion and sing-passenger trips.
Service Promote quality service through an excellent workforce	Transit ITS can provide transit staff with improved tools and more comprehensive data with which to perform their jobs, resulting in a more productive workforce.

Source: Caltrans, 2012

both public and private organizations. Table 20-2, for example, shows how California views the potential role of ITS transit technologies in helping to achieve agency goals in non-urban and rural areas.

Many rural transportation studies also consider potential and innovative transit service as a viable investment alternative. [Ripplinger and Brand-Sargent, 2010] In most cases, transit in rural areas (and for tribal nations) historically have had, and continue to receive, a greater portion of their operating costs funded through federal formula programs, at a higher rate than their urban counterparts (See the 5311c program at http://www.fta.dot.gov/grants/15926_3553.html, and the 5311 program at http://www.fta.dot.gov/documents/MAP-21_Fact_Sheet_-_Formula_Grants_for_Rural_Areas.pdf. Federal grants can also cover a significant portion of capital acquisitions).

Many states have federally supported transit services and human service transportation programs that serve rural communities. In others, private organizations have been established to provide rideshare services. In most cases, the rural transit services are heavily subsidized by government funds, with fare structures covering only a portion of the operating cost in recognition of the fact that transit is ensuring basic access to health and services for citizens over distances that would otherwise be cost-prohibitive to serve. In the case of transit options in rural and tribal nations communities, in addition to collecting ridership, population, and travel pattern data, it also often helpful to collect information on existing transportation assets and community organizations within the area. For instance, some local governments may already own vans or small buses that could potentially form part of a transportation solution, while community service agencies that may already be in place to deliver health and outreach programs may be good candidates to help oversee dispatch or delivery of transit programs.

While financial and technical resources are usually much scarcer than they are in larger centers, rural and tribal communities usually have stronger social connections and a greater willingness to develop creative solutions through partnerships. For instance, the Skeena Regional Transit System in British Columbia operates through a funding partnership and shared services model that includes three First Nations (tribal) communities, two small municipalities, a regional government, a health authority, a private operator, and the provincial transportation agency, BC Transit.

Similarly, British Columbia's Mt. Waddington Transit System is operated by a similar tribal/local government/provincial partnership and is able to leverage much greater service to its area through it operation by the local community service agency. Since the community service agency also delivers services like a Volunteer Transportation Network and a meals-on-wheels program for seniors, it is able to better coordinate transit with these volunteer options. In turn, the transit funding provided to the agency helps ensure the longer term financial sustainability of the volunteer programs.

Transit System	Pop.	Vehs.	Service Hours	Rides per Hour	Cost per Ride	Trips per Day (M-F)	Service Description
100 Mile House	3,300	3	1,988	4.0	$18.94	7 scheduled, dial-a-ride	Systems are mostly self-contained with little or no service in surrounding rural areas; may have limited connection to urban center via Health Connections route.
Ashcroft-Clinton	2.264	2	1,976	1.5	$46.13	3 scheduled, dial-a-ride	
Bella Coola	3,300	2	3,521	5.2	$13.61	6 scheduled, dial-a-ride	
Boundary	3,985	2	1,606	4.4	$15.89	Dial-a-ride	
Kaslo	2,700	1	586	2.9	$36.95	2 scheduled, dial-a-ride	
Princeton	2,724	2	1,976	3.4	$19.92	Dial-a-ride	
Clearwater & area	2,331	3	2,092	3.0	$23.44	6 scheduled, dial-a-ride	Systems provide service between multiple small rural communities within their regions, with no or limited connections to urban centers.
Hazeltons' Regional	2,158	2	2,553	5.7	$14.82	5 scheduled, dial-a-ride	
Mt. Washington	6,513	3	4,285	7.1	$11.65	20 scheduled, limited dial-a-ride	
Nakusp	1,759	1	1,976	3.1	$24.09	2 scheduled, dial-a-ride	
Agassiz-Harrison	5,664	4	5,379	7.3	$9.55	10 connections, deviations	Systems provide daily connections to neighboring urban centers as well as some level of local service within the community.
Okanagan-Similkameen	1,647	1	1,690	5.0	$16.57	4 connections	
Osoyoos	4,845	1	1,454	3.3	$17.68	2 local/connections, dial-a-ride	
Nelson-Slocan Valley	2,800	4	5,792	7.2	$12.59	4 connections	
Pemberton Valley	3,675	2	1,953	13.3	$8.51	7 local, 4 commuter	
Port Edward	544	1	2,063	16.9	$6.84	7 connections	

Table 20-3. Rural Community Transit Statistics, British Columbia ($2014 CAN)

Source: [BC Transit, 2014]

The section under "Paratransit and Specialized Services" in chapter 12 provides a good overview of the many creative transit service types that can be used to serve small community, rural, and tribal public transportation needs. Another key resource is the TRB Transit Cooperative Research Program (TCRP) Report 101: *Toolkit for Rural Community-Coordinated Transportation Services*, as well as other resources described at the end of this chapter. As an example of possibilities and performance, Table 20-3 shows the population, ridership, and service types of all transit systems in British Columbia serving total populations of 7,000 or less.

4. Evaluating and Prioritizing Alternatives

Sufficient funds are seldom available to implement all study recommendations. This is especially true for rural communities. Thus, it is important to establish some means of determining which of the many alternatives being considered provide the most cost-effective investment of limited dollars.

Evaluation Criteria. Evaluation criteria or measures of effectiveness (MOEs) serve as the basis for analyzing alternatives. Evaluation criteria are directly related to the goals and objectives established for the study (see chapter 7 for more discussion and examples of evaluation criteria). Thus, for example, if a study goal is to provide a safe road network, and a corresponding objective is to reduce the number of fatal crashes, then an evaluation criterion for investment alternatives would be the level of crash reduction expected for each alternative. Many different evaluation criteria can be identified for a study, depending on the study's goals. [Amekudzi and Meyer, 2005] A word of caution is warranted, however. In most cases, the more evaluation criteria included in a study, the more data that have to be collected and the more analysis that must be undertaken. In communities where resources are limited, it is important for decision makers, planners, and the public to determine the most critical set of criteria (the type of information that will be produced during the analysis process) that will guide the decision-making process.

Not surprisingly, data availability again becomes a key factor in the usability of evaluation criteria. If data are not available, too costly to obtain, or difficult to forecast into the future, a criterion will not be useful unless sketch planning methods are used (see chapter 6 on travel demand modeling). However, sketch planning methods sacrifice accuracy for efficiency. These methods have more application in systems planning than project planning, where more information should be available and where decisions are being made that will shortly thereafter result in the construction of actual projects.

Safety. Road safety is one the most important issues in rural communities. In most cases, road congestion is not as significant an issue as it is in larger metropolitan areas, except where seasonal tourism overwhelms local streets or where rapid economic development is occurring due to proximity to a metropolitan area. Road crashes in rural communities on two-lane roads are often statistically more serious than crashes in the rest of the state and nation. In 2012, rural areas accounted for 53 percent (16,443) of the fatal crashes and 54 percent (18,170) of the fatalities. [NHTSA, 2014]

Traffic safety analysis is often the purview of transportation engineers, but transportation planning should incorporate safety considerations into recommendations and into planning documents (see [Washington et al., 2006]). Chapter 23 discusses safety and transportation planning in more detail.

Environmental Factors. Transportation planning of all types must consider the impacts of investment on the natural, built, and social environments. Environmental regulations do not differentiate between the resources available to small communities and large ones, so there are no shortcuts available to small communities. Several environmental considerations are often found to be especially important in rural community (and tribal nation) planning. Air quality is a concern that can be regional in nature or site-specific. In recent years, many small communities have been added to the list of air-quality nonattainment areas as a result of additional EPA requirements. Little documented experience exists for small communities dealing with these issues, but that experience is evolving rapidly. An excellent source for obtaining this information is the website for the Transportation Research Board (TRB) Committee on Transportation Planning for Small and Medium-Sized Communities at http://www.trb.org/ADA30/ADA30.aspx.

Water quality, habitat disruption, archaeological and historic resources, community cohesion, and aesthetics are other environmental issues that are often of great concern to transportation studies in rural communities and tribal nations. Potential impacts in each area result not only from the physical construction of a transportation facility but could occur as a secondary impact from economic or community development that follows the new transportation investment. Thus, the evaluation process for sensitive natural and community environments must consider potential indirect and cumulative effects of transportation improvements.

Prioritization. Several transportation analysis software packages score alternatives with respect to overall effectiveness and study goals, but few recommend a best alternative for the decision maker. Even with those that provide a relative comparison among alternatives, the users must still assign scoring weights to the different measures that reflect the level of importance to the ultimate decision.

Chapter 7 provides a more detailed description of evaluation tools and methods. This information will not be repeated here; however, it is important to note that the most appropriate evaluation methods for rural community transportation planning will most likely include cost/benefit analysis and scoring methodologies. The range of alternatives and the number of alternatives to be evaluated are fewer than for large metropolitan areas, where thousands of projects must be considered. Thus, prioritizing projects rural transportation planning is usually more straightforward and easily applied.

Rural transportation planning occurs within the context of statewide planning, and thus a rural transportation plan must be cognizant of relevant state plans and prioritization criteria. State DOTs have often established criteria to prioritize projects in rural areas. For example, the Texas DOT developed a plan in 2012 for rural transportation investments that used the following criteria to assign priorities (only two goals were used for the prioritization). [TxDOT, 2012]

Goal: Connectivity

- State trunk highway system
- System gap
- Commodity flow by truck to/from county (annual tonnage)
- Composite travel time to/from population/employment centers
- Hurricane evacuation route

Goal: Mobility

- Population within a 5-mile buffer
- Cost per future VMT
- Current volume/capacity
- Forecast volume/capacity
- Forecast level of service change with project
- Truck percentage
- Existing truck traffic
- Projected truck traffic
- Existing average daily traffic
- Forecast average daily traffic
- Safe passing needs

The criteria were assigned weights (that is, indicators of relative importance) by rural transportation stakeholders who participated in the plan development process.

5. Involving the Public

Public outreach efforts in transportation planning for rural communities are often very different than for larger metropolitan areas, primarily because of the familiarity that participants have with each other and with local decision makers. Thus, although it is quite common in larger metropolitan areas to use websites, focus groups, surveys and newsletters to reach those potentially interested in a transportation study, in rural communities, community meetings are probably as effective if not more so than other outreach efforts. This is especially true if the community meeting is held under the auspices of locally elected officials or other community leaders (see chapter 24 for more details on public participation and engagement).

It is important to note again that federal law requires consultation with planning partners for nonmetropolitan transportation planning. Such consultation is an opportunity to understand different partners' concerns relating to transportation system performance, coordinate the planning and implementation of potential improvement strategies, and promote a cooperative approach toward public outreach during a study.

III. TRIBAL NATIONS

A. Context

As of 2013, there were 566 Indian tribes, bands, nations, pueblos, rancherias, and Alaska Native villages recognized by the U.S. government (note: this section will use the terms tribal nations and tribes to represent all of these communities). The states with over 10 percent of their population being Native American include: Alaska (19.5 percent), Oklahoma (12.9 percent), New Mexico (10.7 percent), and South Dakota (10.1 percent). [National Congress of American Indians and the Leadership Conference Education Fund, 2013] The federally recognized Native American tribes range in population from 200,000 for the Navajo Nation to six for the Augustine Band of Cahuilla Indians in California. [Myers, 2014]

Tribal nations exist in a variety of settings, some sharing reservation land, some with reservations straddling state lines, and some with no reservation lands. However, each often has similar concerns and needs for a transportation system that provides access to and from jobs, residences, recreation, cultural centers, services, shopping, and other destinations. This transportation system should provide convenient and affordable transportation, while being consistent with community values and preserving cultural heritage and the natural environment.

An important aspect of tribal transportation planning is it must take place within the cultural value system of tribal members. This is well-described in a Washington State DOT *Tribal Transportation Planning Guide*:

> *Tribal transportation planning takes a unique approach to the traditional planning process by setting community goals specific to a tribe's ancestral lands, unique culture, and circumstances.*
>
> *The development of options and recommendations in a tribal transportation plan considers the usual natural, built and social environments under an overlay of guiding cultural and environmental values. Elected Tribal Council and tribal community members who base decisions about the future on a developed plan may expect to see these values incorporated into the document.*
>
> *Tribal communities expect that their own patterns of travel and movement, their own pace of life, that of wildlife, and sometimes undisclosed, pathways and culture, will provide guidance for plans and projects on tribal lands. Tribal transportation plans must maintain cultural integrity, and consider environmental quality within themes of preservation and protection of ancestral lands, and the right of tribal members to live and travel to these places regardless of accessibility. [Washington State DOT, 2009]*

Recognizing tribal nations as sovereign creates a layer of complexity for the planning process that does not exist for nontribal governments. Adding to this complexity is the fact that many tribal lands contain a mix of federal, state, county, township, municipal and tribal roads and, in some cases, other types of transportation facilities. As noted by Myers [2014], for example, the following Native American people use very different forms of transportation:

- Native villages of Alaska have ice roads, unique roadways maintained on and off major waterways. Methods of transportation include snowmobiles, dogsleds, boats and bush planes.
- The Indians of Puget Sound in Washington state use a variety of boats for travel, work, and moving freight.
- The Yurok and Hoopa on the Klamath River in Northern California use jet boats and other types of boats to fish, travel, and deliver supplies.
- The Indians of the Southwest use on- and off-road vehicles, as well as animals, to travel the desert and the harsh High Plains areas.
- The Great Lakes tribes and the eastern seaboard tribes use on- and off-road vehicles as well as boats, with surface facilities ranging from unpaved roadways to expansive waterway routes.

Thus, although much of the focus on tribal transportation planning is on unpaved and unsafe roads, in many cases, other forms of transportation should be addressed as well.

For issues that transcend transportation, the National Congress of American Indians is "the major national tribal government organization." [http://www.ncai.org] Another group, the Intertribal Transportation Association (ITA), holds a national conference annually, publishes a quarterly newsletter and has subcommittees that address specific issues.

B. Legislative Requirements

The history of U.S. federal legislation relating to tribal nations reflects changing attitudes on how Native Americans should be treated and supported. This section will not present this history that spans well over

150 years (see [Glaze and Amdur-Clark, 2014] for a detailed history of this history). Most importantly for today's world, the policy of the federal government is to promote self-determination and self-governance among tribal nations. Much of the recent legislative history in tribal transportation has focused on programs to foster such an outcome.

For example, Moving Ahead for Progress in the 21st Century (MAP-21), the U.S. transportation law passed in 2012, established the Tribal Transportation Program (TTP), known formerly as the Indian Reservation Roads program. For transit, it changed the Public Transportation on Indian Reservations Program from a grant to a formula allocation program. Title 23, Section 135 of the U.S. Code requires states to consider a tribe's concerns in carrying out their planning processes and to consult with them in developing the state's long-range transportation plan and the statewide transportation improvement program (STIP). MPOs have similar requirements. [Note: As of the January, 2016, only draft MAP-21 regulations for guiding tribal nation transportation planning have been produced by the federal government; readers are encouraged to check the FHWA website on guidance (http://www.fhwa.dot.gov/hep/guidance/#t23) for the most up-to-date federal rules and regulations concerning Tribal transportation planning.]

The most recent U.S. transportation legislation passed in 2015, Fixing America's Surface Transportation (FAST) Act, provided funding for the Tribal Transportation Program and authorized funding for the Tribal Transit Program. It also establishes and expands a Tribal Self-Governance Program within the U.S. DOT. The law also included a provision for tribal data collection, a reporting requirement for tribes that receive Tribal Transportation Program funds to report on the description of projects funded, the current status of projects, and the number of jobs created.

Transportation law also requires that coordination and consultation with tribal nations should occur during corridor plans, multimodal studies, modal studies, and any other transportation study where jurisdictions overlap. A state or MPO can perform these studies for an area entirely within tribal lands, if agreed to by the parties. Other transportation agencies can and should coordinate with tribal nations. Cities, counties and townships may have roads that enter or cross tribal lands. Ports and other freight service providers could be adjacent to or use tribal nation land. Transit agencies can provide important services to tribal nations, and these nations may also be funding partners with transit systems. Special transit services such as dial-a-ride can provide dedicated operations, and if appropriate, fixed-route bus service can provide a reliable and higher capacity level of service (see [Stoddard et al., 2012]).

The Bureau of Indian Affairs (BIA) and the FHWA operate the Tribal Transportation Program, which supports planning and provides funding for road projects on tribal nation land. As noted by the FHWA, "the Tribal Transportation Program (TTP) provides funding for safe and adequate transportation and public road access to, within, and through tribal reservations, tribal lands, and Alaska Native Villages. TTP projects range from board roads for all-terrain vehicles on the marshy Alaskan tundra to significant road construction." [FHWA, 2013] For a project to receive TTP funding, it must appear in the tribe's long-range plan and be in the TTP transportation improvement program (TIP). Planning funds come from a national TTP tribal allocation and must be approved by the Bureau of Indian Affairs. FHWA and Federal Transit Administration (FTA) allocations to states and MPOs for transportation planning purposes can also be used for TTP planning in some cases. These funds, when used to study tribal transportation problems, will usually be administered by the state or MPO.

Legislation related to Aboriginal people in Canada may be accessed through Aboriginal Affairs and Northern Development Canada at, https://www.aadnc-aandc.gc.ca/eng/1100100010023/1100100010027. Similar to the United States, Canada, has treaty obligations to aboriginal peoples, primarily to the First Nations, Inuit, and Métis.

C. The Job of Tribal Nation Planners

If a tribe has well-defined needs and a community consensus exists on where limited funding should be allocated, selecting funding priorities might be relatively straightforward. However, where there are numerous needs and where types of projects differ greatly, additional approaches to prioritize needs will likely be needed. Helping to identify priority investments is one of the most important responsibilities of the tribal nation transportation planner.

As with rural communities, tribal nations can help address unfunded needs and other transportation issues by partnering with other agencies and organizations. In most cases, these agencies would be the state or provincial DOT, an MPO (if the tribe resides in an MPO study boundary), or an RPO/RTPO. Because of the sovereign nation status of tribal nations, a formal partnership with such agencies can be complex, but there are examples where this has been done successfully. In the state of Washington, the Swinomish Tribe has full membership on the Policy Board of the Skagit Regional Transportation Planning Organization (RTPO), the Lummi and Nooksack Tribes have membership on the Transportation Policy Board of the Whatcom County Council of Governments, and the Pascua Yaqui Tribe in Arizona is a full partner in its MPO. Similarly, within British Columbia, the Westbank First Nation is a member of the Sustainable Transportation Partnership of the Regional District of Central Okanagan, which coordinates transportation programs and projects within the Kelowna area.

Perhaps the most important strategy for a tribal nation conducting transportation planning for the first time is to examine the work done by other tribes. This can lead to one-on-one relationships among the tribes and their planners. Some helpful resources include:

- *Transportation Decision-Making Information Tools for Tribal Governments, Developing A Long Range Transportation Plan*. [FHWA, 2005]
- Related sites for tribal transportation planning, http://www.tribalplanning.fhwa.dot.gov/reference_related.aspx.
- Many states have developed their own tribal transportation planning guides, with California, Minnesota and Washington being some of the best examples. The Navajo Nation's Transportation Plan 2009 is another example of a comprehensive transportation systems plan. [Navajo DOT, 2009]

D. Transportation Planning for Tribal Nations

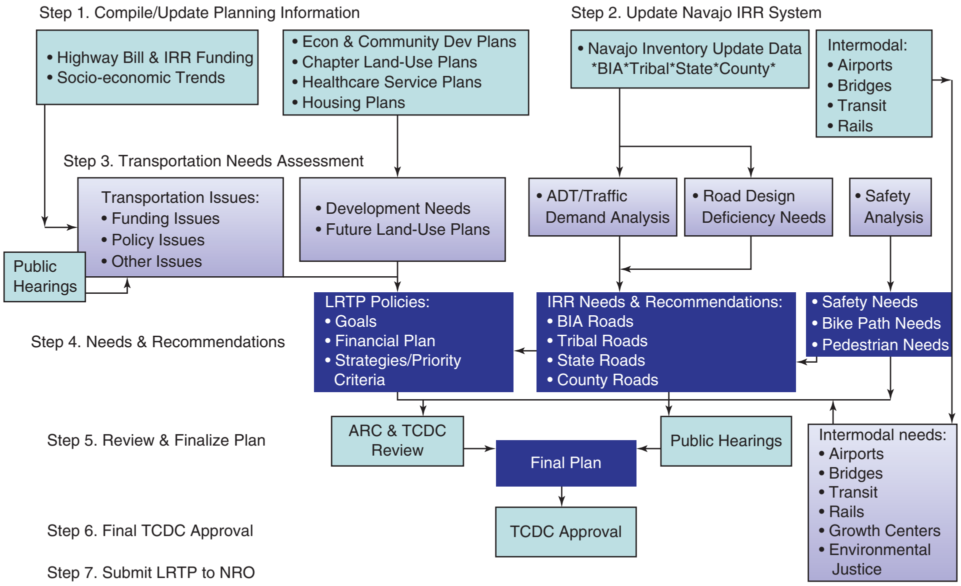
The primary challenges facing tribal nation transportation planning include addressing different/overlapping/often conflicting demands for transportation, and identifying transportation strategies that are most appropriate to a tribal nation context. Given a diverse set of strategies and actions, identifying the most appropriate methods to undertake planning in tribal nations becomes a necessary first step. Research and guidance exists on appropriate planning methods; some of this information is integrated into the general literature on transportation planning, but is scattered among many different sources. Consolidated information is available on some specific topics such as intelligent transportation systems (ITS), transit, and safety. [Caltrans, 2012]

According to FHWA and BIA draft planning regulations, a tribal long-range transportation plan should include:

- An evaluation of a full range of transportation modes and connections between modes such as highway, rail, air, and water, to meet transportation needs.
- Trip generation studies, including determination of traffic generators due to land use.
- Social and economic development planning to identify transportation improvements or needs to accommodate existing and proposed land use in a safe and economical fashion.
- Measures that address health and safety concerns relating to transportation improvements.
- A review of the existing and proposed transportation system to identify the relationships between transportation and the environment.
- Cultural preservation planning to identify important issues and develop a transportation plan that is sensitive to tribal cultural preservation.
- Scenic byway and tourism plans.
- Measures that address energy conservation considerations.
- A prioritized list of short and long-term transportation needs.
- An analysis of funding alternatives to implement plan recommendations. [BIA, 2014]

An example of the steps for a tribal transportation plan is shown in Figure 20-2, which is the transportation and decision-making process for the Navajo Nation, the largest tribal nation in the United States. This process shows some similarities to other planning process steps, such as the development of a transportation improvement program

Figure 20-2. Transportation Planning Process for the Navajo Nation



Source: NDOT, 2009

(TIP) and the identification of needs. However, there are also some differences, particularly in the role of the BIA, which must approve the allocation of construction dollars.

1. Understanding the Problems

Tribal nations face similar types of transportation problems as rural communities, while at the same time experiencing challenges that are specific to a tribal study area. The Tribal Transportation Planning Organization in the state of Washington has identified the most important transportation challenges as being:

1) High crash rates on reservation roads, attributable to many factors, including poor road design and condition.
2) Inadequate funding, and an overwhelming multiplicity of funding sources and application procedures.
3) Incomplete transportation data on crashes, traffic counts, and others combined with multiple jurisdictional involvement in data collection and analysis.
4) Lack of adequate reservation transportation planning staffing to pursue all funding possibilities and interact with all potential partners.
5) Geographic isolation and remote locations of transportation facilities and roads on or near Indian reservations is a barrier to efficient and cost-effective delivery by providers of fire, safety, maintenance, and public transit.
6) Incomplete Indian Reservation Road (IRR) Inventories, and the challenges of meeting complex BIA rules and regulations for update of the inventory.
7) Inequities in implementing IRR Funding brought about by changes in the regulations.
8) Outdated tribal Transportation Improvement Programs (TIPs) that no longer reflect current priorities and needs of tribal communities.
9) Historical frictions with local governments to form partnerships and collaborate on regional transportation projects.
10) The need for funding that is consistent and adequate. A dwindling federal budget, with an appropriation for the IRR (Now Tribal Transportation) Program that falls short of actual needs on reservations. [Washington State DOT, 2009]

The Navajo Nation *Comprehensive Transportation Plan* illustrates the types of transportation problems facing the Navajo communities (the Navajo Nation consists of portions of Arizona, New Mexico, and Utah):

- The Navajo Nation is the largest tribe in both land area and population, but due to inadequate funding for the Navajo IRR Program, 76 percent of the Navajo-BIA road system is unpaved.
- Community transportation survey respondents identified the following important topics
  - Safety improvements were the highest transportation goal, ranked above economic development, access to recreation, connection to transit and connection to freight;
  - Safety improvements (roadway striping, signage, traffic control, guard rail and street lights);
  - Road improvements (paving existing dirt or gravel roads);
  - Road maintenance (pothole repair and blading of dirt roads); and
  - Bridge improvements.
- The poor condition of local roads, coupled with increased traffic and safety issues have become a primary concern for chapters, school administrators, health care providers, and tribal and transportation leaders. Lack of paved roads has been identified as affecting quality of life. [NDOT, 2009]

The plan further identified the characteristics of special problems facing the transportation system. For example, the road safety problem was defined as follows:

- From 1999 to 2007, the Navajo fatality rates made up 15.34 percent of total crash fatalities in the state of Arizona. (The Navajo Nation represented 1.6 percent of Arizona's population in 2010).
- Compared to the 1992–1996 statistics, the crash total for 1999-2007 (1,253 crashes annually) had increased by 26 percent.
- Approximately 41 percent of the crashes resulted in injuries, a rate that was 10.5 percent higher than the rest of the state.
- Single-vehicle crashes represented 55 percent of the total crashes and 43 percent were two-vehicle crashes.
- A large majority (86 percent) of the crashes occurred in clear weather.
- Dry road conditions characterized 73 percent of the crashes, 8.2 percent occurred on snow-packed roads, 5.8 percent happened on loose sand and gravel, and 4.7 percent occurred on wet roads.
- The causes of crashes were driver inattention (20 percent), driving under the influence (DUI) (17 percent), animals on the road (16 percent), and speeding (14 percent). Only 1 percent of the crashes involved pedestrians. DUI crashes were 2.9 times the statewide Arizona rate.

The Fond du Lac Reservation illustrated the range of transportation modal issues that could be covered in a transportation plan. [Arrowhead Regional Development Commission, 2011] The types of actions covered: road condition and safety issues on a major interstate highway running through the reservation, trunk highways, county state-aid highways, county roads, township roads, and tribal roads; the Fond du Lac transit system; and bicycles/ pedestrians.

It is interesting to note that many of the issues and problems facing the Navajo (and similar) Nation are different from those identified in state and metropolitan transportation planning. There is much more emphasis on the need for paved roads, access to community facilities (especially health centers), and the strong enabling characteristic of transportation investment in spurring economic development. In addition, many of the factors contributing to road crashes differ as well.

2. Developing a Vision, Goals, Objectives, and Performance Measures

Similar to other planning studies, tribal nation transportation plans should establish a vision for the study area, and identify the goals, objectives, and performance measures that can be used to achieve this vision. The Navajo Nation *Comprehensive Transportation Plan* identified the following transportation goals:

- Provide a comprehensive transportation system that encompasses all modes of transportation, including rail, bus and air.
- Provide safe and efficient transportation network to and within the Navajo Reservation.
- Improve overall road and bridge conditions to achieve a reduction in the number and severity of traffic accidents.
- Develop the necessary multimodal transportation system to foster and support economic development and increase employment opportunities.
- Provide a high level of connectivity between growth centers, including Shiprock, Tuba City, Chinle, Fort Defiance, Window Rock, Crownpoint, and Kayenta. [NDOT, 2009]

Program-specific objectives were identified for each infrastructure area. For example, the road investment program was determined based on:

- Upgrading and improving class 2, 3, and 4 roads to meet design standards and management system requirements to correct deficiencies and improve overall travel mobility and accessibility.
- Improving travel safety and reduce accidents on the Navajo-BIA roads.
- Meeting existing and future transportation needs in order to promote community and economic vitality.

The airport investment program had the following goals and objectives:

- Develop a system of safe, efficient airports which meet acceptable development standards of federal, state, and local agencies, as well as the aviation industry.
- Plan for future growth of the aviation system consistent with national, state, and local air transportation needs through continuous updating of the Navajo Nation Aviation Systems Plan and to take actions to land bank and avoid operational restrictions at existing and new airports.
- Provide a system of airports, which will provide a minimum level of service and meet acceptable performance standards.
- Identify improvements needed to ensure adequate access to all system airports and users.
- Enhance opportunities for local economic development and improved employment consistent with local growth policies and plans.
- Finance aviation facility development to maximum feasible extent with innovative techniques taking full advantage of private sector initiatives and opportunities to assist in developing and operating facilities in the public aviation system.
- Establish operating procedures, budgets and an organizational structure to ensure proper maintenance of all Navajo Nation airports.
- Provide a framework for aviation planning and programming to meet needs in areas of airport development, airspace utilization and air navigation facilities and services.

Interestingly, the plan identified growth center-specific street goals and objectives that recognized the unique cultural and environmental nature of different communities in the Navajo Nation. For example, the street plan goals and objectives for the Shiprock community were:

- Create networks of streets to expand the use of land for the purpose of economic development toward the south and serve the government center.
- Create two street networks separated by the San Juan River, each providing an efficient distribution of traffic to reduce congestion and accidents.
- Provide an alternate crossing of the San Juan River towards the west.

- Create alternate routes and increase accessibility.
- Minimize environmental and cultural impacts by conserving areas adjacent to the San Juan River for recreation, and building new improved routes on existing dirt roads.
- Strengthen the historical sense of the place by creating a new government/town center upon the old settlement area known as the Shiprock chapter house/BIA compound.
- Enhance multi-modal options and mobility by providing a pedestrian bridge across the San Juan River, safely linking the two primary development areas within Shiprock.

Another example comes from the Warm Springs Reservation Transportation Plan in central Oregon. [Confederated Tribes of the Warm Springs Reservation, 2014] The goal and objectives for this plan included:

<u>Traffic Safety</u>

- Improve vehicular, pedestrian, and bicycle safety, particularly in the Warm Springs Community.
    - Provide additional pedestrian/bike paths.
    - Provide sidewalks with streets that serve urban level development.
    - Provide crosswalks at appropriate locations.
    - Include "Traffic Calming" techniques in the design of new residential streets.
- Support safety improvements to SR 26 throughout the reservation corridor.
- Implement a system to record and track "crash" data on reservation roads.

<u>Access</u>

- Provide access to future housing areas and other developments planned by the tribes.
- Ensure that roads that provide access to homes in rural areas of the Reservation have an all-weather surface.

<u>Maintenance</u>

- Develop and implement a maintenance program for tribal and BIA roads to protect the public investment in the existing road network and to enhance traffic safety.
- Establish and fund an annual budget for maintenance functions.

<u>Transit</u>

- Maintain funding for operations and maintenance and capital needs through grants from the state and FTA.
- Coordinate with regional transit providers when there are opportunities to improve efficiency, maximize service, or reduce costs.

One sees in this list an emphasis on safety and accessibility to reservation facilities and services. These are often the two most identified goals in tribal transportation plans.

3. Identifying Needs (through Data Collection) and Analyzing Alternatives

Tribal transportation planning uses data on a variety of community facilities, services, and land uses as input into the planning analysis. Data are usually collected on the following:

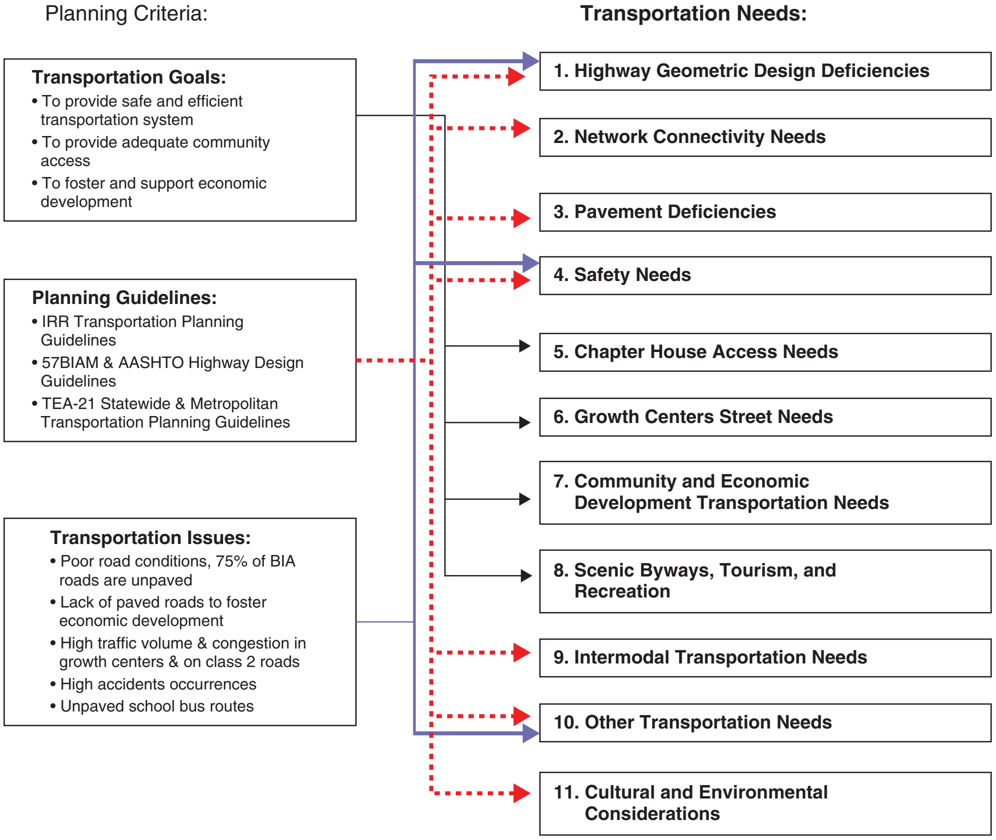
- Crashes
- Current land and development characteristics
- Development plans and proposed development sites

- Demographic information on population and employment
- Environmentally sensitive areas, for example, natural habitats or wildlife refuges
- Funding levels, usually over the past 5 to 10 years
- Historic/cultural sites
- Infrastructure inventory, for example, miles and location of roads or trails
- Pavement/bridge conditions
- Public attitudes and desires, usually through surveys
- Traffic operations, for example, turning movements and signal timings
- Transportation performance, for example, congestion or delays
- Transportation use, for example, volumes, pedestrian/bicycle counts, transit riders
- Topographic data

Data collected on existing systems help identify transportation needs, which then can be analyzed to achieve the most cost-effective program of investments. Figure 20-3 shows the needs assessment process for the Navajo Nation *Comprehensive Transportation Plan,* and shows how transportation needs (and thus data needed for planning) are defined for different modal networks (such as roads, airports, and intermodal facilities) and for different economic contexts (such as growth centers and tourist sites).

A Wind River Indian Reservation study on pedestrian and walking is an example of a study that is more targeted on a particular topic. Thus, the data collection and analysis is not as broad as in a more comprehensive transportation plan.

Figure 20-3. Planning/Needs Assessment Process for the Navajo Nation Transportation Plan



Source: NDOT, 2009

Table 20-4. Survey Data on Factors Influencing Mode to School, Wind River Indian Reservation

	Percentage		
Issue	**Yes**	**No**	**Not Sure**
Distance	12.7%	56.4%	30.9%
Convenience of driving	24.1	51.9	24.1
Time	24.5	43.4	32.1
School activities	26.4	49.1	24.5
Speed of traffic	43.7	38.0	18.3
Amount of traffic	42.6	34.4	23.0
Adults to walk/bike with	50.0	21.2	28.8
Sidewalks or pathways	59.0	19.7	21.3
Safety of intersections	44.8	37.9	17.2
Crossing guards	39.6	35.4	25.0
Violence or crime	45.5	38.2	16.4
Weather or climate	46.9	32.8	20.3

Source: Wind River Indian Reservation, 2012

[Wind River Indian Reservation, 2012] The Wind River Indian Reservation, located in eastern Wyoming, had experienced several pedestrian/vehicle injuries and fatalities in the years preceding the study. Surveys were used to solicit information from parents and school children on issues relating to transportation to school. Table 20-4 shows some of the results of the parent survey, which was aimed at identifying those factors that influence the mode used to access schools. Using such data, the planners were able to identify a program of improvements to enhance the safety of walking and bicycling in the Reservation.

The project alternatives considered in tribal transportation planning are straightforward given the problems and eligibility requirements of funding programs. Thus, for example, the goals stated for the Navajo Nation road network lead to a limited number of potential investment strategies—enhanced maintenance, pavement rehabilitation, road reconstruction, and new paved roads. Similarly, bridge deficiencies can be resolved with a limited number of engineering applications. The more difficult analysis process occurs when decisions focus on major new infrastructure or service provisions. This is where the process of analyzing alternatives becomes more important and often more complex.

4. Evaluating Alternatives

The evaluation process is very similar to that described for rural areas. In some cases, such as that for intersection improvements or the application of safety countermeasures in high crash locations, the evaluation approach can be quantitative. For example, crash modification factors (CMFs) can be used to determine the likely reduction in crashes given the implementation of certain countermeasures (see chapter 23 on safety). Or, traffic intersection software can be used to determine the future operational characteristics at key intersections and then assess the benefits of intersection improvements. Table 20-5, for example, shows the expected intersection performance for key intersections in the Warm Springs Reservation for the year 2030. [Confederated Warm Springs Indian Reservation, 2014]

In many cases, information from the data analysis is presented in public forums and attendees are asked to prioritize the projects based on the information produced by the transportation planning process. The transportation planners then apply the results of the analysis, consider tribal priorities, incorporate anticipated development schedules, and identify available funding to define the projects that should receive priority.

5. Involving the Public

Public participation for tribal transportation planning uses many of the same techniques and tools as other planning studies, but only provided for different types of groups. Depending on the size of the study, the planning process might simply rely on an advisory committee or public meetings as outreach opportunities, or for larger studies, a public involvement plan could be developed that outlines the key audiences/stakeholders for the study and the types of techniques and strategies that will be used to reach them. An example of the latter will be used below to illustrate the characteristics of a public involvement outreach effort.

Table 20-5. Example Intersection Analysis, Confederated Tribes of Warm Springs

Location	Level of Service	Delay (secs)	Volume/Capacity (V/C)	95% Queue (feet)[2]			
				EB	WB	NB	SB
US 26 @ Paiute Ave.	C	21.1	0.43	16	33	59	83
US 26 @ Hollywood Blvd.	B	14.0	.030	8	57	70	-
Tenino @Hollywood Blvd.[1]	B	14.4	0.39	75	85	99	113
US 26 @ Walsey Rd.	E	39.2	0.67	44	13	37	111
US 26 @ Mill Entrance	C	16.5	0.28	54	0	-	67

[1]Intersection average used.

[2]Queues in bold italics represent queues that would extend beyond available storage capacity.

Source: Confederated Tribes of Warm Springs, 2014

As part of the Hualapai Indian Tribe long range transportation planning effort, a public involvement plan (PIP) was developed by the Arizona DOT to "describe in detail how the Arizona Department of Transportation (ADOT), the Hualapai Indian Tribe and the project team will solicit public input; inform and involve the public, tribal officials, agencies and stakeholders." [ADOT, 2013] The goals of the PIP were to: (1) engage stakeholders to help ensure the final report incorporates agency and public input, (2) provide clear and accurate information that encourages informed public participation and input, (3) provide multiple, convenient ways for interested parties to provide comment, and (4) provide multiple means through which the public can learn about the project.

Key stakeholders were identified and interviewed for their thoughts on the transportation challenges facing the Tribe. These stakeholders included:

- Tribe Law Enforcement Liaison Board
- Tribe Education Committee
- Transportation Enhancement Review Committee
- Department of Soil & Water Conservation
- Boys & Girls Club
- Grand Canyon Resort Corporation Board
- Game & Fish Committee
- Youth Camp Planning Committee
- Hualapai Youth Council
- Head Start Policy Council
- Health Board
- Hualapai Justice System Advisory Board
- Tribe Cultural Advisory Team
- Tribe Recreation Committee

The plan recommended establishing a technical advisory committee consisting of representatives from agencies having technical knowledge and expertise valuable to the study. In addition, it was recommended to establish a study website, hold open houses and other public meetings, reach out to the Tribal Council, tribal elders and other key groups in the tribe, and establish a telephone comment line. As noted above, such a public involvement plan is usually not prepared for a tribal transportation planning study, but it does show the types of outreach strategies that can be used.

6. Transportation Safety Planning

Transportation safety, in particular road safety, has consistently surfaced to the top of the major issues facing tribal nations. The prominence of road safety in tribal transportation planning has been acknowledged by both the federal government and state DOTs that coordinate planning efforts with tribal nations. The FHWA has produced technical guidance on how to develop a tribal transportation safety plan. [FHWA, 2015] A transportation safety plan was defined as "a collaborative and comprehensive document that identifies transportation safety issues and strategies to address them. Effective Transportation Safety Plans lead to projects that make the transportation system safer." Such plans are to be data- and evidence-driven such that they can:

- *Identify problem areas:* Data can help tribes develop priorities by identifying the locations with the most serious safety problems and the greatest potential for improvement.
- *Evaluate safety strategies:* Data can be used to track or measure progress by creating and comparing "before" and "after" conditions at a project or community-wide level.
- *Assess outcomes:* Data are essential for tracking progress and evaluating the outcomes of projects and programs to understand their effectiveness.
- *Justify funding:* Tribes often have to demonstrate that a safety problem exists to be eligible for grant funding under federal safety programs.

The guidance identified a seven-step process for conducting transportation safety planning in tribal communities.

Step 1: Establish a Safety Leadership Framework.

a. Identify a champion.
b. Convene a working group.
c. Identify and contact stakeholders.
d. Develop a vision, mission statement, and goals.
e. Gain tribal council support.

Step 2: Collect and Analyze Safety Data.

a. Gather data.
b. Supplement limited data.
c. Analyze data.

Step 3: Determine Emphasis Areas.

a. Identify potential emphasis areas.
b. Prioritize emphasis areas.

Step 4: Research and Identify Potential Strategies.

a. Research strategies.
b. Identify potential strategies.
c. Identify target outcomes.

Step 5: Prioritize and Incorporate Strategies.

a. Prioritize and select final strategies.
b. Identify responsibilities for each strategy.

Step 6: Draft the Plan.

Step 7: Evaluate and Update the Transportation Safety Plan.

a. Evaluate the transportation safety plan.
b. Update the transportation safety plan.

Table 20-6. Illustrative Strategies and Outcomes for Tribal Safety Transportation Plan				
	Strategies	**Target Outcomes**	**Organizations and Individuals Responsible**	**Target Date of Completion**
Education	Conduct public education and outreach sessions to raise motorists' awareness of pedestrian and bicyclist safety needs.	Conduct public education	Conduct public education	Conduct public education
Enforcement	Strictly enforce laws regarding yielding to pedestrians.	Reduced incidence of crosswalk violations	Transportation Safety Plan champion (for example, Wind Lake Tribe law enforcement officer)	On-going
Engineering	Implement effective engineering counter measure, such as pedestrian crossing islands.	Reduced risk for pedestrians through increased visibility	Wind Lake Traffic Engineering Chief Safety Engineer	Dec. 2014
Emergency Medical Services	Improve the response time of emergency services in the case of pedestrian crashes.	Increased response time to pedestrian crashes	The Wind Lake Reservation EMS coordinator	On-going

Source: FHWA, 2015

The guidance provided an example of the type of outcomes from transportation safety planning, shown in Table 20-6. The strategies were organized in four categories—education, enforcement, engineering, and emergency medical services. In addition, target outcomes were identified for each type of strategy along with target dates.

An example of how this approach has been applied to a tribal nation is found in the Red Lake Nation *Transportation Safety Plan*. [Red Lake Nation, 2015]

IV. SUMMARY

Much of the interest and focus of transportation planning is on statewide and/or metropolitan issues. Many of the planning tools and data collection techniques are oriented to this scale of urban and metropolitan planning. However, there are important and significant transportation challenges facing rural and tribal nation communities as well. In some cases, given the economic status and isolation of some of these communities, these challenges are even greater than those found in metropolitan areas. The transportation planning process for rural communities and tribal nations follows similar steps to other planning efforts. The types of problems tend to differ, however. Typically, more emphasis is placed on road safety and conditions, accessibility to community centers, and the need to preserve heritage and cultural resources. Data availability and data management are particularly difficult in rural and tribal nation studies simply because of the costs involved. Many of the planning tools, such as demand models, may not be appropriate for use in such contexts. Additionally, the types of strategies used for public outreach need to be more targeted to the populations being served.

Even with these challenges, the need for effective transportation planning is probably even greater for rural communities and tribal nations than other contexts simply because effective transportation investment can make a significant difference in the lives of rural and Native American residents.

Note: Besides those references already mentioned in the text, the Community Transportation Association of America has Rural and Tribal Passenger Transportation Technical Assistance Programs, as well as other resources. FTA has a Rural Transit Assistance Program (RTAP) with a rural toolkit that highlights TRB Transit Cooperative Research Program (TCRP) Report 101: Toolkit for Rural Community-Coordinated Transportation Services. The American Public Transportation Association has an online publications section and a TCRP section where reports on rural transit can be selected. All of the TCRP reports are available for sale or in downloadable PDF format. FHWA's Local Technical Assistance Program (LTAP) and Tribal Technical Assistance Program (TTAP) are a tremendous resource for small community and tribal agencies.

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Recreational Areas[1]

I. INTRODUCTION

Visits to recreational areas and major parks have been one of the fastest growing travel markets in the United States—and in the world—during the past 50 years. Primarily due to increasing population, but also because of increasingly accessible remote parks and recreational areas, planning for the access to, and circulation within, recreational sites has become part of the transportation planning field. Recreational attractions, especially national parks or wildlife refuges, often have unique ecological value to a nation; thus, the resources they represent need to be managed sustainably. This requires a strategic perspective on how visitors, workers, and those who deliver goods access and use a park's transportation system. In many locales, the road and path networks are in themselves fragile and often not designed to handle large volumes or heavy vehicles. The vulnerability of these networks to climate change and extreme weather events that could shut down a park leads to a concern for incorporating resilient transportation design into recreational transportation planning.

There are many different types of recreation areas. In the United States, there are over 400 units of the National Park System and over 6,600 state parks. Recreation areas are also managed by other federal agencies, including the U.S. Forest Service, U.S. Fish and Wildlife Service, and the Bureau of Land Management. At the state and local levels, recreation areas can include lakes, rivers, and the seashore; and there are also privately owned recreation areas. While the concepts of transportation planning for recreation areas apply to all of the above, many of the examples in this chapter are from U.S. national parks.

This chapter describes the unique characteristics of transportation planning for recreational communities, with primary focus on large parks or recreational areas. The next two sections present characteristics of recreation travel and of the transportation systems that visitors use. The following section discusses the transportation-related characteristics of the visitors themselves, and how these characteristics lead to transportation system needs. The transportation planning process for recreational areas is presented in the following section, organized by the major planning steps shown in Figure 1-1. The importance of communication with both recreational visitors and with surrounding communities is explained in the next section, and the final section discusses some of the future challenges facing transportation planning for recreational areas.

II. CHARACTERISTICS OF RECREATIONAL TRAVEL

Understanding the characteristics of travel that occurs in a study area is an important first step in any transportation planning process. This is particularly true for recreation-related transportation planning, given that the characteristics of recreational areas themselves, the transportation systems that serve them, and the people who visit are very different from commute travel or travel for other trip purposes.

Tourism and recreational travel is increasing in terms of activity, importance, and transportation complexity. In the United States, 18 units of the National Park System each had more than four million visitors in 2014 and 42 units each had more than two million visitors. Growth in the visitation at all types of recreation areas has caused increasing levels of road congestion, greater stress on the natural environment and, in many areas, refocused attention on air quality concerns from transportation sources. These issues affect one of the underlying attractions of vacation

[1]The original chapter in Volume 3 of this handbook was written by Anne E. Dunning, Ph.D., Associate Professor, Department of Planning, University of Kansas. Changes made to this updated chapter are solely the responsibility of the editor.

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spots—experiencing a vacation-quality environment. When on vacation, people want to escape from the daily exposure to traffic congestion, parking difficulties, crowded transit systems, and poor environmental quality. Transportation systems in recreational communities need to make visitors feel comfortable (despite a degree of unfamiliarity with the system), well-served, relaxed, and satisfied with the travel experience.

Recreational communities are defined as any community whose economy depends heavily on tourism. This definition can be interpreted loosely because a wide range of communities prefer to identify themselves as recreational destinations. National parks have *gateway communities*, most often located immediately adjacent to the parks. However, communities located several miles from park entrances also identify themselves as gateway communities. The reason for this is not surprising . . . . major recreational attractions can positively affect economies and resources over large areas. For instance, 3.88 million visitors to Yosemite National Park in 2014 spent $405 million in the communities near the park. That spending supported 6,261 jobs in the local area and had a cumulative benefit to the local economy of $535 million. [National Park Service, 2015]

Although some large cities target much of their economy on attracting tourists (for example, Las Vegas, Nevada, and Orlando, Florida), most recreational communities are small- to medium-sized cities. Thus, whereas major cities have transportation systems geared to the local population with some consideration for visitors, many smaller recreational communities have a local year-round population and a substantially larger tourism population. Transportation systems in these communities are often focused on handling the influx of visitors, rather than on the mobility needs of the relatively small local population.

Recreational travel differs from urban travel in important ways:

- Peak demand can occur at unusual times, for example, around meal times and at sunset, rather than at the start and end of the business day. Recreational destinations near urban areas might have heaviest visitation on weekends, whereas remote destinations might have consistent traffic on weekends and weekdays.
- Although many recreational areas are in remote locations, recreational visitors typically come from metropolitan areas, making visitors sensitive to travel time and transit frequency. Thus, transportation systems need to provide vacation-quality service. If transit service quality fails to meet high standards, tourists might choose other destinations for their vacations.
- Although transportation planning often focuses on visitor mobility, transportation for recreational areas must accommodate the commuting needs of the local workforce. In addition, unless year-round visitation merits continuous service, transit and the operation of the local transportation system must also consider the travel demands of a seasonal workforce.
- At many recreational areas, more than half of the users of the transportation system might be visiting the area for the first time; thus, there is a special need for effective information dissemination on the transportation services available to visitors.
- Many recreational areas are attractive because of the beauty of difficult terrain and climates, which might require special vehicles and driving skills. Unique ecosystems and the presence of wetlands might also necessitate special ecological protection. Because of the often ecologically sensitive nature of the recreational site, transportation planning for recreational communities should demonstrate heightened sensitivity to environmental sustainability and quality of life. These traits attract visitors to recreational areas in the first place, and they must be maintained or enhanced.
- Recreational areas featuring natural attractions might create challenges with the interaction of wildlife and transportation operations. Highway safety engineers in these areas need to design for the safety of both drivers and wildlife, public relations professionals need to sensitize unfamiliar drivers with the unique local dangers, and environmentalists need to work with transportation professionals to protect smaller species and plant life from the threats of pedestrians and vehicle traffic damaging habitat.
- Planning in recreation areas must accommodate the requirements and needs of multiple jurisdictions given that the movement of visitors could entail travel on public and private venues, local streets, state highways, and possibly federal lands. Somewhat different from the metropolitan context, however, is the greater participation in the planning process of organizations and groups whose purpose is primarily to protect the environment.

- Recreational travel demands place a great deal of stress on the local transportation system. Often, the funding for system improvements will rely on fares or other fees obtained from the visitors themselves. Where transportation system funding comes from other governmental sources, the significant seasonal variation in travel demand is not reflected in the traditional allocation formulas that distribute funds according to residential population.

In the most popular U.S. national parks, the most common transportation issues are entrance station congestion, parking congestion, and crowding on transit systems.

III. CHARACTERISTICS OF TRANSPORTATION SYSTEMS SERVING RECREATIONAL AREAS

The following characteristics are important considerations for improving transportation system performance in recreational areas.

A. Modes of Travel

Part of the transportation analysis for recreational areas includes matching modal attributes with the characteristics of the recreational area and of the travel markets that are likely to generate visitor demand. An important characteristic of many recreational communities is the multimodal nature of accessing many of their attractions, such as a waterfront inn that is accessible by taxi, motor vehicle, bus, bicycle, walking, or boat. Given this diversity in mode use, it is important that the transportation system itself fosters intermodal connectivity, such as visitors putting a bicycle on a bus rack to access distant bicycle trails.

The mode that people use to access a recreational area influences their travel behavior and mode choice when circulating within the area. If visitors rent a car to visit, they will likely use that vehicle during their stay. If visitors arrive at an airport and find convenient public transit or taxi options to take them to their destinations, they might never need a private vehicle to enjoy the recreational site. Transportation planners should thus view gateways as modal portals to recreational areas, points where visitors make decisions on which modes they will use. By focusing on such early travel decision points, planners can influence travel demand throughout the recreational area.

Some recreational destinations in remote locations, such as islands or in Alaska, cannot be accessed easily or at all by road vehicles. Visitors at these locations use local modes such as boats and small airplanes to reach the destination, and nonmotorized or shuttle systems might be the norm for internal circulation. For example, half of the visitors to Alaska's Denali National Park and Preserve arrive by cruise ship in Anchorage, Alaska, take a railroad to the park, and use Denali's bus system for sightseeing. Modal planning in these types of locations frequently focuses on assuring sufficient capacity to handle the demand.

Passenger Cars and Light Trucks. Congestion caused by private motor vehicles is a growing problem in many recreational areas. Dealing with this congestion with traditional infrastructure approaches (such as adding more road lanes) is often infeasible given natural barriers, historic preservation requirements, jurisdictional difficulties from local governments, lands owned privately or by the state or federal government, and so forth. In Glacier National Park, for example, the most congested road facility is the Going-to-the-Sun Road, which is listed on three historic registries. Due to its historic designation, it cannot be widened beyond its historic two, 11-ft (3.4-meter [m]) lanes. This historic width, combined with mountain switchbacks, prevent modern recreational vehicles (RV) and large pickup trucks from using the road.

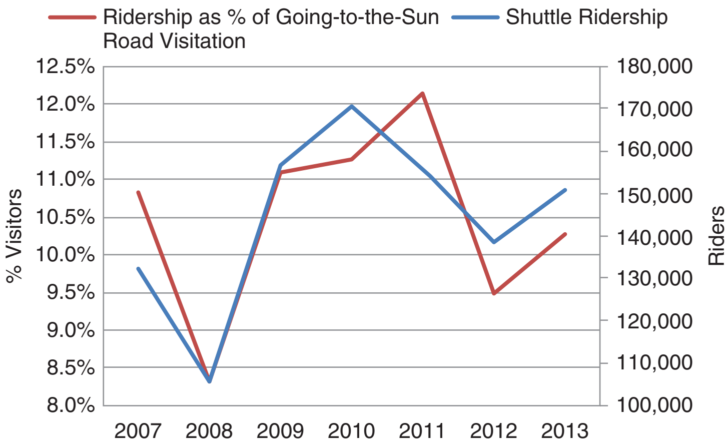
In many recreational areas, much of the road congestion is associated with parking. Many visitors drive to a parking location and then walk a short distance to see an attraction. For highly desirable sites, this can cause substantial backups at the parking lots, with vehicles waiting in line for spaces to become available. If local hotels have built sufficient parking capacity within walking distance of recreational attractions, this problem might be alleviated. Where demand for parking exceeds supply of designated spaces, visitors often create informal parking spaces along roadsides, which can damage sensitive ecosystems.

Traffic safety problems also emerge in unique forms. Drivers could be unfamiliar with road networks and the best locations for available parking. These distracted drivers are often on the same streets with families and children roaming local villages or hiking along the road. Further challenges arise in the form of difficult driving terrain in mountains and along winding coastlines.

Nonmotorized Modes. One of the distinctive characteristics of many recreational communities is the large amount of visitor walking. According to the National Park Service *Transportation Planning Guidebook,* "Bicycling and walking, particularly when combined with affordable and efficient transit service, are effective and pleasurable alternatives to automobile travel. For these alternatives to gain popularity, they must be safe, enjoyable and convenient. Ideally, visitors should learn about alternatives to automobile travel before they leave home so they can take advantage of pedestrian, bike, and transit facilities, and services available within the park." [NPS, 2014] The *Guidebook* outlines the need and means to provide signs, distinguish bike lanes, improve crosswalks, enhance shoulders, create safe zones, enhance bridges, build route linkages, enforce rules of the road, raise visibility, reduce obstructions, and regulate trail time. The *Guidebook* endorses facilities for transit compatibility with bicycles, bicycle storage, and bicycle rentals.

Transit. Transportation studies in recreational areas often begin with an examination of potentially viable public transit services. Public transit could lead to fewer parking requirements and reduced traffic congestion (to the extent that auto users are substituting transit modes for their auto trips). Figure 21-1, for example, shows the transit ridership for Glacier National Park in terms of ridership and percent of total visitors. The eight-year average of ridership was 144,000 per year for an operating season that lasted approximately 10 weeks.

Figure 21-1. Transit Ridership, Glacier National Park, 2007–2013



Source: Glacier National Park, 2012

To be effective, public transit systems in recreational areas must offer vacation-quality service that people will consider preferable to private vehicle travel. In some cases, this is helped by policies restricting vehicle use, such that transit is the only means of accessing some areas. Where no such restrictions apply, marketing campaigns should be used for the different traveler markets visiting the recreational site.

Within the broad definition of public transit, several types of vehicles and services exist. *Rubber-tire transit* (primarily buses of various shapes and sizes, including open-air shuttles and buses configured to look like trolleys) provides the greatest service flexibility to transit operators. Where demand emerges either due to long-lasting trends or a temporary event, capacity can be allocated to meet the need.

Bus services can serve both tourists and employees. A high proportion of the people who operate recreational area attractions have no private vehicle, and high land values make affordable housing scarce. Outside Myrtle Beach, South Carolina, for example, service workers ride buses for two hours each way to access minimum-wage service jobs. Local affordable housing is most likely the solution to this problem, but public transit serves as a stop-gap measure.

One of the biggest disadvantages of buses is that they use existing roadways and thus often get caught in congestion just like other vehicles. This disadvantage can be mitigated with entrance gates dedicated to buses and signal preemption (in urban areas) to activate a green light for transit vehicles. The other primary disadvantage of buses relates to visitor uncertainty of where the bus will go, but sound planning and marketing can address this problem. Although information dissemination is a key factor for transit success, simple geometric design can sometimes deliver the message even more powerfully. Zion National Park found that bus pullouts on the side of the road oriented visitors to the direction of the bus, whereas stops located in parking lots confused visitors and led to numerous questions on the bus routes.

Except in highly urban park environments, *rail transit* (light rail, monorail, streetcar, and, less likely in recreational settings, heavy rail and commuter rail) is not likely to be an option for park visitors. Rail systems offer little flexibility for evolving service demands. One particular rail mode deserves special attention in a discussion of rail for recreational areas. Monorail has assumed a reputation (rightly or wrongly) as a rail technology intended for recreational sites. Few cities have adopted monorail since it debuted at the 1962 Seattle, Washington, World's Fair, although Disney theme parks and Las Vegas now have such systems. While the Disney Company does not report ridership to government agencies, the Monorail Society [2013] reports monorail ridership in Florida's Disney World exceeds 150,000 riders per day.

Snowmobiles. The use of snowmobiles has grown significantly over the past several decades. In 2014, there were 1.4 million registered snowmobiles in the United States. (Minnesota and Michigan far surpassing other states) and 594,276 registered snowmobiles in Canada. [International Snowmobile Association, 2014] Similar to the jet ski, snowmobile use is often criticized because of the associated environmental impacts of noise and air pollutants. While some parks, such as Glacier National Park, have prohibited snowmobiles in the park, other parks that already allow snowmobiles have done so in a carefully managed way.

Modes That Need Intermodal Connections. Several commonly used travel modes in recreational areas are not usually the subject of transportation plans, but their use often requires intermodal connections to personal vehicles or transit services. *Boating and personal watercraft,* both motorized and nonmotorized, have become very popular in many recreational areas. Boaters typically participate in a range of activities. Only 8 percent spend their time boating, while 80 percent of rental boaters (40 percent of nonrental boaters) engage in picnicking and 15 to 20 percent of boaters go hiking. Island communities, parks and resorts frequently foster travel by *small airplane*; Alaska has the highest frequency of general aviation activity in the United States because harsh winter conditions make maintenance of small runways at origins and destinations more pragmatic than building (and plowing) highways connecting long distances.

Cruise ships bring unique transportation planning challenges by depositing thousands of passengers into a community over a short period of time. Communities might find their transportation infrastructure significantly affected if many cruise ships arrive at similar time. All of the passengers arrive without private vehicles; therefore, pedestrian areas, transit, and bus tour services will likely serve the majority of transportation needs for cruise ship passengers.

Aerial touring allows people to view sites from the sky, typically in helicopters or small planes. Some controversy has arisen over their use in certain types of recreational areas. The noise of aircraft engines interrupting the solitude of nature has resulted in years of conflict between preservationists and the aerial touring industry. The National Parks Overflights Act of 1987 (49 USCS § 40128) established more stringent noise standards for national parks.

B. Peak Travel Activity

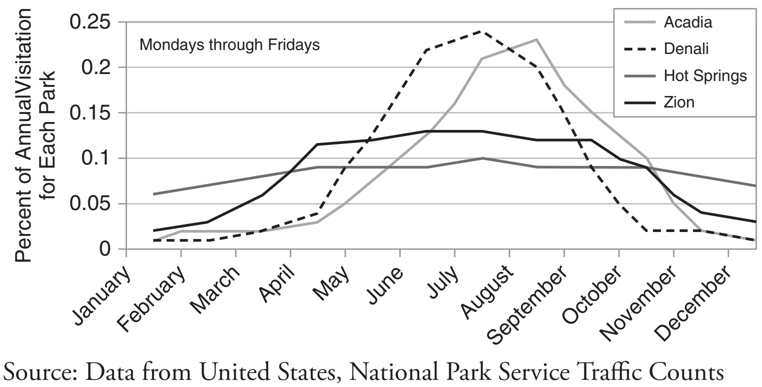
Peak travel activity in recreational areas differs substantially from that found in urban transportation systems. Peak travel can occur by time of day, day of week, and month of year. Visitation at recreation areas can spike on summer holiday weekends.

Annual Peaks (Month of Year). Recreational areas typically have three types of seasons: peak, shoulder seasons, and off-season. The peak season refers to the months of the year when the most visitors go to a recreational area. Peak season in the United States typically occurs in the summer months of June, July, and August when schoolchildren have summer vacations. The length of peak season varies from park to park; weather and climate usually determine the time and duration of peak seasons.

Shoulder seasons occur during the weeks leading into the peak season and the weeks immediately following. Visitation in recreational areas transitions from low off-season numbers to the high visitor count of the peak season. Similarly, after the peak season, the time in between peak season and low season often sees a moderate number of visitors. Shoulder seasons refer to these times of moderate visitation.

During the *off-season,* recreational areas usually host only a small number of visitors. Frequently, attractions, businesses, and amenities close off-season because they cannot financially justify keeping staff and continuing operations.

Figure 21-2. Duration and Intensity of Peak Visitation Seasons in Four National Parks: Acadia in Maine, Denali in Alaska, Hot Springs in Arkansas, and Zion in Utah, 2015



Source: Data from United States, National Park Service Traffic Counts

The geographic location of a recreational area can affect the duration and intensity of its visitor season (see Figure 21-2). Recreation within a day's drive of cities might have a steady stream of weekend visitation throughout the year, as in the case of Hot Springs National Park (Arkansas), but most recreational areas get the majority of their visitors during the summer (except, of course, those sites catering to ski tourism). Northern destinations, such as Denali, Alaska, and Acadia, Maine, have few summer months with passable roads, whereas southern attractions without such limitations might start their peak season earlier and end later. The desert heat of Zion National Park in Utah with average summer temperatures of 95°F to 107°F (35°C to 42°C), results in lower summer visitation compared to locations in cooler climates.

The length and intensity of seasonal visitation influence local transportation service. Most notably, transportation services and infrastructure are often unnecessary and unused in the off-season. Recreational areas with steep peaks of short duration face difficult challenges of providing sufficient capacity for a couple of months to meet visitor needs and then maintaining the costs through the long off-season. Infrastructure-based transportation systems, such as road networks and bicycle pathways, do not suffer substantially from seasonality except that congestion is felt most at the height of the peak. Intelligent transportation system (ITS) technologies (see chapter 10) can generally be switched off when the demand no longer justifies their operation (and cost). Service contracts are often negotiated accordingly.

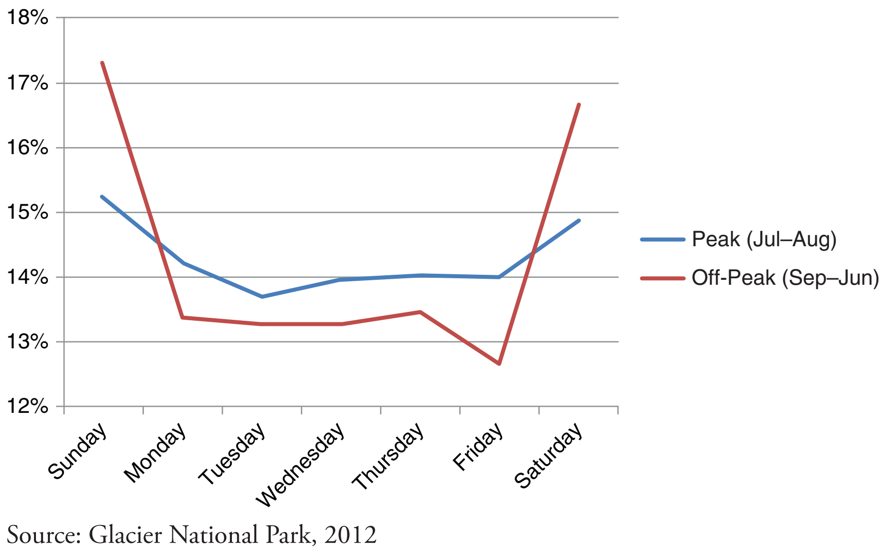
Transit operates best where a large number of people want to move between a concentrated number of points, so the crowds of a high peak season can move efficiently on transit. However, a short season with a high peak means that a large number of drivers need to be hired for short-term work. With a lower peak and a longer season, a smaller number of people need transportation over a longer period of time. A transit system in this type of area requires a smaller number of seasonal drivers, but might have difficulties amassing enough riders to justify the cost of transit operations, particularly if the area has dispersed visitor destinations. Furthermore, recreational areas with long visitor seasons might need to operate before Memorial Day and after Labor Day, which might make it difficult to hire drivers, many of whom drive school buses when not working in seasonal transportation.

Weekly Peaks (Day of Week). Weekly peaking behavior also depends on the type of recreational area. Vacation destinations in remote locations that require substantial pre-trip planning and often lodging reservations tend to encourage longer stays. In such locations, little difference exists between weekend and weekday visitation. However, recreational areas within or near population centers often attract shorter trips on weekends.

Glacier National Park, a destination park, sees little variation in visitor volumes from day to day, but some differences emerge when weather and wildfires turn away casual weekend visitors. Vacationers traveling over long distances tend to continue with their plans, as indicated by the stability of weekday visitation (see Figure 21-3).

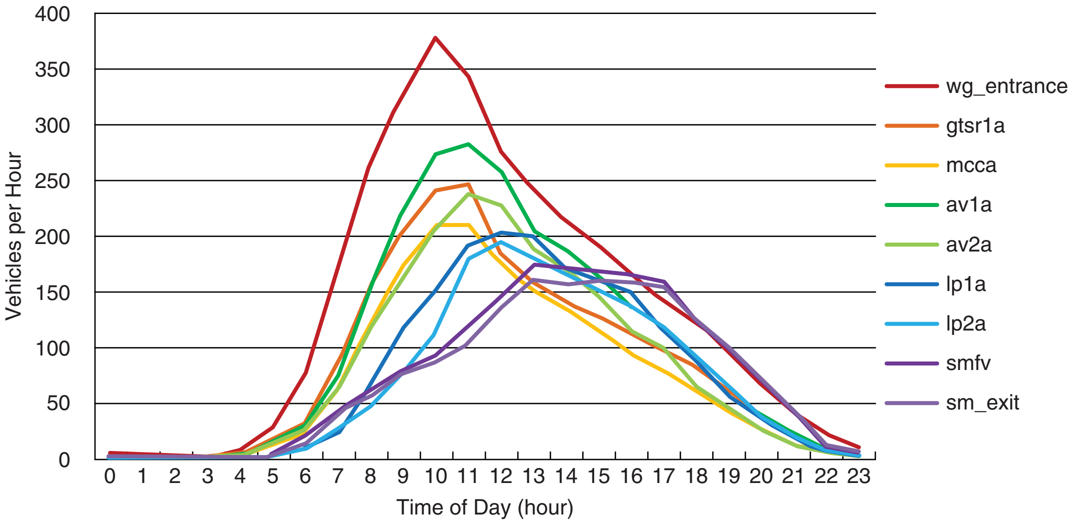
Daily Peaks (Time of Day). Urban areas display distinctive peaking during the mornings and afternoons on weekdays when commuters travel to and from work. Smaller peaks occur at lunchtime and when school days end for children. Recreational areas also experience the phenomenon of people leaving their lodging at similar times to visit attractions, but the demand often does not follow the traditional dual-peak pattern (see Figure 21-4). Whereas urban peak traffic hours occur around traditional commute times, recreational peak hours for traffic and riding transit often occur around events, meal times, and sunset. Morning peaks start later in most recreational sites.

Figure 21-3. Percent Traffic by Day of Week, Glacier National Park, 2012



Source: Glacier National Park, 2012

Figure 21-4. Vehicles per Hour at Different Locations on the Going-to-the-Sun Road in Glacier National Park by Entrance to Park, 2012

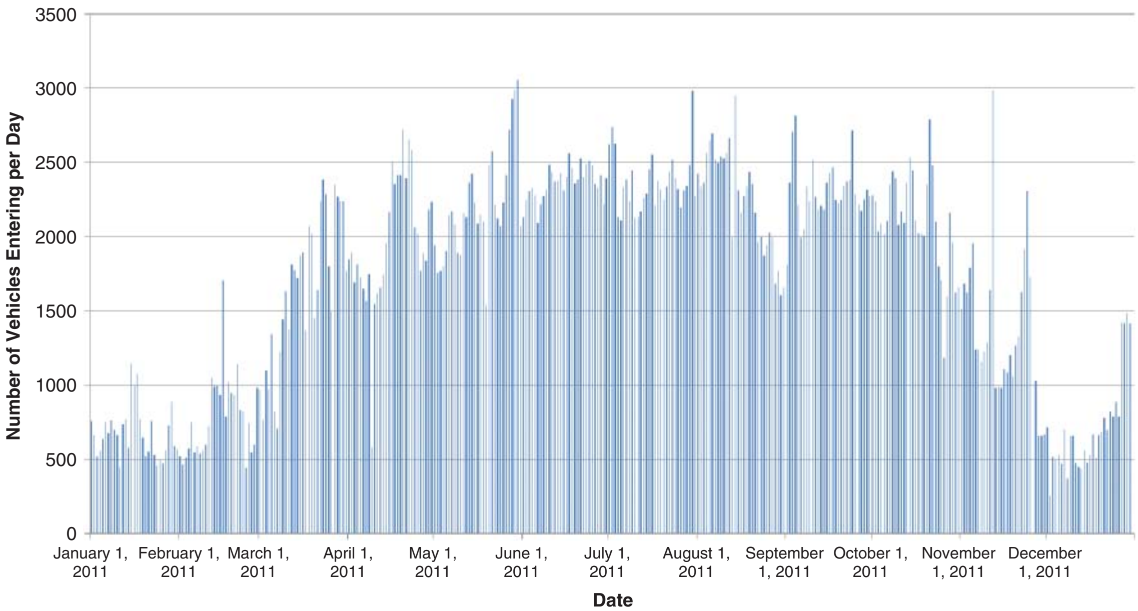


Source: Glacier National Park, 2012

If a recreational area features special events, the event schedules likely determine peak activity. Frequently, mountain climbers start their journeys before dawn, which might create a special need to ensure clear roads earlier than in metropolitan areas. Fireworks at night bring increasing volumes of traffic up to the start of the event, cause distracted drivers and congestion during the show, and create a sudden surge of transportation demand back to lodgings after the finale.

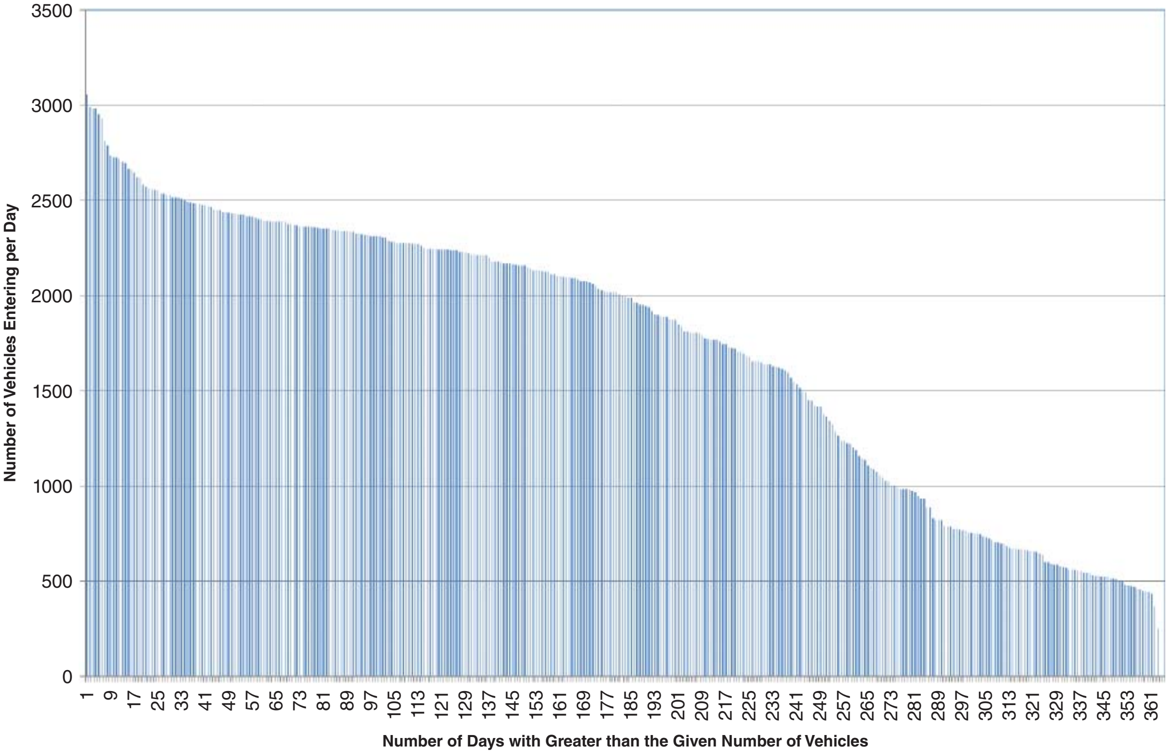
Day of the Year. Variation in recreational area visitation can also be portrayed by each day of the year. For example, Figure 21-5 shows the number of vehicles passing through the South Entrance Station at Zion National Park for each day in 2014. Spikes in visitation are evident for Presidents' Day, Spring Break, Easter, Memorial Day, Independence Day, Labor Day, Veteran's Day, Thanksgiving, and the Christmas–New Year's Day period. Similar day-by-day profiles have been found for other National Park units. In some parks the "shoulder seasons" are narrow and in other parks the shoulder seasons are quite wide. Some parks exhibit spikes on many weekends. Figure 21-6 takes the number of vehicles entering on each day of the year and presents the data in a highest to lowest histogram format. This format

Figure 21-5. Vehicles Entering Zion National Park, Day of Year, 2014



Source: Courtesy of Dr. Jonathan Upchurch

Figure 21-6. Vehicles Entering Zion National Park, Ranked Highest to Lowest, 2014



Source: Courtesy of Dr. Jonathan Upchurch

reveals the challenge of accommodating transportation demand on the 10 highest days of the year. This effect likely holds in most recreational areas, whether they be national parks, state parks, or other types of recreational areas.

C. Travel Companions and Vehicle Occupancy

People typically do not visit recreational areas alone. The National Park Service estimates visitation based on average vehicle occupancies ranging around 2.8 or 2.9 passengers per vehicle. This average occupancy contrasts with the 2010 United States national average vehicle occupancy of 1.67, which includes all trip types. Given a higher number of people traveling together in recreational areas, transportation planners should be sensitive to the following:

- Transit fare structures should consider the total cost for groups, rather than individuals. A $10 individual fare amounts to a $40 out-of-pocket cost for a family of four. The family will compare $40 for transit against a $15 parking fee and make its mode choice accordingly.
- Rest areas, rest facilities, and shopping areas should be designed with potentially large pedestrian volumes as a design standard.

D. One-Way Transportation

Certain recreational activities, typical in natural settings, result in visitors ending a trip several miles away from where they began. In parks where one-way backcountry hiking, river boating, or paragliding attract large numbers of participants, transportation planners can reduce surface transportation and parking congestion by providing transit service. One-way modes might require special provisions depending on the characteristics of the recreational area. For example, where river boating is highly popular, transportation planners might need to establish a reservation system to prevent river congestion from becoming a safety hazard. In such situations, a scheduled transit service between launch and take-out points will reduce traffic and parking problems. In areas with a small but significant number of boaters, an on-demand service might make sense.

Public provision of one-way transportation might become challenging in situations where the visitors do not wish to return to their point of origin. In the case of river boating, people typically want to return to where they left their vehicles and need some means of return. In the case of general touring, people typically do not want to see the sites a second time as they head back to their parked vehicle. For instance, Yellowstone National Park handles substantial auto volumes, yet many people who visit that park do so as part of a tour of other parks in the region, such as Grand Teton and Glacier National Parks. Visitors who enter from the south might wish to leave to the north, making it difficult to leave vehicles at the south entrance, take a bus tour during the day, return in the afternoon and drive back through the park in the evening to continue the journey to the north exit. These types of travel patterns suggest the need for good trip data and analysis so that planners can understand the underlying motivations for trip-making in the recreational site.

IV. TRANSPORTATION-RELATED CHARACTERISTICS OF VISITORS TO RECREATIONAL AREAS

Recreational visitor demographics vary by type of recreation available in an area. Amusement parks can be expected to draw families with children, resorts might lure adults, and historic attractions might draw mostly seniors and educated hobbyists. Transportation services for each visitor market will most likely require their own special characteristics. However, there are some factors germane to most recreational visitors.

A. Time Sensitivity

Travel demand research has repeatedly shown that travel time and travel cost are the primary factors affecting travel choices. Although people frequently take vacations to “get away from it all” and leave demands on their time behind, transportation planners should not mistakenly assume that recreational travelers have little time sensitivity. Visitors often have a limited number of days away from work, and that time is valuable. Some visitors at recreational sites are there for conferences rather than vacations and must often adhere to strict schedules. Even people who are relaxing must meet golf tee times, dinner reservations, bus schedules, ferry departures, and airplane flight times. Young parents with tired children are often not willing to wait a long time for a bus or to sit in traffic. At the other end of the spectrum, seniors might find it difficult to stay out all day without a chance to rest.

Core concepts of travel time should thus be considered carefully in recreational area transportation planning. As in urban contexts, time spent sitting in congestion or waiting for buses feels more onerous to travelers than time spent in moving vehicles.

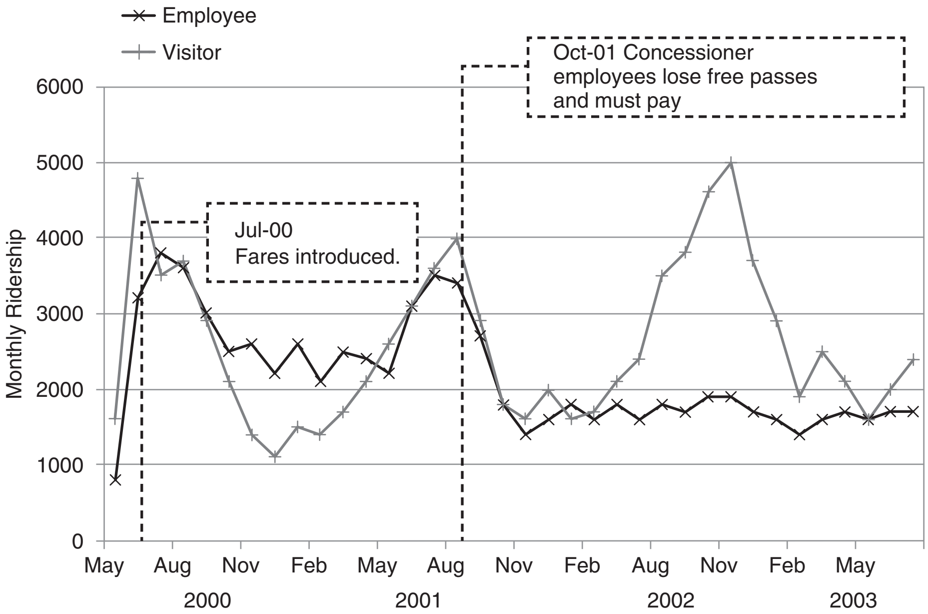
B. Cost

Travel costs influence travelers’ decisions, in particular, costs associated with actual expenses for a trip. If public transit requires a fare, but there is no charge for parking a car, much of the travel will occur by car. Conversely, if drivers must pay to park, while transit is offered free, transit services will be more attractive. Figure 21-7 shows the aggregate mode shift experienced at Yosemite National Park when park concession employees lost free passes on the park’s shuttle service … the seasonal peak in commuter ridership disappeared as employees took private vehicles to work.

C. Service Flexibility

Transportation systems should meet as many visitor travel needs as is cost effective. Thus, accessing the recreational site itself is probably the most important purpose for a transportation system in such a community, but services might also be needed for connecting to grocery, religious and medical facilities, intermodal transfer centers (such as airports or ferry terminals), and other business/restaurant locations. If visiting a restaurant for breakfast requires a private vehicle, that vehicle will likely stay on the road throughout the day, or if a bus route fails to reach a popular store, visitors will rely on the motor vehicle to shop there. To the extent possible, transportation options should be flexible to meet the majority of intended trips. Of course, special transportation services often cannot serve every trip purpose in a study area; system design inherently includes service/cost trade-offs that should be considered during the planning process.

Figure 21-7. Transit Ridership in Yosemite with Loss of Fare Subsidy



Source: Data from United States National Park Service Traffic Counts

D. Personal Belongings

People on vacations tend to have more luggage and personal belongings than for nonrecreational trips. Not only does this luggage include the normal change of clothes and toiletries, but it often encompasses a range of specialty items such as beach gear, ski equipment, cameras, and bicycles. Handling luggage on public transit services can be a challenge, thus, some form of personal storage might be necessary for certain types of visitors. Security concerns at amusement parks might even prohibit visitors from carrying backpacks or substantial camera equipment.

E. Information Needs

Visitors to recreational sites are often not familiar with the local transportation network. Drivers are unfamiliar with the roads or road closures; transit riders do not know the locations of stops and the time needed to access them; and pedestrians have little awareness of how to navigate the community. This lack of familiarity suggests the need to disseminate information. This information should be available via website to allow visitors to plan their itinerary, as well as on-site so visitors can obtain information while they attempt to use the transportation system. It also makes the training of front-line employees (hotel clerks, waiters, and so forth), as well as traffic management personnel, vitally important.

F. Safety

Travelers unfamiliar with their surroundings can also cause safety problems. Visitors will be distracted by sights and confused by trying transportation services and modes for the first time. In some situations, travelers might even cause special needs for emergency access. For example, rangers at Glacier National Park must routinely rescue people driving on the Going-to-the-Sun Road because some drivers panic when they see the steep cliffs at the road edge. [Glacier National Park, 2014]

V. TRANSPORTATION PLANNING FOR RECREATIONAL AREAS

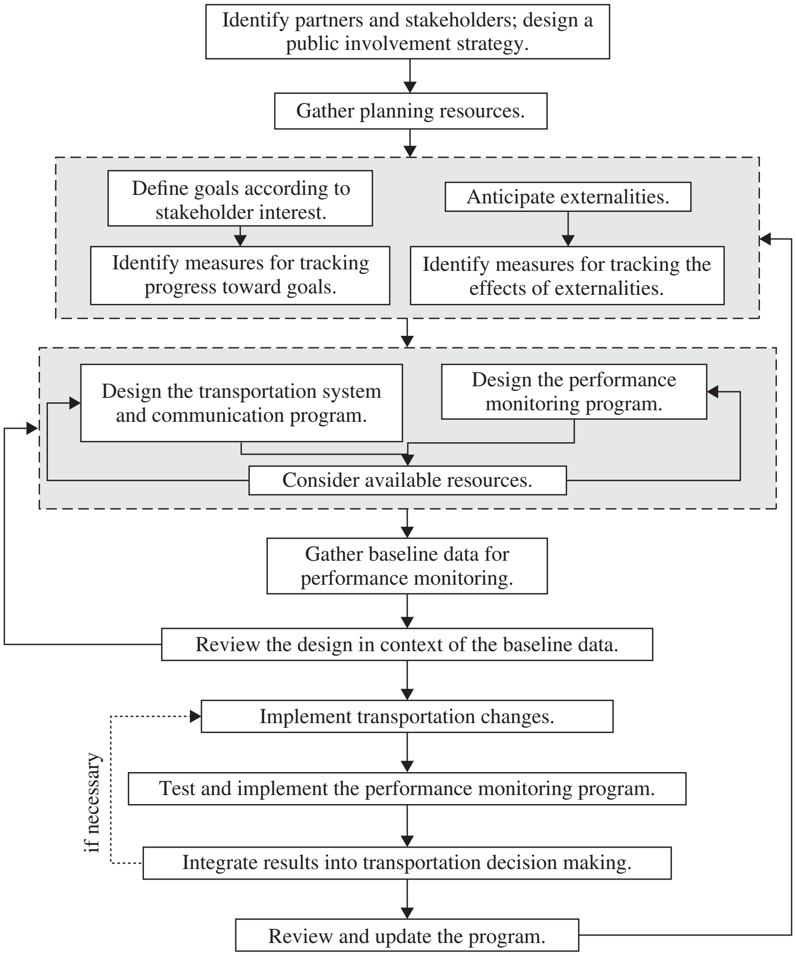
Recreational planning is the process of examining the transportation access to recreational areas along with the circulation of visitors, workers, and goods distributors within such sites. Transportation planning for recreational areas is illustrated in Figure 21-8. This process is similar in structure to the overall transportation planning process presented in Figure 1-1, as well as reflects the guidance for national park planning developed by the National Park Service. [NPS, 2014] The following sections provide more detail on the planning steps shown in Figure 21-8.

A. Partnering and Public Participation

Transportation planning in general involves multiple parties, each having a stake in the outcome. This is certainly true for recreational transportation planning. In addition to local stakeholders (see Table 21-1), a number of state and federal government agencies could provide expertise and financial support for transportation systems, depending on the type of recreational area being considered. Such involvement is unlikely for local parks and recreational areas.

Transportation planners in the National Park Service (NPS) have found that partnerships among government agencies, private firms, nonprofit organizations, and other stakeholders have led to transit systems that have been well-received by park visitors and gateway communities. For example, when community partners participated in the planning process at Zion National Park, a planned transit design changed from a park-only system to a two-loop system serving the gateway community and the park. The resulting system reduced the need for parking inside the park and provided auto-free access to restaurants and shops for visitors. [Shea, 2001] Transit planners for Acadia National Park also give credit to partnering for creating a system that provided for the needs of patrons and employees of local businesses, as well as park visitors and staff. [Volpe Transportation Systems Center, 2003]

Figure 21-8. Transportation Planning for Recreational Areas



Source: Dunning, 2005

Table 21-1. Recreational Area Stakeholders	
Local Group or Sector	**Possible Representatives**
Business community	Chambers of commerce Tourism agencies Park concessionaires
Local population	Elected representatives (mayors or council people) Town managers
Local economic development planning	Town planning departments Planning commissioners
Transportation operators	Transit operators Private taxi and tour operators Traffic control centers Emergency responders Towing companies
Attraction administration	Varied titles in public, private, and nonprofit sectors
Holders of general local knowledge	Varied titles

Source: Dunning, 2004

When the Commonwealth of Massachusetts and the Cape Cod National Seashore wanted to develop a transportation plan for Cape Cod, Massachusetts, one of the most environmentally sensitive areas in the United States, the Secretary of Transportation for Massachusetts appointed members to an advisory task force representing the following groups:

- U.S. Congress (local delegation)
- Office of the Massachusetts Secretary of Transportation
- Cape Cod Commission
- Cape Cod Central Railroad
- Cape Cod Chamber of Commerce
- Barnstable County Human Services
- Southeastern Massachusetts Private Motor Carriers Association
- Barnstable Assembly of Delegates
- Lower Cape Health and Services Coalition
- Massachusetts Highway Department
- Cape Cod National Seashore
- Woods Hole, Martha's Vineyard, and Nantucket Steamship Authority
- Cape Cod Regional Transit Authority
- Transit Dependent Consumer, [Federal Transit Administration, 2012]

Many opportunities were also provided for public input into the planning process.

Partners in the process must have an ability to introduce their needs into the planning process and to influence service design. This requires information dissemination and often education on the specific nature of the transportation challenges facing a recreational area. For instance, local businesses need information on what to expect with changes in transportation accessibility and how to create benefits or mitigate potential impacts of transportation services. If business owners know what they can expect and what is happening, they will respond with more of a sense of involvement in the planning process. This level of partnership with businesses requires more than a short e-mail list and established committee meetings. It requires personal communication, published materials, and information sessions. It entails explanation on many different levels and to many diverse interests.

Interaction with the communities affected by recreational travel needs to occur during the transportation planning process as well as on an ongoing basis. In particular, those individuals who are serving visitors on a daily basis need to be informed of the transportation options available to visitors. Zion National Park offers a model example of how this can be done. Organizers of the Zion Canyon shuttle educated front-line workers in the gateway community of Springdale, Utah, which is located directly outside the national park's border. When seasonal employees were able to inform people about the shuttle, ridership on the town route increased and eased congestion at the entrance gate to the park. The local chamber of commerce also collaborated with this effort to give visitors information about the types of businesses located near transit stops.

Potential means for communicating with local communities include:

- *Pre- and early-season orientation sessions* for all seasonal employees who interact with the public, whether employed by recreational venues, with concessionaires, or by local businesses, should provide the employees with answers to typical transportation questions.
- *Websites and local newspapers* should post planning milestones and reports about transportation options, so the local public knows what infrastructure, service changes and development to expect.

- *Transportation planning representation at town and chamber of commerce meetings* provides another essential means of communicating transportation system strategies to the public affected by the system.
- *Published multimodal maps and schedules* provide useful handouts that can be taken by visitors to better plan their transportation routes.

Effective communication channels should avoid misunderstandings that could lead to loss of credibility in transportation providers. The Island Explorer shuttle at Acadia National Park offers an example. Soon after service began, local businesses who believed they were doing all the advertising for the system, wanted to see more aggressive marketing of the service. However, with ridership demand regularly reaching or exceeding capacity, marketing efforts for the Island Explorer had been purposely limited. Some means of making sure both groups were informed of the status and operations of the services would have avoided this misunderstanding. [Daigle and Lee, 2000]

Recreational community leaders commonly express frustration over the portrayal of their community's transportation system performance in the media. For example, Yosemite National Park businesses noted that when the media reported that the park was closed due to traffic congestion triggering the implementation of a Restricted Access Plan, visitors expressed concern that they would not have access to the park. In reality, riders on the Yosemite Area Regional Transportation System (YARTS) shuttle had guaranteed access; the Restricted Access Plan only delays entering vehicles until space is created by vehicles leaving Yosemite Valley. [Nelson and Tumlin, 2000]

B. Goals, Objectives, and Performance Measures

Planning partners need to identify the goals and objectives associated with a planning study. This could entail determining what kind of visitor flow and mobility levels are desired, what kind of outcomes they would like to see in the region, and how to attain the desired future. The design of the transportation system will differ depending on the intended results, and performance monitoring should target both progress toward these goals and the externalities associated with the selected transportation systems. A comprehensive national study of transit needs for federal lands identified the following goals for park-related transportation planning:

- Enhance visitor mobility and accessibility.
- Preserve sensitive natural, cultural, and historic resources.
- Provide improved interpretation, education, and visitor information services.
- Reduce pollution.
- Improve economic development opportunities for gateway communities. [Cambridge Systematics and BRW, 2001]

Some less common goals have also appeared, such as:

- Create partnerships in the local community.
- Enhance visitor experience by providing services.
- Achieve services comparable to the services offered by other recreational areas in a region.

Another example of plan goals comes from the Alternative Transportation Plan (ATP) for the Mississippi National River and Recreational Area. [HDR, 2011] The plan was developed to "provide NPS with a framework for implementing the development of an alternative transportation system that serves both NPS staff and MNRRA visitors, and for identifying projects in the 72-mile corridor that could support the vision and goals of the ATP." The plan vision was:

> *"Working with partners, the MNRRA ATP will promote a leadership framework for the development of a multimodal transportation system to and along the river that serves as a catalyst for the region's sustainable cultural, economic, and environmental future."*

The planning goals were:

- Improve and enhance the visitor experience by integrating and enhancing opportunities for transportation, recreation, education, and scenic enjoyment along the Mississippi River.
- Provide access to the MNRRA for everyone through integration into surrounding transportation systems.
- Integrate MRT with area transit and trails to increase visitation to MNRRA without increasing congestion.
- Establish a transportation system to and in the MNRRA that preserves, enhances, and interprets natural and cultural resources.
- Promote development of environmental, economic, and socially adaptable and sustainable transportation and recreational facilities.

Public agency goals do not always align with those of businesses in recreational areas. Business owners do not want to see businesses suffer from changes in visitor mobility. Thus, for example, moving transportation facilities or services to a more efficient location will almost always cause some businesses to suffer even as other opportunities are created.

The next part of the transportation planning process relates to defining desired and acceptable levels of service provisions and likely outcomes, and monitoring overall achievement of study goals and objectives. Defining desirable levels of performance first requires understanding how to measure them. Transportation professionals need to determine which performance measures will indicate progress on achieving community goals and what monitoring of externalities must occur. They must also consider who can best gather these data and the data collection costs.

Given the often large number of stakeholders with interests in recreational areas, many individuals and groups should contribute to the ongoing evaluation of transportation systems. Different stakeholders have access to different types of data, and the data used to monitor system performance should serve the many various interests represented. The types of data required will vary based on local needs and goals (see Table 21-2). Data on travelers' choices come from traffic and ridership counting programs and surveys. These tools can indicate trends in visitation, as well as transportation choices that people make. Analysts need to examine these data in the context of comparable venues and regional and national economic trends.

Trend data often provide insight even without extensive analysis. For instance, tracking traffic counts over time allows the transportation planner to determine where in the road system the greatest increase in volumes is occurring. Wherever possible, automated systems should contribute to basic data collection—traffic counters can provide automatic vehicle counts by time of day. Vehicle counters spread throughout a recreational area offer a sense of circulation within the area. Because parking poses a challenge in many places, automatic counters at parking entrances and exits or parking meters monitoring duration of stay could offer important information about visitor flow at major attractions.

Regional airports will track information on airport enplanements and operations. The enplanements indicate how many passengers get onto commercial flights at the airport. Operations show how many take-offs and landings occur. These operations include both tour flights and general aviation traffic to and from the area (the numbers rarely differentiate these two groups). Any airport receiving federal funding must track these air traffic measures, so data are typically readily available for analysis.

Passenger ferry counts come from either private or public sources. Some ferries run as government operations and some companies run private ferry businesses. Private operators might hesitate to share passenger counts because that information might have competitive sensitivity; however, those operators might make willing partners in the transportation planning process. At a minimum, data on the percentage change of ferry passengers against a base year will inform travel demand analysis.

Cruise ship operators do not readily share data on passenger counts due to the highly competitive nature of the business; however, communities with harbors can receive a large amount of tourism traffic via cruise ships. Although the passenger counts might not be available, the number of cruise ship arrivals and the capacity of those ships are readily available and should be tracked over time.

Table 21-2. Examples of Measures for Monitoring Performance				
		Measures	**Monitoring**	**Reporting**
Traffic, Parking, and Crowding	**Input**	• Traffic policies (description) • Parking policies (description) • Private vehicle restrictions (description) • Enforcement (funding and jobs)	Transport departments, state and local government and venues	When changed
	Output	• Roadway capacity (vehicles per hour) • Parking capacity (count of spaces, locations, and typical distribution of parking durations)	Transport agencies	When changed
	Outcome	• Vehicle counts at attractions (count by road, time of day, day of week, and time of season; peak periods; and peak hours) • Vehicle counts in the community (count by road, time of day, day of week, and time of season; peak periods; and, peak hours) • Vehicle counts on state roads (count by road, time of day, day of week, and time of season; peak periods; and peak hours) • Local household vehicle ownership (survey) • Parking revenue (amount)	Transport departments, state and local government and venues	Annual
Transportation Safety	**Input**	• Transportation alternatives in dangerous traffic locations (location count or yes/no) • Marketing for transportation alternatives (funding) • Private vehicle restrictions (yes/no) • Enforcement (funding) • Enforcement staff (employees)	Attraction operators and local governments	Annual
	Output	• Ridership in dangerous traffic locations (count)	Transit operator	Annual
		• Reduced traffic in dangerous traffic locations (vehicle count)	Transport departments	
		• Visitation in dangerous traffic locations (survey or observation)	Venues	
	Outcome	• Incident reports (count) • Complaints (count) • Observed near-incidents (count) • Severity (injuries or damage value)	Law enforcement	Annual
	Input	• Attraction visitor capacity (visitors)	Venues	Decennial

(*continued*)

Table 21-2. (*Continued*)

		Measures	Monitoring	Reporting
Environmental Impact		• Visitor education (funding) • Enforcement (funding) • Enforcement staff (employees)	Venues	Annual
Environmental Impact	Output	• Use metering (visitors/time) • Visitor education programs (funding) • Signs and physical barriers (funding or count) • Transportation volume caps (parking or vehicle)	Venues	Annual
Environmental Impact	Outcome	• Violations (count) • Duration of noise in specified locations (time) • Noise levels in specified locations (measure) • Air pollutants (count/volume) • Space used for informal parking (are contaminants in ground and streamount/volume)	Venues	Annual
Mobility and Coverage	Input	• Roads within attraction borders (distance) • Attractions deemed should be served (count)	Attraction operators	As needed
Mobility and Coverage	Input	• Roads in community to serve (distance)	Local government	Quinquennial
Mobility and Coverage	Input	• Businesses to be served (count)	Business community	Quinquennial
Mobility and Coverage	Output	• Roads covered within attraction borders (distance) • Attractions transit serves (count and percentage) • Businesses transit serves (count and percentage by fixed stop and by flag stop)	Transit operator	Annual
Mobility and Coverage	Outcome	• Visitors traveling by private vehicle (survey count and percentage) • Visitors traveling without a private vehicle (survey count and percentage) • Visitors using transit (survey count and percentage) • Visitor demographics (survey counts by season)	Attraction operators	Quinquennial
Visitor Experience	Input	• Transit information and communication (funding) • Transit amenities (funding, count, and description) • Interpretation for transit passengers (funding, employees, materials, and description)	Designated partner	Annual
Visitor Experience	Output	• Media used to communicate (descriptions and counts) • Training and education for seasonal workers (session and participant counts) • Interpretive programs along transit routes (session description and count)	Designated partner	Annual

Table 21-2. (*Continued*)

	Measures	Monitoring	Reporting
Outcome	• Requests for information (count) • Website hits (count) • Telephone calls (count)	Designated partner	Annual
Outcome	• Complaints of confusion (count and percentage) • Perception of information availability and communication (survey scale 1–5) • Wildlife sightings (survey count of sightings and count and percentage of visitors who sight) • Trip purpose (survey count) • Trip destination (survey and stop alighting counts) • Trip origin (survey and stop boarding counts) • Rider satisfaction (survey scale 1–5)	Transit operator	Annual

Beyond trend tracking, performance measures offer important information when multiple data sources combine into a unique measure. For instance, traffic counts when compared to estimated parking or roadway capacity show the percentage of capacity used, a more understandable measure of need to many of those participating in the planning process. With this information, transportation managers can determine if uncomfortably crowded conditions exist just at extreme peak times or if the problem exists throughout the period of operation.

Safety conditions should be a particular concern for data collection. Most safety conditions reveal themselves through basic tallies of traffic crashes, pedestrian injuries, and visitor complaints about dangerous conditions. If particularly dangerous intersections or other sites exist, transportation engineers should consider conducting annual studies that observe traffic behavior at the site. With well-defined guidelines for observation of incidents and near-incidents, analysts can establish an historic database to indicate trends in safety.

Automatic counting technology can similarly count bus riders, and global positioning systems (GPS) can indicate route and vehicle performance, and when combined with automatic ridership counting can determine the locations of passenger activity. Automated data collection provides consistency in tracking methods. If transit service already exists, transportation planners need to establish a “base year” of operations to serve as a benchmark for comparison with service changes. If no service exists, one aspect of the new service planning will be to define desired performance measures and to establish the process for such monitoring. If the service is to be contracted out, a data monitoring plan will likely need to go into the service contract itself.

Setting levels for acceptable and desired transit performance poses a challenge in regions that have never offered public transportation. Table 21-3 shows typical data that is usually collected by transit operators. Ridership tallies are the most basic numbers to collect. Some transit operators also offer data on driver workforce size, wheelchair-assisted trips, and deadhead time and distance, indicating when buses operate with no passengers aboard (for example, trips from the bus depot to the start of a route). Beyond these widely used metrics, transportation planners should consider whether measures of local relevance should appear in the performance monitoring program.

Transit ridership data offer some indication of how visitors feel about transit service. Increased ridership can indicate one of two things (or a combination of the two): either more people are taking transit or existing riders are taking more trips by transit. Factors such as the perception of transit service quality, the level of perceived congestion on the road network and areas restricting private vehicles will affect trip-making for both visitors and local residents. Demographic characteristics of the different traveler markets will likely affect both the proportion of people using transit and the number of trips taken per person.

Table 21-3. Transit Operator Performance Measures
• Annual fleet inventory including make, age, and mileage of vehicles/vessels
• Annual inventory of other facilities (maintenance, storage, shelters, etc.)
• Ridership by route and month
• Revenue by route and month
• Accident/safety record
• Operations and maintenance cost
• Headways
• Dates and hours of operation
• Fares
• Vehicle miles of service by month
• Vehicle hours of service by month
• Missed trips

Source: Cambridge Systematics Inc. and BRW Group, 2001

The ease of collecting information on tour buses will depend on the structure of each recreational area. Places with open access to all sites might have difficulty monitoring them, but places with managed venues probably track tour buses in some way. For instance, most national parks charge fees for tour buses to enter park boundaries, so park fee-collection offices should have information on either the number of tour buses or the amount of money collected from tour bus operators.

The visitor is the primary unit of analysis in evaluations of recreational transportation mobility strategies. Visitor surveys provide the most direct means of getting information on visitor behavior and provide a means of assessing how visitors might react to transportation options. A survey program should start before major transportation changes are initiated and continue after, usually one or two years after, to determine what changes have occurred. Visitor surveys should also be conducted periodically (no less than every 5 years) to monitor changing trends or visitor characteristics. The information from this type of survey program will allow transportation planners to provide appropriate transportation strategies in the places where they are needed and give local businesses information to develop strategies to attract and serve customers better (see chapter 2 on data collection and analysis). Understanding what transportation options college students, young families, or the elderly use most frequently will help planners target supporting services to the needs of particular demographic groups. Demographic profiles will also help in planning for target groups that are reticent to use service options that local leaders would like to promote.

Visitor surveys often include questions on daily expenditures, durations of stay, and other economic variables. The results can show the places people frequent and the modes of transportation used. These surveys also classify visitors demographically. When designing visitor surveys, analysts should include questions that will allow isolating visitor spending by visitor category. For example, how much do return visitors spend in the park compared to first-time visitors? How much do daily visitors spend (and where) compared to those who camp in the park for multiple days? It is good practice to ask some of the same questions from one survey to the next to allow comparisons over time; some questions will be removed, and new questions will be added.

Local businesses often have data and information that could be useful to transportation planners. For example, business listings and data on store activity can offer important insights into local economic health and trends, while business surveys and interviews can tap into visitor demographics. Business composition in the local economy could change as a result of transportation changes that affect visitor needs. Businesses and concessionaires in and around Zion National Park found that fewer people bought souvenirs after access to Zion Canyon was restricted to buses and nonmotorized modes. Visitors who previously would have put souvenirs in the trunks of their cars knew they would have to carry the items on the bus or on the trails, so they reduced the amount of items they had to carry. On the other hand, demand for service industries increased. For instance, local businesses noted an increase in bicycle rentals because people felt safe riding on roads with reduced traffic volumes.

A business survey provides information on employment trends in hiring, layoffs, seasonal and permanent employment opportunities, the duration of seasonal employment, and the turnover of employees. If transportation planners want to conduct a business survey as part of the planning study, they should start with a complete business listing. The business listing may already exist. Some local governments keep detailed lists of businesses, though they might record businesses coming into existence without recording the ones that have gone out of business. Local chambers of commerce can play a strong role in securing this listing; however, chamber membership alone does not necessarily describe local business communities accurately. At a minimum, the business list should indicate the business name, address, and the type of business. The address can be used to analyze how close businesses are located to transportation services, such as transit stops. In small communities, business revenues are likely too sensitive to obtain because anonymity cannot be guaranteed.

An example of how surveys can be used as part of a planning process is found in the development of the Mt. Hood Multimodal Transportation Plan. As part of this planning effort, interviews were held with key stakeholders, including the partner agencies and staff, mountain resorts, business operators, and interest groups. These interviews were used to "determine stakeholders' wants, needs, and core values that were used to guide project selection." [Evans and Assocs. 2014] Two public surveys were also used. The first was aimed at identifying travel patterns and public support for safety and types of travel options. A second survey focused on public support for a set number of project options that had been identified as part of the process. Table 21-4 shows the results of the project selection survey and the desires of three market audiences, Portland Metropolitan Area (PMA) residents, village residents, and Hood River Area/East of Mt. Hood residents ("all respondents" includes these three), with respect to transportation system improvements. Shaded areas in the table indicate the project was selected as part of the top 5 for that respondent group.

Table 21-4. Survey Response on Priority Projects, Mt. Hood Multimodal Transportation Plan

	Percent of Respondents that Selected a Project as a Top 5 Priority			
Prioritized Projects	**All Respondents (1,862)**	**PMA (1,434)**	**Village Residents (200)**	**Hood River Area/East of Mountain Residents (112)**
PriT-1: Intra-forest transit service	16%	16%	19%	16%
PriT-2: Aerial tram	48%	50%	58%	20%
ITS-1: Traveler webpage	16%	16%	11%	28%
ITS-4: Increased cell phone coverage	43%	41%	47%	45%
PB-1: Bike/ped intersection improvements	14%	15%	17%	4%
PB-3: Mirror Lake Project	25%	25%	33%	8%
PB-4: Government Camp pedestrian overcrossing	21%	21%	33%	5%
PB-5: Widen shoulders for bikes	18%	18%	15%	20%
PubT-1: Expanded transit from Hood River	6%	4%	2%	39%
PubT-2: Mt. Express from Sandy to ski areas	19%	18%	28%	13%
PubT-3: Transfer hub down the mountain, shuttle service, establish mass transit	26%	27%	22%	31%
PubT-3b: Government Camp transit hub	19%	19%	27%	9%
PubT-4: Expand park and rides	14%	12%	15%	30%
Safe-9: Timberline intersection improvements	20%	22%	17%	10%
Safe-10: Government Camp Loop road west improvements	18%	20%	16%	6%
Safe-11: Government Camp Loop road east improvements	15%	16%	14%	8%
Safe-12: Ski bowl west intersection improvements	13%	14%	7%	7%
Safe-13: Ski bowl east intersection improvements	15%	15%	22%	5%

Source: Evans and Assocs., 2014, appendix B

C. Ecological Impacts and Benchmarks

The ecological impact of transportation systems and of their use will usually be much greater in recreational areas than that found in nonrecreational areas because of the sensitivity of the surrounding natural or cultural environments to disturbance. Active recreation areas such as amusement parks might not be as affected, but natural and heritage recreational areas often attract visitors to unique and sensitive resources. Impacts can occur in a number of ways:

- Diminished air quality and viewsheds from vehicle emissions.
- Impaired groundwater quality from asphalt pavement runoff.
- Vegetation loss due to driving, parking, riding, or stepping on species.
- Erosion in mountainous and beach areas from human activity.
- Reduced nesting and breeding due to invasion of habitat.
- Severed migration routes due to facility rights of way.
- Wear and tear on historic structures.

While private vehicles are often blamed for many of the negative ecological impacts, destructive impacts can come from other forms of transportation as well. For example, Zion National Park found that its transit system was very effective in delivering large numbers of visitors to trailheads at shuttle bus stops. However, the intense pedestrian activity caused trampling of vegetation. The transit system also created crowded conditions in terms of numbers of people in one place at one time.

The transportation system should be designed with the local ecology in mind. In areas with endangered species, transportation facilities and parking (formal and informal) might need to be relocated. Where vehicle emissions diminish viewsheds, public transit vehicles should be equipped for alternative fuels that minimize the pollutant emissions of most concern. Before designing the transportation system, an inventory of ecological assets and threats should be conducted to create a context-sensitive solution appropriate to the local area.

Many recreational areas already have established air or water quality monitoring. Changing numbers of visitors, the number of trips per visitor, and mode choice will alter the way that the movement of people interacts with the environment. Moving people from cars to transit will reduce some environmental impacts and create or exacerbate others. For instance, moving visitors from gasoline-powered private vehicles to diesel-powered buses will reduce nitrous oxide emissions, but might increase particulate matter in the air. This trade-off makes sense in an area with sensitivity to nitrous oxides and a capacity to handle more particulate matter. When recreational regions initiate transit service, supporting groups implicitly accept the trade-off between the environmental impacts of public and private vehicles and judge that the local environment can better tolerate the impacts of transit vehicles. Performance monitoring for recreational transit should include ways to measure both environmental improvements and the negative consequences of transit.

Measures to determine trends and changes in environmental quality have commonly appeared in transportation analysis, but sensitive natural environments might require new types of monitoring. Typical measures include common air pollutants and visibility. For noise pollution, the National Parks Conservation Association conducted a study over a President's Day weekend to determine the pervasiveness of snowmobile noise pollution in Yellowstone National Park. Assigning volunteers to survey each of 13 sites for 20 minutes of each hour between 9:00 a.m. and 1:00 p.m. on both days of the weekend, the study found the human ear could detect the sound of snowmobiles more than 75 percent of the time at most sites. Mitigating factors, such as high winds, were documented in the study.

Many other measures could be developed to address local needs and concerns. Such measures might include the area of vegetation loss incurred when informal parking damages natural roadsides. Yosemite National Park's general management plan specifically designated the need to reduce glare created by vehicles. Wildlife sightings and traffic incidents affecting wildlife could also serve as important environmental indicators. Stakeholders in the transportation planning process need to determine what environmental impacts of transportation will most affect the sensitivities of their specific local region to indicate the types of measures needed in performance monitoring.

D. Analysis and Evaluation of Strategies and Actions

Transportation planners can use a variety of tools to analyze transportation needs and potential solutions of recreational areas. The traditional transportation four-step model can be applied to certain types of recreational areas (depending on the size and complexity of the study area), but a number of unique considerations must enter into the analysis and modeling effort (see chapter 6 on travel demand modeling). For example, whereas most models try to minimize travel time for those traveling in a network, in recreational areas, people want to spend more time seeing and experiencing the environment. Other differences relate to the input variables that precede the actual modeling of travel behavior, the most important being land-use patterns.

Land-use patterns affect where trips come from and where they go. For example, if residential patterns are spread throughout a community, it would be very difficult to serve the community with transit. Strip development along highways also discourages transit and pedestrian use. Alternatively, development around transit stops can put complementary businesses, such as restaurants, hotels, and gift shops, within walking distance of each other. In this scenario, visitors have easier access to local amenities, and they spend less time looking for parking or going from one place to another. Complementary businesses receive the benefits of sharing customers through agglomeration. Policy makers in recreational communities should familiarize themselves with the current literature on transit-oriented development to see how modern principles for integrating transit into community development can apply within local community character to facilitate pedestrian and transit mobility (see chapter 3 on land use and urban design).

Among the different types of land use, parking is one of the most important in defining trip patterns. Local leaders in many recreational areas are realizing that they cannot satisfy ever increasing demands for parking without seriously damaging the resources and quality of life that define their areas. In some cases, physical barriers such as buildings and natural features prevent parking expansion. In other cases, local leaders want to set policy limits regarding how much infrastructure will support private vehicle traffic. In California, the Yosemite Valley Plan calls for reduction of parking capacity in response to a goal in the park's 1980 general management plan to eliminate private vehicles in the valley. However, even if all visitors take transit, parking must exist somewhere to handle the vehicles that visitors use to reach recreational areas.

1. Trip Generation

Whereas typical trip generation approaches pay particular attention to residential areas as the starting point for the first trips of the day, analysis of recreational communities needs to focus primarily on hotel districts and entranceways to the community. Some trip generators and trip generation characteristics of the study area that might have a particularly important influence on travel demand depending on whether the recreational area serves as a vacation destination or a short-term outing include:

- Major hotels and concentrations of small bed and breakfasts
- Campgrounds
- Day trips and other arrivals from outside the area following the seasonal peaking trends discussed earlier
- Housing for seasonal service workers
- Local owner-occupied housing

There is little question that movement for work is different than movement for recreational purposes. Both cases need to be considered in the trip generation step. Such differences also mean that in almost all cases a trip origin-destination survey will be needed to understand the travel characteristics of the recreational area being studied.

2. Trip Attraction

Visitors do not behave the way they do at home; travel origins and destinations have very different characteristics than more traditional work-based trips. More trips are made to specialty stores and restaurants, while grocery shopping might fall to an unusually low frequency. Typically, the major trip attractors in recreational areas are easy to identify because they appear in all of the tourism literature. Businesses that support dominant forms of local recreation will also receive above normal patronage, such as scuba supply stores near the ocean. Identifying trip attractors will most likely require some data collection and could be part of the survey mentioned above, unless the community already has developed trip flows based on historical trip patterns.

3. Mode Split

Predicting how many trips will be made by each available mode is probably the weakest part of the analysis in a recreational community context. Most mode split research has been focused on the work trip and the desire of travelers to choose modes that provide the fastest means of arriving at their destination. As previously mentioned, this basic assumption of traveler behavior is inappropriate for recreational communities. Riding a bike on nature trails or using a heritage trolley in a historic downtown might be selected as the preferred experience in lieu of the most efficient trip. The duration of a visitor's stay might also affect mode split, though it could have conflicting effects. A visitor who has time in an area might feel more willing to try new transportation options than someone who feels rushed into using familiar modes. Conversely, a visitor who stays in a recreational area for several days might grow tired of tourist transportation systems (particularly if the same tour information is given on every trip) and default back to private modes. Mode split data will be unique to many local areas. Mode split analysis for recreational communities needs to consider both the often wide variety of modes available to visitors and the fact that they have not established routine travel patterns.

As crowding has become more of a problem in many recreational areas, researchers have attempted to determine the effects of crowding on visitor experience and their modal and recreational choices. Visual preference surveys and self-assessment techniques for crowding norms have offered some insights, though the results are not always consistent. The self-assessments in combination with contingent valuation, which measures the validity of respondent self-assessment, offer some means of adding validity. [Manning et al., 2001] A complete discussion of current thought on evaluating crowding can be found in Manning's *Parks and Carrying Capacity* [2007].

4. Route or Path Assignment

The primary difference between route choice between recreational and nonrecreational areas lies in traveler motivation. People do not necessarily assign themselves to the shortest path routes from origin to destination, the basic assumption in urban models. Travelers might take scenic loops or they might return "the long way" because they are familiar with that route. Whereas scenic views might be more important than speed for visitors, locals might excel at taking back routes to avoid visitor traffic. In most cases, the size of the network is much smaller than what is typical for urban road networks. Finding reasonable paths through such networks is not as challenging as it is for networks that have thousands of links in the network coding.

The results of analysis feed into the evaluation process. Evaluation is one of the most important steps in planning because information is summarized and presented to decision makers for selecting desired actions (see chapter 1). Evaluation criteria serve as the basis for the evaluation process. Such criteria should be related to the goals and objectives established for the planning process as well as reflect the different target "markets" for transportation investment, for example, through traffic, local travelers, winter visitors, and summer visitors. It is prudent also to keep the number of evaluation criteria to a manageable level so that decision makers can focus on those issues of most importance. As an example, the following evaluation criteria were used to assess the relative worth of different transportation strategies for the Mt. Hood (Oregon) National Forest. [CH2MHILL, 2012]

- *Increased transportation options*—Does the strategy provide additional transportation options or expand existing transportation options?
- *Leverages existing transit*—To what extent would the strategy utilize, expand, or integrate with existing transit services/systems or modes that are in place today?
- *Leverages existing or creates new transportation demand management (TDM) programs*—To what extent would the strategy leverage existing or create new TDM programs?
- *Improves safety*—To what degree would the strategy increase safety or promote safe transportation conditions? Higher ratings will be assigned to strategies that are qualitatively determined to improve safety along U.S. Route 26/Oregon State Route 35 (OR 35). Strategies that meet this criterion may indirectly improve safety through reducing congestion on U.S. 26/OR 35, or may meet the criterion directly through a safety-oriented program.
- *Considers unique needs of seasonal recreation markets throughout the year*—How well does the strategy address the varying needs of recreational users season to season? For example, does the strategy consider seasonal changes in gear-hauling needs, destinations, and trip durations?

- *Considers unique needs of employees*—How well does the strategy meet the needs of employees within the study area? Consider the places from which employees commute, such as Sandy, Portland, and Hood River, and the time of day of their commute.
- *Considers unique needs of residents*—How well does the strategy meet the needs of area residents, including circulation between mountain communities?
- *Reduces freight or through traffic demand in the U.S. 26 and OR State Route 35 corridors*—TDM strategies can be aimed to reduce freight or through traffic demand in the U.S. 26 or OR-35 corridors by suggesting different routes, time of day for travel, and perhaps even mode. Strategies aimed at reducing or shifting demand would receive higher ratings.
- *Increases economic opportunities for commercial enterprises*—Could the strategy help support and expand existing businesses and promote new business opportunities along U.S.-26/OR-35? Consider full range of winners and losers, for example, a strategy that increases economic growth in one area may become a limiting factor for economic growth in another area.
- *Provides financial or travel time incentives for alternative modes of transportation*—What financial incentives would users (both forest visitors and employees) receive by using the travel alternative offered by the strategy?
- *Provides implementable and financially sustainable solutions*—Is it possible to implement the strategy within the five-year window of this pilot program? Could the strategy be financially sustainable for multiple years after the project study period? Is there committed funding for implementation (grants for capital expenditures are more easily obtained than funding for operational costs)?
- *Benefits from support of multiple entities/partnerships*—Does the strategy provide for implementation by multiple entities? And does the strategy form partnerships to support it, financially or otherwise? Does the strategy identify a lead entity to implement, and does that entity support the strategy?
- *Higher magnitude of benefits*—What is the magnitude of benefits? Do the benefits accrue to many or few users/markets? Do the benefits accrue over a greater number of user days? Strategies that benefit more users, markets, or number of user days receive higher ratings.
- *Equity*—Consider the distribution of benefits and impacts from the strategy, and work toward fair access to transportation options for all users, all ages, and all abilities. Strategies that minimize burdens on different populations and user groups, particularly the transportation disadvantaged (low-income, transit dependent, minority, elderly, and children) would receive a higher rating.
- *Capital costs*—What is the order of magnitude capital cost for the strategy?
- *Operating costs*—What is the order of magnitude operating cost for the strategy?
- *Affected parties support*—Does the strategy have the support of affected parties? Affected parties could include agencies or businesses that would be responsible for implementing a strategy. For example, does the implementing agency support the strategy? Does the implementing or affected party have a legal barrier to implement that may not be able to be overcome in the near term?

Each of the criteria was then assessed qualitatively with a "full circle," meaning accomplishment of the criterion; "half circle" meaning some lesser accomplishment; and an "empty circle" meaning no accomplishment. For example, the measures of achievement for the circles were:

- Full circle: Greatly increases alternative options for transportation or expands existing transportation options (two or more additional options)
- Half circle: Moderately increases alternative options for transportation or expands existing transportation options (one additional option)
- Open circle: Minimally or does not increase alternative options for transportation or expand existing transportation options

Other forms of evaluation, such as quantifying changes in system performance or using benefit/cost methods, are sometimes used. The reader is referred to chapter 7 on evaluation and prioritization methods for further discussion of such methods.

E. System Needs and Recommendations

As shown in Table 21-5, the types of strategies that can be considered as part of a recreational planning study ranges from traditional road improvements to the application of intelligent transportation system (ITS) technologies. The importance of modal presence cannot be overstated when designing a service. Presence indicates the degree to which transportation options are incorporated into visitor experience. As one aspect of presence typical for transit systems, service identity and visibility make a transit system recognizable with its logos, vehicle design, and stop design, among others. Equally important, presence captures how visitors see a transportation option as part of their experience in a recreational area, such as a pedestrian area, bike trail network, or a horseback ride to a vista. As an example of a transportation option with strong presence, the Red Bus of Glacier National Park appears in most brochures as an activity that would appeal to visitors as a signature experience, and when the buses went out of service for vehicle reconstruction in 1999, people complained that they did not see the buses running. The following sections examine the types of strategies that can be considered as part of a transportation planning study.

Table 21-5. Priority Strategies for Improving Multimodal Transportation at Mt. Hood, Oregon

	Type	ID	Project Description	Timeframe
Implementation Plan Projects- Group A Action Plan (0–5 years)	Pedestrian & Bicycle	PB-1	Mt. Hood Highway US 26 bike/ped intersection improvements in coordination with potential transit stop locations in Clackamas County.	0–5 years
		PB-3	Mirror Lake Project: Safety improvements including relocating trailhead and adding parking.	0–5 years
		PB-5	Mt. Hood Highway shoulder widening analysis for bicyclist use.	0–2 years
		PB-7	Bike/ped info and wayfinding along Mt. Hood Highway.	0–4 years
		PB-8	Bike intersection improvements at OR 35 and Historic Columbia River Highway (HCRH) (E. State St.) in Hood River.	0–2 years
	Public Transit	PubT-2	Bus: Mountain Express extension of service to the ski areas from Sandy.	0–4 years
	Safety and Road Improvements	Safe-1	OR 35 intersection improvement updates to signage at Central Vale Dr./Booth Hill Rd. (Milepost [MP] 93.5).	COMPLETED
		Safe-2	US 26 roadway departure safety improvements between MP 47.2 and 48.9—rumble strips.	0–5 years
		Safe-3	US 26 roadway departure safety improvements between MP 44.9 and 46.6—rumble strips.	0–2 years
		Safe-4	US 26 roadway departure safety improvements between MP 36.9-39.77 and 42.6-43.2—rumble strips.	0–2 years
		Safe-5	OR 35 roadway departure safety improvements between MP 60 and 93.75—rumble strips and curve warning signage.	0–2 years
		Safe-6	OR 35 intersection improvement at Dethman Ridge Dr.—striping and siging.	0–2 years
		Safe-17	OR 35/US 26 Timberline to Nottingham Roadway Safety Audit Implementation (MP 54.2-MP 70.2)—upgrading signs.	0–4 years
	Intelligent Transportation Systems	ITS-2	Intelligent Transportation Systems along the US 26/OR 35 corridor.	0–3 years

Source: Evans and Assocs., 2014

F. Infrastructure

1. Roads

Roadways usually serve as the backbone of a recreational area's transportation network, which means that they largely shape both visitors' first impressions and subsequent visitors' experience. Roadway capacity indicates how many vehicles a road can accommodate in a given amount of time. Terrain, speed limits, points of access to parking lots and driveways, onstreet parking, and vehicle size can reduce the amount of throughput a roadway can accommodate. Many of these factors are exaggerated in recreational areas as roads wind through mountains, popular recreational areas have many stops downtown, and people drive recreational vehicles (RVs). Wide lanes and large parking lots might accommodate these needs; public transit in heavily visited areas (even a simple loop in the restaurant district) might be another viable option. In some cases, policies restricting oversized vehicles might be necessary. For instance, the Zion-Mount Caramel Tunnel was constructed before the advent of RVs. Drivers of oversize vehicles must reserve passage through the tunnel and pay a fee for opposing traffic to be stopped because the lanes cannot accommodate two-way traffic with an oversized vehicle.

Road design generally follows design standards for recreational areas as found in transportation agency design guidelines and the operating principles found in the *Highway Capacity Manual*. [TRB, 2010]

Several questions should be asked as part of the infrastructure design process, including:

- To what extent are the roads simply a means of getting to a visitation site versus serving as a visitor experience?
- How do roadways impact local natural or cultural resources? For example, does traffic noise impinge on ambient noise levels?
- Can context-sensitive design principles (see chapter 9 on road and highway planning) be used to better integrate road design with the environmental context? What is the right local balance of infrastructure cost versus aesthetics in design?
- Can roads also be designed to safely handle other means of transportation, such as bicycles?
- What are the appropriate trade-offs between preserving a roadway's historic characteristics and improving the roadway's design to provide better operation and safety?

Given that approximately one-third of the land mass in the United States is owned and managed by the federal government, the types of design principles and standards used by responsible federal agencies become important guidance on how roads, bridges, and culverts should be designed. The following definitions from the Federal Lands Division of the Federal Highway Administration are helpful in understanding the different terminology in roadway design that might find their way into the planning process.

Policy. Guiding principle; general course of action to be followed without exception. Where policy is cited the source of the policy is also referenced, when applicable and appropriate.

Standard. A fixed reference to guide the outcome and content (product) of the work . . . . Standards are established where there is a consistent level of risk, or there is a consistent technical or performance expectation for a specific product to work well in most cases . . . .

Criteria. Tests or indicators, in addition to standards, used to measure/judge achievement of applicable policy or standard objectives. Criteria may vary from project-to-project . . . .

Standard Practice. Standard practices are established methodology that the Office of Federal Lands Highway (FLH) imposes to guide the approach to the work, and which will generally produce a consistent outcome that meets FLH expectations. Standard practices are established where a certain process or method is necessary, in addition to or as assurance, for achieving a sufficient end result product . . . .

Guidance. Suggested actions to meet policies and standards, and expectations for applying discretion . . . .

Discretion. Where the practitioner is expected to exercise engineering judgment to apply an optimum technique or solution that is within an acceptable range of values. [FHWA, 2012]

Readers interested in National Park-related road design considerations are referred to http://www.nps.gov/transportation/library_manuals.html.

Scenic roadway capacity can be reduced by people stopping to view scenery or wildlife, thus reducing capacity for emergency access as well as the general traffic. Vehicles tend to move in platoons behind one slow leader, making pullouts for slow-moving traffic important considerations in road design. Topography and the built environment might limit options for infrastructure development and, in some cases, policy standards might restrict the use of traditional capacity expansion to address such problems. For instance, early in the management of the National Park System, federal park administration guidelines limited road widths to two lanes accommodating cars and trucks; recreational vehicles (RVs) as a consideration were added later. [Albright and Schenck, 1999]

Wayfinding signs and directions to information centers are important given the large proportion of unfamiliar drivers on the roads. The enhanced need for information must be considered in light of information overload for slightly disoriented drivers. Sign warrants should adhere to the design principle of confronting drivers with only a single simple decision to make at a given time. Sign ordinances might be considered for limiting the amount of on-street advertising in confusing areas, though on-street advertising might be an important means of attracting customers to businesses. The safety implications of signs along roads need to be discussed in the local context.

The extreme conditions of many remote recreational areas might require special road management systems. Glacier National Park sends a maintenance vehicle onto the Going-to-the-Sun Road once or twice a day to remove rocks that have fallen onto the road, and snow plows might be necessary in any month of the year. Deserts and coastal areas with substantial sand might require special engineering to keep sand off the road surface and from creating traction hazards. High winds and other dangers specific to local recreational areas pose their own unique challenges for maintaining the integrity and performance of road infrastructure.

Given the nature of parks and recreational areas, roadways might impinge upon wildlife mating grounds, migration routes, or other habitats in ways that can endanger a species over the long term. In such cases, road designers should consider wildlife overpasses and underpasses as possible mitigation measures. [Morrall and McQuire, 2000]

2. Parking

Transportation planners for recreational areas spend considerable time thinking about parking. Private vehicles crowd lots around attractions; shopping areas fill up at meal times and people often park on the side of scenic roads. Even in recreational areas where nonmotorized modes or public transit dominate, the private vehicles that transport people to the area must be stored somewhere.

Many parks experience a daily tide of vehicles flowing into the park early in the day and flowing out of the park later in the day. Peak parking accumulation thus occurs in the midday to midafternoon time period in many parks.

Parking supply can take numerous forms. The City of Hot Springs, Arkansas, for example, built a new parking garage across the street from the city's signature bathhouses. In other instances, parking expansion faces obstacles. For instance, many national parks have limited land for parking where most visitors want to go. In other cases, adopted policy limits how much infrastructure will support private vehicle traffic. For example, the Yosemite Valley Plan calls for a reduction in parking capacity in response to a goal in the park's 1980 general management plan to eliminate private vehicles in the Yosemite Valley. [Yosemite National Park, 1980]

The strategy chosen for a park-and-ride plan will affect the way that visitors interact with a transit shuttle system and with local businesses. Bryce Canyon and Zion National Parks in southwest Utah use strikingly different parking plans. At Zion National Park, the local parking strategy expects many visitors will leave their vehicles parked at their hotels or in town. Two parking lots with about 550 spaces accommodate some vehicles next to the visitor center near the park entrance, and the gateway community provides a small overflow parking lot just outside the park. However, these two lots combined cannot accommodate all of the vehicles for the 3.5 million annual boardings of the Zion Canyon Shuttle. Indeed, in 2012 these two lots filled to capacity on 109 out of 153 days during peak season.

Whereas Zion disperses much of its parking demand across the gateway community and among local businesses, Bryce Canyon National Park concentrated its parking at one dedicated location. The park utilizes a parking area in the gateway community outside of the park.

Each parking strategy has strengths and weaknesses. A dedicated staging area offers a secure place to leave vehicles, use restroom facilities, and obtain general information on the park. System designers want to create the feeling of entering park lands from the point of accessing transit. On the downside, the staging area defeats one of the well-documented benefits of transit—commerce has an opportunity to develop where people change modes of transportation. People are far less likely to get off a bus to buy a souvenir than they are to stop in a store while they wait for a bus after they get out of their cars. With no businesses around the parking lots, the staging area does not provide potential economic benefits to the gateway community.

Another economic consideration relates to parking fees. Such fees can be used to generate public funds or to shape travel behavior. Parking fees serve as effective means of encouraging carpooling or mode shift. [Golias, Yannis, and Harvatis 2002] Given that many visitors already arrive in multiple occupant vehicles, implementing a carpooling program is not an effective strategy in recreational areas, so high parking fees should be used only in locations with high-quality transit service or where a convenient pedestrian environment that serves the visiting population well. Town parking lots in Provincetown, Massachusetts, charge $25 to $35 per day in the municipal lot, and people are willing to pay it because parking is scarce. [Town of Provincetown, 2015]

Most discussions of parking capacity refer to the number of passenger vehicles that a parking area can accommodate. Because vehicle sizes differ, parking capacity for passenger vehicles must accommodate large recreational vehicles (RVs). RV hookups might also be necessary, but private, dedicated campgrounds typically provide for this need.

3. *Pedestrian Walkways and Paths*

Pedestrian environments should receive the attention they deserve from transportation planners and from the traveling public (see chapter 13 on bicycle and pedestrian planning). Recreational areas, in particular, offer situations where pedestrian access could be the ideal mode. In many cases, the pedestrian environment of the recreational area defines the quality of visitor experience. The average hike in national parks lasts four to five hours. One in 10 hikers stays overnight, and these people are typically young. Short hikes and nature walks, however, appeal to people of all ages. [Dunning, 2005] The Americans with Disabilities Act (ADA) of 1990 has focused attention on providing at least some trails with wheelchair access in each trail area, though the natural features of many remote areas create obstacles to making all trails accessible.

In urban areas, recreational communities create unique local character through sidewalks, shopping and restaurant districts, street festivals and so forth. Many major cities have historic trail tours, such as the Atlanta, Georgia, Martin Luther King, Jr. Historic District; the Boston, Massachusetts, Freedom Trail; and the Washington Mall in Washington, DC.

4. *Bicycle Paths, Lanes, and Trails*

Bicycle use in parks will vary from one park to another. The Grand Teton National Park created a bicycle system plan and a pedestrian circulation plan as primary recommendations in its most recent transportation study. As noted, "This initiative intends to increase the share of visitor and employee travel by bicycle, improve opportunities for bike touring, and enhance the quality and safety of the Grand Teton visitor experience through selective implementation of bike lanes (that is, wide paved shoulders), stand-alone pathways, traffic calming, bicycle signage, bicycle/transit integration, and improved bicycle parking." [NPS, 2006]

The Great Smoky Mountains National Park created time periods with motor vehicle restrictions to allow bicycles and pedestrians safe and unthreatened use of the 11-mile loop road through an historic district. [Byrne, 1999] The road often has bumper-to-bumper traffic, particularly in the summertime, making bicycling dangerous. As a test, the park closed the road to motor vehicles for one day a week from sunrise to 10 a.m. The closure was so popular that the park extended it to two days a week (Wednesdays and Saturdays). On Saturdays in December, the park keeps the loop road closed to motor vehicles until noon.

In contrast, Glacier National Park forbids bicycles on hiking trails, citing environmental reasons. The concern of mountain bikers leaving the trails and abusing the natural resource has guided park policy. Most of the hiking trails in the park lie in areas proposed for wilderness designation, which means they must be treated as if they are so designated until Congress accepts or rejects the proposal. The Wilderness Act of 1964 states that "there shall be no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport and no structure or installation within any such area." [Public Law 88-577 16 U.S. C. 1131-1136] In Glacier National Park, the use of any type of nonmotorized wheeled vehicle (that is, canoe dolly, cart, and so forth) on backcountry trails is prohibited. Persons with disabilities as defined in the ADA may use wheelchairs on trails.

Aside from parks, many urban recreational communities have established bicycle networks as key components of their transportation systems for visitors. Fire Island in New York and Mackinac Island in Michigan are notable examples where motorized vehicles have a substantially diminished presence compared to bicycling.

From a design perspective, bicycling facilities exist on separate bike paths (Class 1), on demarcated bike lanes (Class 2), or on designated bike routes with shared right of way (Class 3). Average cyclists can sustain speeds of 10 miles per hour (mph) on level terrain, making trails ranging from between 3 and 6 miles to between 10 and 30 miles desirable. Trails should avoid short gradients exceeding 10 percent and sustained gradients of 4 to 8 percent. Effective design can mitigate concerns of threats to safety, trail user conflicts, and resource damage. Best practice attempts to separate bicyclists from other trail user, where possible, and provide safe bicycle access on park roadways. The design criteria for paths, lanes, and trails can be found in the adopted design guidance for a particular park or park jurisdiction (see FHWA [2008, 2015b] for a good resource on both federal and non-federal design guidance, and ways to encourage bicycle use in national parks).

In the United States, federal-aid funds may be used for bicycle and pedestrian projects where eligibility criteria are met. These projects are broadly eligible for all of the major funding programs where they compete with other transportation projects for available funding at the state and metropolitan levels. [FHWA, 2015a] This funding has been used for a variety of nonmotorized transportation options, such as turning abandoned railways into trails, providing streetscapes in urban areas and providing basic sidewalks. These types of nonmotorized facilities have a place in recreational areas. Readers interested in bicycle and pedestrian transportation in national parks are referred to the following website: http://www.nps.gov/transportation/pdfs/Federal_Transit_BikePedPlan.pdf.

5. Trails

Table 21-6 shows nine commonly identified trail types. Trails will sometimes follow utility line rights of way where the environment has already been disturbed. Rails-to-trails initiatives in recent decades have put trails along abandoned railways, such that the trails have gentle grades and curves and possibly connect to town centers. For nature trails, hiking trail classifications range from short trails to long loops for day hikers; overnighters traverse cross-country trails. Hikers can share low-demand equestrian trails, but horse excrement, accelerated erosion, spooking of horses, and different trail length leads to a recommended separation. [Fogg, 1990]

Urban trails (sidewalks) should be designed with a capacity to move masses of people comfortably, depending on levels of visitation. Sidewalks on the Strip in Las Vegas are 15 feet (4.6 meters) wide with substantially more capacity in the plazas of casinos. While that width of sidewalk would overwhelm most recreational areas, sidewalks greater than a 3-foot (0.9 m) width should be considered, especially if utility poles and street furniture block pedestrian right of way.

Beyond the requirements of the ADA, transportation planners for recreational areas must recognize that a disproportionately high proportion of the visiting population might require extra consideration for accessibility. Retirees already constitute a large proportion of touring populations, particularly in the fall after children return to school. The retiring baby boomers have money and time to travel, but as their numbers increase, their physical requirements will also increase. Sidewalks must have ramps, ramps must have tangible indicators to alert the blind of an approaching roadway, and crosswalks need audible messages. Transit station platforms need widths to accommodate wheelchairs. Wayfinding information must be available for people with various disabilities. Rest areas and assistance should be available at reasonable intervals to accommodate people as they tire.

Table 21-6. Commonly Identified Trail Types

Nonmotorized	Winter Use	Special Use	Water
Hiking	Cross country skiing	All-terrain vehicle	Canoe, raft, or boat
Bicycling	Snowmobile	Motorcycle	
Equestrian		Off-road vehicle	

Source: Fogg, 1990

For trails in northern climates, summer hiking and bicycling trails can turn into winter cross-country ski trails, though skiers require wider trails and gentler curves than often found with summer backcountry trails. Snowshoeing might take the place of hiking. In most cases, the most pressing issue associated with winter uses is the adequate marking of where such paths are, especially in areas that receive high snow pack or drifting snow.

G. Transit Service

Although transit services also require infrastructure to support vehicle operations and passenger movement, this chapter considers transit separate from the infrastructure discussion because of the passenger orientation of successful service. The following website from the U.S. Federal Transit Administration (FTA) provides examples of the types of transit services that are available in national parks (http://www.fta.dot.gov/documents/TransitInParks2011POST.pdf).

Transit service serving recreation areas can take a variety of forms. It can bring visitors from other locations to the recreation area. Or, it can be service within the recreation area that distributes visitors to various locations. Within U.S. national parks, transit service is sometimes mandatory (private vehicles are not allowed on the roadway) and is sometimes voluntary (the visitors have a choice of using transit or their private vehicle).

Bus systems can typically enter service with minimal start-up costs by using the existing road network for right of way. Initial capital funds are devoted to buying vehicles and building shelters. The importance of building shelters, erecting signs, and installing intelligent transportation system (ITS) technology (see next section) cannot be overstated for bus-based systems. Easy-to-understand route structures and system amenities are critical for this mode because recreational transit systems serve a market that is unfamiliar with the area. Visitors could be confused where multiple routes meet and where bus stops do not make the direction of the bus obvious. In other words, when a bus pulls to the side of the road and still points in the direction of travel, passengers understand where it will go, but when it goes off the road into a cul-de-sac or parking lot, passengers unfamiliar with the area lose orientation.

The strategy of where to place bus stops also affects how people interact with the system. Different functions are served by fixed bus stops and situations where passengers must request stops by flagging the bus driver. Experience suggests flag stops benefit neither visitors nor gateway community businesses as much as fixed stops. For visitors, people do not know where to ask to stop when they are visiting an unfamiliar vacation community. For businesses, no one will ever accidentally get off at a flag stop and decide to wander into a souvenir shop.

Bus stop structure largely follows from pre-established priorities, such as where parking exists or whether businesses need to pay to have a bus stop in front of them. Common sense can also dictate many of the decisions, such as putting stops near major activity centers (scenic attractions, large hotels, or popular restaurant areas) and avoiding places that contain safety hazards. Geographic analysis of local businesses can determine where stops would serve the largest number of tourism-oriented businesses. As a general rule, many transit planners assume that most people will walk no more than one-quarter mile (400 meters) to one-half mile (800 meters) to a bus stop depending on the context, so businesses within that distance of a fixed stop can be considered well served by transit. [Kittelson et al., 2013]

Depending on system size and established priorities, transit plans might also require the construction of fueling stations and maintenance facilities. Locating fueling stations can be tricky because they need to be centrally accessible to buses yet out of sight. New fleets of 50 or more vehicles within metropolitan areas and supported by federal funding need to incorporate alternative fuel components under the Energy Policy Act of 1992, necessitating consideration of the supply line for the fuel and location of the fueling station. Executive Order 13423 of January 23, 2007, strengthened the requirements for federal agencies operating fleets, which affects federal recreational areas operated by the National Park Service, U.S. Forest Service, U.S. Fish and Wildlife Service, and Bureau of Land Management. Cost efficiencies might be available if other fleets (public or private) in recreational regions can be identified and converted to selected alternative fuels. The U.S. Department of Energy's Clean Cities program offers support for building local and regional coalitions for alternative-fuel and vehicle-technology initiatives. [USDOE, 2015]

For rail transit, few regions with recreation-oriented economies have achieved sufficient year-round volume of activity to justify the cost of rail infrastructure; however, notable exceptions exist such as Disney theme parks and Las Vegas. Right-of-way for rail typically requires substantial reconfiguration of existing infrastructure when new rail is installed. Right-of-way acquisition is the most expensive aspect of start-up, which makes rail expensive to install over distances unless the system will use existing abandoned or shared tracks (see chapter 12 on transit planning).

Characteristics of travel demand and the cost structure for operating transit in recreational communities are important factors when considering service options.

- Operating costs largely occur only during peak and possibly shoulder seasons, with many systems lying dormant during the off-season. Recreational communities can save or spend money on transportation services by altering the dates of operation. Operations-based systems require consideration of labor costs and the availability of skilled workers (typically drivers) who want to work for only part of the year.
- Capital costs for infrastructure and vehicles occur upfront and need payment regardless of time of year or robustness of visitation. Capital-based systems thus require stable demand and a steady revenue stream.

Bus-based systems incur high operating costs because systems require one driver for every operating unit (or for every two in the case of articulated buses), but capital costs can be minimized by using existing roads for operations. Rail-based systems incur high capital costs for acquisition of right of way and rail construction, but an installed system can move large numbers of passengers with relatively low operating costs per passenger.

Fare structure is another important consideration in transit service planning. In rural areas, transit operators typically recover a smaller proportion of fares than their urban counterparts. Thus, most discussions of recreational transit finance will likely begin with an underlying understanding that transit service requires a subsidy. With this subsidy often coming from public agencies, it is not surprising that broader public policy goals become part of the goals and objectives for transit services, such as reducing auto emissions, reducing the number of registered complaints about parking availability, or raising the number of wildlife sightings in natural recreation areas. One possible option for charging a fee for the transit service is to bundle the cost as part of a park entrance fee, and thus transit would be considered part of what visitors are paying for, and perhaps used more often.

In recreational areas, transit vehicles must provide service attractive enough that people will choose to spend their vacation time using the service. The National Park Service conducted a vehicle-design workshop to identify special considerations for transit vehicles in recreational areas. The workshop resulted in a recognition that the characteristics of a given region determine the unique needs for fuel type, propulsion, seating, cargo, safety options, and vehicle size. Comfort and unobstructed views emerged as primary considerations in recreational areas. Recognizing the needs of foreign visitors, automated language translators were recommended for onboard messages. Another consideration is that national parks emphasize maintaining the historical nature of the park roads and paths, and thus minimize the number of parking spaces. Integrating transit service into this perspective on infrastructure could be very difficult.

In urban areas, transit services allow passengers to stand in the aisle while the vehicle is moving. Not all recreational areas are conducive to allowing standees. Topography affects the ability of buses to accommodate standing passengers safely. In Yosemite National Park, for example, when ridership exceeds the number of seats in the vehicle, drivers deny boarding to people waiting for the bus because buses traverse winding mountain roads.

Another consideration for transit in recreational areas is accommodating the needs of short-distance travelers on longer distance bus services. Thus, for example, buses need to accommodate bicycles, skis, and other paraphernalia necessary for the next leg of passengers' trips. Acadia National Park has an extensive network of bicycle trails that visitors enjoy during the day, but as afternoon brings fatigue, many of the visitors ride the bus back to their hotels. Buses equipped with bicycle racks can typically handle two bicycles and sometimes as many as four. Demand quickly overwhelmed the capacity of bicycle racks on Acadia's Island Explorer shuttle buses; transportation operators sent a trailer to carry bicycles in the late afternoon.

H. Intelligent Transportation Systems (ITS)

Providing information to park or recreational area users on the performance of the transportation system or on the shortest routes to desired destinations is an important means of providing the most efficient system operation possible given prevailing conditions. Variable message signs indicating when the next transit vehicle will arrive or where parking is available provide visitors with confidence that they are in the right place and not working with outdated information. Traveler information 511 service has been adopted in many localities across the country and can be used as another source of information on system performance.

ITS technologies could play an important role in some (especially larger) recreational communities (see chapter 10 on transportation systems management and operations for more discussion on ITS technologies). On the pragmatic level, the operational expense of transportation technology requires a minimum threshold of congestion to make the system worth supporting. In addition, in very large national parks, internet network connectivity is very poor and the primary source of information is the telephone, which also has spotty service. Thus, in some cases, unless the park is going to provide a dedicated network within the park, the opportunity to apply ITS solutions is limited.

However, because parking is a major focus of transportation systems in recreational areas, innovative parking technologies can substantially affect traffic efficiency. Real-time parking information at Acadia National Park and its gateway communities changed the way people traveled: 43 percent of visitors using parking information changed the time they visited destinations; 38 percent of parking information users changed their destinations and 44 percent of the people who looked at the real-time parking information decided to take the bus instead. The average number of vehicles parked outside designated spaces in eight high-demand lots fell from 325 in 2001 to 274 in 2002 even though total visitation had increased. Real-time parking availability information has been shown to spread demand over time, change destination choices and alter mode split, but in many recreational situations, parking lots serving remote destinations are themselves located far from the last transportation option. For instance, parking lots on mountain tops and other scenic viewpoints can fill beyond capacity, frustrating people who have driven 30 minutes or more to learn that the lot is full.

With ITS technology still making initial forays into park and recreational community environments, new ideas for customized innovation continue to emerge. Denali National Park and Preserve has fixed cameras on wolf dens, eagle nests, and other unique areas of ecological intrigue, such that a wireless-equipped bus arriving near a targeted area will respond to a sensor and broadcast the camera feed onto a monitor in tour buses.

Real-time information regarding bus departures can help many transit systems overcome difficulties associated with low-frequency routes. Surveys of transit riders have shown that people will consult schedules whenever buses depart at intervals greater than 10 minutes. The real-time information of global positioning system (GPS)–equipped buses gives confidence in the reliability of transit where first-time visitors have no experience riding the system. Experience with Acadia National Park's Island Explorer has demonstrated that visitors respond to technology and make choices accordingly, as evidenced in the 2002 survey of visitors that showed that 80 percent of bus riders made the decision to ride at least in part due to seeing signs with real-time bus departure information. [Daigle and Zimmerman, 2003] Good examples of ITS transit applications in parks is found at http://www.nps.gov/transportation/pdfs/ITS_In_Parks_2011_Update.pdf.

I. Demand Management

Although most transportation strategies will be similar from one locale to another, there will likely be some strategies that are very specific to a particular community. One such strategy includes transportation demand management (TDM) actions, which are aimed at managing travel demand usually in lieu of building more capacity (see chapter 14 on travel demand management).

While few recreational areas would want to reduce the number of visitors to their areas, many would like to manage the demands on the transportation system to make it more efficient. Transportation demand management for recreational areas can take several forms. It might mean encouraging mode shifts, encouraging greater activity at under visited sites, or flattening demand such that peak loads are not as severe. Many parks practicing demand management have onsite communication systems with no opportunity for visitors to get advance information before making a long journey to the parks. Table 21-7 shows example TDM strategies for a transportation study of Mt. Hood in Oregon.

At many attractions, large percentages of visitors go to the same destinations. For instance, most first-time visitors to Yellowstone National Park will likely visit Old Faithful. As a result, these destinations receive large crowds, resulting in congested parking conditions, wear on the natural resource, and a diminished visitor experience due to perceptions of crowding. Meanwhile, other attractions might have capacity to handle far more visitors. Policies for spreading visitor demand can take the simple form of instructing seasonal employees to recommend two or three site visits, alternating as each motor vehicle enters the site. For example, the first car at the entrance gate hears about attractions A and C, the next car hears about A and D, and the third car hears about B and C. Consequently, if A has traditionally received all three cars, it now only receives two-thirds as many. Glacier National Park identified the need to level the use of park

Table 21-7. Transportation Demand Management Strategies for Mt. Hood, Oregon	
Strategy	**Potential Impact**
Develop a Transportation Management Association or other organization to coordinate transit and TDM programs.	High
Transportation System Management and Intelligent Transportation Systems.	High
Increase and extend existing public transit.	High
Increase and extend existing private transit.	Medium/Low
Advertise and improve carpooling information sites.	High/Medium
Create a "one stop" Mt. Hood traveler webpage with dynamic information on parking, weather, road conditions, travel time, and available transit.	High
Increase cell phone coverage on the mountain.	High

Source: CH2MHILL, 2012

resources in its transportation and visitor use study when the Going-to-the-Sun Road was being rehabilitated. This plan established *use leveling* as a means of reducing congestion and crowding during a period of reduced accessibility and mobility in the park. [Glacier National Park, 2014] Other parks can extend this concept to handling typical surges and spikes in visitation.

J. Supporting Policies

Land-use, pricing, and development design policies can influence how well transportation systems perform. Planning agencies, chambers of commerce, transit operators, and other agencies can each make policies that affect travel behavior and have repercussions on local economies (see Table 21-8). Land use tremendously influences travel behavior and traffic flow for all modes, yet often communities of small and medium sizes that economically depend primarily or solely on recreation do not have the planning expertise for sustainable land use. Also, the long-term nature of changes in land use makes it difficult to identify the role of land use without a trained eye. The process of transportation planning for recreational areas should include the education of local leaders on the significant future impacts that land-use strategies (or a lack thereof) will have on local mobility.

Table 21-8. Policies Potentially Affecting Travel Behavior	
Agency	**Policy**
State or local departments of transportation	• Parking policies • Modal infrastructure development • Traffic signal preference for buses • Communications policies
Chambers of commerce or visitors' bureaus	• Discounted membership for businesses advertising or encouraging recommended transportation options • Training and education programs for seasonal workers • Transportation information dissemination • Communication policies
Transit operators	• Route design • Fare policies • Communication policies
Localities	• Zoning • Parking guidelines for businesses • Communications policies

At the start of transportation planning processes, planners should document relevant policies across all agencies and look into policies in comparable communities and model sites for ideas on other policies worth considering. The local list of policies should reflect changes in policies. Records should indicate when policies begin, so future analysis can identify the influence of the policies in trend data.

K. Additional Types of Studies

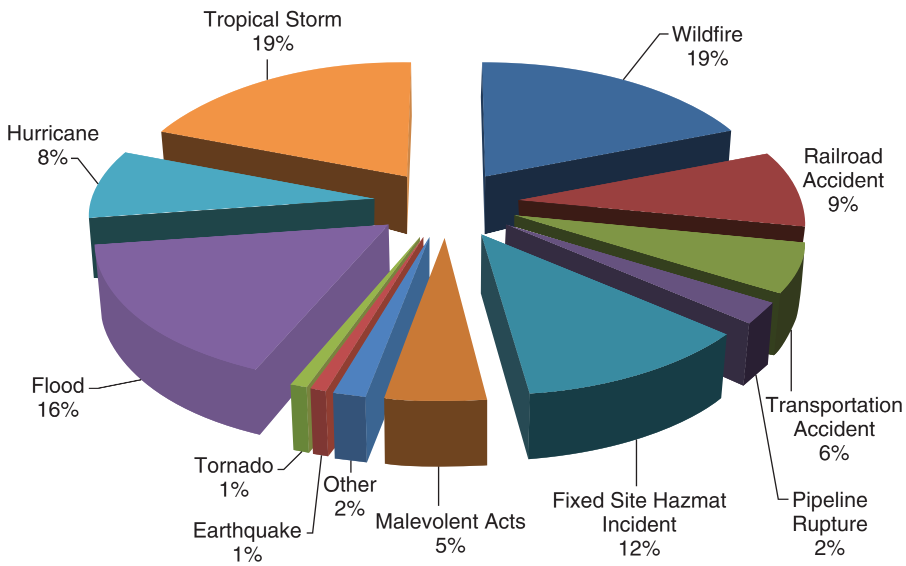
Recreational travel often has a unique influence on the economy, environment, demographics, financial solvency, and many other aspects of a recreational community. Because of this, a number of different types of studies might be necessary before implementing transportation system changes. Important types of studies to consider include: (1) environmental impact assessments, (2) economic evaluations, (3) socioeconomic and equity analyses, (4) financial impact analysis, and (5) project evaluation. Examples of these types of studies are found in [National Park Service, 2006; Thomas et al., 2014].

Evacuation planning has grown in importance since the 1990s, especially for coastal communities where evacuation in response to extreme weather events can overwhelm the transportation network. Evacuations are not solely related to recreational areas; entire states and metropolitan areas can be affected by evacuation-causing events. However, such planning is discussed in this chapter simply because recreational areas could be considered one of the challenging contexts for evacuations . . . . most areas have a limited transportation network and most recreational travelers are unfamiliar with this network. These challenges become particularly acute with dealing with some population groups that are particularly vulnerable (for example, of the 853 Hurricane Katrina storm-related fatalities in Louisiana, at least 584 (nearly 70 percent) were over the age of 60 and 388 (nearly 45 percent) were over the age of 75). [Wolshon, 2009]

Figure 21.9 shows the different types of causes for evacuations. Although somewhat dated, the relative distribution of evacuation causes is most likely similar today (although with climate change, the frequencies of severe weather-related evacuations might increase). Importantly, the focus of evacuation planning and the different types of strategies involved varies by whether advance notice is available of an upcoming event (e.g., hurricane) or whether there is no advance warning (for example, earthquake). In both cases, clearly identifying the roles and responsibilities of the different agencies that will be involved with evacuations need to be part of the plan.

Wolshon [2009] summarized the planning approach used by the U.S. Army Corps of Engineers for evacuation planning, which is similar in concept to the overall planning approach described in Chapter 1. This approach includes the following steps:

Figure 21.9. Principal Causes of Large-Scale Evacuations in the United States (1990 to 2003)



Source: Dotson and Jones, 2005

- Define evacuation transportation zones based on storm scenarios. These zones represent origin and destination zones that will be used in the analysis.
- Develop dwelling unit data for each zone, including detailed characteristics of the population, number of dwelling units, and number of vehicles.
- Identify the transportation network (usually roads) that can be part of an evacuation network, and key characteristics such as capacities and potential use of contraflow lanes.
- Forecast the number of expected evacuation trips based on historic data or surveys. This must consider the number of people and vehicles that will go to local public shelters; homes of local friends and relatives; local hotels, motels, churches, and other types of local destinations; and all destinations outside the local area. As noted by Wolshon [2009], in nuclear power plant travel analyses, a variety of day-night, weekday-weekend-holiday, summer-winter, and clear-rainy-snowy conditions are assessed.
- Distribute trips among evacuation transportation zones, resulting in origin-destination matrices for each storm scenario.
- Assign evacuation trips to the road network that connects the origin and destination zones, and identify bottleneck points.

As discussed in chapter 1, this approach relies very heavily on the four-step planning process described earlier.

Information on evacuation planning can be found in a variety of sources. Many public documents have been released, including the following two from federal agencies:

- Federal Highway Administration: *Using Highways During Evacuation Operations for Events with Advance Notice Routes to Effective Evacuation Planning Primer Series*, Accessed August 16, 2015 from http://ops.fhwa.dot.gov/publications/evac_primer/00_evac_primer.htm
- National Oceanic and Atmospheric Administration, Planning and Impact Assessment Reports: http://coast.noaa.gov/hes/hes.html?redirect=301ocm

Interested readers are also encouraged to review [Wolshon, 2009].

VI. NEED FOR INFORMATION AND COMMUNICATION

Given the first-time experience for many visitors, the dissemination of information concerning transportation system options is an important element of a transportation strategy. In addition, however, the often diverse set of stakeholders interested in effective transportation services requires the exchange of information and communication among those involved in providing such services and the community groups affected by them. Communication encompasses educating and keeping informed the people designing and operating transportation systems (planners, engineers, and political leaders), the people using the system (visitors), and the people who interact with the people using the system (local businesses, front-line workers, and local citizens). Communication plays a vital role in shaping public opinion and influencing travel choices.

A. Communication with the Visiting Public

Except for targeted information campaigns that are part of start-up services, transportation planners cannot expect a strong public familiarity with their recreational transportation systems. The tourist population of recreational areas, where typically more than half of the people visiting are doing so for the first time, will not know about the transportation options available to them. Public service providers in some communities benefit from residents gaining familiarity with the services over time and sharing their knowledge with newcomers. Knowledge also carries over from year to year as some visitors and seasonal workers return. The largest need for outreach to all of the publics impacted by recreational traffic comes when changes are made to the transportation system—the time when most resources are typically dedicated to making the change rather than working on public relations.

Tourism industry market researchers monitor the best ways to disseminate information to the visiting public, and parks often include in visitor use surveys questions about what information sources people use to plan their recreational visits. Typical media include travel guides, tour books, and Web pages about recreational attractions and surrounding businesses and amenities. Once visitors arrive in the local area, they refer to sources such as local tourist publications, visitor centers, chambers of commerce, and local residents. Messages that target one audience will sometimes filter to other audiences, and some groups might fall into more than one category. For instance, local citizens frequently use the same recreation amenities as the general visiting public, and the information that goes to local citizens often is picked up by visitors.

With respect to transportation, visitors need to know about and understand transportation options before they will be willing to use them. This means that information on options, venues served, schedules, and stops must be readily available at entrance points to recreational communities, at visitor lodging, and at other easily accessible locations. For real-time information, various ITS technologies such as kiosks and variable message signs can be used to provide information on the current status of transportation services.

Planners for each locality need to tailor communication programs to their own situations. Visitor surveys can help identify how visitors get information on their recreational regions. Past surveys have indicated that the widening use of the internet has gradually changed the sources people use to get information, particularly since the late 1990s. On the other hand, traditional media, such as tourism guidebooks and telephone inquiries, continue to influence vacation planning. Transportation operators should design public communication programs consisting of different media, where this strategy is informed by research that is updated through regular visitor surveys (see chapter 24 on public participation and engagement).

B. Communication with the Local Community

Sometimes even the most thoughtful public outreach efforts can have unintended reactions. When the Maine Department of Transportation designed a campaign to publicize its 511 tourism information network, part of the campaign involved showcasing the ITS information outreach implemented in and around Acadia National Park. The Bar Harbor Chamber of Commerce objected for fear that alerting visitors to full parking lots might scare potential visitors away.

Although some might object to the media reporting congested conditions, in reality, the media are often the most effective means of getting the message out. Developing good relationships with radio, internet, newspaper, and television outlets is an important part of the transportation planning and transportation system management processes.

VII. SUMMARY

People have long used recreational areas as places to get away from the perceived ills of urban society—traffic congestion, pollution, and crowding. But these characteristics of modern society are following them into their vacations. Transportation planning is becoming increasingly important to maintain vacation-quality visitor experience in recreational areas. Given that recreational areas serve special roles in unique locations, they also differentiate characteristics that need to be considered in transportation planning. While priorities will vary depending on recreational community types, locations, and cultures, any community dependent on tourism for the majority of its economy will consider visitor experience and quality of life paramount in transportation system design. Information and communication are critical from the basic word of mouth of front-line employees to sophisticated intelligent transportation systems.

Transportation planning for recreational areas needs to take into consideration a wide range of impacts, thus the need for a systems approach toward planning. A systems approach anticipates externalities and trade-offs among desired goals and prepares stakeholders to understand the trade-offs necessary for achieving the best transportation strategy for the community. These trade-offs form the basis for balancing the interests of different stakeholders and the best interests of the recreational site. After adopting desired goals and operational objectives, monitoring system performance provides critical information on the extent community goals are being achieved, the associated costs, and the external effects generated. Transportation planners, recreation managers, and transportation system operators can use this information to achieve more effective and sustainable outcomes.

The potential positive and negative consequences of transportation initiatives can affect many people in different ways. Transportation planners for recreational communities need to adopt an open planning approach to prepare for the impacts of system changes and to create the most desirable effect for a given local environment. Rather than focusing on economic, environmental, financial, or any other specific type of impact, transportation must be considered through a systems approach that anticipates and educates people about externalities and trade-offs among goals.

Rather than asking what impacts transportation changes can be expected to generate, transportation planners should articulate the types of impacts they intend to create. These objectives formed in local context need to balance across the interests of different stakeholders and the trade-offs inherent in pursuing any given objective.

For those wanting additional information, an excellent resource for information on transportation in park areas is found at the Federal Lands Transportation Institute, Resource Library http://www.fedlandsinstitute.org/ResourceLibrarySearch/Repository.aspx.

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Chapter 22

Integrating Freight into the Transportation Planning Process[1]

I. INTRODUCTION

For many years, the transportation planning process focused almost exclusively on passenger transportation. The models developed, the data collected to support these models, and the resulting policy and investment strategies were each concerned primarily with the movement of vehicles and people. Freight movement entered into planning consideration primarily as a truck–passenger car equivalent factor used to estimate freeway capacity. With the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, transportation planners and policy makers became more interested in the concept of intermodal transportation as applied to both passenger and freight movement. Although much of the freight and goods movement in a typical state or metropolitan area is the responsibility of private firms, a large portion of this movement occurs on the highway network and thus has significant implications to those responsible for planning, building, and managing the road network. In addition, laws, operating regulations, and zoning codes can have a significant impact on freight operations, and thus the interface between the freight sector and public decision making is an important part of the transportation policy framework.

Transportation planners need to know how much freight and what type of goods are moving on the transportation network, and from which distribution/ warehouse centers these flows are originating. These and other data about the mode of transportation, vehicle or vessel characteristics, and types of facilities used are needed to track and monitor system conditions and performance to assess the many ways freight affects the transportation system. The U.S. economy depends on an interconnected transportation network to move a vast array of raw materials and manufactured goods. More than ever, consumers can buy imported fresh foods at their local supermarkets, receive goods they purchased over the internet, and track express packages online to know their whereabouts at any given time. These everyday occurrences are made possible by a vast transportation network combined with freight delivery services and continuing improvements in freight logistics, which are due in large part to advancements in information technology.

Public agencies charged with operating and maintaining the U.S. transportation system are increasingly challenged by the strain that freight movements are putting on the system. This chapter was developed to assist planners in integrating freight into their planning process. The next section provides an overview of domestic freight flows in the United States. This is followed by a discussion of the impact of freight flows on the community and on the transportation system. The fourth section presents the freight planning process, including the institutional aspects, the need for system designation, data collection, and the models and analysis tools used to identify and assess different freight-related strategies. The next section describes some of the important aspects of freight terminal planning and design. The final section offers thoughts on some of the key aspects of integrating freight concerns into the transportation planning process.

II. OVERVIEW OF DOMESTIC FREIGHT FLOWS

The amount of freight the U.S. transportation system carries is impressive. Freight traffic carried by air, truck, rail, water, and pipeline totaled more than 20 billion tons and an estimated 6.2 trillion ton-miles in the United States in 2013—an increase of more than three trillion ton-miles from 2001. This 100 percent growth in ton-miles, the primary physical measure of freight transportation output, represents a 0.9-percent compound annual growth rate between 2001 and 2013, the latest year for which complete data are available. Table 22-1 summarizes domestic freight flows by tons and value for 2013. In 2013, trucked freight accounted for about 70 percent of the domestic freight tonnage and

[1]The original chapter in Volume 3 of this handbook was written by Dr. Paula Dowell, Principal, Cambridge Systematics, Inc. Changes made to this updated chapter are solely the responsibility of the editor.

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

Table 22-1. Shipments by Mode, Value ($2007) and Weight (2013), United States		
	Tons (millions)	**Value ($2007 billions)**
Truck	13,955	$11,444
Rail	1,858	$577
Water	808	$284
Air	15	$1,167
Multiple Modes[1]	1,554	$3,065
Pipeline[1]	1,539	$1,003
Other	333	$363
Total[2]	20,063	$17,983

[1] Intermodal includes U.S. Postal Service and courier shipments and all intermodal combinations except air-truck.

[2] Data do not include imports and exports that pass through the U.S. from a foreign origin to a foreign destination by any mode.

Note: Numbers may not add to total due to rounding.

Source: FHWA, 2013; BTS, 2015

64 percent of the domestic freight value. Trucking dominance in domestic freight movements is expected to continue in the future.

Terms Used in Freight Planning

Commodity—A way of classifying the type of freight being shipped. Commodities in the same class are assumed to have the same value per ton, density, and handling characteristics. The most common classification schemes for commodities include the Standard Transportation Commodity Classification (STCC) of the American Association of Railroads and the Standard Classification of Transported Goods (SCTG) developed by the U.S. and Canadian governments.

Shipment—A shipment is a single movement of goods, commodities, or products from an establishment to a single customer or to another establishment owned or operated by the same company as the originating establishment (for example, a warehouse, distribution center, or retail or wholesale outlet). Full or partial truckloads are counted as a single shipment only if all commodities on the truck are destined for the same location.

Value of shipments—The value of shipments is the market value in dollars of goods shipped by businesses. It represents the net selling value, excluding freight charges and taxes. However, it does measure the value of shipments of materials used to produce or manufacture a product, as well as the value of shipments of the finished product itself.

Tonnage of shipments—This measure represents the total weight of a shipment reported by businesses in pounds. As with the value of shipments above, the tonnage of a product could be counted multiple times depending on the number of times the product is transported in the production and consumption cycle.

Ton-miles—Ton-miles measure the shipment weight multiplied by the mileage traveled by the shipment. Mileage is calculated as the distance between the shipment origin and destination zip codes. For shipments by truck, rail, or shallow draft vessels, the mileage excludes international segments. For example, mileage from Alaska to the contiguous states exclude any mileage through Canada.

The U.S. Census Bureau periodically undertakes a survey of freight movement in the country, which provides a snapshot of several characteristics of the U.S. domestic freight market of interest to transportation planners. For example, the latest survey results (2012) showed: [Census Bureau, 2015]

- Most U.S. freight shipments by value and tonnage move less than 250 miles (402 kms), representing slightly more than 77 percent of the weight and slightly more than 60 percent of the value of the shipments surveyed. However, trips exceeding 250 miles represented 84 percent of the ton-miles estimated in the surveyed data. Only 4.5 percent of the shipments (by weight) traveled more than 1,000 miles (1,609 km.), but this represented about 32 percent of the ton-miles.

- Package delivery services have experienced significant growth. Packages less than 500 pounds (227 kgs.) accounted for 25 percent of the value of shipments carried and grew by 14 percent between 2007 and 2012. The total value of packages weighing less than 50 pounds (23 kgs) increased by 24 percent.
- By value, the top five commodity types moved by freight were: mixed freight, gasoline, motorized and other vehicles, electronic and other equipment, and pharmaceutical products.
- By weight, the top five commodity types moved by freight were: gravel and mixed stone, gasoline, coal, fuel oils, and non-metallic mineral products.
- By ton-miles the top five commodity types moved by freight were: coal, prepared foodstuffs and fats and oils, agricultural products, cereal grains, and basic chemicals.
- Shipments exceeding 50,000 pounds (22,680 kg) comprised 64 percent of the ton-miles and 51 percent of the tons shipped, but only 16 percent of the value. The changes in the prior 5 years for these heavier loads were a 1.6 percent decrease for ton-miles, 4.3 percent decrease for tons, and 3.6 percent increase for value.
- Hazardous materials are categorized into nine different classes in the U.S., ranging from radioactive residue to contaminated blood. The 2012 survey estimated that 2.58 billion tons of hazardous materials were transported in the United States. Of this amount, trucks carried 54 percent, pipelines carried approximately 24 percent, and the rest traveled by rail, water, and air. However, the travel mode varied by type of hazardous material. For example, trucks carried 98 percent of explosives, 59 percent of flammable liquids and 63 percent of what are referred to as Class 2 gases.

One caveat with these trends is the uncertainty of what commodity markets will look like in the future. For example, Caplis and Phadnis [2013] conducted a study on the characteristics of future markets by using scenario analysis. They found the forces that appeared to have the most impact and the most uncertainty on future markets were the level of global trade, potential re-domestication of manufacturing currently overseas, and resource availability (for example, petroleum fuel). Trends they concluded would continue from the past included high and volatile fuel prices, increased use of battery vehicles, widespread use of sensing technologies in managing transportation networks, and increased use of virtual working and online retailing. The aging of the population (and the impacts on consumer spending) and increasing urbanization were determined to be a "given."

In addition, often not discussed in descriptions of freight movement, the transportation of data can be an important stimulant in freight movements (for example, more efficient ordering of goods) or it can become substitute for freight trip-making. For example, 3D printing could have a dramatic impact on the movement of goods; simply send the product dimensions and it can be manufactured on site rather than having to ship it in.

Each freight mode has its own historical and expected growth trends. The U.S. DOT Bureau of Transportation Statistics (BTS) is a useful source of freight modal data. Some of the key characteristics of each freight mode described below come from BTS reports.

A. Trucking

There were 2.4 million truck tractor trailers registered in the United States in 2012. [FHWA, 2015] The trucking industry, both for-hire and private own-use, transported more than $12 trillion worth of shipments, weighing more than 13.8 billion tons, and generating about 2.5 trillion ton-miles in 2012. The primary driving force behind trucking's increasing modal share has been the growth in the service sector, which combined with manufacturing has become more important to the national economy. The two major impacts of truck movements on an urban area's road system are: (1) their effect on the capacity of roads serving major travel flows (trucks take up more space and are not as mobile as passenger cars), and (2) the congestion and safety consequences of trucks accessing distribution/warehousing and other major destinations, often on local roads.

Urban goods movement, sometimes called urban freight and service activity, is an important consideration for metropolitan transportation planning. National Cooperative Freight Research Program (NCFRP) Report 19, *Freight Trip Generation and Land Use*, for example, concluded that: (1) the average commercial establishment in an urban area generates about 2.5 freight trips/day and about 0.3 service trips/day; (2) 40 percent of the traffic is generated by establishments of less than four employees; and, (3) the retail/accommodation/food services sector generates about 40 percent of the traffic. [Holguin-Veras et al., 2012] The service component of this traffic has greater demand on curbside space as service vehicles park for extended periods of time. Providing locations for pick-ups and deliveries is a challenge in many dense urban centers where road space is shared with many different groups.

In some metropolitan areas, land gateways are important ports of entry into the United States, not only for the economic activity it generates, but also for the amount of travel demand placed on the region's transportation network. For example, in 2013, the top five land gateways from Mexico handled just over five million truck containers, with Laredo, Texas, handling just over four million. [BTS, 2015, Table 1-54] On the Canadian border, the top five crossings handled 3.8 million truck containers, with Detroit, Michigan, handling 1.5 million. [BTS, 2015, Table 1-52]

At a broader policy level, some argue that more freight should be carried on railroads for environmental and road capacity reasons. The U.S. Internal Revenue Service (IRS) has observed that, in general, under 100 miles, truck/rail competition occurs only on shipments weighing more than 60,000 pounds, that is, trucks carry most of the freight. At 100 to 300 miles, competition occurs on shipments weighing between 60,000 and 90,000 pounds; at 300 to 500 miles, competition occurs on shipments weighing between 30,000 and 90,000 pounds; and at 500 miles or more, competition occurs for commodities weighing between 10,000 and 60,000 pounds. As noted, "for trips under 100 miles, it is private carriers who are providing the competition. For trips over 100 miles, it is the for-hire motor carriers who are doing so. The only exception is for loads weighing between 30,000 and 60,000 pounds moving between 100-200 miles. Here, private trucking seems to be the carrier of choice." [IRS, 2015]

One of the potentially important changes in truck operations is the development of autonomous trucks, that is, trucks that will "drive themselves" or at a minimum have such advanced vehicle technologies that drivers will simply have to make sure the vehicle is operating efficiently. The widespread application of such technology could have significant impacts on both the trucking and railroad industries, as well as on the type of infrastructure provided by transportation agencies (for example, truck-only lanes).

B. Rail

Freight railroads transport an array of commodities and products, ranging from manufactured goods to bulk resources, such as coal and grain. In 2013, seven Class I railroads (the largest railroads) in the United States transported 1.76 billion tons of originating freight, using 28.8 million carloads and 12.8 intermodal car loads (container or truck on rail car). U.S. railroads carried about 3 percent of the nation's freight shipments measured by value, and 11 percent by weight. [FHWA, 2013] Coal and chemicals accounted for 50 percent of the rail tonnage in 2013. With respect to urban transportation, the major impact of rail flows is twofold, (1) in those communities with rail/highway at-grade crossings, long trains can disrupt the operation of roads, and (2) railroad intermodal yards can attract a large number of trucks delivering or picking up goods, possibly contributing to congestion on the local roads.

The railroad industry in particular, as the freight sector in general, is very sensitive to the state of the economy. During the economic recession of the early 2010s, rail revenues declined as fewer goods were transported. The railroad industry did not have the capital to reinvest in its infrastructure. By the mid-2010s, this had turned around and railroads were investing in track and new yards to handle expected increases in freight volumes.

C. Inland Water and Maritime

Some component of nearly 9 percent of the total tonnage transported in the U.S. in 2012 occurred on water. [Bureau of Census, 2015] The total tonnage of U.S. waterborne freight, including domestic commerce and international trade, was nearly 576 million tons in 2012, up from 404 million tons in 2007. In 2012, water transportation carried 74 percent of the weight and 47 percent of the value of U.S. international merchandise trade. [FHWA, 2013]

Seaports are important contributors to the national economy as well as to the economies of individual states and metropolitan areas. In 2013, nine of the top 20 freight gateways into the United States (by value) were seaports, with the Port of Los Angeles at the top spot, handling $213 billion worth of trade. [BTS, 2015, Table 1-51]

The inland waterways system includes 12,000 miles of commercially navigable channels, with over 200 lock chambers. In addition, inland water transportation includes freight movement on the Great Lakes and intra-coastal waterways. More than 566 million tons of freight move through the inland waterway system annually, valued at more than $152 billion. It is estimated that the inland waterways and rivers carry the equivalent of about 51 million truck trips each year. [ASCE, 2013] The types of vessels and thus the type of cargo moved include tankers, container barges, gas, roll on-roll off, bulk, and general cargo. In 2013, the three largest ports of entry for tonnage handled at U.S. ports and terminals for vessels over 1,000 gross tons were the Sabine-Neches waterway (Beaumont, Texas); New Orleans, Louisiana; and Houston, Texas. These top three handled primarily petroleum products.

An Inland Waterways Trust Fund based on a $0.20 per gallon tax on barge fuel has been established by the federal government to invest in the inland waterways network. Currently, the tax revenues raised is approximately $85 million per year; however, the estimated investment needs are an average of $900 million annually. [ASCE, 2013]

D. Air Cargo

In 2014, all-cargo carriers and other commercial airlines generated 65 billion freight revenue ton-miles. [BTS, 2015b] Air freight revenue ton-miles have grown faster in the international market than in the domestic market. For example, in 2014, the domestic air cargo market, measured in revenue ton-miles, grew by 3.36 percent whereas growth in the Pacific market alone grew by 6.01 percent. Ton-miles from the international market now exceed those from the domestic market. Air cargo accounted for a much larger proportion of the value (22.5 percent) than the weight (less than 1 percent) of overall freight movement.

In 2013, Memphis, Tennessee (Federal Express consolidation center), handled the largest amount of domestic air cargo, some 22 billion pounds. Anchorage was second (many flights from Asia land in Anchorage, Alaska, to go through customs) with Louisville (UPS consolidation center) in third place. [FAA, 2015] John F. Kennedy (JFK) International Airport in New York City is the leading overall gateway for U.S. international air freight by value.

E. Pipelines

Transportation planning seldom examines the movement of liquid commodities by pipelines. However, substantial volumes are transported by the nation's pipeline network. In 2012, U.S. pipelines carried just over 1.5 billion ton-miles (2.41 billion ton-km) of crude oil, petroleum products, and natural gas—approximately 8 percent of the total freight ton-miles by all modes. Natural gas liquids accounted for about one-third of this total. In 2014, the United States imported more than 3.37 billion barrels of crude oil and petroleum products, and pipelines helped to transport a large proportion of these imports on some part of the journey from points of entry to refineries, terminals, and markets for final consumption. [EIA, 2015a] Additionally, there were more than 2.6 million cubic feet of natural gas imports coming from Canada by pipeline each year into the United States. [EIA, 2015]

F. Intermodal Freight

A particularly important element of the international trade handled at seaports has been the increasing use of containers as a means of transport. In 2013, just over 44 million 20-foot equivalent container units (TEUs) of merchandise moved in and out of U.S. ports, up 35 percent from the 32.7 million containers in 2003. [World Bank, 2015] These container units arrive and leave the seaports either by rail or truck, or by some intermodal truck-rail combination. The Ports of Los Angeles and Long Beach, California, handle the largest number of containers in the United States, reflecting increased trade with Asia and Pacific Rim countries. In terms of growth rate, Savannah, Georgia, has consistently shown the fastest growth in annual percent change over the past several years. Beginning in 2003, the revenue generated from intermodal services produced more revenues for the Class 1 railroads than coal, accounting for 43 percent of gross revenue. The widening and deepening of the Panama Canal could have a significant impact on the movement of international containers into the United States.

III. IMPACT OF FREIGHT FLOWS ON THE COMMUNITY, FREIGHT SECTOR, AND TRANSPORTATION SYSTEM

The growth in freight movements affects transportation agencies in many ways. With respect to physical infrastructure, larger and heavier vehicles cause more damage to roads than lighter and smaller vehicles. For many years, transportation engineers, for example, have examined the effect of heavy vehicles on bridge and pavement designs. With respect to economic development, modern economies depend on the ability to move resources and goods. Therefore, providing such accessibility and mobility becomes an important part of a national, state, or metropolitan economic development policy. Finally, similar to other transportation facilities, freight terminals and operations have an effect on the environment and communities that is often of great concern to community leaders and residents.

A. Community Impacts

National Cooperative Highway Research Program (NCHRP) Synthesis Report 320, *Integrating Freight Facilities and Operations with Community Goals*, identified numerous freight-related issues of concern to community officials. [Strauss-Wieder, 2003] As noted in the report, the need for understanding the relationship between a freight facility or operation and the surrounding community is becoming more important for several reasons: (1) the amount of freight traffic is increasing, (2) the general population is less involved in goods production and therefore may not be as familiar with the steps needed to produce and deliver goods to consumer markets, (3) the continued growth in U.S. population and land development increases the likelihood of conflicts between different types of uses, and (4) there is continuing pressure to keep freight transportation costs low. In a survey of U.S. communities, the following freight-related issues were raised by community officials. [Strauss-Wieder, 2003]

Traffic Flow and Congestion

- Volume—The volume of trucks affects available road capacity for other transportation users.
- Operational characteristics—Trucks accelerate and decelerate at different speeds than passenger vehicles.
- Road geometrics—Trucks, especially larger trucks, require different lane widths, turning radii, and turning lane requirements.
- At-grade rail freight crossings—Freight trains, particularly long trains, can cause significant backups when traveling through at-grade crossings.
- Trucks at commercial and retail establishments—Larger trucks backing into or parked at the loading docks of retail and commercial establishments can block roads. Trucks double-parked outside of buildings also contribute to congestion.
- Truck parking on shoulders and ramps—Inadequate truck parking and rest areas have resulted in trucks parking along shoulders and ramps, a practice that can affect roadway operations.

Safety and Security

- Safety of at-grade rail crossings, given the significant damage that a train-vehicle collision causes.
- Movement, handling, and storage of hazardous materials.
- Vehicle size, speed, stopping distance, sight obstruction, and weather-related impacts to pedestrians, bicyclists, and drivers.
- Trespassing and potential injury or loss of life along rail corridors.
- Safety concerns on roadways with heavy truck volumes.

Economic Development

- Assessing how to best use freight transportation assets to achieve economic development goals.
- Implications of off-shoring of manufacturing and the implications of such operations returning to the United States.
- Air and rail service to retain or attract businesses.
- Determining situations where existing freight transportation operations and facilities conflict with an area's economic development goals.

- Leveraging an area's freight transportation assets to attract industries.
- Maintaining or developing rail service to retain or attract business to areas.

Environmental Concerns

- Release of invasive aquatic species from vessel ballast discharges and the effect on harbors and waterways.
- Environmental implications of hazardous materials spills and accidents on waterways and in communities.
- Potential impact on low-income and minority communities as a result of freight operations and facilities (environmental justice).
- Vehicle and facility-specific air pollutant emissions.
- Potential impacts of freight facilities and operations on endangered species and habitats.
- Impact of the light given off by freight facilities on nearby communities during nighttime operations.

Noise and Vibration

- Noise resulting from train whistles and train movements.
- Noise from aircraft engines, especially cargo aircraft that operate at night, and sometimes from older equipment.
- Noise associated with the loading and unloading of trucks at retail stores and freight facilities abutting residential areas.
- Noise and vibrations associated with higher levels of freight traffic.
- Vibrations from heavy truck traffic, heavier and more frequent trains, marine channel deepening, and aircraft operations.

Land Use and Value

- Marine freight operations competing with other land uses for waterfront property.
- Potential alternative land uses for property currently occupied by freight facilities.
- Productivity of and economic value generated by the land used by freight facilities.
- Rail line reactivations or increases in rail operations on rights of way adjacent to residential neighborhoods.
- Non-maintenance of rights of way, allowing litter and overgrowth to occur.
- Increases in truck volumes on local roads.

These types of issues are important starting points for transportation studies aimed at enhancing the economic development opportunities associated with freight facilities and operations, while at the same time doing so in an environmentally sensitive way. In most cases, these types of issues surface during the early stages of a planning study and often are incorporated into the goals and objectives statement.

California has been leading the way in researching the health effects of ozone emissions from freight transportation. Diesel particulate matter (diesel is a major fuel used in freight transportation) is of special concern to human health because 50 to 90 percent of the particles are very small (that is, ultrafine) and can readily enter into and deposit within the lungs, passing through the bloodstream at the cellular level. However, it should be noted that ultrafine particulate matter is not exclusive to diesel emissions; ultrafine particles originate from combustion processes using any fuel, including gasoline, compressed natural gas, and liquid natural gas. Table 22-2 shows the health effects and valuation of freight emissions contributing to particulate matter (2.5 microns) for California in 2012, and projected to 2030 and 2050.

Table 22-2. California Statewide Health Effects and Valuation (2013 $) Associated with Freight Emissions Contributing to PM2.5—Uncertainty Ranges**			
PM2.5 and NOx	**2012**	**2030**	**2050**
Mortality	1,700–2,700	770–1,200	830–1,300
Hospitalizations*	43–770	19–340	20–370
ER Visits†	600–1,300	260–570	280–620
Valuation (billions)	$16–$24	$7–$11	$7–$12

*Includes respiratory and cardiovascular hospitalizations

**Uncertainty ranges only reflect uncertainty in the concentration-response function, and do not reflect uncertainty in emission projections, spatial interpolation, and aggregation.

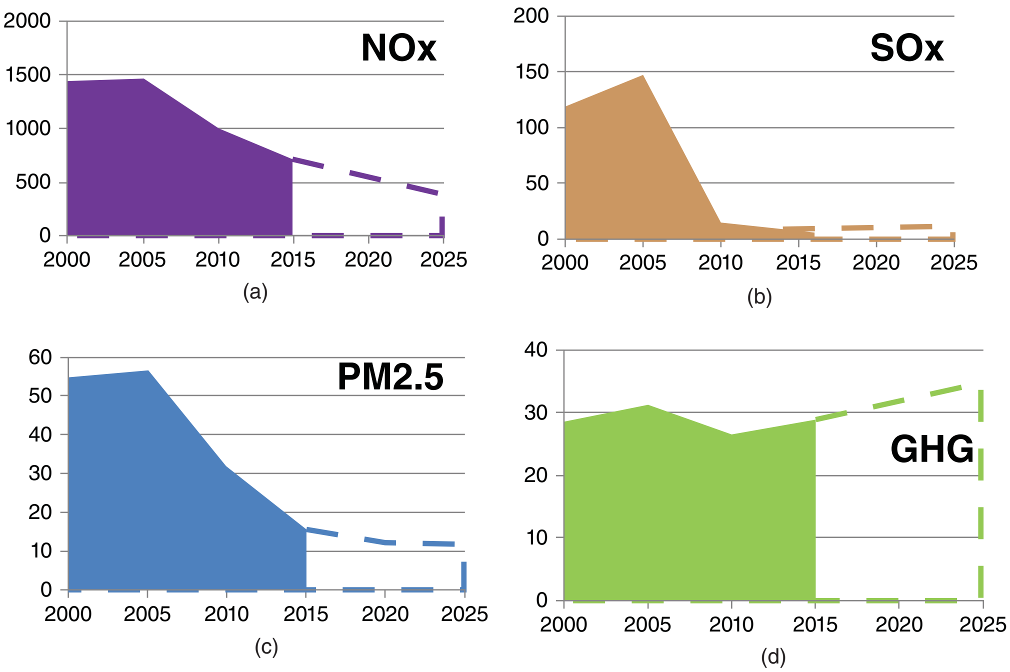
†Includes asthma and cardiovascular emergency room visits

Source: CARB, 2015

In recent years, the California Air Resources Board (CARB) has focused its attention on the pollutant emissions from the freight sector and possible strategies to reduce emissions. CARB has adopted and implemented over a dozen regulations, as well as agreements with industry and incentive programs, to reduce freight emissions. As shown in Figure 22-1, these efforts, along with the benefits of national and industry initiatives to reduce freight-sector emissions, have had an important impact on air quality in California by reducing the most important freight-related pollutant emissions.

Some illustrative strategies being pursued by CARB to reduce emissions even more in the future include (not a complete list): [CARB, 2015]

Figure 22-1. (a): California Statewide Nitrous Oxide (NOx) Emissions from Freight Sources (tons per day); (b): Statewide Sulfur Oxide (SOx) Emissions from Freight Sources (tons per day); (c): Statewide Particulate Matter (PM2.5) Emissions from Freight Sources (tons per day); (d) Statewide Greenhouse Gas (GHG) Emissions from Freight Sources (million metric tons CO2-e per year)



Source: CARB, 2015. Reprinted with permission of the Sustainable Freight Initiative of the California Air Resources Board.

For cleaner combustion:

Trucks

- Develop and propose strategies to ensure durability and in-use performance.
- Develop and propose increasing flexibility for manufacturers to certify advanced innovative truck engine and vehicle systems in heavy-duty applications.
- Develop and propose California-specific standards for new heavy-duty truck engines to provide benefits above national standards.

Ocean-Going Vessels

- Define criteria for "Super Low Emission Efficient Ship" and achieve early implementation of clean technologies (liquefied natural gas, Tier 3, or better) for newer vessels via existing and enhanced seaport incentive programs (for example, Green Ship, Ship Index, etc.).
- Develop and propose amendments to the At-Berth Regulation to include other vessel fleets and types to achieve additional emission reductions.

Locomotives

- Develop and propose a regulation applicable to all non-new locomotives to maximize the use of Tier 4 engines, liquefied natural gas, for better line-haul, medium horsepower, and switch locomotives (provide credit for zero emission track miles and zero emission locomotives).

All Sectors/Freight Hubs

- Collect data (such as facility location, equipment, activity, and proximity to sensitive receptors) from seaports, airports, rail yards, warehouse and distribution centers, truck stops, etc. to identify and support the proposal for a facility-based approach and/or sector-specific actions to reduce emissions and health risk, as well as efficiency improvements.

For zero emissions:

Delivery vans/small trucks

- Develop proposal to accelerate penetration of zero emission trucks in last mile freight delivery application with potential incentive support.

Large spark-ignition equipment (forklifts, etc.)

- Develop proposal to establish purchase requirements to support broad-scale deployment of zero emissions equipment.

Incentive programs

- Develop modifications to existing incentive programs to increase the emphasis on and support for zero and near-zero emission equipment used in freight operations, including introduction of truck engines certified to optional low-NO_x standards.

Because of the societal impacts associated with freight transportation, one often finds many public policies, laws, and regulations that regulate the operations and performance of freight equipment and land uses. Table 22-3 shows some of the policies often used by government agencies, and the potential impact on the freight industry.

B. Impacts on the Freight Sector

Many of the impacts associated with transportation system performance, both improving and deteriorating conditions, are first encountered by private freight carriers. Travel time, cost, reliability, accessibility, and/or safety benefits or costs are system performance characteristics of concern to the carriers. NCHRP Report 463, *Economic Implications of Congestion,* identified five classes of trips affected by congestion. Three of these cost categories were business-related costs, including regional freight delivery (vehicle operating costs, driver wages, and inventory/logistics costs),

Table 22-3. Examples of Freight System Impacts from Public Policies	
Type of Policy	**Potential Impacts**
Direct taxes or charges to carriers (fuel taxes, vehicle excise taxes, tolls)	Change in carrier costs Change in shipper costs Shifts in modal share between truck and rail Change in freight volumes in corridors
Environmental regulations that increase equipment or fuel prices	Change in carrier capital and operating costs Change in shipper costs
GHG cap and trade program	Loss of rail carrier revenue Increase in carrier fuel costs Possible short term loss of jobs and economic activity during the transition
Renewable fuel standards	Potential increase in rail carrier revenue Increase in carrier costs
Air cargo screening on passenger flights	Degraded service in air cargo Shift to all-cargo carriers
Fingerprint rules for outbound ships and planes	Increase in carrier costs
Rules that directly change operations (truck route restrictions, parking restrictions, restrictions on rail operations)	Increase in carrier costs Change in freight volumes in corridors Degraded service
Land-use policies that affect location of freight facilities	Increase in carrier costs Increase in shipper costs Possibly degraded service
Dredge spoil disposal policies	Increase in shipper costs Shifts to other ports
Driver hours of service rules	Increase in costs for some carriers
Truck size and weight rules	Change in fuel use Change in shipper costs
Truck speed limits and speed governor rules	Decrease in fuel costs Increase in capital costs for some carriers Change in profitability for some carriers

Source: ICF et al., 2011

interregional freight delivery, and regional services delivery (such as those relating to professional services, package delivery, and couriers whose time in transit is incorporated into the cost of service).

Depending on market conditions, the impact on carrier performance and costs is typically passed onto freight shippers and their customers. The freight shippers (rather than the carriers) are the ultimate users or customers of the freight transport system. Additional benefits or costs may accrue to shippers as a result of the ability or necessity to restructure their business. Examples of restructuring costs to shippers arising from the deterioration of system performance include the costs of introducing redundancy into freight deliveries and increasing inventory stocks to avoid stock-outs. Ultimately, shippers must reconfigure their business operations and logistics processes to mitigate the effects of inefficient freight transportation.

Changing costs to carriers and shippers have implications for the receivers of freight shipments as well—primarily retailers and wholesalers. These can have further consequences for the market pattern of the production, distribution and sales of supply materials, intermediate goods, and final products for other businesses. These effects can occur locally, regionally, nationally, and globally.

The ultimate consequence of freight transportation operations is on business productivity, which directly affects profitability. Higher freight transportation costs lead to higher prices and/or lower returns for shareholders. Ultimately, the consumers, workers, and owners bear the burden of inefficient freight transportation or obtain the benefits from improved freight transportation system performance.

C. Transportation System Impacts

Increasing freight demands on the nation's transportation system will likely increase the number of bottlenecks in the system. These bottlenecks can occur at major terminal locations where the sheer volume of arriving cargo overwhelms port access facilities and services, or they can occur along the mainline, such as on major metropolitan freeway systems where truck movements mix with passenger vehicles. Congestion levels have been increasing in the United States as well as in other developed nations. The Texas Transportation Institute [Schrank et al., 2015] reports that between 2000 and 2014, the cost of highway congestion in the nation's urban areas increased from $114 billion to $160 billion, an increase of 40 percent. U.S. DOT estimates that the cost of congestion across all modes of transportation could be three times as high if productivity losses, costs associated with cargo delays, and other economic effects were included. Among these are losses accruing to auto drivers, freight carriers, businesses, consumers, and the public.

Forecasts indicate that freight demand and truck traffic will continue to grow. Figure 22-2 illustrates the projected truck flows on U.S. highways in 2040. Demand along key east–west interstate highway corridors, as well as north–south corridors serving trade to and from Canada and Mexico, will increase. The map also suggests that nearly all urban areas can expect significant growth in the number of trucks using their road system, while rural interstates can expect more moderate growth. Figure 22-3 shows those segments of the U.S. national highway system expecting more than 10,000 trucks per day in the year 2040. As shown, many of the nation's major urban freeways experiencing peak-period congestion in 2040 are also major truck routes.

Freight movements affect not only the capacity of the U.S. transportation system but also its operations and maintenance. The U.S. highway system, especially the Interstate Highway System, has made trucking possible. Bridge design and pavements allow for trucks weighing at least 80,000 pounds gross vehicle weight to travel long distances

Figure 22-2. Estimated Average Daily Long-Haul Truck Traffic on the National Highway System, 2040

Average Daily Long-Haul Traffic on the NHS: 2040

Notes: Long-haul freight trucks typically serve locations at least 50 miles apart, excluding trucks that are used in movements by multiple modes and mail. NHS mileage as of 2011, prior to MAP-21 system expansion.

Source: BTS, 2015

Figure 22-3. Peak-Period Congestion on Segments of the National Highway System with More Than 10,000 Trucks Per Day, 2040

Source: BTS, 2015

without reconfiguring. Along with weather and geologic conditions, heavy vehicles are largely responsible for the wear and tear on U.S. highways. According to data submitted by the states, freight trucks (heavy, single-unit, and combination trucks) comprise 21 percent of the volume of traffic on U.S. rural interstate roads, but cause more than 97 percent of the damage to pavements, as calculated by the impact of an equivalent single-axle load (ESAL), a term used by pavement engineers to measure the effects of heavy vehicles on pavement. On the urban Interstate Highway System, heavy trucks comprise 9 percent of total traffic volume, but are responsible for 96 percent of pavement damage. [AASHTO, 2012]

Another important system impact reflects the interconnectivity of the freight system. In many markets, the choice of freight mode is influenced by the respective price of moving freight by one mode versus another, the reliability and convenience of delivery, and the security associated with making sure goods arrive without damage or pilferage. Whenever a change in the market occurs, or when some other event causes disruption in the freight network such as a port strike or a bridge/tunnel failure on a major freight route, other parts of the freight system will likely be affected. Examples of such disruptions have occurred in the United States over the past several decades, including numerous hurricanes, major labor strikes at ports, the closure of rail lines due to snow or floods, and the shutdown of the national aviation system during 9/11. Internationally, disruptions in supply chains have also been caused by health concerns, such as the avian flu.

As noted by NCHRP Report 732, *Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System*, the economic impact of severe bottlenecks and disruptions could affect a wide range of supply chain participants, not just the ocean carriers, truckers, railroads, and shippers that are using the network to transport the goods. These participants include public agencies, local labor unions, local retailers, warehousing and distribution providers, and potentially a significant number of consumers and economic organizations throughout the United States.

The types of actions or strategies that can address the issues discussed above are shown in Table 22-4. Some of the strategies are applicable to all freight modes while others are meaningful for one or two. The planning process focuses on which strategies make most sense in the specific context of a planning study.

Table 22-4. Practices to Balance Freight Transportation Facilities and Operations With Community Issues

	Issue Areas						Freight Types					
Practice	**Traffic Flow**	**Safety/Security**	**Econ. Dev.**	**Air Quality/Environ**	**Noise/Vibration**	**Land Use & Value**	**Pipeline**	**Rail**	**Truck**	**Air Cargo**	**Water**	**Community Actions**
Replace at-grade rail crossings with grade-separated crossings	X	X		X	X			X	X			
Replace at-grade rail line with below-grade rail line	X	X	X		X	X		X				
Modify rail hours of operation to minimize conflicts	X				X	X		X				
Develop truck-only access routes	X	X	X	X	X	X		X	X	X	X	
Require developers to make necessary highway access improvements for trucks	X	X	X			X			X			
Participate in interstate corridor analyses	X		X					X	X			
Motivate mode shift from truck to rail	X			X				X	X		X	
Undertake integrated freight/economic development program	X	X	X			X	X	X	X	X	X	X
Close at-grade rail crossing	X	X		X	X			X	X			
Designate routes for heavy-weight trucks	X	X			X		X		X			
Ban or limit trucks on routes	X	X			X	X			X			
Build more truck rest areas and parking	X	X							X			
Undertake spot improvements	X	X							X	X	X	
Create incident management program or safety hotline	X	X						X	X			X
Use ITS technologies	X	X		X				X	X	X	X	
Develop rail spur	X		X	X		X		X				
Relocate rail yard	X		X			X		X			X	
Encourage reuse of brownfields	X		X	X		X		X	X		X	
Retain existing industrial areas	X		X	X		X		X	X	X	X	
Require staging areas for trucks at buildings	X			X				X				
Schedule truck appointments	X			X		X	X	X	X	X	X	
Reduce number of empty truck movements	X			X					X		X	
Undertake public education		X						X	X	X	X	X
Hire locally			X				X	X	X	X	X	X
Install upgraded rail crossing gates/barriers		X						X	X			
Create walls/pedestrian path to reduce trespassing		X						X				
Create truck-based Highway Watch Program		X							X			X
Strengthen cargo inspection		X						X	X	X	X	
Develop driver training programs		X		X					X			

(*continued*)

Table 22-4. (*Continued*)

	Issue Areas						Freight Types					
Practice	**Traffic Flow**	**Safety/Security**	**Econ. Dev.**	**Air Quality/Environ**	**Noise/Vibration**	**Land Use & Value**	**Pipeline**	**Rail**	**Truck**	**Air Cargo**	**Water**	**Community Actions**
Promote beneficial reuse of dredged materials			X	X							X	
Purchase abandoned rail line and/or facility			X					X				
Create neighborhood investment fund			X			X		X		X	X	
Undertake public charrettes								X	X	X	X	X
Create public outreach video								X	X	X	X	X
Create “no whistle” rail zone					X			X				
Attend public meetings							X	X	X	X	X	X
Continuously engage the public and elected officials								X	X	X	X	X
Build sound walls/berms					X	X		X	X	X	X	
Include buffer zones					X	X	X	X		X		
Use specialized fixtures to reduce light spillage				X				X	X	X	X	
Limit truck/loading dock hours of operations				X	X	X			X			
Use lower-emission locomotives/reduce idling				X				X				
Facilitate meetings between community and providers							X	X	X	X	X	X
Install hush kits on aircraft				X	X					X		
Encourage/use alternatively fueled vehicles				X					X	X	X	
Install electric gantry cranes/“green”port technologies				X							X	
Create uniform national program for ballast discharge				X							X	
Develop cleaner fuels				X				X	X	X	X	
Use equipment to reduce need to run truck engines				X			X		X			
Create 800 number or website for community input								X	X	X	X	X
Establish advisory committees								X	X	X	X	X
Create channels for information dissemination							X	X	X	X	X	X
Undertake sound proofing program					X					X		
Retire old cargo aircraft				X	X					X		
Install continuous welded rail					X			X				

Source: Strauss-Wieder, 2003

IV. FREIGHT PLANNING

Freight planning encompasses many of the same steps found in any transportation planning process. The vision, goals, and objectives of a general transportation planning process usually include topics relating to freight and goods movement. Just as in other planning efforts, a freight planning study uses data, analysis tools, and a set of evaluation criteria targeted at finding the most cost-effective strategies and actions for implementation. [Holguin-Veras et al., 2015]

There are many different types of freight-oriented transportation planning studies. At the most general level are the standard transportation planning studies conducted periodically for a state or metropolitan area. The challenge in these studies is to incorporate freight considerations commensurate with the freight problems facing the state or community. Many agencies have also been conducting freight-specific planning studies that focus exclusively on truck, rail, air, water, and intermodal freight movements in and through a study area. Thus, for example, it is not uncommon to find state rail plans, air cargo plans, and seaport/river plans. A final type of freight planning study is one that examines a specific freight issue, such as truck parking or enforcement strategies. The following list from the San Diego Association of Governments (SANDAG), the metropolitan planning organization (MPO) for the San Diego region, gives a sense of the wide range of freight-related studies that might occur in a regional planning process:

- *State Route 11 and Otay Mesa East Port of Entry:* This innovative project will improve the efficient movement of people, goods, and services between the United States and Mexico.
- *Analysis of Freeway Operational Strategies Related to the Use of Managed Lanes by Trucks:* Analyzes different strategies for accommodating and managing trucks on the region's freeways.
- *Freight Gateway Study Update:* Provides a forecast of regional freight traffic in San Diego and Imperial Counties through 2050.
- *Port of San Diego Freeway Access Improvements:* Includes improvements at Bay Marina Drive at I-5, Civic Center Drive at Harbor Drive and I-5, and 10th Avenue at Harbor Drive.
- *LOSSAN Freight Rail Corridor:* Improvements include double tracking, curve realignments, and the addition of crossovers to increase capacity and enhance reliability.
- *South Line Rail Freight Capacity Project:* Provides expanded freight operations through the construction of improved San Ysidro Yard capacity, trackage, and train control safety improvements.
- *State Route 905:* The completion of SR 905 will provide a critical connection to the Otay Mesa Port of Entry.
- *Goods Movement Strategy and San Diego Forward:* The Regional Plan considers the importance of freight and goods movement to the region's economic prosperity and seeks to balance regional and national freight priorities. [SANDAG, 2015]

Not all MPOs have such a repertoire of freight planning activities. However, this list does provide some indication of the types of issues that transportation planners and engineers might be involved with in transportation planning.

The following sections discuss some of the key aspects of a freight transportation planning process. Space does not permit an exhaustive coverage of every aspect; however, as previously noted, many freight planning activities share characteristics with the general transportation planning process. See chapter 2 on data collection, chapter 4 on environmental considerations, chapter 6 on travel demand modeling, and chapter 7 on evaluation for additional information on freight-oriented planning studies.

A. Institutional Structure

As noted earlier, traditional transportation planning did not usually include freight concerns in the planning process. As such, representatives of the freight sector seldom participated in transportation planning. As more planning studies began to consider freight issues, and as freight-specific planning was undertaken in an increasing number of states and metropolitan areas, it became apparent that the participation of freight interests in the planning effort was essential. One of the important lessons in early freight-oriented transportation planning efforts was the need for a study structure that promoted the participation of carriers and shippers. The following examples illustrate a variety of planning/program approaches.

Atlanta Freight Advisory Task Force. As part of a regional freight transportation planning process, the Atlanta Regional Commission (ARC), the MPO for the Atlanta metropolitan area, created a freight-advisory task force. The task force, which meets quarterly, includes representatives from railroads, trucking companies, the airport, chambers of commerce, major shippers, local planners, and a local university. The objectives of this task force are to:

- Provide input on policies and improvements for freight mobility.
- Identify freight mobility characteristics and needs.
- Highlight the significance of freight to the region.
- Improve safety of the transportation system.
- Prioritize freight transportation needs and investments.

Albany, New York, Goods Movement Advisory Committee. The MPO for the Albany, New York, region created a goods movement task force that brought together private freight operators and public freight planners to share information on local freight issues and events. The task force provides input into the long-range transportation plan update as well as individual planning projects. Given the importance of goods movement to the region, the task force has evolved into a permanent freight advisory committee.

Philadelphia Goods Movement Task Force. The Delaware Valley Regional Planning Commission (DVRPC), the MPO for the Philadelphia metropolitan area, has included freight representatives in the transportation planning process for many years. DVRPC's freight advisory committee, the Delaware Valley Goods Movement task force, is open to all trucking, railroad, port, airport, shipper, freight forwarder, economic development, and member government representatives. The task force is co-chaired by the state DOT and the MPO. The adopted objectives of the task force are to:

- Ensure the participation of the freight industry in the planning process.
- Identify improvements to facilitate the safe and efficient movement of freight.
- Implement regional congestion and intermodal management programs.
- Improve communications and data and technology sharing.

Task force members have participated in technical studies, identified capital improvements to transportation facilities, and promoted greater consideration of freight movement in short- and long-range plans.

Oregon Freight Advisory Committee. The mission of the Oregon Freight Advisory Committee (OFAC) is to advise the Oregon Department of Transportation (ODOT), Oregon Transportation Commission (OTC), and Oregon legislature on priorities, issues, freight mobility projects and funding needs that affect freight mobility, and to advocate the importance of a sound freight transportation system for the economic vitality of Oregon. The OFAC bylaws state that it should, among other activities:

- Serve as a forum for discussion, an opportunity for joint action, and a source of knowledge and advice for state transportation decisions affecting freight mobility.
- Promote the cross-sharing of information between private and public sectors on freight issues.
- Advocate the importance of freight mobility to the economic well-being of the state of Oregon and the region.
- Champion a sound multimodal freight and goods delivery network.
- Communicate and coordinate regional priorities with other organizations, including ODOT regions, area commissions on transportation, MPOs, regional partnerships, regional investment boards, ODOT advisory committees, economic revitalization teams, and the like.
- Inform and advise the OTC and ODOT director on policy, issues, freight mobility projects, and funding requirements that affect freight mobility.

Washington State Freight Mobility Strategic Investment Board (FMSIB). One of the more institutionalized structures for including freight representatives in transportation investment decision making is found in the Washington State FMSIB. In line with its mission to create a comprehensive and coordinated state program to facilitate freight movement between and among local, national, and international markets, FMSIB has provided funding for projects and technical assistance for project sponsors and freight advocates. The board also has included in its mission statement a goal of lessening the impact of freight mobility on communities.

These examples of institutional structures to provide freight sector input into transportation planning simply illustrate the different ways that such involvement can occur. The exact form for a particular study will depend on the desired role for such participation, and the degree to which freight participants will find the effort valuable.

B. Goals, Objectives, and Performance Measures

As in other planning processes, freight planning studies usually start with the identification of goals, objectives, and performance measures.

1. Goals and Objectives

Some examples of goals and objectives for freight studies include:

Atlanta, Georgia [ARC 2008]

Goals

- Create a level playing field for freight in the regional planning process.
- Address the differing regional and corridor needs of freight movement and activities.
- Minimize the cost and improve the reliability of goods movement within the region.
- Improve goods movement in terms of ease, reliability, and transportation system-related cost.

Objectives

- Improve the movement of goods in the region by encouraging expedient and cooperative multimodal shipment of goods.
- Improve the physical characteristics of the transportation system for freight-related transportation between shipping and receiving points.
- Understand and address issues of concern to the freight community.

Melbourne (Australia) [Melbourne, 2012a and 2012b]

- Melbourne will have innovative and efficient freight and logistics infrastructure, optimizing the flow of goods locally and globally. Melbourne's freight system will strengthen the municipality's economy. It will be environmentally sustainable, and freight traffic will be designed and managed to enhance the municipality's livability.
- The major freight task associated with the Port of Melbourne is enabled by efficient road and rail infrastructure.

New York City [New York Metropolitan Transportation Council, 2015]

- Improve transportation of freight by removing burdensome government regulations and restrictions.
- Improve the physical infrastructure of the transportation system for freight-related transport between shipping and receiving points.
- Improve the reliability of overall movement of freight in the region by encouraging multimodal shipments.
- Improve the reliability and overall movement of freight in the region by expanding alternatives for trucks.

San Diego [SANDAG, 2014]

- Increase economic growth and prosperity that supports communities and businesses.
- Reduce environmental and community impacts from goods movement operations to create healthy communities and a clean environment, and improve quality of life for those communities most affected by goods movement.
- Provide safe, reliable, efficient, and well-maintained goods movement facilities.
- Promote innovative technology strategies to improve the efficiency of the goods movement system.
- Preserve and strengthen an integrated and connected, multimodal goods movement system that supports freight mobility and access, and is coordinated with passenger transportation systems and local land-use decisions.

Stockholm, Sweden [2015]

- Enable more reliable delivery times.
- Facilitate commercial freight vehicles.
- Promote the use of clean vehicles.
- Advance the freight delivery partnership between the city and other stakeholders.

Vermont Agency of Transportation [2015]

- Establish a demographic and economic profile of the state that identifies major and emerging industries and recognizes trends and opportunities in trade between Vermont and domestic and international markets.
- Provide an up-to-date assessment of the condition of the state's freight infrastructure and the impacts of current and future freight traffic.
- Assemble, through analyses and stakeholder involvement, a comprehensive list of infrastructure, operational, institutional, and regulatory needs.
- Develop packages of programs, policies, and projects that address Vermont's freight needs and position the state's economy to be competitive today and in the future.

2. Performance Measures

As in other modern transportation planning processes, performance measures are used to monitor the performance of the transportation system with respect to freight movement. The value of performance measures to the freight transportation planning process was best described in a freight planning effort for Alameda County, California:

- *Linking Strategies to Vision and Goals*. Performance measures can be developed and applied to help link plan strategies to the vision and goals of the plan. Linking performance measures to the Vision and Goals is central to developing a performance-based project evaluation process.
- *Needs Assessment and Strategy Development*. Performance measures can be applied to assess condition, performance, and use of the transportation system. They also help identify system gaps where additional projects, programs, or policies may be needed.
- *Project Evaluation and Prioritization*. Performance measures can provide information needed to know when and where to invest in projects and programs that provide the greatest benefits. Performance measures can help determine which projects, programs, and policies should be included in high-priority strategies and can also help in the analysis of tradeoffs and/or synergies between different projects, programs, and policies.
- *Managing Performance*. Applying performance measures can improve the management and delivery of programs, projects, and services. The right performance measures can highlight the technical, administrative, and financial issues critical to governing the fundamentals of any program or project.

- *Communicating Results*. Performance measures help communicate the value of public investments in transportation and provide a concrete way for stakeholders to see an agency's commitment to improving the transportation system and help build support for transportation investments.

- *Strengthening Accountability*. Performance measures promote accountability with respect to the use of taxpayer resources and reveal whether transportation investments are providing the expected performance or demonstrate the need for improvements. [Cambridge Systematics, 2014a]

As noted in other chapters, the U.S. federal government is responsible for identifying national categories of performance measures, with the state departments of transportation (state DOTs) and MPOs expanding the list. Freight is one of the areas where performance measures are to be identified. As an example of state-level performance measures, the following list comes from the Washington State DOT. [WSDOT, 2014] Performance measurement occurs in what the DOT is calling Freight Economic Corridors, which handle the most important freight flows in the state.

Truck Freight Performance Measures

Reducing:

1. Truck travel time—Annual hours of delay, defined as travel time above the congestion threshold in units of vehicle hours for commercial vehicles on the Interstate Highway System. To evaluate project proposals, WSDOT uses regional travel demand models to estimate the reduction or change in truck travel time.

2. Direct truck operating cost—Using the value of time collected from national truck carrier surveys, the following formula is used to determine direct cost: *change in commercial vehicle hours traveled x truck operating cost per hour = change in direct truck operating cost*.

3. Truck engine emissions—The U.S. Environmental Protection Agency's (EPA's) Motor Vehicle Emission Simulator (MOVES) modeling system estimates emissions for mobile sources covering a broad range of pollutants and allows multiple scale analysis. WSDOT uses regional factors derived from MOVES for the analysis.

Improving:

1. Economic output—Defined as employment, and regional and state economic output. WSDOT developed a methodology to account for the economic output of highway projects with truck freight benefits.

2. Network resiliency—Defined as the ability to reduce closures of the state's designated Truck Freight Economic Corridors that are due to severe weather or natural disasters and lasting 24 hours or more.

3. Reliability—Spot speed data collected as part of the DOT's performance monitoring program. The formula for the 80th percentile reliability index is:

$$Freight\ RI_{80} = \frac{80th\ Percentile\ Travel\ Time}{Agency\ Travel\ Time}$$

Waterway Performance Measures. Performance goals for the state's coastal deep-draft and shallow harbors, waterways, and the Columbia-Snake River waterway include improving the state of good repair by:

- Maintaining the federally-authorized navigation channel depths.

- Blocking the spread of invasive species.

Potential Freight Rail Performance Measures. The state's Rail Plan recommends that WSDOT "should partner with other state agencies, stakeholders, and shippers to identify key performance measures that will help to inform the condition of the system to users and provide guidance on any public funding for infrastructure improvements. WSDOT should look at planning goals and consider important industries in the state when identifying the measures." Data availability will also be key.

Examples of potential performance measures:

- Benchmark container freight rates to Chicago from Canada, Los Angeles/Long Beach, and the Pacific Northwest.
- Monitor train on-time performance on key corridors.

Potential Air Cargo Performance Measures. A potential performance measure for Washington's air cargo facilities includes improving airport ground access by coordinating with airports and modal planners to identify needed ground access improvements to enhance truck access.

Another state example is shown in Table 22-5 from Florida.

An example of freight performance measures from an MPO is shown in Table 22-6. This example comes from Savannah, Georgia and reflects the region having one of the nation's fastest growing seaports (and thus the emphasis on combination trucks).

Table 22-5. Freight Performance Measures, Florida DOT

Mode	Performance Measure	Mobility	Reporting Period
Highway	Combination truck miles traveled	Quantity	Daily
	Truck miles traveled	Quantity	Daily
	Travel time reliability	Quality	Peak Period
	Combination truck hours of delay	Quality	Peak Period
	Combination truck average travel speed	Quality	Daily
	% miles severely congested	Quality	Peak Hour
	Vehicles per lane mile	Utilization	Peak Hour
Aviation	Tonnage	Quantity	Yearly
Rail	Tonnage	Quantity	Yearly
Seaport	Tonnage	Quantity	Yearly
	Twenty-foot container equivalent units (TEUs)	Quantity	Yearly

Source: Florida DOT, 2016

Table 22-6. Example Freight Performance Measures, Savannah, Georgia

Mode	Example Freight Performance Measures	Parameters
Highway	Combination truck miles travelled	Determined using combination truck traffic volume and segment length. Combination truck is defined as FHWA Classification 8-13.
	Truck miles traveled	Determined using truck traffic volume and segment length.
	Travel time reliability	Freight travel time reliability is defined as the percentage of travel greater than 45 mph on freeways.
	Combination truck average travel speed	The calculation of combination truck average travel speed is identical to the methodology for (passenger) vehicle's average travel speed, except that combination trucks are assumed to have a lower free flow speed. The free flow truck speed is assumed to be equal to the speed limit.
	Vehicles per lane mile	Vehicles per lane mile (freight) is calculated as the summation of each roadway segment's peak hour vehicle miles traveled divided by the number of lane miles.
Aviation	Tonnage	All air cargo landed at public airports.
Rail	Tonnage	Tons of freight carried by rail mode originated or terminated for a specific area.
Seaport	Tonnage	International and domestic waterborne tons of cargo handled at both public and private terminals in port areas for a specific area.
	Truck equivalent units	Includes international and domestic waterborne cargo handled at both public and private terminals in port areas for a specific area.

Source: CDM Smith, Inc., 2014

Table 22-7. Freight Performance Measures, Portland, Oregon	
Performance Measure	**Description**
Hours of truck delay in the p.m. peak and mid-day	Tracks delay as a result of congested roadways. The current baseline data compares hours of truck delay for the entire City street system with regional delay. Enhancements to current measures include truck delay at key intersections and along freight corridors, and distinguishing between causes of congestion by reoccurring vs. non-reoccurring events. Intersections and truck streets should be selected based on their direct accessibility to freight terminals and transfer facilities.
Travel time in Intelligent Transportation System corridors for average p.m. peak, a.m. peak, and off-peak	Evaluates the travel time performance in corridors using ITS technology to manage system operations. Expand the current selection of corridors to include those critical for freight movement including Rivergate, Airport Way, Columbia Blvd, US 30, and interstate freeways in Portland. Track travel time for truck trips in addition to auto trips, as is current practice.
Assessment of unmet pavement need	Tracks success in reducing pavement maintenance backlog. Assess and report on pavement condition in Freight Districts and along major freight corridors.
Employee participation in Transportation Management Associations (TMA)	Tracks progress in expanding the use of and participation in TMA programs to encourage use of alternatives to the single-occupancy vehicle for work commute trips.
Annual truck collisions/million vehicle miles of travel	Measures the number of reported collisions involving trucks and other modes, including rail, as reported for all City locations.
Elimination of weight-restricted bridges on truck streets	Tracks progress in rehabilitating or replacing weight-restricted bridges.
Assessment of truck complaint resolution	Evaluates the number of freight-related complaints received by PDOT and status of resolution.

Source: City of Portland, 2006

An example from a city comes from Portland, Oregon, shown in Table 22-7. Note the performance measures range from operational characteristics (hours of delay) to infrastructure condition (pavement condition) to public complaints.

C. System Designation

One of the important initial steps in freight-related transportation planning is identifying the facilities, services, and/or market areas that serve freight movements. This usually entails designating a specific freight network (for example, truck routes, major railroads, or air cargo airports) or those portions of the transportation network used by substantial numbers of freight movements (for example, major roads with large volumes of trucks). In addition, this system designation can also identify locations where freight movements intersect with passenger movements (such as at railroad/highway crossings), creating the potential for crashes.

State DOTs and MPOs have used a variety of strategies for identifying a freight system. For example, the Washington State FMSIB identifies a freight corridor as:

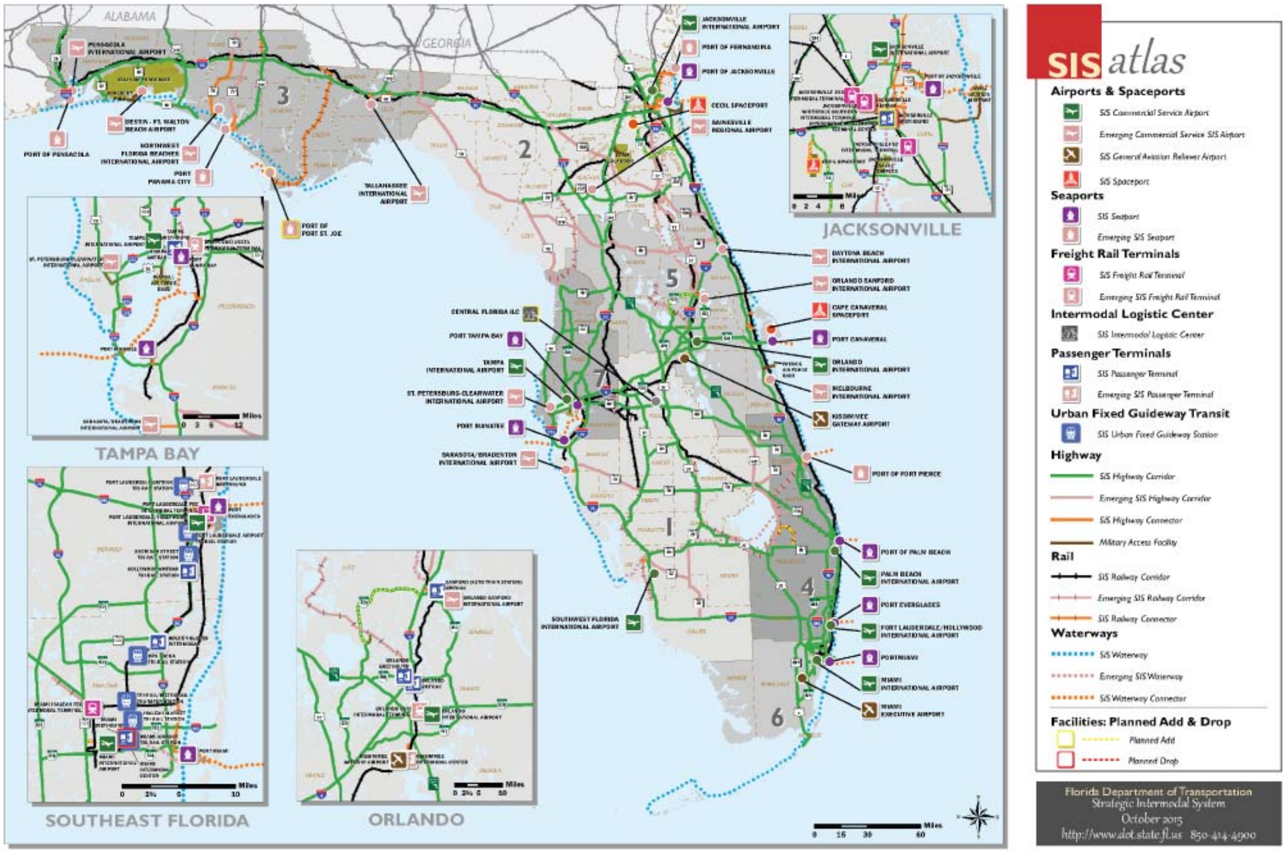
"A transportation corridor of great economic importance within an integrated freight system that:

- Serves international and domestic interstate and intrastate trade;
- Enhances the state's competitive position through regional and global gateways;
- Carries freight tonnages of at least:
    - Four million gross tons annually on state highways, city streets, and county roads;
    - Five million gross tons annually on railroads; or
    - For facilities to be built in the future, new links to strategic corridors that enhance freight movement may qualify, even though no tonnage data exists." [State of Washington, 2008]

The Virginia DOT identifies transportation corridors of statewide significance for both passenger and freight movement. The criteria for the selection of these corridors include those corridors that:

- Involve multiple modes (that is, highway, rail, interregional transit, airport, port) or are a freight corridor and extend beyond an individual region.
- Connect regions/states/major activity centers.
- Provide a high level/volume of transport, including:
  - Class I rail.
  - Commercial and/or reliever airports.
  - Interregional public transportation and stations.
  - Interstate highways.
- Provide a unique statewide function and/or addresses statewide goals:
  - Evacuation route or critical redundancy.
  - Security (military access, STRAHNET, STRACNET).
  - Tourism.
  - Truck route.
  - State bicycle route or interregional trail.
  - Economic development.

Figure 22-4. Florida's Strategic Intermodal System



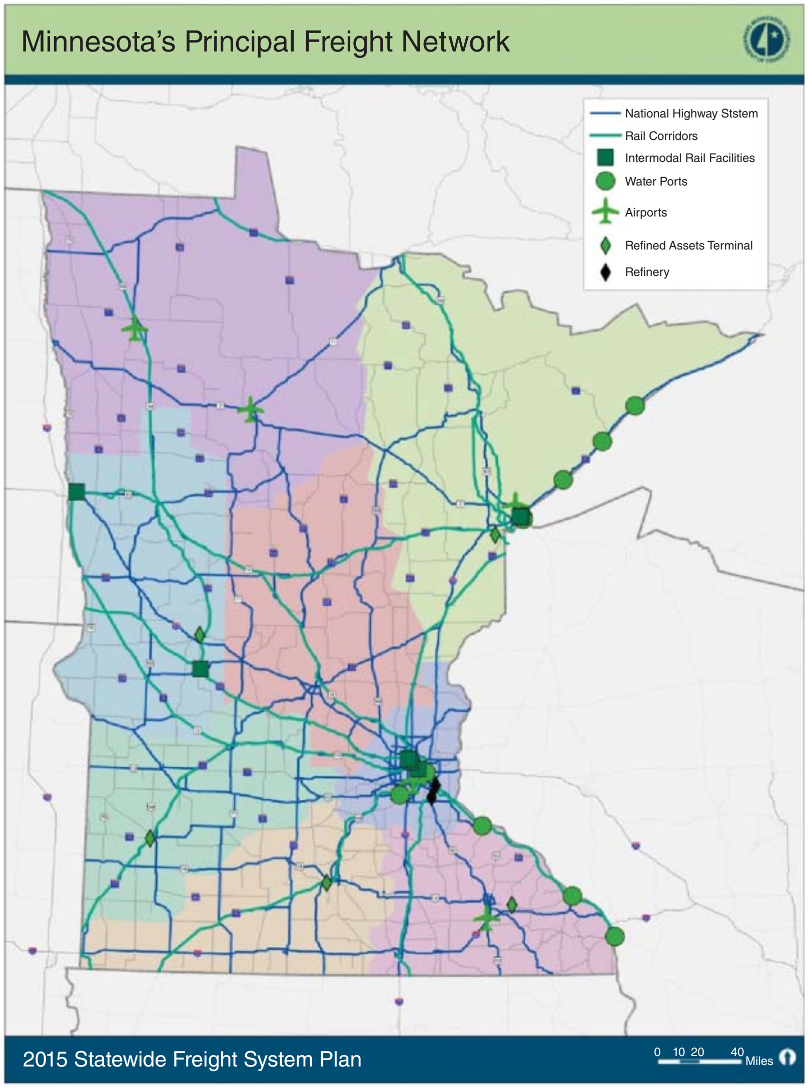
Source: Florida DOT, 2014a

One of the most extensive freight network designations comes from Florida where the state has identified a Strategic Intermodal System (SIS). This network includes all facilities of a certain threshold and significance enabling freight movement in the state. The following list shows the freight-oriented facilities that are part of this network (the intermodal network includes passenger intermodal facilities as well). [Florida DOT, 2014a, 2014b] Figure 22-4 shows the SIS network in Florida.

- Commercial service airports
- General aviation reliever airports
- Spaceports
- Seaports
- Freight terminals
- Intermodal logistics centers
- Freight rail corridors
- Waterway corridors
- Highway corridors
- Intermodal connectors

Figure 22-5 illustrates a type of truck route designation found in most jurisdictions. In this case, the truck network is viewed as connecting the major economic centers in the state of Minnesota. In many cases a truck route network is simply defined as those roads having the highest volume of trucks.

Figure 22-5. Designated Freight Network in Minnesota



Source: *Statewide Freight Plan*. St. Paul, MN: Minnesota Department of Transportation, 2005.

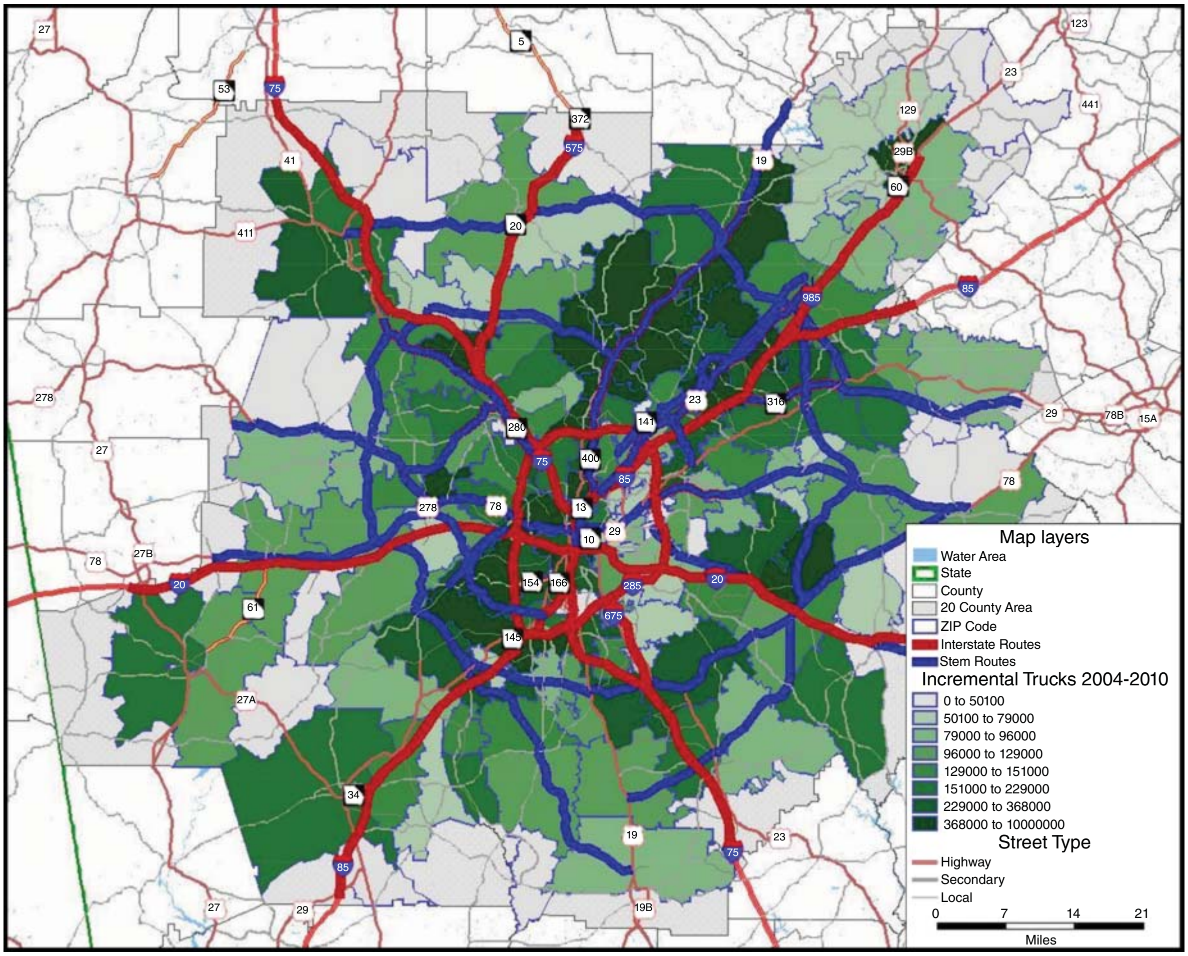
Figure 22-6 presents a slightly different representation of truck routes from Atlanta, Georgia. It shows the major highways serving truck movements in and through the metropolitan area. It also shows those areas in the region expecting to see large increases in trucks originating from their area during the period from 2004 to 2010. Not surprisingly, many of these areas are adjacent to the designated truck network.

Although major planning studies begin with some sense of the major freight systems and networks in their study area, these systems are often refined as the planning study progresses. Many times the designated networks are outdated or major new areas of growth have occurred that lead to an expansion of existing networks.

D. Data Collection and Analysis

As with most types of planning, freight studies depend a great deal on the collection and analysis of data. One of the challenges with data collection for freight studies is that much of the data needed to understand freight flows is often proprietary and held by private companies. Not surprisingly, these companies are not anxious to put data

Figure 22-6. Priority Freight Road Network and Zones of High Future Truck Volume, Atlanta, Georgia



Source: ARC, 2008

and information on their services and production characteristics into the public domain. Therefore, transportation planners often have to rely on existing databases or must collect data through a variety of means. Such data can relate to statistics on inbound and outbound freight flows and commodity types as well as survey information from shippers, carriers, and other handlers of freight. Tables 22-8 to 22-10 and Figures 22-7 and 22-8 show the types of data typically used in freight planning. Table 22-11 shows some of the data sources used in the San Francisco Bay area freight study to "fine tune" estimates for commodity flows.

Several different types of trip movement are of particular interest to transportation planners. New applications of global positioning systems (GPS) and geographic information systems (GIS) provide planners with important information on truck flow patterns. [Zmud et al., 2014]

1. External-Internal Movements

External-internal freight movements, which have one end inside and the other end outside of a study area, are primarily intercity movements. They represent a study area's interaction with other nearby areas as well as those located far away. In some cases, external-internal freight movements include international trade. These freight movements are related to the economic base of an area and usually involve several modes of transportation, such as truck, rail, air, water, and pipeline. Furthermore, external-internal movements usually involve different modal freight terminals located in a study area.

For planning studies related to these movements, commodity-flow data are useful. For studies involving external-internal movements, the area's MPO should work closely with other agencies, such as the state DOT, chamber of commerce, and in some cases airport and seaport authorities.

Table 22-8. Common National Freight Data Sources, United States	
Public Freight Data Source	**Agency**
Air Carrier Financial Reports	U.S. DOT, Bureau of Transportation Statistics (BTS)
Air Carrier Statistics	U.S. DOT, BTS
Annual Survey of Manufacturers	U.S. Department of Commerce (DOC), Census Bureau
Business Dynamic Statistics	U.S. DOC, Census Bureau
Carload Waybill Sample	Surface Transportation Board
Commodity Flow Survey	U.S. DOT, BTS
County business patterns	U.S. DOC, Census Bureau
Energy Information Administration Data Services	U.S. Department of Energy (DOE), Energy Information Administration (EIA)
Fatality Analysis Reporting System	U.S. DOT, National Highway Traffic Safety Administration (NHTSA)
Federal Railroad Administration Safety Database	U.S. DOT, Federal Railroad Administration (FRA)
Foreign Trade	U.S. DOC, Census Bureau
Freight Analysis Framework (FAF)	U.S. DOT, FHWA
Highway Performance Monitoring System	U.S. DOT, FHWA
Pipeline and Hazardous Material Safety Administration	U.S. DOT, Pipeline and Hazardous Material Safety Administration (PHMSA)
Maritime Statistics	U.S. DOT, Maritime Administration (MARAD)
Motor Carrier Management Information System	U.S. DOT, Federal Motor Carrier Safety Administration (FMCSA)
Motor Carrier Safety Measurement System	U.S. DOT, FMCSA
National Agricultural Statistics Service (NASS)	U.S. Department of Agriculture, NASS
National Highway Planning Network	U.S. DOT, FHWA
Service Annual Survey	U.S. DOC, Census Bureau
Statistics of U.S. Businesses	U.S. DOC, Census Bureau
Survey of Business Owners	U.S. DOC, Census Bureau
Topologically Integrated Geographic Encoding and Referencing	U.S. DOC, Census Bureau
Transborder Freight Database	U.S. DOT, BTS
Transportation Services Index	U.S. DOT, BTS
U.S. Economic Accounts	U.S. DOC, Bureau of Economic Analysis (BEA)
U.S. Highway Statistics Series	U.S. DOT, FHWA
U.S. Waterway Data	U.S. Army Corps of Engineers
Vehicle Inventory and Use Survey	U.S. DOC, Census Bureau
Vehicle Travel Information System	U.S. DOT, FHWA

Source: Walton et al., 2015

2. Through Movements

Through (external-external) movements have both trip ends located outside the study area. Although these trips do not affect the local street network (except for those roads serving truck service areas), they can sometimes cause serious problems. For example, heavy volumes of large trucks passing through an urban area can contribute to traffic congestion as well as environmental impacts. Rail movements through an area can cause delay and safety problems at rail-highway grade crossings.

In many cases, solutions for freight-movement issues include capital-intensive actions, such as bypass facilities for large trucks and grade separation of busy rail tracks. Often, studies covering a large area beyond the urban area may be needed to identify other types of solutions, such as shifting freight to other modes. For problems relating to through movements, a coordinated effort of local and state agencies is needed.

Table 22-9. Freight Performance Measures Data Sources

Performance Measure	Potential Data Source
Safety	
Highway	Accident Crash Reporting Systems (state level)
	Fatality Analysis Reporting System (FARS)
	Motor Carrier Management Information System
	Safety Measurement System
	Safety and Fitness Electronic Records
Rail	FRA State Freight Rail Safety Statistics
Air	Accident/Incident Data System
	Aviation Safety Reporting System
	Near Midair Collision System
	Runway Safety Office Runway Incursion Database
Ports/Marine	Marine Information for Safety and Law Enforcement
Maintenance/Preservation	
Highway	Pavement Management System (state level)
	National Bridge Inventory
Rail	Rail Network Data (state level)
Air	Airport Pavement Management System (state level)
Ports/Marine	U.S. Army Corps of Engineers Navigation Data Center
Mobility, Congestion and Reliability	
Highway	Highway Performance Monitoring System
	American Trucking Institute National Corridors Analysis and Speed Tool
	INRIX Probe Vehicle Data
	Weigh-in-motion Data
Rail	Association of American Railroad's Railroad Performance Measures
Air	Air Carrier Statistics
Ports/Marine	U.S. Army Corps of Engineers Lock Performance Measurement System
	Maritime Safety and Security Information System
Accessibility and Connectivity	
Highway	State, regional, or MPO-level GIS databases
Rail	Carload, Waybill Sample
Air	Air Carrier Statistics
Ports/Marine	U.S. Army Corps of Engineers Lock Performance Measurement System
Commodity Flow Data	State-level Commodity Flow Models
	Freight Analysis Framework
	Transsearch Database
	Commodity Flow Survey
Environment	
Highway	Environmental Protection Administration's MOVES model

Source: Walton et al., 2015

3. *Internal Movements*

Internal (such as intra-urban) freight movements almost always occur by truck. The majority of these movements are for pick-up and delivery (PUD) of freight items using single-unit trucks and vans. However, large combination trucks also move freight between terminals and hubs located inside an urban area. Internal freight movements have a hierarchical pattern and require different sizes of trucks. For example:

- PUD movements between major activity centers such as an airport and a hub terminal of a freight company (such as the United Parcel Service) often use large combination trucks.

- PUD movements of containers from one rail terminal to another are known as rubber-tired interchanges and are common in certain large urban areas such as Chicago and Memphis, which are served by multiple rail services.

- PUD movements between warehouses and distribution centers on one end and stores and offices at the other end may use medium-sized trucks.

- PUD movements between a break-bulk truck terminal at one end and offices, homes, and stores at the other end usually use small trucks and vans.

In addition to trucks and freight-carrying vans, freight planners should be aware of service vehicles/automobiles and small vans used by plumbers, electricians, office equipment maintenance personnel, and others providing similar services. These vehicles often have commercial license tags, but do not carry large amounts of freight. An important question for transportation planners is whether these vehicles should be given the same privileges as trucks in using certain special areas such as curbside loading zones.

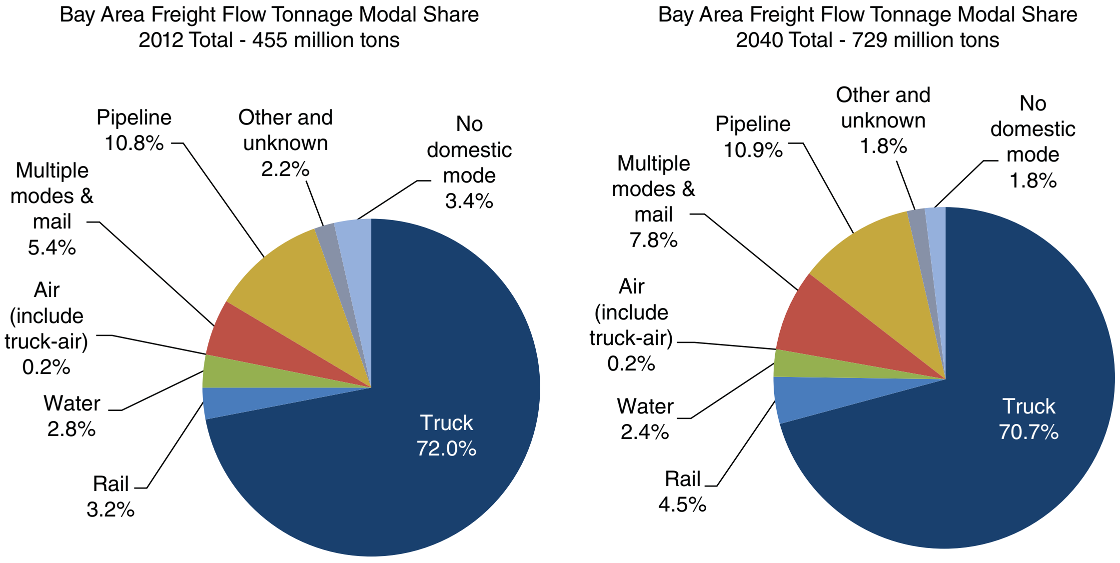
Although planners and traffic engineers may not need to analyze internal freight movements by commodity flow, they should be aware of the variety of freight items carried by trucks inside an urban area. These include construction materials, food products, consumer goods (such as television sets and furniture), petroleum, small packages, and mail.

Table 22-10. Data on Existing and Future Freight Movements in San Francisco

County/Region	2012 Tons (1,000s)	2040 Tons (1,000s)	CAGR* (2012–40) Tons	2012 Value ($ millions)	2040 Value ($ millions)	CAGR* (2012–40) Value
Entire Bay Area	454,246	728,767	1.7%	643,836	1,484,944	3.0%
Alameda	143,863	232,239	1.7	234,667	487,577	2.7
Contra Costa	148,901	226,063	1.5	105,306	206,682	2.4
Marin	16,602	25,388	1.5	13,454	30,466	3.0
Napa	16,275	23,557	1.3	17,847	32,302	2.1
San Francisco	56,946	93,872	1.8	56,501	129,022	3.0
San Mateo	57,399	91,445	1.7	109,489	286,650	3.5
Santa Clara	121,423	183,044	1.5	211,955	493,986	3.2
Solano	38,340	58,216	1.5	31,192	71,241	3.0
Sonoma	43,089	65,344	1.5	42,756	98,137	2.9

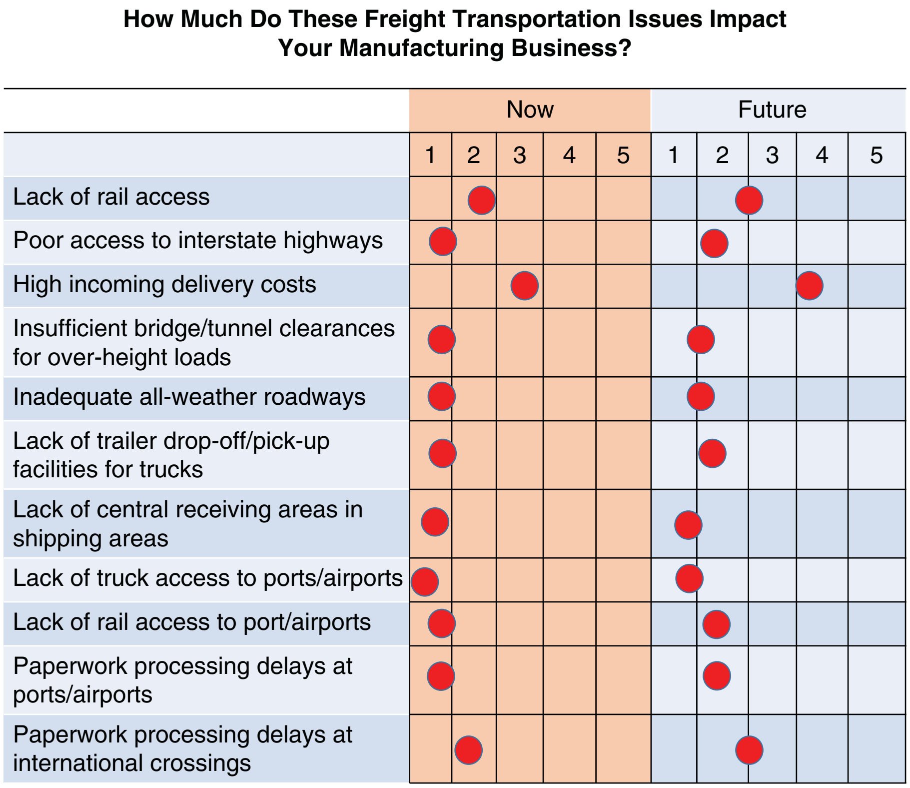
*CAGR = Compound Annual Growth Rate

Figure 22-7. Current and Future Freight Mode Share, San Francisco Bay Area



Source: Cambridge Systematics, 2014c

Figure 22-8. Typical Results from Industry Survey, Detroit, 2011



Source: SEMCOG, 2011
1 = Not important 5 = Very important

Table 22-11. Data Sources for Adjusting Flow Forecasts, San Francisco Bay Area

Commodity	Basis for Adjustment of Production Factor	Source of Production Factor Calculation	Basis for Adjustment of Attraction Factor	Source of Attraction Factor
Textiles/ Leather	Employment in textile mills, apparel, leather, and allied product manufacturing by county.	U.S. Census 2012 county business pattern employment data.	Total population by county.	Association of Bay Area Governments 2010 population data for Bay Area counties; California Dept. of Finance 2010 population data for counties outside Bay Area.
Crude petroleum	Employment in oil and gas extraction by county.	U.S. Census 2012 county business pattern employment data	Refining capacity by county.	U.S. Energy Information Administration's refineries' total operable atmospheric crude oil distillation capacity as of Jan. 2014.
Coal and petroleum products	Employment in coal and petroleum products manufacturing by county.	U.S. Census 2012 county business pattern employment data.	Total population by county.	Association of Bay Area Governments 2010 population data for Bay Area counties; California Dept. of Finance 2010 population data for counties outside Bay Area.

Source: Cambridge Systematics, 2014c

Much of the data described can be collected locally. However, most freight studies rely on data collected and tabulated nationally. A useful source of national freight data is found in "Data Sources Related to Freight Transportation," http://www.ops.fhwa.dot.gov/freight/freight_analysis/data_sources/index.htm. Many of these have a national scale of application, thus planning studies will most likely have to manipulate the data to make them relevant to the specific context and scale of the study.

Transportation planners must often collect original data for a planning study. In such cases there are a variety of techniques and tools that can be used (see chapter 2 on data collection for a more detailed discussion of relevant tools). A 2008 regional freight study in Atlanta illustrates the different types of data collection tools that might be employed in a freight study. [ARC, 2008] A survey of truck drivers was conducted at selected locations on the region's major freeway network. Hand-held computers were used to expedite data collection and a printed map was available to allow drivers to trace their route through the road network. The types of data collected included date and time stamp, weather conditions, vehicle type, trip origin and destination, number of stops in the study area, trip frequency, trip purpose, facilities visited, vehicle load status, routes avoided, and route flexibility. The sample was just less than 10 percent of the total volume passing by the survey sites.

Some findings from this data collection included:

- 95 percent of the survey sample was tractor trailers.
- 37 percent of the trucks had no origin or destination in the Atlanta region while 20 percent had both an origin and destination in the region.
- The most significant generators of the freight movements were warehousing and distribution (46 percent), manufacturing (17 percent), retail (11 percent), airport-related, including construction (10 percent), other construction (4 percent), and rail yards (4 percent).
- 30 percent of the trucks were empty.
- 85 percent of the drivers had some flexibility in their routes.
- 3 percent were carrying hazardous materials.

Another data collection effort obtained information from major carriers on what they perceive to be the major bottlenecks in the region's road network. The information collected included locations of poor merge areas, inadequate interchange capacity, narrow lanes, poor intersection geometric design, and lack of signing and pavement markings.

A business stakeholder survey was also conducted online with shippers and carriers that were major freight movers in the region. The information collected from the survey included business type; number of deliveries to warehouses, distribution centers, and businesses; day of week that deliveries occur; time of day for deliveries; number of inbound and outbound loads; the destinations of loads; and routes taken. The important findings from this survey included:

- Delivery location security was the biggest concern among the respondents. From a carrier perspective, focus on the security of the cargo and trailer assets was paramount. Poor lighting, access, and inadequate staff levels inhibit secure and safe freight transfers.
- Monday, Tuesday, and Wednesday were recorded as having the highest amount of shipping activity, which mirrored the carrier responses.
- The peak season for the shippers occurred during the spring months (March, April and May) and late fall to winter months (September through December). Retail and food shippers often have the same delivery schedules due to the various products offered. For example, clothing retailers see an upward shift in late summer due to back-to-school promotions followed by the holiday season.
- From a shipper perspective, the most important element that influenced outbound transportation was cost, followed by service performance.

Rail service was perceived as a cost-effective mode of transporting goods, but was rated only "fair" in on-time reliability. Security was noted as a potential liability because of the potential for cargo theft.

Targeted stakeholder interviews were held with 70 public- and private-sector officials. The selection of candidate stakeholders reflected industry type, county location, and size (including both small and large companies/agencies). An important requirement was to reach the sectors generating economic growth in the study area. Those interviewed provided information on both freight-related issues facing the region and suggestions on the types of strategies that should be adopted to deal with them.

A freight task force can also act as a primary means for stakeholder outreach. Task force members participated in a variety of activities including soliciting stakeholder candidates to participate in interviews, defining goals and objectives, reviewing the needs assessment findings, providing input into the project selection and prioritization process, and identifying "quick-start" projects.

An excellent source of freight-related data created by the FHWA is found at: http://www.ops.fhwa.dot.gov/freight/freight_analysis/data_sources/index.htm.

E. Needs Analysis and Models

The freight analysis process can examine a range of questions concerning the movement of freight in a study area. Such analysis is applicable not only for large metropolitan areas, but also for small- to medium-sized communities. [Cambridge Systematics, Inc. et al. 2007] The most recent version of the Federal Highway Administration's (FHWA) *Quick Response Freight Manual* provides an overall framework noting the types of questions that can serve as the basis for a freight analysis:

- *Why* freight moves—the economic/industrial/commodity factors giving rise to the demand for freight.
- *Who* moves freight—the logistics factors determining the spatial relationships, shipment sizes, and frequencies influencing shippers and receivers, and other factors governing shipments.
- *What* moves freight—the modal factors determining the costs and service levels covered by the modes that carry freight—truck, rail, water, and air.
- *Where* freight moves—the vehicles/volumes factors concerned with the movement of freight on the various modal networks to various destinations.
- *How* freight moves—public policy that sets the rules and regulations under which freight must operate. [Beagan et al., 2007]

Identifying current and future system needs is an important step in freight planning. Determining current needs is usually undertaken by examining system performance data, such as congested areas, areas of slow freight operations, or locations with high truck or rail crash rates. Surveys and interviews of shippers and carriers are an important tool for identifying problems in the existing transportation system. Table 22-12 shows in general terms the types of needs and issues related to freight system performance in the San Francisco Bay area. [Cambridge Systematics, 2014b]

The more challenging task is to forecast future freight movements. Using the above questions from the *Quick Response Freight Manual,* the forecasting process must examine these topics from the perspective of future conditions and demands. For example, understanding why freight moves requires an examination of the changing future economic factors in a study area influencing the quantity of freight moved and the corresponding travel patterns. Table 22-13 shows the types of data necessary for model calibration and validation (see chapter 6 on demand estimation), and Table 22-14 shows typical costs for the data collection methods used to obtain such data.

Perhaps even more challenging, the analysis must consider future modal factors affecting the costs and service levels of different modal options. However, the uncertainty associated with this issue is large: What types of fuels and fuel costs are likely to exist in 20 years? What new vehicle or infrastructure technologies could provide increases in productivity in one mode versus another? These questions are almost impossible to answer with any level of certainty; thus, the analysis should employ sensitivity assessment and other means such as scenario analysis.

The *Quick Response Freight Manual* describes a range of models and analysis approaches that can be used to predict future freight growth, along with detailed descriptions of how these tools can be used. The following paragraphs, based on the manual, provide a shortened description of the most common tools.

Table 22-12. Goods Movement System Needs and Issues by Functional Area, San Francisco Bay Area, California	
Goods Movement System Needs and Issues by Functional Area Function	**Needs and Issues**
Global Gateways: Major maritime facilities and international airports that handle freight, as well as passenger cargo	• Port of Oakland land constraints, deficiencies in cargo handling equipment. • Intensifying port competition. • Marine terminal congestion and its associated impacts on drayage drivers and neighborhoods. • Need for improved communication between truck drivers and marine terminal operators. • Impacts and opportunities for heavy haul networks around ports. • Expanding demand for bulk export facilities. • Conflicts between industrial/warehouse space needs to support growth and impacts on neighborhoods. • Changing mix of air cargo (less computer-related exports) and uncertain growth in domestic markets.
Interregional and Intraregional Corridors: Primary highways and rail lines that serve to connect the megaregion to the rest of the state and to domestic markets beyond	• Congestion and delay on shared use freight corridors with passenger traffic, such as I-880 and I-580, and Capitol Corridor. • Truck safety issues along freight corridors due to merging and weaving. • Pavement and bridge condition issues along freight corridors. • Rail bottlenecks, especially along Martinez Subdivision. • Safety issues at rail-highway grade crossings. • Increasing need for third party logistics space and local access to integrator (for example, Federal Express, UPS) hubs at OAK, Port of Oakland and connections to inter and intraregional corridors.
Local Goods Movement System: Roads supporting local pickup and delivery, and last-mile connectors—roads that provide critical connections between major freight facilities (global gateways, domestic rail terminals, warehouse/industrial centers, and industrial parks), and the interregional and intraregional systems	• Public health impacts on neighborhoods with intense freight activities. • Land use conflicts in traditional industrial corridors. • Lack of truck parking/neighborhood parking encroachment. • Conflicts between trucks and other street users (autos, pedestrians, bikes, transit) on collector routes and in commercial areas. • Cut through traffic to avoid congestion on major corridors. • Lack of truck route connectivity across city boundaries. • Local road and street pavement damage. • Problems with roadway and street design that impede truck deliveries.

Source: Cambridge Systematics, 2014b

1. Growth Factors

One of the most straightforward approaches to forecasting future freight movement is to examine trends and predict future volumes based on historical growth factors. Several growth-factor methods can be used.

Straight Line or Linear Projections. This method simply extrapolates past growth into the future by assuming the rate of growth as determined between two historical points continues into the future. For example, if freight flow occurs at a volume of F_1 at year 1 and at a volume of F_2 at year 2, the predicted freight flow at a future year 3 can be

Table 22-13. Data Needs for Alternative Freight Modeling Methods

Aspect		Commodity Generation Models	Distribution Models	Input-Output Models	Freight Choice Models	Empty Trip Models	Spatial Price Equilibrium Models	Trip Generation Models	Distribution Models	Micro Simulation Models	Micro Simulation Hybrid Models	Spatial Price Equilibrium Models	Freight Origin/Destination Models
Information/insight into logistical patterns			C	C			C		C	C	C	C	
Freight generation data	Production	C		C,F				C		C,F	C	C	C,F
	Consumption	C		C				C		C,F	C	C	C,F
Delivery tours	Sequence									C.F		C,F	
	Location									C.F		C,F	
	OD flows		C,F	C,F		C,F			C,F	C,F	C,F	C,F	
	Empty flows					C							
Economic characteristics of participating agents	Shippers	C,F						C.F		C,F	C,F	C.F	
	Carriers	C,F						C,F		C,F	C,F	C,F	
	Receivers	C,F						C,F		C,F	C,F	C,F	
Spatial distribution/Location of participating agents	Shippers	C,F								C,F	C,F	C,F	
	Carriers	C,F								C,F	C,F	C,F	
	Receivers	C,F								C,F	C,F	C.F	
Network characteristics	Travel times and costs		C,F	C,F		C,F			C,F	C,F	C,F	C,F	C,F
	Use restrictions		C,F	C,F		C,F			C,F	C,F	C,F	C,F	C,F
	Capacity		C,F	C,F		C,F			C,F	C,F	C,F	C,F	C,F
	Traffic volumes												C
Special choice processes	Mode choice				C					N/A			
	Delivery time									N/A			
	Mode attributes				C,F					N/A			
Other economic data	Production functions						C,F						
	Demand functions						C,F						
	Input-Output Coefficients			C,F									

C = Calibration

F = Forecast

Source: Holguin Veras et al., 2010

Table 22-14. Example Unit Costs for Data Collection Techniques				
Data Collection Method	**Cost Description**	**Type**	**Average Cost**	**Comments**
Vehicle Classification Counts	Unit cost per site for conducting 24-hour vehicle classification counts	Manual counting	$650	To reduce costs availability of count data from existing counting programs should be considered.
		Video counting	$500	
		Automated counting	N/A	
Roadside Intercept Surveys	Unit cost per site for conducting 24-hour intercept survey	Roadside interviews	$5,000	Actual costs of data collection can vary significantly depending on characteristics of the site, the quantity and quality of data collected, and the firm collecting the data.
Establishment Surveys	Cost per survey	Mail-out/mail-back survey	$100 (10% response)	N/A
		Telephone survey	$250 (20% response)	
		Combined mail and telephone survey	Expected to be higher than telephone surveys	
Travel Diary Surveys	Cost per survey	Not assisted by GPS	N/A	Cost major issue in GPS-assisted surveys because of equipment costs and installation costs on trucks.
		GPS assisted	N/A	

Source: Beagan et al., 2007

mathematically denoted as:

$$F_3 = F_2 + \frac{(F_2 - F_1)}{(T_2 - T_1)}(T_3 - T_2)$$

where:

F_i = Freight flows in year i
T_i = Year i

Compound Growth. Often, growth in traffic volumes is expressed as a certain percent per year. Given the base of growth changes from one year to the next (that is, next year's growth uses this year's growth plus the percent change as the basis for next year's change), the growth in volume is not linear. This is called the compound growth rate. Analysts can use the simple interest equation:

$$F_2 = F_1\ (1 + i)^n$$

where F_2 stands for a future dollar value, F_1 is a present value, i is the interest rate and n is the number of time periods, to calculate the value of i, which is the compound growth rate. In this case, i or the compound growth rate, equals:

$$i = \left[\left(\frac{F_2}{F_1}\right)^{1/n}\right] - 1$$

The future freight volumes (F_3) would be estimated where the F values are the same as before and the $T_3 - T_2$ is the number of years in the future the freight volume is to be calculated.

$$F_3 = F_2\ (1 + i)^{(T_3 - T_2)}$$

Planning studies often use the growth in economic or commodity demand to determine the future freight volumes. In this case, the compound growth factor approach is used to determine the future economic values and then a modal factor is used to estimate how many freight movements this would imply. The trip generation factor (the number of trips generated per unit of economic activity) is usually based on historical records. As noted in the *Quick Response Freight Manual*, "For most commodity groups, the relationship between value of output (measured in constant dollars) and volume shipped (measured in pounds, tons, cubic feet and such) may change over time. These changes may be due to a change in the mix of commodities being produced within a given commodity group (for example, more aluminum and less steel) or a change in the average real value per ton of major products within the group. These changes may result in a changing value per ton in either direction . . . .when there are one or two commodity groups of particular interest, some consideration should be given, at least in an informal way, to determine how real value per ton for these groups has been changing and how it is likely to change during the forecast period."

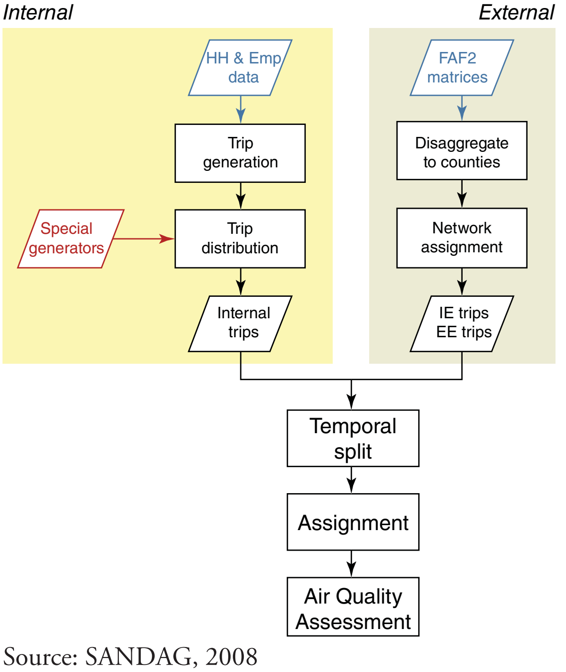
As previously noted, one of the important strategies for incorporating uncertainty into the analysis is to conduct a sensitivity assessment. This is done by changing some of the key assumptions in the analysis, such as the compound growth rate, to see if the results or conclusions change in any significant way. According to the manual, key assumptions incorporated into the forecasting process, and thus candidates for sensitivity assessment, include:

- Economic growth—both nationally and locally.
- Growth in the economic sectors generating significant volumes of freight handled by the facility.
- Transport requirements of these sectors, which may be affected by increased imports or exports or by changes in production processes.
- Modal choice, which may be affected by changing transport requirements or changing cost and service characteristics of competing modes.
- Facility usage per unit of freight volume, which may be affected by changes in shipment size or container size.
- The availability and competitiveness of alternative facilities.
- Value per ton of output.
- Output per employee (if employment is used as an indicator variable).

2. Four-Step Model

For those states or metropolitan areas having a four-step demand model, a more sophisticated analysis of freight flows can often occur. See chapter 6 on urban travel demand modeling for more detail on this approach to modeling, as well as [Beagan et al., 2007; Bassok et al., 2013; and Southworth, 2010]. As shown in Figure 22-9, this modeling approach consists of four major steps—trip generation, trip distribution, mode split, and network assignment. Each step uses mathematical relationships to determine an output, for example, the number of tons for trip generation. Some of these relationships can be determined using historical data from the study area, while in others national default values can be used.

Figure 22-9. Four-Step Freight Model for Truck Flows, San Diego



Source: SANDAG, 2008

Trip Generation. Trip generation models are based on a set of annual or daily trip generation rates or equations by commodity by zone. Based on the zonal activity factors of either population or employment, these rates are then used to determine the annual or daily commodity flows originating or terminating in the geographic zones. Given most metropolitan areas have a system of traffic analysis zones (TAZs), these zones usually serve as the reference for trip generation in metropolitan areas. For states and multistate studies, counties often serve as the zonal unit. The key differences between trip generation for passenger demand modeling and for freight transportation are shown in Table 22-15.

It is important to classify trucks by type of truck and/or trip purpose/sector. Classification schemes include the FHWA vehicle classification system (see chapter 2), gross vehicle weight ratings, type of goods carried, number of

Table 22-15. Key Differences in Trip Generation between Passenger and Freight Modeling		
Characteristic	**Passenger**	**Freight**
Demand generated.	Passenger trips.	Tons produced or consumed at a given location.
Traffic generated.	Car trips, bus trips, etc.	Truck trips, van trips, etc.
Influencing variables.	Income, land use, family structure, car ownership, activity concentration.	Economic activity performed, line of business, business size, land use.
Correspondence between demand and traffic generated.	Very tight, almost one to one in areas where transit share is low.	Very loose due to: (1) the role played by the shipment size that leads to a situation where large businesses, while generating large amount of cargo, produce proportionally less traffic because of their large shipment sizes; and (2) the indivisibility of freight trips that translates into small businesses generating proportionally large freight trip generation in relation to the demand generated.

Source: Holguin Veras et al., 2012

tires/axles, and body type. For example, a 2007 regional model update in the Seattle, Washington region defined three types of trucks—light trucks (four or more tires, two axles and less than 16,000 pounds), medium trucks (single unit, six or more tires, two to four axles and 16,000 to 52,000 pounds), and heavy trucks (double or triple unit, combinations, five or more axles and more than 52,000 pounds). [Puget Sound Regional Council, 2007] In addition, the regional model used employment in the following industries as factors in estimating the number of truck trips—agriculture/forestry/fishing, mining, construction, manufacturing (products), manufacturing (equipment), transportation/ communication/utilities, wholesale, retail trade, finance/insurance/real estate (FIRES), and education/government.

Trip generation includes both the number of trips produced in and attracted to each zone. Equations (usually linear regression models) are developed for both types of trips either by each commodity group or truck type. In addition to the truck trips generated in the TAZs, it is often important to segregate freight trip-generating activity associated with special trip generators such as airports, ports, or major distribution centers.

Holguin Veras et al. [2012] provides an excellent reference for freight trip generation.

Trip Distribution. This step in the modeling process uses the information produced in trip generation to determine the origin-destination pairs of freight trips in the study area. The important variables for distributing the trips are the productions and attractions by zone, and the impedance (usually some measure of travel time) between each zonal pair. A popular approach to estimating origin-destination flows is the use of a gravity model that approximates travel attraction by level of economic activity or "mass" occurring in each of two zones and is inversely proportional to the impedance between the two.

The key to a valid trip distribution approach is ensuring that the predicted trips match what is observed on the road network. For the gravity model, this is done by comparing the trip length distributions of the modeled trips to historical data and modifying the travel "friction factor" for different truck trips until the distributions closely match. The Seattle modeling exercise developed the following friction factor equations to accommodate different types of truck types and trip lengths:

- Light Trucks, Short Trips = {EXP(3.75 − 0.08 × "daily travel time"). max. 1}
- Medium Trucks, Short Trips = {EXP(4.75 − 0.05 × "daily travel time"). max. 1}
- Light Trucks, Long Trips = {EXP(2.1− 0.005 × "daily travel time"). max. 1}
- Medium Trucks, Long Trips = {EXP(4.2 − 0.003 × "daily travel time"). max. 1}
- Light Trucks, Kitsap Pen. = {EXP(4.0 − 0.05 × "daily travel time"). max. 1}
- Medium Trucks, Kitsap Pen. = {EXP(5.0 − 0.10 × "daily travel time"). max. 1}
- Heavy Trucks, All Trips = {EXP(4.0 − 0.10 × "daily travel time"). max. 1}

Travel demand models are also developed on a time-of-day basis; travel demand is thus usually estimated by different time periods.

Mode Split. This step identifies which mode of travel commodities and products will use between a specific origin and destination. This step is not needed in studies where the only feasible mode is truck. Where different modes are possible, the mode choice is often classified by average distance traveled, with the logic being that some modes (such as rail) might be preferable for longer distance trips than others. Some examples of mode split approaches from selected studies include the following: [Beagan et al., 2008]

Indiana Commodity Transport Model. This mode split model identified nine individual modes (such as private truck, for-hire truck, rail, and air) and eight multiple or combined modes (such as truck and air, truck and rail, inland water, and Great Lakes). In addition, each of the modes was categorized by length of trip, for example, less than 50 miles, 50 to 99 miles and up to "greater than 2,000 miles." Categories were calculated based on data from a base-year commodity flow survey and the probabilities for modal transport of commodities by distance. These probabilities were then used with future year trip tables to estimate the mode split during the timeframe for the study.

Florida Intermodal Statewide Highway Freight Model. This model estimates annual tons shipped by truck, bulk/ carload rail, container/intermodal rail, air, and water. A logit model (see chapter 4) was developed based on observed modal shares in a base year and is then used to predict future modal percentages (by tons). The determining factor in a logit mode split model is the utility function associated with each mode, where the utility function represents the travel costs associated with the mode. Thus, for example, the cost for truck travel was defined as $0.0575 per mile traveled; for rail, $12 +$0.025 per mile; and for intermodal, $26 + $0.028 per mile. In addition, a cost per hour of service was incorporated into the utility function. The model results estimated the number of tons split among the available modes of travel. Each tonnage amount was then converted to trips by using the historical data that had established this relationship.

Cross Cascades Corridor Study. This study was undertaken by the state of Washington to examine interregional passenger and freight travel patterns between Seattle and Spokane, Washington. The mode split component of the travel demand model included the following freight modes: air freight, rail freight, heavy truck freight and medium truck freight. The determination of the modal distribution of freight movements depended on the monetary values of time, distance and cost. Logit models were used to assign probabilities of freight choosing one mode versus another. Some of the characteristics associated with the freight cost functions are shown in Table 22-16.

Network Assignment. This step in the modeling process assigns trips to the freight networks. As noted earlier, one of the steps that must occur prior to this is to convert tonnage or other measures of trip volumes to trips. This is done using conversion factors based on historical relationships between average tons moved per trip. With respect to rail, air, and water assignments, in which the networks are less extensive than the road network, the assignment process follows a rules-based approach. This means that tonnage predicted to go by one of these modes does so subject to the supply constraints and operational characteristics of the service being provided. For truck assignments, in which trucks are using the road network (along with everyone else), the model determines the performance characteristics of the highway network by time of day, such as network path travel times, and then assigns truck trips based on least-cost routes. The more sophisticated models use a stochastic assignment process that takes into consideration some level of uncertainty on how trucks will be routed through the network.

A state freight plan will analyze all of the freight modes that are of state significance and thus very different analysis tools will likely be used. For example, the Georgia Statewide Freight and Logistics Plan analyzed nine different freight modes using a variety of methodologies, including: [Georgia DOT, 2015]

Marine Port Projects	Recent reports
Rail Projects—Crescent Corridor	Previous analysis
Rail Projects—Other improvements	Top-down estimate using previous reports
Highway Projects—Add capacity	Georgia DOT statewide travel demand model
Highway Projects—Improve interstate Interchanges	"Off-model" analytical technique
Highway Projects—Urban "bypasses"	Georgia DOT statewide travel demand model
Highway Projects—Rural freight corridors	Georgia DOT statewide travel demand model
Highway Projects—Safety projects	"Off-model" analytical technique
Air Cargo Projects	Qualitative descriptions from discussions with airport staff

Table 22-16. Factors in Freight Cost Functions, Washington State			
Mode	**Terminal Cost**	**Distance Rate Range (including terminal cost)**	**Dollars/Ton-mile Assumed**
Light truck	$0	$0.04–$0.10 / ton-mile	$0.10
Medium truck	$20.50	$1.25–$2.50/mile	$0.08
Heavy truck	$25.63	N.A.	$0.10
Rail freight	$37.50	$0.02–$0.04/ ton-mile $2.20–$2.73/mile	$0.03
Air freight	$70.00	$4.90–$7.50/ ton-mile	$3.00

Source: Cambridge Systematics et al., 2008

F. Evaluation and Prioritization of Freight Strategies

The needs analysis leads to a set of strategies or projects to improve a region's or state's transportation system. The range of feasible project types can be quite large. For example, the types of strategies that surfaced from the Atlanta regional freight planning study included: [ARC, 2008]

- Mitigate interchange bottlenecks.
- Maintain and enhance intermodal connectors.
- Add mainline rail capacity.
- Implement rail grade separations.
- Use intelligent transportation systems (ITS) technologies.
- Implement management and operations strategies—public-sector operational techniques to optimize freight travel (traffic signal timing, signage, and geometric design restrictions on weight or clearance) and private-sector operational techniques to optimize freight travel (off-peak operations, consolidated deliveries, and regional drop yards).
- Preserve lands for freight uses.
- Implement institutional changes to improve feasibility of freight projects of regional significance (public-private coordination and/or partnerships).
- Enhance freight network safety.
- Improve data and analytical methods.
- Promote regional approaches and leadership.
- Enhance public awareness of freight transportation.
- Expand highway infrastructure.

Notice these strategies range from the more traditional infrastructure-oriented road improvements to improving the MPO's freight data and analysis capability. Some of these actions might be very difficult to evaluate with any quantitative methodology; thus, it is not surprising a variety of approaches are used to evaluate freight strategies. Another example of the types of strategies that could be considered to meet freight-related needs is shown in Table 22-17 from the Metropolitan Transportation Commission (MTC) in the San Francisco Bay area.

Beagan et al. [2007], Rhodes et al. [2012], Bassok et al. [2013], Holguin-Veras et al. [2015], and Cambridge Systematics, Inc. [2015] are good references for the types of strategies and projects that can be used to improve freight system performance.

Evaluation consists of examining the relative merits of different freight strategies to determine which ones will produce the best benefits for the least cost. Figure 22-10 shows an evaluation framework for freight planning. [Cambridge Systematics et al., 2011] As can be seen, the major categories of impacts are expected changes in travel distance, travel time, and travel quality.

Table 22-17. Summary of Needs and Strategies of the Bay Area Regional Goods Movement System, Metropolitan Transportation Commission, San Francisco Bay Area		
Types of Needs Identified	**Description of Need**	**Key Potential Strategies to Address Need**
Safety		
Highway	• Highest crash locations on I-880, I-580, I-80 • Crash rates highest near high volume interchanges	• Interchange improvements, mainline, auxiliary lanes, truck interchange bypasses, and geometric improvements • ITS technology and traveler information, truck safety programs, improved signage for truck movements
Rail	• Potential hazards from increased movement of crude oil by rail to regional refineries and potential of crude by rail traversing region to Central Coast refineries	• Monitor and advocate in federal regulatory proceedings and state and federal legislation for increased rail tank car safety standards, hazardous materials transport operations safety procedures, and information to local first responders on hazardous materials transport through cities • Consider policies to support the recommendations of the California Interagency Working Group that studied the crude by rail issue • Coordinate regional efforts to work with railroads to ensure training and information exchange between railroads and first responders regarding hazardous spill emergency response
Local streets and roads	• Analysis from Alameda County suggests high levels of truck-involved crashes on local roads at freeway access locations. • Potential safety hazards on high speed rural commuter routes that also provide access to areas of goods movement activity (for example, wineries and agricultural producers)	• Signalize freeway access and ensure signal timing considers acceleration/deceleration characteristics of trucks • Turn lanes with adequate storage for trucks at freeway ramp access points
Infrastructure Condition		
Highway	• Selective highway pavement and bridge conditions needs along north U.S. 101, east SR 4	• Targeted bridge or pavement improvements • Identify/establish programs to maintain roadways in a state of good repair
Congestion, Mobility, and Travel-Time Delay		
Global Gateways	• Gate queues at Port of Oakland • Truck delays at grade crossings at Port of Oakland • Rail delays accessing Port of SF • Limited bulk terminal capacity for growing demand (all ports) • Congestion at OAK access roads	• FRATIS and ITS at Port of Oakland and access roads around OAK • Projects to reduce queuing and crossing delays at Port of Oakland • Expansion of bulk and cold storage terminal improvements (all ports) • Rail lead (spur) improvements at Ports of Oakland and SF • Longer-term expansion of intermodal terminal capacity

Table 22-17. (*Continued*)

Types of Needs Identified	Description of Need	Key Potential Strategies to Address Need
Congestion, Mobility, and Travel-Time Delay		
Highway	• Significant delay and reliability issues on many truck corridors (I-880, I-80, US 101, SR4, I-580, I-680) • Critical freight bottlenecks (I-80/I-680/SR12)	• Interchange improvements, mainline, auxiliary lanes, truck interchange bypasses, and geometric improvements. • Improved signage for truck movements • ITS based solutions coordinated with arterial systems. • Long-term development of alternate modes (for example, short-haul rail)
Rail	• Growth in international intermodal traffic and bulk movements (along with potential growth in crude oil by rail shipments) straining Martinez, Oakland, Coast, Niles and Stockton Subdivisions • Impacts on capacity on Martinez Subdivision created by switching of trains on the mainline. • Future needs to expand domestic intermodal terminal capacity in Oakland to reduce truck traffic from Central Valley intermodal terminals.	• Capacity improvements on Martinez Subdivision (sidings and increased track in selected locations) • Expanded capacity and coordinated strategy for Niles and Oakland Subdivisions to make better use as southern route to Port of Oakland • Future expansion of intermodal terminals at Port of Oakland (OHIT Phase 2 expansion). • Industrial rail spur program to improve industrial access (also promotes economic development in locations such as Contra Costa Northern Waterfront, North Bay agriculture production areas, industrial areas near Ports of San Francisco and Redwood City).
Local Streets and Roads	• Poor LOS on certain major and minor arterial truck routes	• Selective widening projects • SMART corridors including arterials • Signal timing and prioritization projects on truck routes
Passenger System		
Global Gateways	• Potential truck conflicts with autos on Cesar Chavez accessing Port of SF • Potential conflicts with bike and pedestrian trails on truck routes on access to marine terminals at Port of Oakland and Port of Richmond • At-grade rail crossing delays for autos near Port of Richmond	• Improved access planning for autos in South Waterfront area of Port of SF • Physical separations for bike and pedestrian routes at Port of Oakland • At-grade crossing safety and grade separation program
Highway	• Truck traffic conflicts with passenger traffic	• Projects and programs to allow selective use of passenger only facilities.
Rail	• Expansion of Caltrain, ACE, and Capitol Corridor services will strain capacity on several lines • Expansion of SMART commuter service limits growth of NWP shortline services.	• Expanded track and sidings to allow for freight and passenger separation wherever possible. • Potential ROW acquisition or trenching through Emeryville on Martinez Subdivision • Coordinated strategy to separate freight and passenger services on Oakland, Niles, and Coast Subdivisions • Revisit operating window restrictions for freight on Caltrain Corridor in light of new FRA rulings

(*continued*)

Table 22-17. (*Continued*)		
Types of Needs Identified	**Description of Need**	**Key Potential Strategies to Address Need**
Passenger System		
Local Streets and Roads	• Arterial truck routes are often on high frequency bus routes • Bike and pedestrian routes on certain truck routes	• Time of day managements to reduce conflicts • Bike and pedestrian physical separations where feasible • Multiple use delivery pullouts
Multimodal Connectivity		
Global Gateways	• Grade crossing improvements • North rail access to intermodal terminals • Local circulation improvements	• Port of Oakland 7th St Grade separation project • Local circulation improvements at Port of Oakland and OAK • Port of Oakland rail access improvements
Highway	• Limited E-W connections to Central Valley and interior U.S.	• Projects to improve key corridors that provide alternatives to I-580, such as SR 12/SR37, SR4, and SR 152
Local Streets and Roads	• Locations with poor connectivity between freeways and major freight hubs	• Advocate for state and federal programs to improve first/last-mile connectors • Provide guidance for truck route planning • New truck route designations with time of day regulation (where routes must pass through residential areas) • Selective upgrading of routes for trucks where better connectivity between major local truck routes is needed
Rail	• Industrial rail access needs for industrial shippers on Northern Contra Costa Waterfront, North Bay, San Mateo County	• Industrial Rail Access Program, Short haul rail project
Air Quality, Environment, and Community Impacts (Equity)		
• PM2.5 emissions from freight have been declining but reductions may plateau in the 2020–2025 timeframe		• Incentives for engine retrofits to low and zero emission technology • Zero emission vehicle technology demonstrations for trucks. • Low emission rail terminal operations including incentives for conversion to low emission switcher locomotives
• Localized health effects of diesel emissions and rail noise/emissions in major truck and rail corridors (for example, I-880, I-80, SR-4, US101)		• Programs to target low/zero emission strategies (see above) to corridors with Communities of Concern • Improvements to rail at-grade crossings (including selective separations), quiet zones. • Coordination of truck route planning in industrial areas with restrictions and enforcement in adjacent residential areas.
• Vulnerability to sea level rise on major truck, rail, airport, and seaport infrastructure along Bay and other waterfront areas.		• Adaptation strategies and improvements to diking systems to reduce potential flooding

Table 22-17. (*Continued*)		
Types of Needs Identified	**Description of Need**	**Key Potential Strategies to Address Need**
Land Use		
• Modal and land-use conflicts and coordination with passenger systems (for example, residential and commercial development in converting industrial corridors can encroach on active rail and truck corridors) • Lack of truck parking and truck services in industrial corridors		• Land use guidance program • Incentives to preserve buffers around freight corridors incorporated in project plans • Identify sites for overnight and short term truck parking and work with private sector providers to implement truck services in development of these sites • Complete Streets guidance and incorporation in One Bay Area Grants for programs such as delivery windows, curb pullouts) • Night delivery pilot programs
Jobs Programs		
• Near-term truck driver shortages • Near-term lack of logistics professionals • Continued lack of job opportunities in communities close to freight hubs		• Training and workforce development programs coordinated through community colleges • Continued local hiring goals for communities close to freight hubs

Source: Cambridge Systematics, 2015

The types of costs and benefits associated with different freight strategies can vary widely. National Cooperative Freight Research Program (NCFRP) Report 12*, Framework and Tools for Estimating Benefits of Specific Freight Network Investments*, describes the types of costs and benefits typically considered in a freight study. [Cambridge Systematics et al., 2011] They include:

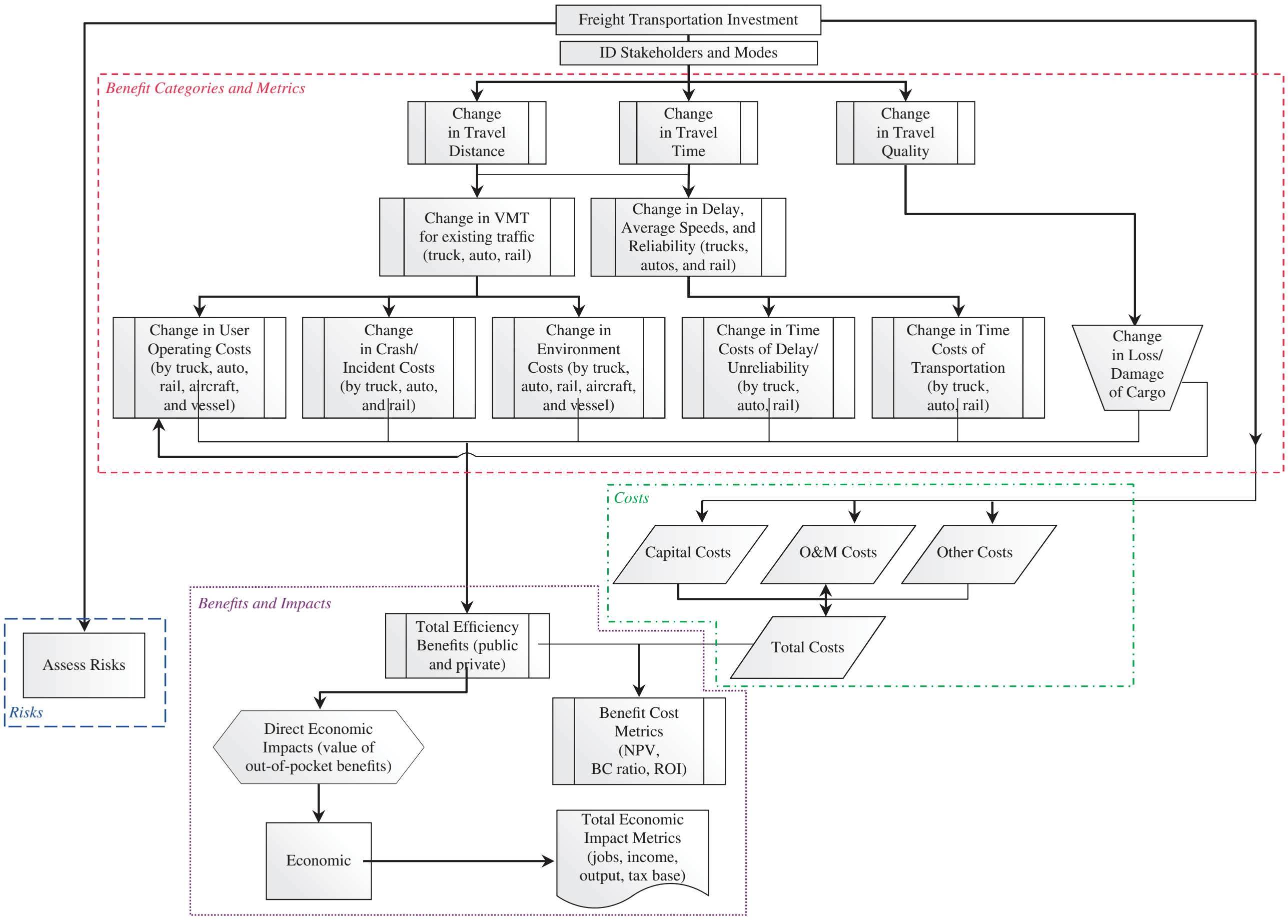
Cost factors:

- Facility capital costs, which tend to be dictated by site location and design, as well as the partners involved in the planning process.
- Facility maintenance costs, or the ongoing costs of maintaining a facility to ensure safe operations and upkeep.
- Operating costs, such as labor costs, fuel costs, equipment costs, and the time lost to congestion or to the breakdown of efficient supply chains.

Benefit and other impact factors:

- Capacity, which includes alleviating the impact of highway and rail system bottlenecks, as well as the throughput attainable on any transportation infrastructure or facility access point.
- Productivity, or the ability to operate a supply chain from start to finish with maximum efficiency.
- Loss and damage, or maximizing the safety and security of freight operations and movements to minimize loss to the shipper, carrier, or community.
- Scheduling/reliability, or the ability to have predictable and timely delivery of goods, allows for streamlined inventories, less disruption in the manufacturing or supply process, and a more efficient supply chain.
- Tax revenue, such as that received by new industrial land development, distribution center, or other freight-intensive land uses.
- Wider economic development, such as increased jobs resulting from a distribution center, transload, or intermodal facility, as well as multiplier effects to regional economies.

Figure 22-10. Evaluation Framework for Freight Planning



Source: Cambridge Systematics et al., 2011

- Safety, or minimizing traffic impacts of freight land uses on neighboring communities, and the safe operation of freight vehicles and facilities.
- Environmental quality, such as mitigation of air or water quality impacts, reduction of truck vehicle miles traveled (VMT), and noise or vibration reduction.

Table 22-18 shows the type of information that can be collected to support the assessment of different types of freight improvement strategies. Many of these evaluation performance measures are estimated by the models described in the previous section.

Another frequently used approach is a subjective assessment of different strategies. In the Atlanta freight planning study, categories of projects were evaluated using criteria based on identified needs, including: [ARC, 2008]

1) *Truck diversion*—How much does the project or strategy shift freight from truck to rail and remove through truck traffic from the region's highway system?
2) *Highway congestion/delay*—How much will the project or strategy reduce highway congestion and delay for both passenger and freight movement?
3) *Rail congestion/delay*—How much will the project or strategy reduce rail congestion and delay for freight movement?
4) *Travel time/reliability*—How much will the project or strategy improve travel time and reliability for both passenger and freight movement?

Table 22-18. Performance Information for Evaluation	
Analytical Needs	**Performance Measures**
Bottlenecks	• Frequency of delays at intermodal facilities.
Commodity flow	• Average cost per trip. • Average shipment time, cost, variability in arrival time for freight shipments (local versus long distance, by commodity, by mode). • Business volume by commodity group.
Modal diversion	• Cost per ton of freight shipped. Cost per ton-mile by mode. • *Delay per ton-mile traveled (by mode).*
Needs analysis	• *Administrative, engineering, and construction cost/ton-mile (owner cost).* • Average crash cost per trip. • *Dollar losses due to freight delays.* • Economic indicator for goods movement. • *Freight transport system supply (route miles, capacity miles, number of carriers, number of ports/terminals) per "demand unit" (dollar of manufacturing output, ton-mile of commodity movement, capita, employee, etc.).* • Fuel consumption per ton-mile traveled.
Operational needs	• Interference of movement at grade crossings—delay time and speed.
Pavement and safety	• *Administrative, engineering, and construction cost/ton-mile (owner cost).* • Average crash cost per trip. • Exposure (annual average daily traffic and daily trains) factor for rail crossings.
Performance measurement	• Average fuel consumption per trip for selected trips (or shipments). • Mobility index (ton-miles of travel/vehicle-miles of travel times average speed).
Project development	• *Average circuity for truck trips of selected O-D pattern.* • Frequency of delays at intermodal facility.
Project prioritization	• Dollar losses due to freight delays.
Terminal access	• Average travel time from facility to destination (by mode). • *Average travel time from facility to major highway, rail, or other network.*
Truck flows	• *Average circuity for truck trips of selected O-D pattern.* • Average speed (passenger and commercial vehicles) on representative highway segments. • Interference of movement at grade crossings—delay time and speed.

Note: Italics indicate more commonly used performance measures

Source: Cambridge Systematics, Inc. et al., 2008

5) *Freight trip times*—How much will the project or strategy improve trip time for freight movement?

6) *Truck traffic peak/off-peak shares*—How much will the project or strategy shift the share of truck traffic from peak to off-peak times?

7) *Freight vehicle miles of travel*—How much will the project or strategy reduce regional truck vehicle miles of travel?

8) *Freight vehicle hours of travel*—How much will the project or strategy reduce regional truck vehicle hours of travel?

9) *Safety*—How much does the project or strategy reduce truck crashes and improve pedestrian safety along corridors?

10) *Truck emissions*—How much will the project or strategy reduce truck emissions?

11) *Community impacts*—How much will the project or strategy reduce community impacts associated with goods movement along transport corridors and freight-intensive areas, including those in dense areas?

12) *Land-use impacts—transport corridors*—How much will the project or strategy reduce land-use impacts associated with goods movement along transport corridors?

13) *Land use impacts—intermodal/warehouse/distribution facilities*—How much will the project or strategy reduce land use impacts associated with goods movement between intermodal yards, warehouse, and distribution facilities?

14) *Regional economic output/competitiveness*—How much will the project or strategy improve the economic output and competitiveness of the region?

15) *Jobs/economic opportunity*—How much will the project or strategy increase the number of jobs and economic opportunity associated with goods movement in the region, including those immediately in proximity to freight businesses?

16) *Cost*—What is the overall cost of the project or strategy?

The resulting criteria were vetted with the planning advisory committee.

With respect to prioritizing projects, a common method is to assign points to different freight-related criteria. An example of this approach is found in Washington State where the Freight Mobility Strategic Investment Board (FMSIB) has established the following major categories and weights for prospective projects: [Washington FMSIB, 2014]

Freight Mobility for the Project Area-35 Points Maximum

- Reduce truck, train, or rail car travel time/delays, 0–25 points
- Increase capacity for peak-hour truck or train movement, 0–10 points

Freight Mobility for the Region, State, & Nation-35 Points Maximum

- Importance to the regional freight system & regional economy, 0–10 points
- Importance to state freight system & state economy, 0–10 points
- Direct access to ports or international border, 0–10 points
- Provide a corridor/system solution, 0–5 points

General Mobility-25 Points Maximum

- Reduce vehicular traffic travel time/delay, 0–10 points
- Reduce queuing & backups, 0–7 points
- Reduce delay from use of alternative railroad crossing, 0–5 points
- Address urban principal arterials; urban principal arterial 3 points; otherwise 0 points

Safety-20 Points Maximum

- Reduce railroad crossing accidents, 0–5 points
- Reduce non-railroad crossing accident, 0–5 points
- Provide emergency vehicle access; essential access route, 5 points
- Otherwise, 0 points

Close additional related railroad crossings

- 2 or more additional crossing closures, 5 points
- 1 additional crossing closure, 3 points

Another example is shown in Table 22-19 where criteria were established for prioritizing freight projects, and points were awarded based on the importance of the project characteristic to desired outcomes.

One can also assign weights to the different criteria and then subjectively determine how many "points" each project achieves in the priority category by multiplying the weight times the score (usually from 1 to 3 or 5), and then summing across all criteria. An example of how one can determine weights for the different criteria comes from the Florida DOT where numerous freight stakeholders were asked to rate the importance of criteria on a scale of 1 to 5, where 5 was of highest importance. Table 22-20 shows the results of this weighting.

See chapter 7 for a more detailed discussion of approaches to prioritizing projects.

An increasingly important area for consideration is the relationship between community development and freight land uses. This is particularly challenging when freight facilities and terminals are located in dense urban neighborhoods where truck traffic and noise/vibration impacts could create community concerns. There are also concerns about urban development infringing upon land uses that had traditionally been used for freight purposes. For example, a freight study in Minneapolis-St. Paul found that pressures to redevelop industrial land along rivers and railroads in the metro region threatened the viability of water and rail-dependent industries and freight terminals. More generally the study found that increased non-industrial land development and encroachment upon industrial land uses in urbanized areas may affect the efficiency of operating freight terminals and may lead to conflicts between industry with residential communities, commercial districts, and parklands. [Metropolitan Council, 2013]

Another planning-oriented opportunity applicable to locations outside a central business district involves the development of transportation parks or freight villages. In most urban areas, freight terminals are located in many different locations, some causing conflicts with surrounding development. If the terminals were concentrated at a few

Table 22-19. Prioritization Criteria for Choosing Among Freight Projects, Miami-Dade County, Florida

Category	Item	Points
Facility Type	Local collector	1
	County road	2
	State highway	3
Adjacent Freight Center Density	Low	0
	Medium	1
	High	3
Truck Average Daily Traffic	<1,000	1
	>1,000	2
	>2,500	3
Project Cost	>$20 million	1
	> $5 million	2
	< $5 million	3
Attraction to General Traffic	Significant	1
	Moderate	2
	Insignificant	3
Type of Project	Capacity	3
	Operations	2
	Intelligent Trans. Systems	1

Source: Parsons Brinckerhoff et al., 2014

Table 22-20. Weights Assigned to Evaluation Criteria for Freight Investment Projects, Florida	
Prioritization Criteria	**Average Importance Rating**
Targeted Industry	4.0
Freight Hub Access	4.5
Intermodal Logistics Center (ILC) Exports	3.9
Unique Niche	4.1
Identified Market Need	4.2
Florida Freight Network	4.1
Freight Bottleneck	4.4
Dedicated Freight Facility	3.6
Information Technology Systems (ITS)	3.7
Truck Parking and Truck Lanes	3.4
Rest Stop Safety and Security	3.3
Marine Highways	3.4
Empty Backhaul	3.8
Alternative Fuels Access	3.4
Supply Chain Costs	3.9
Private Funding Amount	4.1
Local Freight Plans	4.1
Statewide Modal Plans	3.9
Emerging Freight Facilities	3.7
Benefits	4.2
Intermodal	4.1
Cost	4.2
Non-FDOT Funding Status	4.1
Timing and Readiness	4.2
TIP/STIP	3.9
Dependency	4.1

Source: Florida DOT, 2013

locations along with the businesses that serve them, special strategies could be used to create buffer areas and/or provide special access facilities. From the private firms' perspective, such concentration allows a more efficient production process. This is the logic surrounding freight villages or transportation parks. Freight villages represent a similar concept and include more freight-related activities. Transportation parks would not only help the freight community but also would reduce the negative impact of freight terminals on residential and other sensitive land uses. The implementation of this concept needs proactive land-use planning.

A community's land-use planning process should be sensitive to these issues, and planners should ask the following questions during this process:

- Does the land-use planning process address truck terminals and their current and future locations?
- Does it address warehouses and their current and future locations?
- How are the expansion and/or relocation needs of major terminals—airports, seaports, and rail-truck intermodal terminals—addressed?
- Is access to freight facilities being examined?

The answers to these and other similar questions will reveal the adequacy or deficiency of the existing land use-planning process for freight planning. The following section discusses other aspects of freight terminals.

V. FREIGHT TERMINALS

This section briefly describes some of the key aspects of freight terminals as they affect transportation planning. A much more detailed discussion of freight terminals can be found in the 3rd edition of this handbook. [Goodman and Lutin, 2009] See also chapter 12 on transit planning, which includes a discussion of terminal concepts relevant to freight terminals, for example, security issues.

A. Truck Terminals

Terminals of all sizes and shapes form key elements of the truck freight transportation system. While their location and functions are closely related to the public street and highway system, truck terminals are largely, if not exclusively, a private-sector function. They are usually owned and operated by the trucking company (carrier) providing the service.

The terminal's function is defined by workload, volumes by type and source of traffic, service standards, workload availabilities and closeout times for activities, and information needed to plan the terminal. Specific location requirements are defined based on a system operations analysis. The objective is to relate, as specifically as possible, the market characteristics and conditions for the locations where a facility is needed to the overall plan. Finally, an economic evaluation of the facility and its options is prepared, leading to a statement of the detailed requirements for facility design. The steps include a marketing analysis to obtain information concerning the area, such as the trends in the area, growth or decline by industry, and the locations where industry and commerce are expanding.

The first step in developing a terminal site plan is to establish the site specifications, including the general size and configuration of the plot. Next, the search area is defined, alternative sites are evaluated, and the best selected. When the specific plot is known, a plan is prepared making the best use of space and providing for efficient flow (Note: the following information is provided simply to educate the reader on those issues considered when siting a terminal; interested readers should refer to the references in this section for more detail).

1) *Prepare site specifications*. The objective is to determine the size of the plot and its minimal dimensions. The steps include:
   a. Activities and buildings. At this point the dimensions of the dock, its length, and its width are known. The plan should also include the requirements for office, shop, fuel lanes, and any fixed facilities.
   b. Parking areas. The major requirement is for parking of trailers. The facility must be able to accommodate the peak requirements, based on the operations plan. Parking of employee and visitor autos should also be planned for. If line driver parking is required, this must also be included. As a general planning factor, 80 percent of the employees will require a parking space.
   c. Plot size. Depending upon growth projections, the land area required is generally a 25 to 35 multiple of the platform and office space. For a small terminal, such as 12 to 16 doors with a 40-ft (12.2 m) width, the minimal width of the plot will be 280 ft (85.3m). This dimension provides for a 120-ft (36.6-m) apron area for spotting trailers on both sides of the dock. The depth, of course, will depend on the total area required for parking and expansion.
2) *Define search area*. The search area should be defined within about a 5-mile radius. This should be an area well located to support present and future sources of business.
3) *Select site*. The site selection should include the following criteria:
   a. Access. Try to obtain a site within 2 miles (3.2 km) of a state freeway or interstate highway, or with convenient access to another main traffic artery.
   b. Site preparation cost. Obtain estimates for site improvement and determine the length of time required to prepare the land for construction.
   c. Area zoning. Check the zoning requirements and site plan review requirements for proposal.
4) *Prepare a block site plan*. The first step in developing an efficient layout for the plot is to determine a general arrangement of buildings, parking spaces, and activity for the specific plot chosen. Next, prepare a flow chart of what happens in the terminal, including the sequence of steps drivers take from the time they enter the

gate and park their equipment. Allow adequate space in the total employee parking area for the expanded design year, even though all this space may not be paved to begin with.

5) *Design a detailed plot plan*. The plan should show the details of the facility locations, paving, and the construction required.

The preceding material has dealt with the technical processes for developing efficient and well-functioning truck terminal sites. When integrating these technical factors with practice, community and environmental considerations often become important issues. The location of truck terminals can be a major issue and source of controversy. Truck terminals are often not considered desirable neighbors of residential developments. They generate considerable truck traffic on roads leading to the sites, resulting in various types of actual and perceived adverse effects in the vicinity, including traffic congestion, safety hazards, pavement deterioration, visual and psychological impacts, noise, and air pollution. Further, they tend to attract other commercial activities and truck-oriented operations, such as truck repair shops and supply stores. In addition, truck terminals may have other types of physical and psychological effects on adjacent residential areas. For example, the high mast lighting used in terminals for work and security at night can be an irritant for nearby residences, and the noise of trucks moving or idling inside terminals is also undesirable, especially at night.

Suitable locations for truck terminals can be identified through land-use planning studies and engineering studies. Industrial parks are suitable sites for truck terminals. A transportation park may be developed to accommodate a cluster of terminals and, if it is located near a major truck route, then unnecessary travel of large trucks on internal local roads can be eliminated. A transportation park would provide an opportunity and justification for special design features and treatments such as exclusive access roads and buffer strips around the sites.

B. Freight Rail Terminals

Freight rail terminals in the United States have undergone major changes since World War II, particularly since the 1980 Staggers Act that deregulated the railroad industry. The terminal function has changed and will continue to change in response to the increased integration of ocean shipping, rail, truck, and aviation modes. Prior to deregulation, rail freight movement had transitioned from break-bulk techniques to more use of containerization, that is, trailer-on-flat-car (TOFC) and container-on-flat-car (COFC). Prior to this early period of containerization, freight originally came to conventional rail yards from ships, by local truck, or via individual rail cars at shippers' sidings. This changed when TOFC and COFC, more popularly referred to as piggyback, brought pre-packaged freight in a trailer or a container for loading as a unit (rather than break-bulk loading) onto a flat car.

Use of conventional break-bulk, TOFC, and COFC continues. The following material describes the facilities and systems for these rail freight modes. Following this material, present and future conditions are discussed, such as unit trains, yard consolidations (hubs), and double-stack trains.

C. TOFC and COFC

Piggyback is the popular term used to describe a form of service in which one carrier transports a unit of another carrier. For example, highway motor freight trailers are loaded at the shipper's door or at a warehouse, brought by tractor to a railroad loading ramp or yard, placed on flatcars, and hauled in trains to a destination terminal. The trailers are then unloaded and terminal delivery is made to the consignee's door by truck. TOFC line-haul service is potentially faster than highway haul, while the terminal times are practically equivalent. Much of the expense and nuisance of highway haul—traffic congestion, personnel problems, traffic violations, accident hazards, and restrictive limitations on weight and size—are avoided or markedly reduced. Five systems of TOFC (with variations) are generally recognized:

- *Plan I*: Vehicles of common highway carriers are hauled by rail. The shipper deals with the highway carriers, which, in turn, deal with the railroad.
- *Plan II*: Only the railroad's highway trailers are carried. The public deals directly with the railroad or its highway subsidiary.
- *Plan III*: Anyone's trailer, including those of the individual or private trucker, is carried by rail.

- *Plan IV*: An intermediate or forwarding agency or broker secures the freight, loads it into its trailers and onto its own flatcars and turns it over to the railroad to haul. The third party may be a company owned by one or more railroads, but the shipper deals with the third party.
- *Plan V*: Plan I plus joint rail-highway rates with the highway carrier. The shipper deals with either the trucker or the railroad.

Railroad yards serve varied purposes, including storage, holding, consignment, public delivery, and, on a broader scale, supporting nearby industrial activity. The principal type of yard and its function is the classification yard, which also concentrates enough cars to fill out a train. Classification includes the receiving and breakup of trains and the sorting and classifying of the cars into new trains for road haul, transfer to other yards or railroads, or local delivery. A large classification yard usually contains three yard units: the receiving yard into which trains are moved from the main line preparatory to sorting; the classification yard proper, where the sorting or classifying into blocks of common destinations takes place; and the departure yard, in which the sorted groups or blocks are made into trains and held pending main-line movement.

D. Intermodal Yards

As noted earlier, one of the key rail freight strategies developed as part of the containerization movement was the land bridge concept whereby traffic between the Far East and the east coast of the United States is transferred from ship to rail to move COFC across the United States to East Coast cities rather than through the Panama Canal. Transit time for certain ships between Japan and the Atlantic seaboard via the canal is 32 days. By transshipping containers to rail cars at western ports, the transit time to the eastern seaboard can be reduced to 16 days. There are no technological problems with this, but there is the matter of returning empty containers and other administrative and regulatory concerns. With deregulation and increasing intermodal business entities and arrangements, ways have been found to overcome these problems. In fact, empty containers are increasingly being filled in back hauls. This has led to increasing use of, and focus on, domestic containerization, particularly for high-density corridors over 500 miles long.

Double-stacking container rail cars is another important intermodal development. In this case, two containers are carried per rail car. The increasing use of double-stack, with its increased per-train capacity, has had definite impacts on right-of-way geometric planning, on the planning and design of the associated intermodal terminals, and on the performance of access roads at container yards. Large railroads are achieving important savings by consolidating many intermodal ramps (yards) into a few strategically located, highly productive intermodal hubs.

E. Freight Multimodal Terminals

Multimodal freight terminal movements usually involve the following combinations of different modes:

- Truck and rail (for example, piggyback, TOFC, COFC, or Road Railer).
- Ship/barge and truck or rail (ports and containers).
- Pipeline/ship/barge and truck (petroleum distribution).
- Truck and air (air cargo at airports).

Multimodal terminals by nature are land-intensive, and they generate movements of large and heavy trucks. Access roads leading to these facilities and storage space for trucks inside the terminals are important elements of the overall operation. The design of multimodal terminals, in many cases, has failed to provide for the needs of all the modes involved. For example, seaports and rail terminals need to consider adequate access and storage facilities for trucks.

A seaport or river port is a good example of a multimodal terminal. New ports or port extensions become necessary when entirely new traffic has to be handled or when freight volumes are predicted to increase. In principle, new port capacity is justified when the revenues generated by the new capacity and associated economic benefits outweigh the costs. Factors that are not quantifiable in economic terms, such as overall strategic planning for regional or demographic development, often play an important role in port site selection. With these general guidelines in mind, the following elements should be considered for multimodal terminals.

Linkage to the existing and planned highway network. Connectivity to the highway network in the port area is a key consideration. Ideally, port facilities should be located adjacent to a major roadway with adequate capacity for high truck volumes. The Newark/ Elizabeth marine terminal complex in New Jersey, for example, is directly served by I-78 and I-95 and is close to I-278 and I-280.

Linkages to the existing and planned rail network. The area's railroad system should be analyzed to determine the feasibility of providing rail connections between the port facilities and rail lines serving the area. Direct, grade-separated freight rail access is provided, for example, at the Port of Long Beach in California by the multi-track Alameda Corridor project.

Linkages to pipelines. If liquid commodities are to be shipped through the port, the pipeline network should be evaluated to determine if connections to new port facilities are feasible.

For *ocean ports, linkages using waterborne services (barges or short-distance coastal vessels) to smaller ports on rivers or sounds*. Such services operate successfully in Europe.

For *inland waterways, commodities transported via the waterway*. Waterway transportation consists primarily of relatively slow movement of commodities that have low unit value and high unit weight, moved in massive quantities at relatively low cost.

Number and type of industries located near the port. Typically, an area establishes or upgrades a port to improve its economic development by taking advantage of the accessibility to the waterway transportation system.

Container ports are another good example of multimodal terminals. Container terminals are, in principle, rapid transfer facilities at the interface between land and sea transport. Inbound containers continue their inland journey to the consignees soon after arriving in the terminal. Outbound cargo often arrives at the terminal not long before the ship sails. Although the most cost-efficient strategy would be for outbound containers to arrive just before ship departure and for inbound containers to leave the terminal almost immediately after being off-loaded, this often does not happen. Thus, both full and empty containers remain in storage much longer than intended, and the throughput capacity of terminals, which is inversely proportional to the average storage time for containers (commonly called dwell time), is greatly reduced. Figure 22-11 shows a typical layout of a container terminal that uses straddle carriers as yard equipment.

The 20-ft equivalent unit (TEU) container throughput for a given time period is often expressed in the following equation:

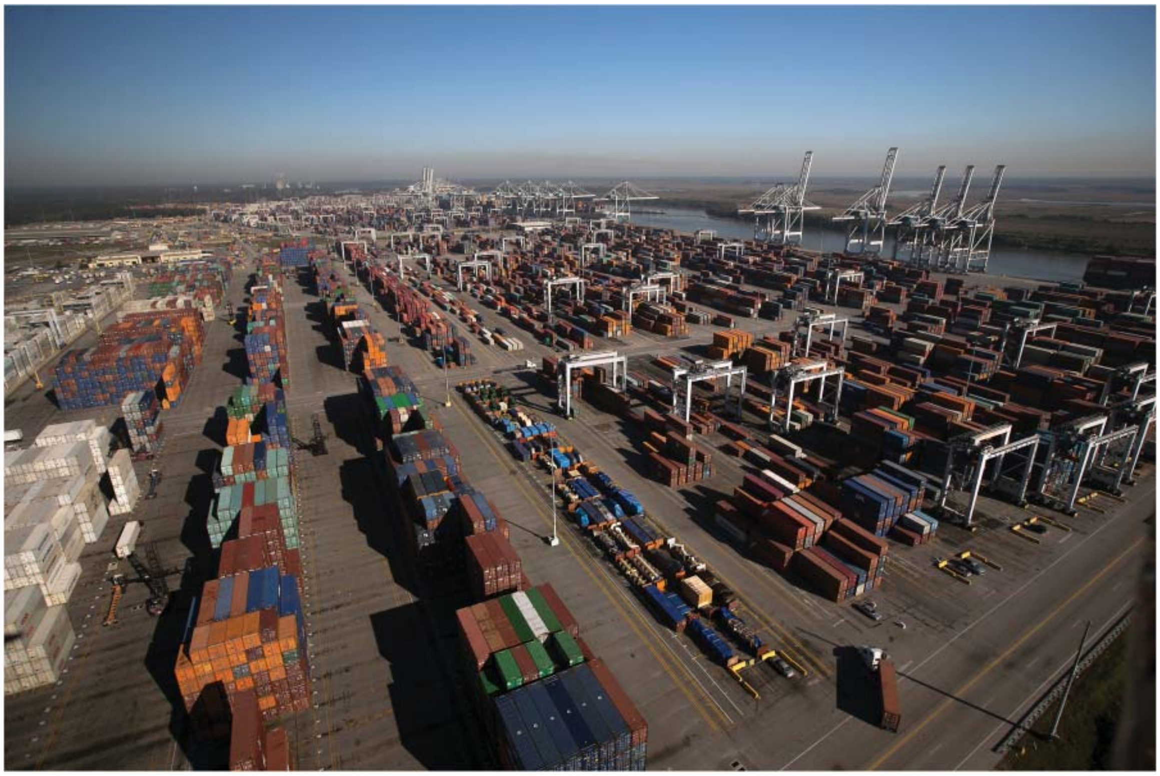
$$C = \frac{L \times H \times W \times K}{D \times F}$$

where:

C = TEU throughput during the period of time
L = Number of TEU ground slots
H = Average stacking height in number of containers
W = Average utilization factor for ground slots
K = Number of days of the period of time
D = Average TEU storage time in days
F = Peaking factor for a combination of higher-than-average TEU throughput, less-than-average stacking height, and more than average storage time

Responding to competitive pressures, ocean port agencies throughout the United States have developed new ways to retain and expand cargo volumes moving through their ports. In the late 1980s, the concept of an inland intercept for an ocean port (that is, a "waterless" inland port) was analyzed and implemented in several locations in the southeast. The Virginia Inland Port (VIP), opened in May 1989, linked to the Port of Hampton Roads. This followed two earlier and somewhat similar inland port projects in the Carolinas, tied to the ports of Wilmington, North Carolina, and Charleston, South Carolina. The VIP facility, located more than 200 miles (322 km) inland at Front Royal, Virginia, provides a rail-truck intermodal terminal linked to the Virginia Port Authority's (VPA's) Hampton Roads terminals by a dedicated Norfolk Southern rail haul. The inland port is positioned to intercept container traffic that is largely

Figure 22-11. Container Terminal Layout, Port of Savannah, Georgia



Source: Courtesy of the Port of Savannah

truck-hauled to rival mid-Atlantic ports. For VPA, the new inland port was intended to produce a significant increase in the volume of import-export container traffic moving through the Authority's Hampton Roads terminals.

VI. SUMMARY

The efficient movement of freight and goods is a fundamental prerequisite for a strong and vibrant economy. Increasingly, this movement has taken a global perspective as the producers and consumers of goods are spread out across the globe. Since the 1980s with the adoption of free-trade agreements and the beginning of steady economic growth, the volume of freight and goods moving in the U.S. transportation system has grown dramatically. Although much of this freight is handled by private firms (railroads, trucking firms, barge companies and air cargo airlines), public agencies are being challenged to support this increase in freight traffic through investments and policy actions that in turn affect transportation service providers across all modes. To help meet the needs of the global trade environment, government agencies responsible for transportation planning must foster integrated modal systems by supplying infrastructure that can support responsive, reliable freight transportation.

Given increasing economic growth and the role international trade will play in this growth, it is likely that freight planning will become even more important in future years. Whereas for years, the movement of freight and the challenges facing freight carriers were considered the purview of the private sector, transportation officials began to realize in the 1990s that the problems facing freight movement can have a significant influence on a state or metropolitan economy and can lead to community impacts that often fall to public officials to solve.

Freight transportation planning examines a range of strategies that can alleviate the problems facing freight movement. These strategies include the more traditional infrastructure projects (for example, bottleneck removal) to the application of ITS strategies to improve the safety and operational productivity of the freight network. Because much of freight movement occurs on the road network, the interplay between the strategies aimed at freight movement and those targeted at passenger movement becomes an important consideration in the planning process. For example, many metropolitan areas have implemented or are considering implementing commuter-rail service, often using freight-rail tracks. This type of service needs to be examined both from the public policy perspective of providing transit options to the region's commuters as well as the potential impacts on rail movements. In port cities, this interplay between public policy and freight productivity often occurs when examining freight-related community impacts (such as noise, air emissions, and vibration). The planning process can be the forum where the trade-offs associated with such issues can be discussed and compromises negotiated.

As noted in this chapter, freight planning is similar to other types of transportation planning discussed in this handbook. The process begins with a vision, goals and objectives; uses data and analysis tools to understand the likely implications of different strategies; and evaluates and prioritizes the strategies so as to develop the most cost effective implementation program for the state or region. However, there are also differences. In particular, some of the most important challenges related to freight transportation planning include:

- *Participation of freight stakeholders is important to the planning process, but often difficult to obtain*. The public planning process tends to be much more drawn out and open to public discourse than most private company officials are used to. This open and often lengthy process has caused many freight officials to hesitate in becoming involved.
- *Data are always an important foundation for good transportation planning*. Freight data, in particular, have great value in understanding current and expected freight patterns. However, much of the data of greatest use are proprietary to private firms, and not surprisingly, they are not willing to make these data available to the general public. Accordingly, many freight studies rely on national freight databases that are modified for the specific study being undertaken. These national databases often do not have site-specific information, such as origin and destination zones, in a study area. It is often the case that freight data must be collected as part of the planning study.
- *It is important in freight planning that freight networks or systems be clearly identified*. This means that the most important truck routes, rail lines, air cargo airports, water terminals and warehouse/distribution centers should be a basic point of reference for the planning study. In some cases, such networks have been in use for some time, but it is important they be examined to see if economic changes or other growth-related phenomena have affected the usefulness of the current designation.
- *Public funding for projects that will primarily benefit one specific firm or industry sector is not often available*. When public funding is used to build a project or operate a service, the general public should have access to it. Unless a clear public purpose can be identified, it is difficult to use public funds to improve warehouse or distribution centers, on-dock facilities, or to purchase freight-loading equipment for a private company. In recent years, one means of avoiding such a problem has been the use of public/private partnerships where both public and private agencies provide specific contributions to a project and where the public and private benefits associated with each contribution are made clear.
- *Models are an important part of a transportation analysis*. Given the often large markets served by the freight industry, freight modeling efforts use much larger study areas than studies for passenger transportation. In some cases, this could include examining global trade patterns and border crossings. If a state or metropolitan area is strategically important to global supply chains, the transportation planner should use an analysis approach that assesses freight flows much beyond the immediate study boundary.

As more transportation planners become exposed to the importance of freight movement, it seems likely that new and innovative approaches to data collection, modeling and evaluation will be developed. It is important that transportation planners monitor the developments in these areas so that freight planning in their study area will include the latest approaches to integrating freight into the transportation planning process.

Useful references for freight planning include:

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In addition, for one of the more advanced freight plans in the world, see City of London's Freight Transport Plan, https://www.tfl.gov.uk/cdn/static/cms/documents/London-Freight-Plan.pdf.

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Chapter 23

Planning It Safe—Safety Considerations in the Transportation Planning Process[1]

I. INTRODUCTION

Physical injury is the leading cause of death in the United States for people ranging in age from about 6 months to 45 years. Because it so disproportionately strikes the young, it is also the leading cause of lost years of productive life. Motor vehicle–related injury is overwhelmingly the largest component of injury losses. Reducing the number of motor vehicle–related crashes should thus be a major component of efforts to reduce the death rate in the United States. Although the United States and other industrialized nations have made substantial progress over the past 30 years, the United States still experiences more than 33,000 road-related deaths annually and nearly 2.5 million injuries. [National Highway Traffic Safety Administration (NHTSA), 2014]

Why is safety an issue that should be of concern to transportation planners? Perhaps the best answer to this question is provided in the preface of the transportation safety plan produced by the Houston-Galveston Area Council (H-GAC), the metropolitan planning organization (MPO) for the Houston area. According to the Houston experience, the importance of safety to transportation planning is:

- Similar to other issues that can be linked to the construction and operation of transportation facilities (for example, air quality, economic development and such), travel safety is clearly an issue that can be affected by how the transportation system is designed, constructed, operated, and maintained. Given that transportation planning leads to changes in this transportation system, safety should be thoroughly integrated into an agency's planning process.
- The costs associated with motor vehicle–related fatalities and vehicle crashes are staggering . . . .
- Motor vehicle fatalities and crashes are a leading public health problem in the United States and in the world . . . .
- The impact of trucking on travel safety is increasing. This is coupled with projected huge increases in truck activity over the next decade due to increased trade and, in Houston's case, associated port activity and dispersion of warehouse activity farther from the port.
- Bicycle and pedestrian users experience a disproportionate number of deaths. These problems, along with transit safety issues, have significant effects on lower-income populations.
- A comprehensive safety program includes a range of different strategies and actions involving many different agencies and groups. Thus, there is a need for collaboration and coordination among many to achieve success . . . .
- Statewide and metropolitan transportation planning in the United States reflects federal mandates. In both cases, safety has been identified by Congress as a national priority issue that must be considered during the transportation planning process . . . .
- Crashes represent a major source of delay (referred to as nonrecurring congestion) for states and metropolitan areas struggling with congestion on freeways and other major roads. The time it takes police and/or emergency

[1]The original chapter in Volume 3 of this handbook was written by Dr. Susan Herbel, principal, Cambridge Systematics, Inc. Changes made to this updated chapter are solely the responsibility of the editor.

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services to reach an incident, secure the safety of crash victims and other responders, attend to the injured, clear the vehicles from the travel lanes, collect relevant crash-related data, and remove disabled vehicles from the roadway can lead to serious traffic delays on critically important roads. [Levine, 2006]

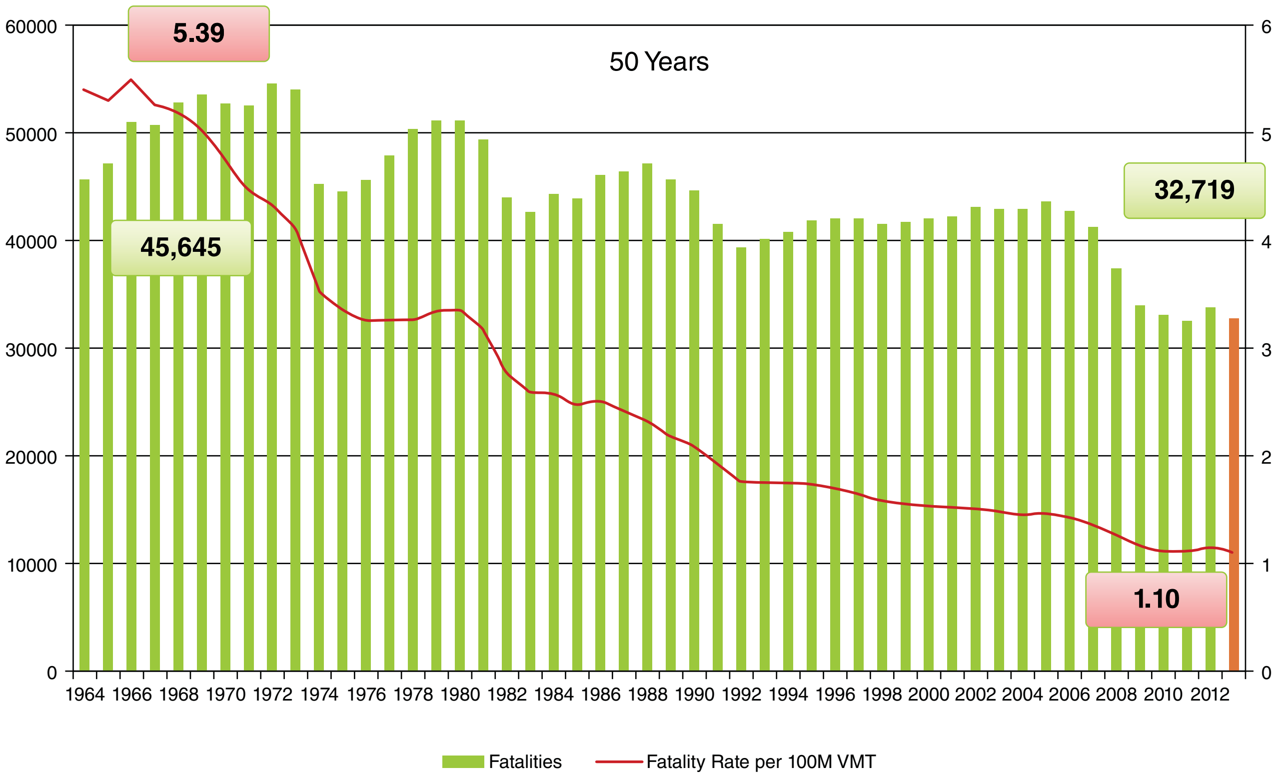
This chapter describes how safety can be integrated into the transportation planning process at all levels. Special focus is given to how safety can be incorporated into the products of the statewide and metropolitan planning processes, that is, statewide transportation plans (STPs), statewide transportation improvement programs (STIPs), metropolitan transportation plans, and transportation improvement programs (TIPs). This chapter also explains why safety planning that only focuses on traditional transportation planning products should be augmented by new processes and institutional relationships that align efforts across organizational boundaries to achieve reductions in highway fatalities and incapacitating injuries.

The next section presents U.S. statistics on crashes and crash rates. In addition, material is presented on the safety history of transit and nonmotorized modes of travel. The following section provides a brief description of the legislative and regulatory history of safety planning in the United States, and the relationship between the STP and the development of a strategic highway safety plan. The next section describes the characteristics of safety transportation planning and how safety concepts can be incorporated into the different steps of the transportation planning process. Given the importance of the American Association of State Highway and Transportation Officials' (AASHTO's) *Highway Safety Manual* to current practice, the following section introduces the key concepts found in the manual and how they can be used as part of a safety analysis. The final section briefly describes safety lessons learned from other countries.

II. U.S. NATIONAL STATISTICS

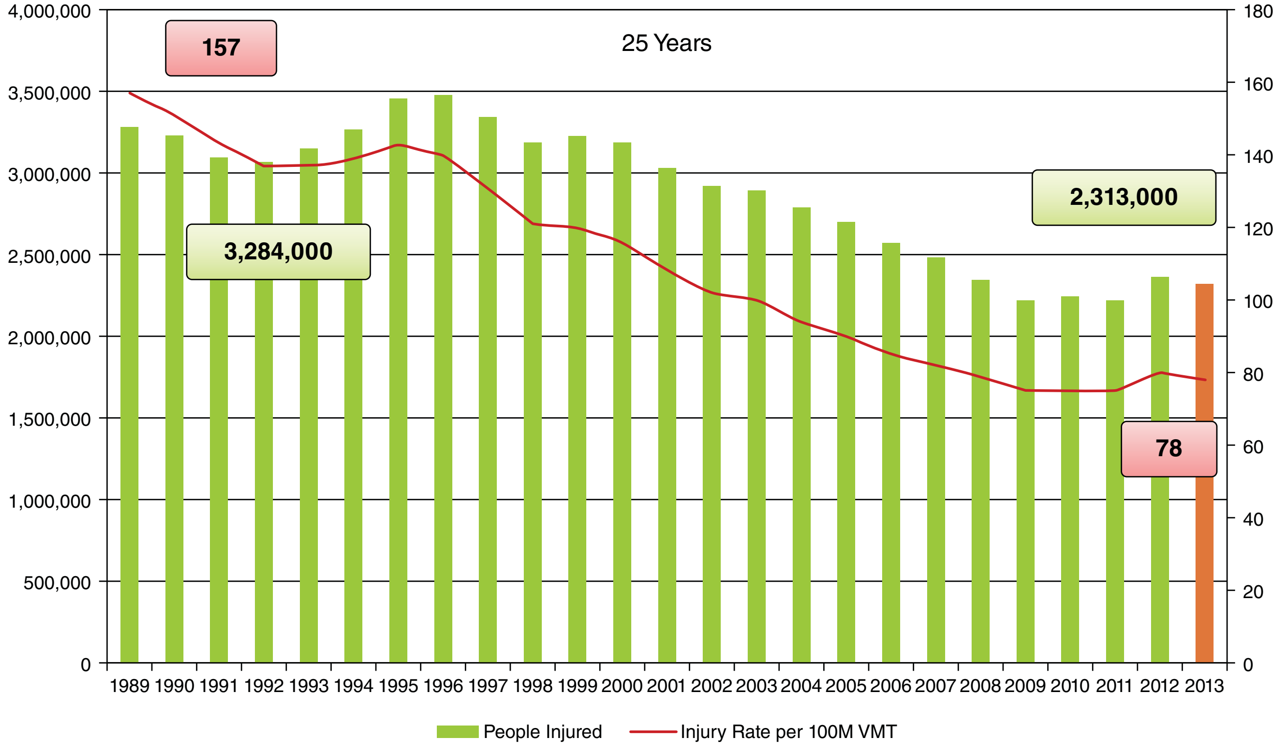
During the past seven years, the number of road-related fatalities in the United States has remained relatively unchanged (although going up or down in any individual year), even with dramatic increases in safety belt use and decreases in the proportion of alcohol-related fatal crashes. [NHTSA, 2014] However, in 2012, as seen in Figure 23-1, the first increase in fatalities in several years was observed. It was the first significant increase since the

Figure 23-1. Motor Vehicle Crash Fatalities and Fatality Rates, United States, 1964–2013



Source: Based on, *Fatalities—National Highway Traffic Safety Administration Fatality Analysis Reporting System* (FARS). Washington, DC, USA: Federal Highway Administration.

Figure 23-2. Injuries and Injury Rate (per 100 Million VMT), United States, 1989–2013



Source: Based on, *Injuries—National Highway Traffic Safety Administration, General Estimates System* (GES). Washington, DC, USA: Federal Highway Administration.

early 1990s. Fatality and injury rates, however, have continued to decrease, as shown in Figures 23-1 and 23-2, because total vehicle miles of travel (VMT), the denominator of the crashes per 100 million vehicle miles traveled rate, have increased over the long term (although in recent years it has declined). If the number of crashes per year remains the same as it is today, more than 330,000 people will die on U.S. roadways over the next decade, at a societal cost of nearly $2.0 trillion, using the current monetary value of a statistical life.

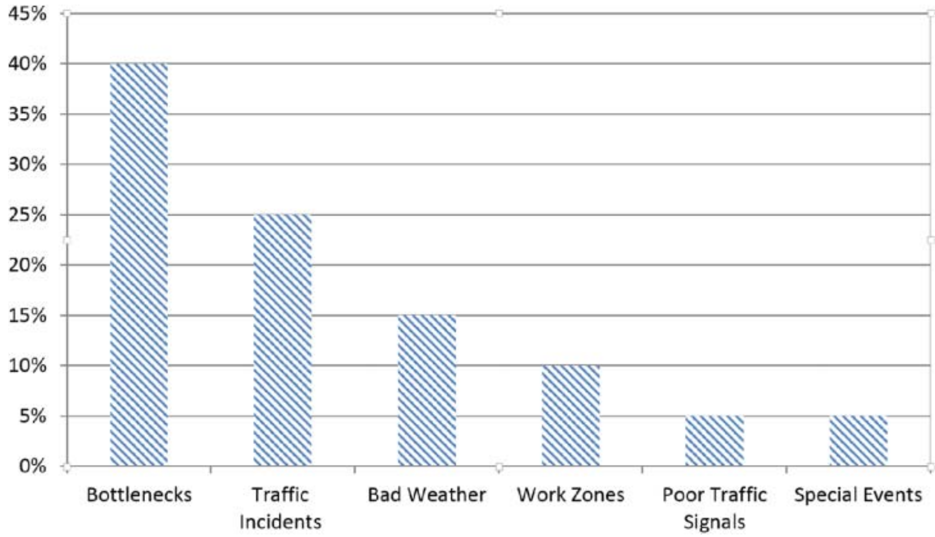
A study by NHTSA concluded that the costs to society of crashes occurring in 2010 amounted to $871 billion in economic loss and societal harm. This included $277 billion in economic costs—nearly $900 for each person living in the United States at that time—and $594 billion in harm from the loss of life and the pain and decreased quality of life due to injuries. [Blincoe et al., 2014] Given this huge loss in human life and the corresponding economic impacts, and given that crashes are to a large extent avoidable, transportation planners should focus on what it will take to improve safety on the transportation system.

While fatal and severe injury crashes appropriately receive the most attention, crashes that result only in minor injuries and property damage also have significant economic impacts. Lost days of productivity, chronic pain, diversion of economic resources into repairs, and increased traffic congestion are each a potential negative consequence of these crashes. Figure 23-3 illustrates this last point. National data suggest that an estimated 25 percent of all congestion is caused by traffic crashes, and in some cases, such as in major urban areas, it might exceed 50 percent. Crashes and other incidents not only cause immediate delay to those caught behind the event, but also have the potential themselves of causing secondary crashes. Crash-caused congestion also tends to slow emergency response, potentially increasing the severity and ultimately the survival rate from crashes.

National statistics also provide good indications of the causes of crashes. According to Blincoe et al. [2014], such causes include:

- *Drunk Driving*—Crashes caused by drivers under the influence of alcohol accounted for 18 percent of the total economic loss due to motor vehicle crashes and cost the nation $49 billion in 2010, an average cost of $158 for every person in the United States. Including lost quality of life, these crashes were responsible for $199 billion or 23 percent of the overall societal harm caused by motor vehicle crashes. Over 90 percent of

Figure 23-3. Contributing Factors to Congestion in the United States



Source: FHWA, 2013a

these costs occurred in crashes involving a drunk driver with a blood alcohol concentration (BAC) of 0.08 or higher.

- *Speeding*—Crashes involving a speeding vehicle traveling over the posted speed limit or too fast for conditions accounted for 21 percent of the total economic loss and cost the nation $59 billion in 2010, an average cost of $191 for every person in the United States. Including lost quality of life, these crashes were responsible for $210 billion or 24 percent of the overall societal harm caused by motor vehicle crashes.
- *Distraction*—Crashes involving a distracted driver accounted for 17 percent of the total economic loss and cost the nation $46 billion in 2010, an average cost of $148 for every person in the United States. Including lost quality of life, these crashes were responsible for $129 billion or 15 percent of the overall societal harm caused by motor vehicle crashes.
- *Pedestrians and Bicyclists*—Crashes involving pedestrians and bicyclists accounted for 7 percent of the total economic loss and cost the nation $19 billion in 2010. Including lost quality of life, these crashes were responsible for $90 billion or 10 percent of the overall societal harm caused by motor vehicle crashes.
- *Seatbelts*—Seatbelt use prevented $69 billion in medical care, lost productivity, and other injury-related costs. Conversely, preventable fatalities and injuries to unbelted occupants accounted for 5 percent of the total economic loss, and cost the nation $14 billion in 2010. Including lost quality of life, failure to wear seatbelts caused $72 billion or 8 percent of the overall societal harm due to motor vehicle crashes.

As can be seen in Table 23-1, the increase in fatalities among motorcyclists and pedestrians, cyclists, and other non-occupants is a troublesome statistical trend. In particular, motorcyclist fatalities over the 10-year period grew by 16 percent. Some interesting statistics regarding motorcyclist fatalities in 2013 include: (1) 43 percent of motorcyclist fatalities occurred in single-vehicle crashes; (2) there were 11 times as many unhelmeted motorcyclist fatalities in states that did not have a helmet law as in those that did; (3) 27 percent of motorcycle riders in fatal crashes had blood

Table 23-1. Fatalities by Type, United States

	2004	2013	% Change
Passenger Car Occupants	19,192	11,977	–38%
Light Truck Occupants	12,674	9,155	–28%
Motorcyclists	4,028	4,668	+16%
Pedestrians, Cyclists, and Other Non-occupants	5,532	5,668	+2%
Total	42,836	32,719	–24%

Source: NHTSA, 2015

Table 23-2. U.S. Transit Fatalities by Mode, 2001 to 2011	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Automated Guideway	0	0	0	1	3	0	1	0	0	1	0
Commuter Rail	87	116	77	86	105	85	124	93	66	97	97
Demand Responsive	5	0	4	0	8	7	8	5	2	4	1
Heavy Rail	59	73	49	59	35	23	32	61	78	87	81
Light Rail	21	13	17	22	19	17	32	14	25	21	25
Motor Bus	95	78	87	77	66	94	90	67	48	68	64
Vanpool	0	0	0	3	0	1	1	0	4	1	0

Source: U.S. DOT, Federal Transit Administration, http://transit-safety.fta.dot.gov/Data/samis/default.aspx?ReportID=2

Table 23-3. U.S. Transit Injuries by Mode, 2001 to 2011	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Automated Guideway	36	28	29	15	2	19	11	17	33	89	104
Commuter Rail	1,813	1,483	1,597	1,364	1,672	1,426	1,548	1,700	1,808	1,928	1,811
Demand Responsive	1,374	347	401	296	447	553	553	703	1,012	524	599
Heavy Rail	10,641	4,806	4,158	4,738	3,814	4,721	4,789	7,030	5,706	7,024	4,731
Light Rail	1,201	557	539	633	618	659	838	956	840	731	601
Motor Bus	38,840	11,995	11,493	11,898	11,560	11,812	12,859	12,796	11,863	13,089	12,585
Vanpool	40	44	18	38	18	48	27	20	44	33	10

Source: U.S. DOT, Federal Transit Administration, http://transit-safety.fta.dot.gov/Data/samis/default.aspx?ReportID=2

alcohol levels of 0.08 or higher; and (4) 25 percent of motorcyclist drivers in fatal crashes were improperly licensed. [NHTSA, 2015] Similarly for pedestrian fatalities, (1) 34 percent (16 years or older) had blood alcohol levels of 0.08 or higher; (2) the age group with the highest fatalities was 45 to 54 years old; (3) 68 percent of fatalities were in urban areas; (4) 31 percent were at intersections; (5) 70 percent occurred at night; and (6) 69 percent were male. For pedacyclists, (1) 20 percent (16 years or older) had blood alcohol levels of 0.08 or higher; (2) the average age was 44 years old; (3) 73 percent of fatalities were in urban areas; (4) 43 percent were at intersections; and (5) 56 percent occurred between 3 p.m. and midnight. (Note: Pedestrian and bicycle crashes are those involving collisions with motor vehicles … in metropolitan areas, the number of collisions between pedestrians and bicycles has been on the rise in recent years.)

Table 23-2 shows the number of fatalities, and Table 23-3 the number of injuries, by transit mode from 2001 to 2011. As shown, the largest number of fatalities is associated with commuter rail, whereas the largest number of injuries occurs with bus operations.

The major focus and commitment to improving roadway safety in the United States during the past two decades has been on enhancing the vehicle's ability to withstand crashes and on changing driver behavior. Yet, as seen in Figure 23-1, the effectiveness of these strategies seems to have leveled off. Similarly, many roadway improvements have focused on modernizing highway ramps and intersections to improve safety, with the result being better traffic flow and higher traffic volumes. These in turn can negate safety benefits. All of this raises the question: What more can be done to improve the safety of the transportation system?

III. INSTITUTIONAL AND POLICY STRUCTURE IN THE UNITED STATES

In 1966, 50,894 people were killed in the United States in motor vehicle crashes, a fatality rate of 5.5 deaths per 100 million VMT. If nothing had been done to address the problem, assuming historical growth rates, highway fatalities would have increased to more than 100,000 annually by today. However, the federal government and the states have been actively engaged over the past 40 years in reducing the nation's highway fatalities. Safety has long been a major focus of highway project development and a consideration for road investment. However, its role and significance as a component of national transportation policy has changed over time, as summarized in Table 23-4 and in the following paragraphs.

Table 23-4. Significant U.S. Road Safety Legislation

Federal Legislation	Year	Significant Road Safety Features
Highway Safety Act	1966	• Created Federal Highway Administration (FHWA) safety grant program. • State highway safety program approved by U.S. Department of Transportation (U.S. DOT). • Created National Highway Traffic Safety Administration (NHTSA). • Included specific initiatives such as bicycle/pedestrian safety, law enforcement, etc.
Highway Safety Act	1973	• Established methodology for improving roadway safety from an engineering perspective. • Required hazardous location survey, analysis of contributing factors, benefit/cost analysis of mitigation alternatives, and project prioritization. • Methodology was expanded through establishment of the Highway Safety Improvement Program (HSIP) methodology in 1979.
Intermodal Surface Transportation Efficiency Act (ISTEA)	1991	• Required planning process with emphasis on state department of transportation (DOT)-metropolitan planning organization (MPO) coordination. • Included systems preservation, construction, preservation, mobility, and environmental protection. • Required management systems, including safety, but requirement later withdrawn.
National Highway System Designation Act	1995	• Made implementation of management systems optional.
Transportation Equity Act for the 21st Century	1998	• Required DOTs and MPOs to incorporate safety and security together as a priority planning factor. • Led to development of safety conscious planning (SCP) initiative.
Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)	2005	• Separated safety and security as planning factors. • Established safety as a core funding program. • Established a strong connection between the strategic highway safety plan (SHSP) and the transportation planning process. • Required states to develop and implement strategic highway safety plans.

Moving Ahead for Progress in the 21st Century Act (MAP-21)	2012	• Required regular update of the strategic highway safety plan
		• Secretary will establish measures and states will set targets for number of injuries and fatalities (and number per VMT)
		• States should:
		  • Use the safety data system to perform safety problem identification and countermeasure analysis that:
		    • Identifies hazardous locations, sections, and elements.
		    • Establishes relative severity of those locations.
		    • Identifies number of fatalities and serious injuries on all public roads by location in the state.
		    • Considers which projects maximize opportunities to advance safety.

Table 23-4. (*Continued*)		
Federal Legislation	**Year**	**Significant Road Safety Features**

		• Adopt strategic and performance-based goals that:
		  • Address traffic safety, including behavioral and infrastructure problems and opportunities on all public roads.
		  • Focus resources on areas of greatest need, and coordinate with other state highway safety programs.
		  • Determine priorities.
		  • Establish and implement a schedule of highway safety improvement projects.
		• Establish an evaluation process driven by SHSP.
		• Expand the list of participants in SHSP.

Fixing America's Surface Transportation (FAST) Act	2015	• Little impact on the relationship between transportation planning and safety. • Established a new competitive grant program for passenger and freight rail safety projects. • Increased accountability of states to ensure rail transit safety performance by bolstering oversight in urban areas. • Allowed flexibility in transporting hazardous materials during major disasters and emergencies in an effort to improve the ability to carry out emergency response and relief efforts.

The Highway Safety Act (1966)

The Highway Safety Act of 1966 established a new method for addressing highway safety problems. The act created a federal highway safety grant program and gave responsibility for the administration of this program to the governors of each state. The governors were directed to appoint a governor's highway safety representative (GR) to administer the program. Funding was provided under Section 402 of the U.S. Code, which became the basic building block of state highway safety programs. The U.S. Secretary of Transportation was assigned the responsibility of approving these programs. To oversee the program, Congress created the National Highway Traffic Safety Administration (NHTSA) within the U.S. Department of Transportation (U.S. DOT).

In effect, the 1966 Highway Safety Act put the federal government in a leadership position in highway safety, but it kept the actual implementation of highway safety programs in the hands of the states, a relationship that continues today. Since 1966, Congress has revised the federal highway safety program a number of times, adding new incentive grants, penalties, and sanctions. Some of the revisions over time have required safety programs to consider factors such as driver and pedestrian safety, bicycle safety, speeding, occupant protection devices, drivers impaired by alcohol or controlled substances, motorcycles, school buses, law enforcement services, and crash data collection and reporting. However, the act did not explicitly address how safety should be considered in the statewide or metropolitan transportation planning processes, nor did it suggest that the state highway safety plan, developed to comply with Section 402, can be eliminated by addressing highway safety within a broader transportation planning process. These NHTSA safety planning requirements are still in force even though federal transportation legislation, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), required the states to develop a strategic highway safety plan.

Highway Safety Act of 1973

The Highway Safety Act of 1973 established additional safety programs to reduce the number and severity of highway-related crashes by addressing high-crash locations. States were required to conduct a survey of all hazardous locations, study the causes of crashes at these locations, conduct a benefit/cost analysis of proposed mitigation, and prioritize improvements. This approach was very much an engineering-oriented perspective on how to improve roadway safety. In 1979, the Federal Highway Administration (FHWA) built upon this methodology in establishing the Highway Safety Improvement Program (HSIP). This program provided the basis for selecting locations for safety improvements. The purpose of the HSIP was to help establish policy for the development and implementation of a comprehensive highway safety program in each state. Three key components were identified: planning, implementation, and evaluation.

Intermodal Surface Transportation Efficiency Act (1991)
In many ways, the Intermodal Surface Transportation Efficiency Act (ISTEA) was benchmark legislation that changed the focus of federal transportation policy. In particular, it made system preservation one of the most important goals of federal policy, along with mobility and environmental protection. The goal of transportation investment was to produce a safe, efficient, accessible transportation system that also protected the human and natural environments.

ISTEA required consideration of 23 planning factors for statewide transportation plans (STPs) and 16 for metropolitan plans, under the general headings of mobility and access for people and goods, system performance, preservation, environment, and quality of life. However, nowhere in the legislation was safety specifically mentioned or mandated in the planning process. ISTEA also required the states to develop and implement six management systems, including one for safety. However, this requirement, except for the congestion management system in transportation management areas, was made optional at the state's discretion by the National Highway System Designation Act of 1995.

At the time, the highway safety management system (SMS) was envisioned to be a process to identify and prioritize safety projects in the states. A comprehensive crash database was to serve as the basis for these decisions, and safety performance measures were to be defined and used to monitor safety progress over time. The SMS process also was expected to include a broad-based coalition of safety stakeholders. In reality, most SMS activities were simply efforts to structure crash databases that allowed transportation officials to identify high-crash locations. After the federal requirement for an SMS was rescinded, very few states maintained and expanded their SMS or continued to develop a collaborative process with others interested in highway safety.

Transportation Equity Act for the 21st Century (1998)
While ISTEA required states to develop and maintain a transportation planning process, the Transportation Equity Act for the 21st Century (TEA-21) provided more focus on specific issues. The key focus of both of these acts was to encourage coordination between statewide planning and metropolitan planning. In addition, TEA-21 identified seven priority planning factors that were to be considered by both planning processes. Prior to TEA-21, safety may have been incorporated into the vision or goals of a state's long-range transportation plan, but specific strategies to increase safety were seldom included in statewide and metropolitan planning processes or documents. For the first time, TEA-21 required state DOTs and MPOs to incorporate safety/security as a priority factor in their transportation planning processes and activities.

Integrating safety into transportation planning became known as safety conscious planning (SCP). [Herbel, 2001] The goal was to prevent the human and economic losses that resulted from motor vehicle and nonmotorized traveler-related crashes. SCP encouraged states and local transportation planners to work collaboratively with officials concerned with highway safety, data management and analysis, commercial vehicle safety, and other areas to include safety as a key issue in all transportation plans and programs.

Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) separated safety and security into individual planning factors. Prior to the terrorist attacks of September 11, 2001, security had been addressed at the federal level, primarily through initiatives for airport security, the security of transit drivers, and, to a lesser extent, personal safety of passengers on the transit system. The issue broadened considerably after 9/11, with the security of bridges, tunnels, airports, and other facilities becoming a bigger public policy issue. Evacuation planning, particularly for mobility-limited residents or residents without cars, has also become more pressing as a security issue as a result of Hurricane Katrina in September 2005.

With respect to safety, SAFETEA-LU required each state to develop and implement a Strategic Highway Safety Plan (SHSP) as part of the HSIP requirements. The requirements for the contents of these plans, the stakeholders who must be involved, and eligible funding categories were quite specific, with the eligible funding categories being broadened considerably (see Table 23-5).

In many ways, the SHSP requirement and the new, flexible safety funding resources of SAFETEA-LU strengthened both the process and goals of SCP and the original SMS requirement of ISTEA. These plans were to be based on data analysis and developed in collaboration with a broad range of stakeholders. Importantly, states must have an

Table 23-5. Strategic Highway Safety Plan Requirements		
Process and Content	**Participants**	**Eligible Funding Projects**
• Use different types of crash data. • Establish crash data systems to identify problems and analyze countermeasures. • Address engineering, management, operations, education, enforcement, and emergency medical services elements. • Identify hazardous locations, sections, and elements; and establish criteria that indicate relative crash severity of these locations. • Adopt strategic and performance-based goals that address the broad spectrum of safety improvements (including behavioral improvements), focus resources on the areas of greatest need, and coordinate with other highway safety programs. • Advance the state's capabilities for traffic records data collection, analysis, and integration with other sources of safety data; include information on all public roads. • Consider the results of state, regional, and local transportation and highway safety planning processes. • Set priorities for corrective action on high-hazard locations, segments, and elements. • Identify opportunities for preventing the development of new hazardous locations. • Establish an evaluation process to assess the results achieved by the HSIPs. • Produce a program of projects that is consistent with the STIP. • Seek approval of the governor or the appropriate state agency.	• State DOT. • State Highway Safety Office. • Regional transportation planning organizations and MPOs. • Operators of major modes of transportation. • State and local traffic enforcement officials. • State persons responsible for administering the federal rail-grade crossing program. • Operation Lifesaver. • State MCSAP administrators. • State motor vehicle administrators. • Major state and local stakeholders.	• Intersection safety improvements. • Pavement and shoulder widening (including passing lanes). • Rumble strips or other warning devices not affecting bicyclists. • Devices that improve the safety of pedestrians and the disabled. • Skid-resistant surfaces at intersections or high-crash locations. • Bicycle or pedestrian safety or the safety of the disabled. • Hazard elimination at railroad crossings (including separations). • Rail-highway grade crossings (including protective devices). • Traffic enforcement at a rail-highway grade crossing. • Traffic calming features. • Roadside obstacles elimination. • Highway signage or pavement markings. • Priority control system at signalized intersections for emergency vehicles. • Traffic control or other warning devices at high-crash locations. • Collection and analysis of crash data. • Planning emergency communications. • Work zones operational improvements or traffic enforcement activities. • Guardrail installation. • Barriers and crash attenuators. • Structures or other measures to eliminate or reduce accidents involving wildlife. • Installation, maintenance, and construction of signs at pedestrian/bicycle crossings and in school zones. • Construction and operational improvements on high-risk rural roads. • Improvement projects on any public roadway or publicly owned bicycle or pedestrian pathway or trail.

Source: Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, Section 148 from Public Law 109-59, Title 6, U.S. Code.

SHSP in place to take advantage of new and expanded safety funding programs. Similarly, the new and expanded dedicated funding programs for safety (Safe Routes to School, Rural Roads, and the like) required that infrastructure investments funded through them be coordinated with enforcement and/or educational strategies.

Some of the specific, safety-related requirements of SAFETEA-LU required states to:

- Consider the results of state, regional, or local transportation and highway safety planning processes.
- Have in place a crash data system with the ability to perform safety problem identification and countermeasure analysis on all public roads. SAFETEA-LU also required states to advance their capabilities for traffic records data collection, analysis, and integration with other sources of safety data.
- Analyze and make effective use of state, regional, or local crash data.
- Develop and implement an SHSP after consultation with a wide range of stakeholders, including governor's highway safety representatives, MPOs, representatives of major transportation modes, traffic enforcement officials, Operation Lifesaver representatives, motor carrier safety program representatives, and motor vehicle administration agencies.
- Adopt strategic and performance goals that address traffic safety(including behavioral and infrastructure problems and opportunities) on all public roads; the goals must focus resources on areas of greatest need and be coordinated with other state highway safety programs.
- Develop an SHSP that addresses engineering, management, operation, education, enforcement, and emergency services elements (including integrated, interoperable emergency communications) of highway safety as key factors in evaluating highway projects. The HSIP was still the means of funding such strategies.
- Determine priorities for the correction of hazardous road locations, sections, and elements (including railway-highway crossing improvements) as identified through crash data analysis.

Moving Ahead for Progress in the 21st Century Act (2012)

One of the key provisions of the Moving Ahead for Progress in the 21st Century Act (MAP-21) was the introduction of performance-based planning and decision making into state and regional investment decisions. According to the law, states would set targets for the number of serious injuries and fatalities, and the per-vehicle miles of travel rate for both. If progress toward its safety targets is not made, the state will have to devote a certain portion of its formula funding to the safety program and submit an annual implementation plan on how the state will make progress to meet performance targets. MAP-21 also required states to incorporate strategies focused on older drivers and pedestrians, if fatalities and injuries per capita for those groups increased. [FHWA, 2012] Regular updates of a state's SHSP were required, and there had to be a clear linkage shown between behavioral safety programs (for example, funding of seat belt compliance) and the SHSP.

For transit, the Federal Transit Administration (FTA) was required to issue a National Public Transportation Safety Plan, which was to include safety performance criteria for all modes of public transportation, and minimum safety performance standards for vehicles not regulated by other federal agencies. Each FTA grantee was also required to have a comprehensive agency safety plan that, at a minimum, included methods for identifying and evaluating safety risks, strategies to minimize exposure to hazards and unsafe conditions, a staff safety training program, and performance targets for safety performance criteria and state of good repair standards established in the national safety plan. MAP-21 also required the FTA to establish a system to monitor and manage public transportation assets to improve safety and increase reliability and performance.

All FTA grantees were required to develop transit asset management plans that included, at a minimum, current capital asset inventories and condition assessments, and investment prioritization. Transit agencies were also required to establish and use an asset management system to develop their capital asset inventories and condition assessments, and report on the condition of their system as a whole, with descriptions of the change in condition since the last report (see chapter 8 on transportation asset management).

This evolution in federal safety legislation was accompanied by varying terms to describe the process of considering safety in agency planning and decision making. A variety of terms have been used over the past several decades, such as Safety Conscious Planning [Herbel, 2001] and Safety Integration. Following the passage of SAFETEA-LU, the term Transportation Safety Planning began to include not only the traditional transportation planning process, but also the development of the SHSPs. Transportation Safety Planning (TSP) is used consistently in this chapter to describe a process, carried out through development of the SHSP, whereby safety is explicitly addressed in transportation planning.

IV. LAYING THE GROUNDWORK FOR TRANSPORTATION SAFETY PLANNING

Safety needs to play a larger, more prominent role in planning decision making. This will help bridge a gap existing between the engineering side of safety project implementation and other more behavioral components of the overall safety program. States normally disperse safety-related responsibilities among multiple functional agencies. For example, programs that address substance abuse are not administered by state DOTs, but normally by agencies focused on health and human services. In addition, to get substance-impaired drivers off the road requires coordination among enforcement (housed in other local, state, and tribal agencies), the court system (yet another agency), and the agencies providing treatment. Cross-agency coordination is much more complicated to resolve than intra-agency coordination, and includes issues such as diverse missions, data inconsistencies, different budget cycles, and restrictions on funding eligibilities.

It is the planning process that prioritizes projects, thus establishing the overall direction of a state's or region's investment program. In almost every case, road projects have been designed and implemented independently from other safety countermeasures, such as enforcement and education. The planning process addresses a variety of issues that are important to state and local decision makers such as congestion, freight, safety, transit, air quality, system preservation, and the like. Often, safety is part of the initial goals formulation and visioning component of this planning process, but is then not incorporated systematically in subsequent steps. There are a number of reasons why this is so. These include a lack of data demonstrating the safety problem and inadequate tools and techniques to evaluate safety alternatives—for example, how do transportation planners predict safety problem areas 25 years in the future?

Successful integration of safety concerns into the transportation planning process, and ultimately into the decision-making process, requires a change in the orientation and business processes of transportation organizations. There are a number of possible ways to accomplish this, one being the creation of an "umbrella" office that coordinates safety activity in all parts of the organization. Other key elements of this strategy are training and increasing the accessibility of safety data across the organization.

Currently, most state DOTs and regional planning organizations identify and prioritize high-crash locations and implement appropriate solutions as resources become available. However, this is a *reactive* approach. TSP turns this around through a process that has several characteristics:

- TSP is a *proactive* approach in that it is designed not only to address high-crash locations, but also to prevent problems before they happen.
- It is *leadership-driven* and has commitment from upper-level management as well as resources dedicated for its development and implementation. Strong and committed leadership is a prerequisite for effective safety planning. Experience shows that a safety champion is necessary to keep the process moving forward. It takes a person—preferably full-time—to identify and provide items such as data, research, and other information; plan agendas; facilitate and document meetings and decisions; track progress; and address challenges.
- It is a *collaborative* process that brings together the DOT, MPOs, rural planning agencies, regional councils, transit agencies, highway safety practitioners and advocates, motor carrier safety professionals, emergency response, and law enforcement. Elected officials, the public, and other professional communities also need to be engaged in the process. At the state level, TSP includes the state DOT, the governor's representative for highway safety, the state director of motor carrier safety, persons responsible for administering the hazard elimination and rail-grade crossing safety provisions, state and local law enforcement, and other state and local safety stakeholders. At a local level, TSP engages local decision makers and elected officials who are already making decisions about the local transportation system through the metropolitan or statewide transportation planning processes.
- It is *data-driven* in that data are used to identify current problems and seek appropriate solutions. Data-driven approaches provide documentation of a safety problem in the planning phase and provide the evidence

needed to develop a more responsive and effective solution in the design and implementation phase of a project.

- It is a *comprehensive* approach because it includes all aspects of transportation safety—engineering, education, public awareness, enforcement, and emergency medical services. It goes beyond the traditional *hot spot* analysis and looks at corridors and systemwide assessments. It is also multimodal and incorporates strategies related to transit and nonmotorized vehicle users, such as pedestrians and bicyclists.
- Effective TSP focuses on *implementation* from the very beginning of the process because many of the strategies it considers require careful consideration of the steps needed for successful implementation. As an amalgamated process, TSP joins together the hard side (infrastructure) of safety with the soft side (behavioral) to develop a more comprehensive set of strategies benefiting from established decision-making frameworks and processes.

V. INCORPORATING SAFETY INTO TRANSPORTATION PLANNING

Figure 1-1 (see chapter 1) presented a generic transportation planning process used here to describe how safety can be considered in each step of the planning process. In particular, safety concerns can be incorporated into the following major steps:

- Step 1: Establish multidisciplinary coordination with transportation and safety stakeholders.
- Step 2: Incorporate safety into the vision, goals, and objectives.
- Step 3: Develop safety performance measures and targets.
- Step 4: Collect and analyze crash data.
- Step 5: Analyze and evaluate transportation safety.
- Step 6: Make safety a decision factor.
- Step 7: Include safety in planning programs and documents.

See NCHRP Report 546 [Washington et al., 2006] for more detail on each of these steps. A brief summary of each step is presented in the following sections.

A. Establish Multidisciplinary Coordination with Transportation and Safety Stakeholders

Improving the safety of the transportation system requires the participation and involvement of many different groups and organizations. In particular, a partnership is needed between the safety and transportation planning communities to support a continued focus on safety in transportation planning. Safety experts and modal experts who address safety in their jobs can make key contributions to the consideration of safety in planning documents.

There is no single recipe for successful collaboration in safety planning. Given different institutional structures, histories of agency interaction, and political influence found in most states and metropolitan areas, this is not surprising. However, there are examples from around the world where such partnerships have been successful. For example, a study of the safety efforts in the State of Victoria, Australia, found that the following institutional factors enabled the state agencies to reduce road fatalities dramatically:

- A history of success with interventions based on legislation and enforcement helped create a political willingness to act.
- Strong relationships existed between the traffic-safety research community and policy makers in each of the government agencies, facilitating evidence-based planning and target setting.
- These relationships have not only helped create sound data sets but also, more importantly, a climate in which the scientific evaluations of interventions are routine.

- Extensive public education on traffic safety was instrumental in creating a climate of community concern for road safety and support for effective interventions.
- The media historically were supportive of effective interventions, which further facilitated political willingness to act. [Washington et al., 2006]

Although Victoria has a different governmental structure than other comparable governmental units, these lessons of success deserve strong consideration in almost any governmental structure. As noted by Herbel and Waldhem [2014], some of the opportunities to foster multidisciplinary collaboration include "establishing a transportation safety committee; creating an ad hoc safety committee to meet during an update of the long-range transportation plan or during project selection; appointing safety representatives to established committees, such as a technical advisory committee or a bicycles-and-pedestrians committee; and identifying and including safety experts in discrete planning activities, such as corridor plans."

See TCRP Report 106 , *From Handshake to Compact: Guidance to Foster Collaborative, Multimodal Decision-Making*, for further guidance on success factors for collaboration efforts. [Campbell et al., 2005]

B. Incorporate Safety into the Vision, Goals, and Objectives

Why is visioning important? If safety is not in the vision/mission statements of the agencies responsible for transportation and safety, then it will not likely be reflected later in the process. Every planning process, not just transportation, begins with some form of visioning. What are the desired characteristics of the community in the future? How does transportation fit into this vision? A vision might be nothing more than a generalized statement of desired end states, but it provides guidance for the rest of the planning process.

Recently, in many countries, a "toward zero deaths" vision has been adopted by national, state, and provincial governments. As noted by a coalition of U.S. national transportation organizations, "the National Strategy vision is a highway system free of fatalities through a sustained and even accelerated decline in transportation-related deaths and injuries. Safety organizations and professionals embracing this vision agree to aggressively work toward an intermediate goal specific to their jurisdiction or the safety issue on which they focus." [Toward Zero Deaths, 2014]

Vision Statement Examples

"The new OTP elevates the standing of safety issues to better reflect ODOT's position that Safety is our number one priority. The upshot is that the OTC has taken a dramatic step to infuse safety discussions at all levels of management of the transportation system. Weaving safety systems into the very fabric of Oregon's transportation systems going forward is the challenge." [Oregon DOT, 2011]

"The mission of Cheyenne's TSMP is to eliminate preventable traffic-related deaths and injuries . . . ." [Cheyenne MPO, 2008]

"To reach destination zero deaths on roadways." [South Central Planning and Development Commission, 2013]

"Zero Deaths – Zero Injuries." [Maricopa Association of Governments, 2015]

The process of developing a vision statement, which usually includes many different stakeholders, is an important opportunity to explain the importance of safety to key stakeholders and decision makers. Usually the data collection and analysis efforts to understand the problem, as discussed earlier, become part of the process of defining the safety vision.

There should be at least one goal, several objectives, and system performance measures that address safety in the transportation planning process. Performance measures are most often related to reduction in crashes, fatalities, and injuries, as well as the monetary savings associated with these reductions. Reductions in specific categories of crashes can be used as performance measures to measure the effectiveness of specific programs. For example, education and enforcement programs targeted toward impaired driving can be measured by reductions in the number of alcohol-related crashes and fatalities. It is extremely important to use performance measures to measure progress and challenge the notion that traffic crashes are unavoidable accidents. Some examples of goals, objectives, and performance measures follow.

In the latest update of the regional transportation plan, the Southeastern Michigan Council of Governments (SEMCOG), the metropolitan planning organization (MPO) for the Detroit region, identified a set of principles to guide development of the plan and subsequent actions. [SEMCOG, 2013] The safety principle was "Creating a Safer Transportation System," and subsequent actions were:

- Improve the safety of all users of all modes.
- Maintain a crash database for use in regional and local safety analysis.
- Focus on key emphasis areas derived from analysis and coordination with other agencies as an efficient way to improve safety.
- Identify and seek funding for improvements to transportation infrastructure to increase safety.
- Facilitate coordinated emergency responses through incident management planning.
- Incorporate future recommendations from the Regional Strategic Highway Safety Plan (SHSP) into the Regional Transportation Plan.
- Promote and coordinate programs that educate people about and market safety.
- Address safety needs of environmental justice population segments, including elderly or disabled people.
- Promote the use of and assist members with auditing services (e.g., road safety, walkable, bikeable) for reducing crashes using low-cost improvements.
- Support appropriate education and enforcement activities to improve safety. This includes building knowledge for necessary legislative initiatives, supporting relevant professional development for law enforcement staff, and educating members of the judicial branch of the consequences of frequently reducing charges.

In light of federal requirements linking transportation planning and the state's SHSP, more and more plans refer to the state's SHSP emphasis areas as the goals for the regional transportation plan. Thus, for example, in Seattle, the Puget Sound Regional Council (PSRC) stated in the latest plan update, "The region explicitly aligns its policies and program direction at the regional level with the state's Target Zero plan. The plan focuses on five key areas: (1) driver behaviors, (2) other users (pedestrians, bicyclists, motorcyclists, and freight), (3) roadway improvements, (4) emergency medical services, and (5) traffic management. The region supports the state's Target Zero goal, and will annually review available safety data for the central Puget Sound region and develop regional program direction that will best contribute to the state's overall goal." [PSRC, 2010]

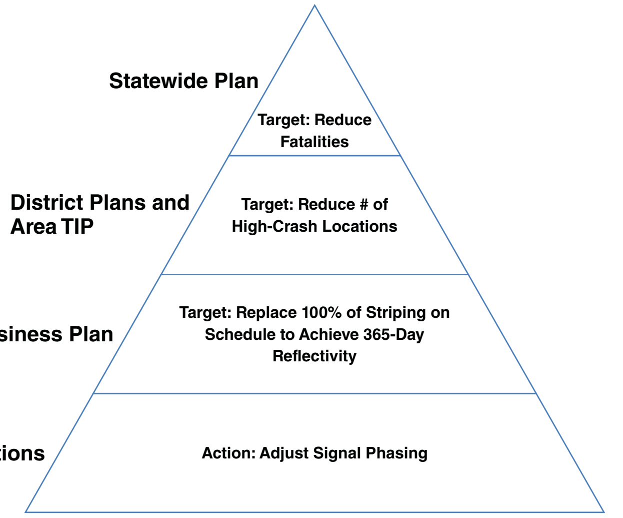
Another example of this linkage between the SHSP and transportation planning comes from the Phoenix MPO, which explicitly shows how the transportation safety plan for the metropolitan area reinforces or depends on the state's safety plan. The MPO's plan then identifies numerous actions that can be taken by the region to improve transportation safety. Interestingly, the MPO safety plan also recommends:

> Encourage submittal of TIP projects that include safety elements, for improving safer access for all modes, by including safety as an explicit project evaluation criterion for all TIP projects that currently have evaluation criteria as a means of prioritizing a list of projects. Exceptions to this practice are those Transit Maintenance and Operations programs funded through the MAG TIP. [Maricopa Association of Governments, 2015]

In other words, safety should be considered in every project programmed by the MPO. With respect to the SHSP, it might be more opportune for MPOs to adopt those emphasis areas that are appropriate for the region.

Figure 23-4 illustrates a very important concept for integrating safety concerns into the planning and decision-making processes of a transportation agency. The figure comes from the Minnesota DOT (MnDOT), which is considered a national leader in performance-based planning. [MnDOT, 2003] As can be seen with respect to safety, targets that are linked to one another have been established at all levels of the DOT. This hierarchy is an important foundation for ensuring that plan recommendations are implemented and that those responsible for implementation are held accountable. Thus, for example, the state-level safety goal is to reduce fatalities. The district offices of MnDOT will contribute to this goal by reducing the number of high-crash locations. The business plans for the districts have a target of replacing road striping to make sure the stripes are visible to drivers. The operations units in the districts will contribute to the overall safety goal by adjusting signal phasing at locations where crash records suggest modifications need to be made.

Figure 23-4. Safety Goals and Objectives Hierarchy, Minnesota DOT



Source: MnDOT, 2003

C. Develop Safety Performance Measures and Targets

As noted in the earlier discussion on legislation, one of the major changes in transportation safety planning (and for that matter, all federally-supported planning) occurred in 2012 with MAP-21 when safety performance measures were required as part of the transportation planning and decision-making process, similar to what was shown in Figure 23-4. MAP-21 required state DOTs and MPOs to track four safety performance measures, including the number and rate (per 100,000 vehicle miles of travel) of fatalities and serious injuries. However, NHTSA and the Governors' Highway Safety Association (GHSA) developed their own required list of performance measures (that must be reported on by the state) that include 10 core outcome measures, one core behavior measure, and three activity measures. These measures are:

Core *outcome* measures—States will set goals and report progress on:

- Number of traffic fatalities (from Fatal Accident Reporting System—FARS): States are encouraged to report three-year or five-year moving averages as appropriate (when annual counts are sufficiently small that random fluctuations may obscure trends). This comment applies to all fatality measures.
- Number of serious injuries in traffic crashes (state crash data files).
- Fatalities/VMT (FARS, FHWA): States should set a goal for total fatalities/VMT; states should report both rural and urban fatalities/VMT as well as total fatalities/VMT.
- Number of unrestrained passenger vehicle occupant fatalities, all seat positions (FARS).
- Number of fatalities in crashes involving a driver or motorcycle operator with a blood alcohol concentration (BAC) of 0.08 and above (FARS).
- Number of speeding-related fatalities (FARS).
- Number of motorcyclist fatalities (FARS).
- Number of unhelmeted motorcyclist fatalities (FARS).
- Number of drivers age 20 or younger involved in fatal crashes (FARS).
- Number of pedestrian fatalities (FARS).

Core *behavior* measure—States will set goals and report progress on:

- Observed seat belt use for passenger vehicles, front seat outboard occupants (survey).

Activity measures—States will report progress on:

- Number of seat belt citations issued during grant-funded enforcement activities (grant activity reporting).
- Number of impaired driving arrests made during grant-funded enforcement activities (grant activity reporting).
- Number of speeding citations issued during grant-funded enforcement activities (grant activity reporting).

Table 23-6 lists potential performance measures that could be considered for many different types of safety problems. Additional information on how safety performance measures can be used in transportation safety planning is found in Herbel et al. [2008].

Two examples of MPO safety performance measures are found in Houston, Texas, and Washoe County, Nevada. The Houston-Galveston Area Council (H-GAC), the MPO for the Houston metropolitan area, identified transportation safety as its number one plan goal. [HGAC, 2014] The corresponding performance measures included: the number of traffic crashes per 100 million annual vehicle miles traveled (VMT), bus accidents per 100,000 vehicle miles, transit rail accidents per 100,000 vehicle miles, rail accidents at public railroad crossings, rate of bicycle accidents per 100 million VMT, and rate of pedestrian accidents per 100 VMT.

The Regional Transportation Commission in Washoe County, Nevada, has emphasized transportation safety in its transportation plan for many years. [RTC, 2014a] As noted in its *2035 Regional Transportation Plan*, "planning and building a safe multi-modal transportation system for the travelling public is the most critical goal of the RTC. Safety is involved in all types of transportation: driving, walking, cycling, and riding transit. RTC engages in innovative planning and data analysis, public education, interdisciplinary collaboration, operations, and design, with the purposeful goal of reducing the number of crashes and injuries in Washoe County." [RTC, 2014b] The performance measures identified for monitoring progress toward this goal were: (1) preventable transit accidents per 100,000 miles of service, (2) number of crashes and number of crashes per VMT, (3) number of serious injuries per VMT, (4) number of fatalities and number of fatalities per VMT, (5) miles of bicycle lanes added and percent of the Bicycle Pedestrian Master Plan completed (because providing designated space for bicyclists is an important element of multimodal safety), (6) miles of sidewalk added or enhanced, and (7) percent of the Americans with Disabilities Act (ADA) Transition Plan completed. In addition, the plan established targets for each performance measure:

- Preventable transit accidents: 0 (ongoing).
- Number of crashes and crashes per VMT: Reduce by 50 percent by 2020.
- Number of serious injuries: Reduce by 50 percent by 2020.
- Number of fatalities and fatalities per VMT: 0; Reduce by 50 percent by 2020.
- Miles of bicycle lanes and percent completion of plan: 3–7 percent of plan implemented per year.
- Miles of sidewalk and percent of plan completed: 3–7 percent of plan implemented per year. [RTC, 2014c]

D. Collect and Analyze Crash Data

The safety problem in a particular jurisdiction can be defined in many different ways and, in reality, it is often a combination of many factors. Examining crash data serves as a point of departure for understanding and articulating safety issues. This is usually an iterative process that begins by looking at the overall number of crashes with special attention to severity—for example, fatalities and disabling injuries. The next step is often to establish crash rates or the number of crashes using an exposure measure such as VMT, number of vehicles entering an intersection, and the like. This step leads to the identification of high-crash locations, road segments, and/or corridors (often referred to as "hot spot" analysis).

An alternative approach to site-specific analysis is referred to as a "systemic approach to safety." The FHWA definition of a systemic approach is one that takes a "broader view and looks at risk across an entire roadway system. A system-based approach acknowledges crashes alone are not always sufficient to determine what countermeasures to implement, particularly on low volume local and rural roadways where crash densities are lower, and in many urban areas particularly those where there are conflicts between vehicles and vulnerable road users (pedestrians, bicyclists, and motorcyclists)." This approach, in essence, relies on the identification of risk factors that could possibly result in crashes. For example, the existence of different types of medians; horizontal curvature, delineation, or advance warning devices; horizontal curves and tangent speed differential; roadside or edge hazard ratings (potentially including side slope design); and driveway density could be indicators of high-risk locations on the road network. Over time, a transportation agency could work to remove or improve the road characteristics that lead to this risk. FHWA has developed a tool that can be used to conduct systemic safety planning (see http://safety.fhwa.dot.gov/systemic/resources.htm#tool).

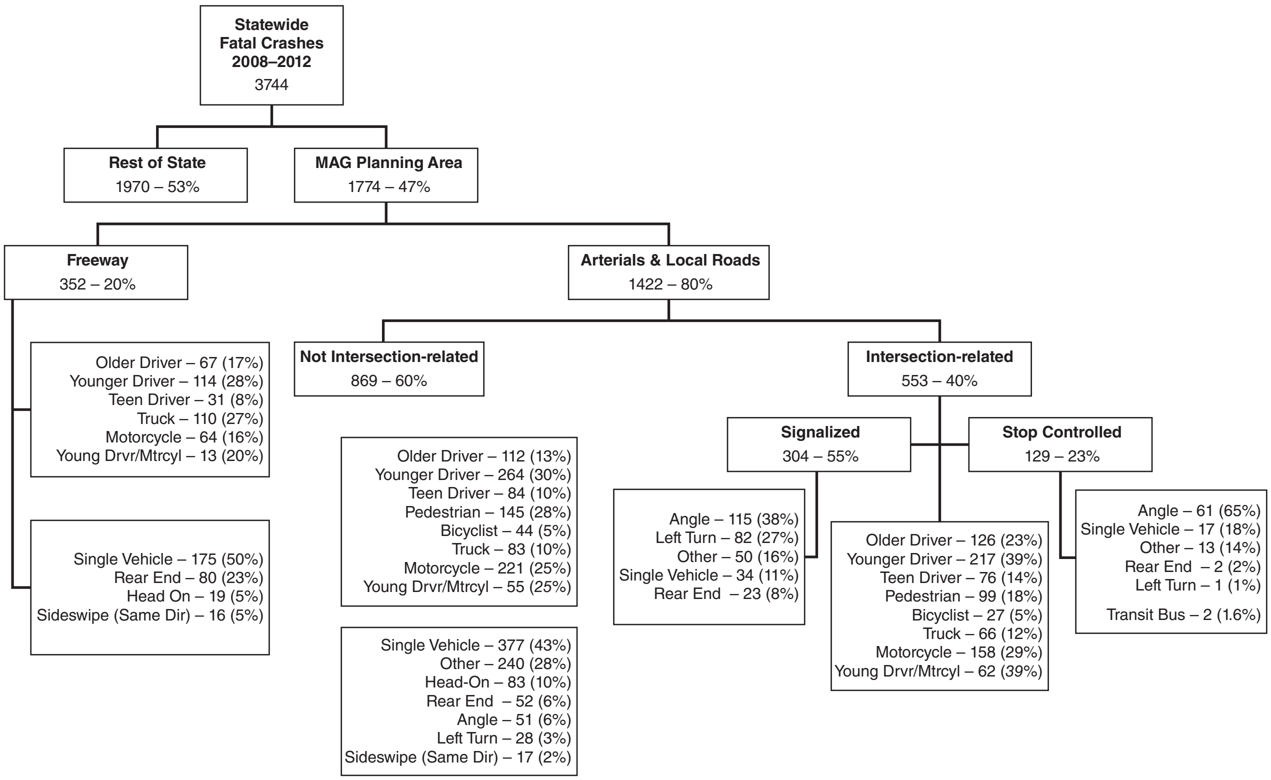
Table 23-6. Possible Performance Measures for Safety-Related Planning
Crash Count-Related Performance Measures:
• Number of total reported accidents. • Number of fatalities. • Number of incapacitating injury crashes. • Number of non-incapacitating injury crashes. • Number of injury crashes. • Number of property damage crashes. • Number of crashes under specific conditions (e.g., head-on, rear-end, sideswipe, angle, rollover, red-light running, run off road, pedestrians, bicycles, motorcycles, school-related, railroad crossing–related, rural, urban, intersection-related, day, night, time of day, wet, ice, snow, etc.). • Crashes in work zones. • Crashes by age, gender, ethnicity.
Normalized Accident Rate Performance Measures:
• Crashes per VMT, PMT. • Crashes per capita or per 100,000 population. • Fatality rate per 1,000 MVMT. • Pedestrian fatality rate per 100,000 population. • Bicycle fatality rate per 100,000 population. • Commercial vehicle crash rate per 100 MVMT. • Crashes per licensed driver. • Crashes per entering vehicle (intersections). • Crashes per unit time (month, year, etc.).
Unit Costs and Cost-Effectiveness:
• Cost per event. • Dollars for DUI enforcement versus alcohol-related crashes. • Dollars for clear zone improvements versus injuries for run-off-road crashes. • Cost per activity. • Dollars per DUI-involved officer. • Dollars per clear zone object removed/protected. • Monetary value of crash reduction.
Alcohol- and Drug-Related Crashes:
• Number of 15- to 20-year-old drivers with BACs 0.02 or higher involved in fatal and injury traffic crashes. • Number of young drivers ages 16 to 21 involved in DWI/drug-related crashes. • Number of male drivers ages 16 to 34 involved in DWI/drug-related crashes.

(*continued*)

Table 23-6. (*Continued*)
Other Performance Measures:
• Crash rates by driver.
• Crashes by age per 10,000 licensed drivers in the age group.
• Number of crash-involved drivers by age.
• Gender of crash-involved drivers.
• Speed as a contributing factor.
• Restraint use by crash-involved drivers.
• Restraint use of all drivers.
• Restraint use of nondrivers.
• Child safety seat use (use/nonuse and correct use).
• EMS response times.
• Cell phone use.
• Enforcement citations (speeding, aggressive driving, traffic violations, etc.).

For the hot spot analysis, once the high-crash locations are identified, analysts begin looking for contributing factors such as roadway condition, driver demographics (age, gender, and others), environmental conditions (time of day, day of week, month of the year, weather conditions, and the like), behavioral characteristics (alcohol involvement and safety belt use), and type of vehicle involved (including passenger vehicles, large trucks, and motorcycles). Figure 23-5 shows an example of the safety challenges facing the Phoenix metropolitan area, prepared by the Maricopa Association of Governments (MAG), the region's metropolitan planning organization. [MAG, 2015] A regional crash database,

Figure 23-5. Crash Tree of Fatal Crashes in the Phoenix Planning Area, 2008–2012

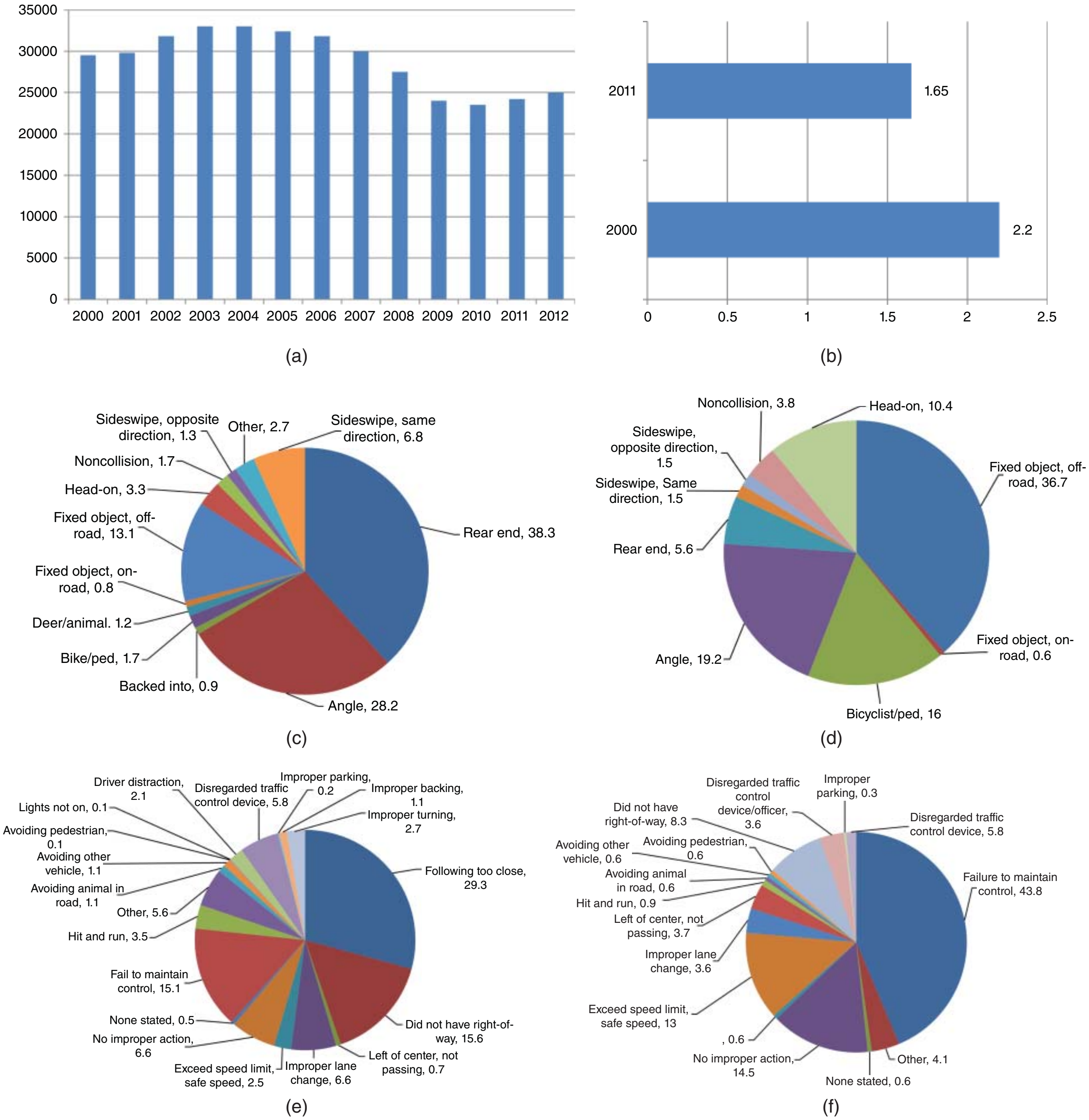


Source: MAG, 2015

called the Regional Transportation Safety Information Management System (RTSIMS), was used to summarize the crash data, with the primary data coming from the state department of transportation's crash database. MAG also compared crash statistics and safety spending among different cities that planners considered to be peers.

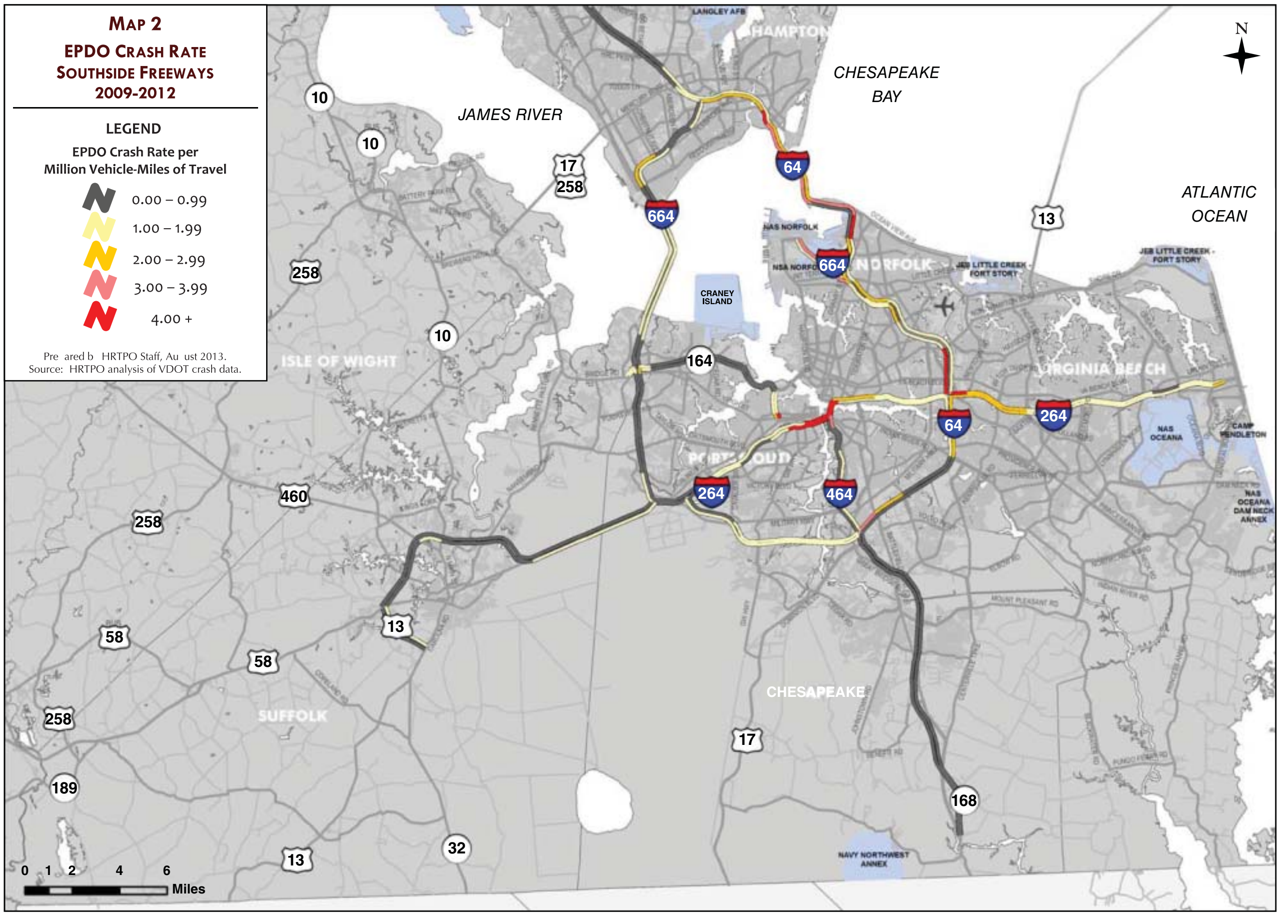
The Hampton Roads Transportation Planning Organization, the MPO for the Hampton Roads (Virginia) metropolitan area, also analyzed the safety characteristics of its region. [HRTPO, 2013] Figures 23-6 and 23-7 show the types of data and information that were part of this analysis. Based on the analysis of such data, the HRTPO concluded that, "Most fatal crashes in the Hampton Roads area are primarily caused by a small number of factors, including drivers traveling under the influence of alcohol and speeding. Many fatal crashes involve more than one of these factors, such

Figure 23-6. Portraying the Safety Problem in Hampton Roads, VA: (a) Annual Crashes, 2000–2012; (b) Crash Rate (per 100 million vehicle miles traveled), 2000–2011; (c) Crashes by Cause, Percent, 2010–2012; (d) Fatal Crashes by Cause, Percent, 2010–2012; (e) Hampton Road Crashes by Primary Driver Action, 2010–2012; (f) Fatal Crashes by Primary Driver Action, 2010–2012.



Source: HRTPO, 2013

Figure 23-7. Portraying the Crash Rate on Key Highways in Hampton Roads, Virginia



Source: HRTPO, 2013

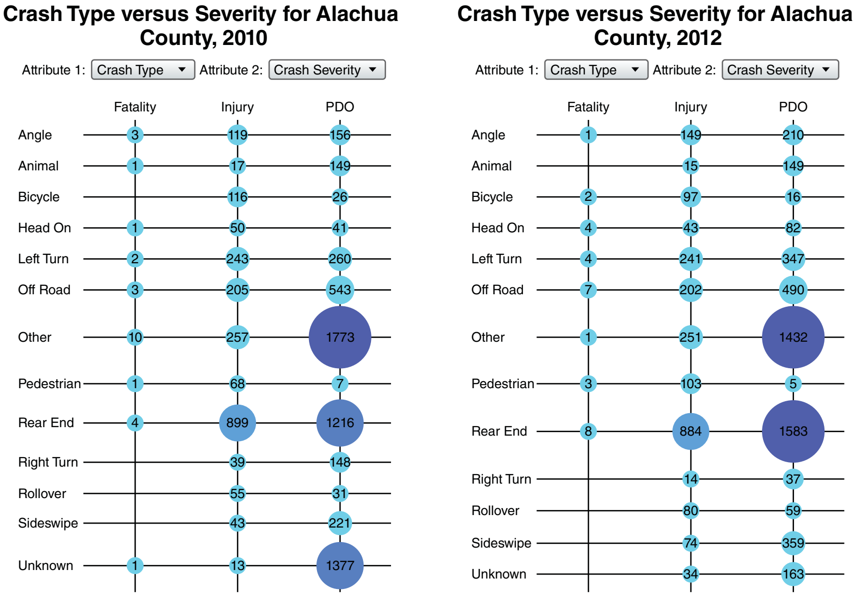
as drivers traveling at a high rate of speed, under the influence, and not wearing safety belts. The number of fatalities involving motorcycle users, bicyclists, and pedestrians is also highly overrepresented compared to their amount of travel." [HRTPO, 2013]

By presenting the data to show the overall safety picture and to identify the most important contributing factors, transportation and safety stakeholders can develop programs and strategies targeting the most important causal factors of crashes—for example, enforcement and education strategies aimed at impaired or distracted drivers.

Educating the public and elected officials is critical to the success of any safety program. In many cases, this is not an easy task because truly effective strategies for reducing fatalities and serious crashes often focus on changing traveler behavior, something that is very difficult to do. In addition, although data such as that shown in Figures 23-6 and 23-7 are important for transportation and safety professionals, they can become overwhelming to elected officials and the general public. In such cases, and where appropriate, safety planning needs to define the problems in understandable and simple terms. (Note: Safety projects that are education-based as well as enforcement projects are found in the Highway Safety Plan and funded as part of the Section 402 program.)

Figure 23-8 from Gainesville, Florida, illustrates one way of showing in very simple terms the types of crashes that are of most importance to a county. Another possible strategy is to compare the societal costs of safety and congestion. For example, the Texas Transportation Institute (TTI) annually produces the list of the most congested cities in the United States. This list receives a great deal of attention, with many public officials declaring that government needs to do better. In most cities, however, the societal costs are far greater for crashes than for congestion. Meyer [2005] estimated the societal cost of crashes in Atlanta in 2001 to be $3.3 billion, compared to congestion costs of $2.0 billion. Comparisons in Kansas City, Missouri, and Houston, Texas, showed similar relationships. By using a measure that can be easily grasped and compared with the benefits of other programs (which is done only for public consumption), officials can gain an understanding of the magnitude of the problem they are facing.

Figure 23-8. Illustration of Crash Type versus Severity for Alachua County, Florida, 2010 and 2012



Source: Metropolitan Transportation Planning Organization for the Gainesville Urbanized Area, 2013

Another strategy for educating elected officials and the public has been to compare crime statistics with those of crashes. Using this method, known as the *crash clock*, jurisdictions typically find that the number of deaths and injuries associated with traffic crashes is greater than for crime. While aggregate measures can be an effective way of summarizing the safety problem, other methods can be effective as well, such as illustrating the consequences of impaired driving or focusing on how individual lives can be affected by unsafe driving.

Data are used to identify high-crash corridors, road segments, and hot spots; analyze impacts; evaluate outcomes; and prioritize and select programs and projects. Monitoring performance data can also lead to mid-project implementation corrections to ensure the most effective use of resources. The most obvious data used are those gathered as a result of a crash, but other types may also be beneficial, such as enforcement data (citations, convictions, experience, and observations), roadway (location) data, exposure data, survey data from elected/appointed officials and the public, road safety audits/assessments, and research data.

Safety planning is a data-driven process; however, data quality and availability are often serious challenges to the planning process for the following reasons.

- *Underreporting*—Minor crashes are seldom reported and investigated.
- *Local road*—State DOTs collect crash data on state highways and other major roads; local roads are often underrepresented in the crash database.
- *Field coding*—Filling out police accident reports is often not a priority at crash scenes; officers are focused on treating the injured and returning traffic flow to normal.
- *Reference system*—Different geo-referencing systems are often used for locating crashes, even among jurisdictions in the same state.
- *Inconsistencies*—State databases contain different variables and are presented in different formats.
- *Timeliness*—Data are often two to three years old, if not more.
- *Accessibility*. Some states and regions do not share data with other agencies for fear of liability.

Knowledge of collection methods, methods used to summarize and report the data, quality control procedures, and statistical accuracy is helpful in determining what data and analytical methods should be used.

Table 23-7. Ranking by MPOs and State DOTs of Most-Used Sources of Data for Safety-Related Transportation Planning		
Data Sources	**MPO**	**State DOT**
Vehicle crashes	1	1
Vehicle miles traveled	2	4
Roadway inventories	3	2
Injury/fatality	4	3
Pedestrian crashes/injuries	5	6
Bicycle crashes/injuries	6	7
Property damage crash	7	8
Air quality/emissions	8	9
Air transport crashes	9	10 (tie)
Water navigation crashes	10 (tie)	15
Transit/paratransit incidents	10 (tie)	10 (tie)
Safety belt/restraint use data	12	14
Emergency medical response	13	16
DUIs	14	12
Rail crashes	15	5
Accident investigation	16	13

Source: Washington et al., 2006, Reproduced with permission of the Transportation Research Board

A number of data sources are useful for transportation safety planning. Table 23-7, for example, shows the results of a survey of state DOTs and MPOs on the types of safety-related data that are most often used in transportation planning. Not surprisingly, vehicle crash data, roadway inventories, and injury data are some of the most important data items for both state DOTs and MPOs. The minimum data elements for safety planning should include crash location, contributing factors, driver characteristics and histories, the manner of collision, crash severity, type of vehicle, exposure data (vehicle miles of travel), and use of safety devices. These data elements are usually found in the following multiple locations:

Congestion Management System/Process Data. Transportation management areas (TMAs) are required to maintain a congestion management process (CMP) to evaluate transportation investment alternatives. In many states the CMP includes an extensive database of roadway classification, geometry, and overall traffic volumes and flows. This can be useful in calculating crash rates or for other safety analysis.

Crowd Sourcing. Modern communication technologies allow planners to reach a large number of individuals through smart phone apps. Crowd sourcing is a process of asking as many individuals as are part of the network where safety problems exist. The input is not statistically significant given the bias in terms of the narrow sample of the population who responds, but it does provide some sense of where safety planners might want to look.

Driver History. Driver histories are recorded for all licensed drivers and unlicensed drivers involved in a crash. The files contain information on the demographics and license status/restrictions, convictions, and sometimes the driver history of crashes. These data can be used to scope and target programs on specific types of driver violations (such as DUI, speeding, red light running, and the like). These data provide only a recent snapshot because data on convictions and crashes (if present at all) are often purged after some time period.

Fatality Analysis Reporting System (FARS). FARS was established in 1975 to collect fatal crash data. The system contains high-quality data on all vehicles and occupants involved in fatal crashes. Queries can be run online and archival files can be obtained. City and county codes for each county in the United States are recorded in the database.

Police Crash Reports. The first step in any safety analysis is examining police-reported crashes. Crash reports provide a range of data concerning the specifics of the incident, contributing conditions, and status of those involved. Many states have adopted uniform report formats for all crashes reported in the state; others still have police agency–specific forms. One of the new technologies that could improve the quality and timing of these data is the use of computers, global positioning systems, and uplink capabilities in the police car at the crash site.

Population Census Files. The U.S. Census Bureau maintains files on gender, age, and ethnicity within political subdivisions. The data can also be used as denominator or exposure data, particularly for identifying road-user problems, for example, young drivers as a percent of the population in comparison to percent of fatal and injury crashes.

Roadway Speeds and Operating Performance. Many states and most major metropolitan areas have traffic operations centers that provide 24-hour surveillance of road operations. Most of these centers use video or imaging technology that permits the collection of real-time data. These data can be used to identify traffic conditions when crashes occur, and, when archived, the data can provide historical information on changing road performance on the network.

Roadway Inventory, State Highway System. In most states, the state DOT maintains a roadway inventory database that contains data on road segments (for example, number of lanes and shoulder width and type). A limited number of states have curve and grade information or an intersection/interchange inventory. Many states use video logging for collecting such data, which could also be used to conduct a safety audit along state routes. A federally required Highway Performance Monitoring System (HPMS), which collects more complete inventory data on sample sections on the state's road network, could be used to get a good understanding of the safety performance of different types of roads, especially if the sample size is expanded to include more sample segments.

Truck Crash Statistics. The Motor Carrier Management Information System (MCMIS) is managed by the Federal Motor Carrier Safety Administration (FMCSA) with data fed into it by state agencies and motor carriers. It is the most comprehensive truck safety database in the United States. The files contain information on vehicle registration, crashes, roadside inspections, compliance with federal regulations, and enforcement actions.

Regional Travel Demand Model Data. MPOs located in air-quality nonattainment areas must conduct an air-quality conformity analysis to show that investments in their plans do not deteriorate air quality. This is usually accomplished through modeling efforts, resulting in systemwide estimates of current and future traffic volumes and flows. Data could be used to calculate crash rates or for other safety analysis.

Roadway Inventory, Local Jurisdictions. Local road inventory databases are generally less complete than state databases, with the data elements often maintained by different departments (public works, traffic, and maintenance). Local jurisdictions sometimes have supplemental data on sidewalk and crosswalks, bike paths, and bus stops. The linkage between these data and the road inventory data, however, is often not well established. Table 23-8, from the *Highway Safety Manual*, shows the type of inventory data used to predict the safety benefits of any particular countermeasure implemented in a project. As can be seen, there are a lot of factors (and thus a lot of data) that can be included in a safety analysis. See also Lefler [2014] for a more detailed discussion of the data collection activities of local agencies.

Traffic Volumes. Traffic counts are usually available at many locations on the state highway system, from which average annual daily traffic (AADT) is estimated. The collection of the data for AADT estimates occurs at permanent (full-time) counters and *short counts* are done on a two- to three-year cycle. Truck percentages and volumes are usually included in this database, but they are generally based on fewer actual counts, so the data are not as extensive. In many states, the number of permanent count stations is limited by budget considerations. There is a similar problem with short counts, which may vary from year to year. Many agencies supplement counts with volume estimates from either their travel-demand models or the roadway inventory databases previously described. While the quality and accuracy of these estimates vary widely, they do provide analysts with a more complete set of data on the roadway system.

Vehicle Registration Data. Registration data are recorded for every vehicle licensed in a state. The file includes information on owners, vehicle types, vehicle identification numbers (VINs), and a variety of other data related to the vehicle. Vehicle registration data are sometimes used as the *denominator* or *exposure* data, for example, the number of crashes per total number of registered vehicles.

Other Safety Data. Some enforcement agencies maintain ticket citation (as opposed to conviction) data. These data may be useful for problem identification and for monitoring the degree to which the courts are following through with penalties and fines. Speed surveys are maintained by some state and local agencies, and observed occupant restraint (shoulder belt) use data have been collected by all states since 1998. NHTSA publishes year-by-year comparisons for each state, but the data only represent daytime and front-seat belt use. Land-use data can also be used to identify places with special safety concerns, such as near schools, senior centers, or parks.

Table 23-8. Data Used for Predicting Safety Countermeasure Benefits from the Highway Safety Manual			
Variables	**Chapter 10 Rural Two-Lane, Two-Way Roads**	**Chapter 11 Rural Multilane Highways**	**Chapter 12 Urban and Suburban Arterials**
Roadways Segments			
Area type (rural/suburban/urban)	X	X	X
Annual average daily traffic volume	X	X	X
Length of roadway segment	X	X	X
Number of through lanes	X	X	X
Lane width	X	X	
Shoulder width	X	X	
Shoulder type	X	X	
Presence of median (divided/undivided)		X	X
Median width		X	
Presence of concrete median barrier		X	
Presence of passing lane	X	X	
Presence of short four-lane section	X		
Presence of two-way-left-turn lane	X		X
Driveway density	X		
Number of major commercial driveways			X
Number of minor commercial driveways			X
Number of major residential driveways			X
Number of minor residential driveways			X
Number of major industrial/institutional driveways			X
Number of minor industrial/institutional driveways			X
Number of other driveways	X		
Horizontal curve length	X		
Horizontal curve radius	X		
Horizontal curve superelevation	X		
Presence of spiral transition	X		
Grade	X		
Roadside hazard rating	X		
Roadside slope		X	
Roadside fixed-object density			X
Roadside fixed-object offset			X
Percent of length with on-street parking			X
Type of on-street parking			X
Presence of lighting			X
Intersections			
Area type (rural/suburban/urban)		X	X
Major-road average daily traffic volume	X	X	X
Minor-road average daily traffic volume	X	X	X
Number of intersection legs	X	X	X
Type of intersection traffic control	X	X	X
Left-turn signal phasing (if signalized)	X		X
Presence of right turn on red (if signalized)			X
Presence of red light cameras			X
Presence of median on major road		X	
Presence of major-road left-turn lane(s)	X	X	X

Table 23-8. (*Continued*)			
Variables	**Chapter 10 Rural Two-Lane, Two-Way Roads**	**Chapter 11 Rural Multilane Highways**	**Chapter 12 Urban and Suburban Arterials**
Presence of major-road right-turn lane(s)	X	X	X
Presence of minor-road left-turn lane(s)		X	
Presence of minor-road right-turn lane(s)		X	
Intersection skew angle	X	X	
Intersection sight distance	X	X	
Terrain (flat vs. level or rolling)		X	
Presence of lighting		X	X

Source: AASHTO, 2010, Reproduced with permission of AASHTO

Beware the Caveats

- Reporting thresholds may differ by jurisdiction, so exercise caution when combining state and local data.
- Analyzing FARS data only produces small, unrepresentative samples, and there are problems associated with combining crash/vehicle/person variables.
- Be careful of multiyear analysis of Motor Carrier Management Information System data. The data are much improved since 2004.
- Remember, AADT is an estimate, not an actual count for most roadway segments. Local jurisdictions often do not have AADT, only intersection turning counts.
- Beware of using vehicle registration data as a measure of exposure because it does not include annual mileage per vehicle, and the odometer may contain errors.
- Speed surveys are generally taken at special locations and do not constitute a random sample for that roadway type or jurisdiction.

Although it is important to continually improve data quality and availability, progress in enhancing transportation safety can occur even without good data. For example, if crash hot spots data are not available, interviews with law enforcement officers, truckers, local engineers, and others may reveal crash problems based on observation and experience. A growing number of jurisdictions are using road safety audits or assessments to proactively identify potential safety problems and develop effective countermeasures and solution strategies. See FHWA's road safety audit website at http://safety.fhwa.dot.gov/rsa/ for further information on road safety audits.

In addition, in the United States, states are required by NHTSA to develop a strategic traffic records improvement plan and must have a traffic records coordinating committee (TRCC). The plans are a key step in integrating the various sources of data for improvement and maintenance.

Best Practice: The Houston/Galveston Area Council (H-GAC) and the Southeast Michigan Council of Governments (SEMCOG) are able to integrate, analyze, and display their crash data. They disaggregate by type of crash and safety issue, for example: truck/pedestrian/bicyclist safety, location (hot spots), impaired driving, and the like. They also (1) provide safety services, such as training for local engineers, mayors and judges, and school education programs, (2) form partnerships with government at all levels, the private sector, nonprofits, and community groups, (3) review project designs for safety, and (4) encourage their constituents to include safety in designs.

Figures 23-9 and 23-10 show how data analysis can be used to assess the safety characteristics of a project moving through the project development process. [Kentucky Transportation Cabinet, undated]. Planning at the project level and in particular as part of an environmental impact statement is usually more site-specific, and the analysis of crash

Figure 23-9. Crash Types for High and Potentially High Crash Segments, Kentucky

High Crash Segments

Ford Parkway
MP 0.000–MP 3.702 (Lyon County)

Crash Type	Crashes in Segment	% in Segment	Crashes on Parkway	% on Parkway
Collision With Animal	16	38%	94	27%
Collision With Fixed Object	15	36%	121	34%
Ran Off Roadway	5	12%	49	14%
All Other Types	6	14%	90	25%

Ford Parkway
MP 3.702–MP 5.610 (Lyon County)

Crash Type	Crashes in Segment	% in Segment	Crashes on Parkway	% on Parkway
Collision With Animal	9	28%	94	27%
Collision With Fixed Object	14	44%	121	34%
Ran Off Roadway	3	9%	49	14%
All Other Types	6	19%	90	25%

Breathitt Parkway
MP 41.002–MP 42.437 (Hopkins County)

Crash Type	Crashes in Segment	% in Segment	Crashes on Parkway	% on Parkway
Collision With Animal	6	6%	156	22%
Collision With Fixed Object	10	10%	134	19%
Rear-end	70	69%	154	21%
All Other Types	15	15%	277	38%

Segments with % of crashes higher than average for respective Parkway

Potentially High Crash Segments

Ford Parkway
MP 24.435–MP 31.581 (Hopkins County)

Crash Type	Crashes in Segment	% in Segment	Crashes on Parkway	% on Parkway
Collision With Animal	17	23%	94	27%
Collision With Fixed Object	30	40%	121	34%
Ran Off Roadway	14	19%	49	14%
All Other Types	14	19%	90	25%

Breathitt Parkway
MP 34.371–MP 37.070 (Hopkins County)

Crash Type	Crashes in Segment	% in Segment	Crashes on Parkway	% on Parkway
Collision With Animal	12	19%	156	22%
Collision With Fixed Object	16	26%	134	19%
Rear End In Traffic Lanes Both Vehicles Moving	7	11%	154	21%
All Other Types	27	44%	277	38%

Figure 23-9. (*Continued*)

Breathitt Parkway
MP 42.437–MP 44.337 (Hopkins County)

Crash Type	Crashes in Segment	% in Segment	Crashes on Parkway	% on Parkway
Collision With Animal	15	16%	156	22%
Collision With Fixed Object	10	11%	134	19%
Rear End	37	40%	154	21%
All Other Types	31	33%	277	38%

Breathitt Parkway
MP 55.003–MP 62.637 (Webster County)

Crash Type	Crashes in Segment	% in Segment	Crashes on Parkway	% on Parkway
Collision With Animal	21	23%	156	22%
Collision With Fixed Object	23	25%	134	19%
Ran Off Roadway	26	29%	107	15%
All Other Types	21	23%	324	45%

Breathitt Parkway
MP 62.637–MP 65.305 (Webster County)

Crash Type	Crashes in Segment	% in Segment	Crashes on Parkway	% on Parkway
Collision With Animal	7	19%	156	22%
Collision With Fixed Object	11	31%	134	19%
Ran Off Roadway	4	11%	107	15%
All Other Types	14	39%	324	45%

Segments with % of crashes higher than average for respective Parkway

Source: Kentucky Transportation Cabinet, undated

reductions is related to specific project characteristics. [FHWA, 2011] As noted in chapter 4 on environmental analysis, a first step in conducting a formal environmental impact study is to describe the purpose and need for the project in the corridor. This needs statement, in many cases, would likely include safety as a motivation for project improvements. Table 23-9 shows the different ways safety could be included in an environmental analysis needs statement.

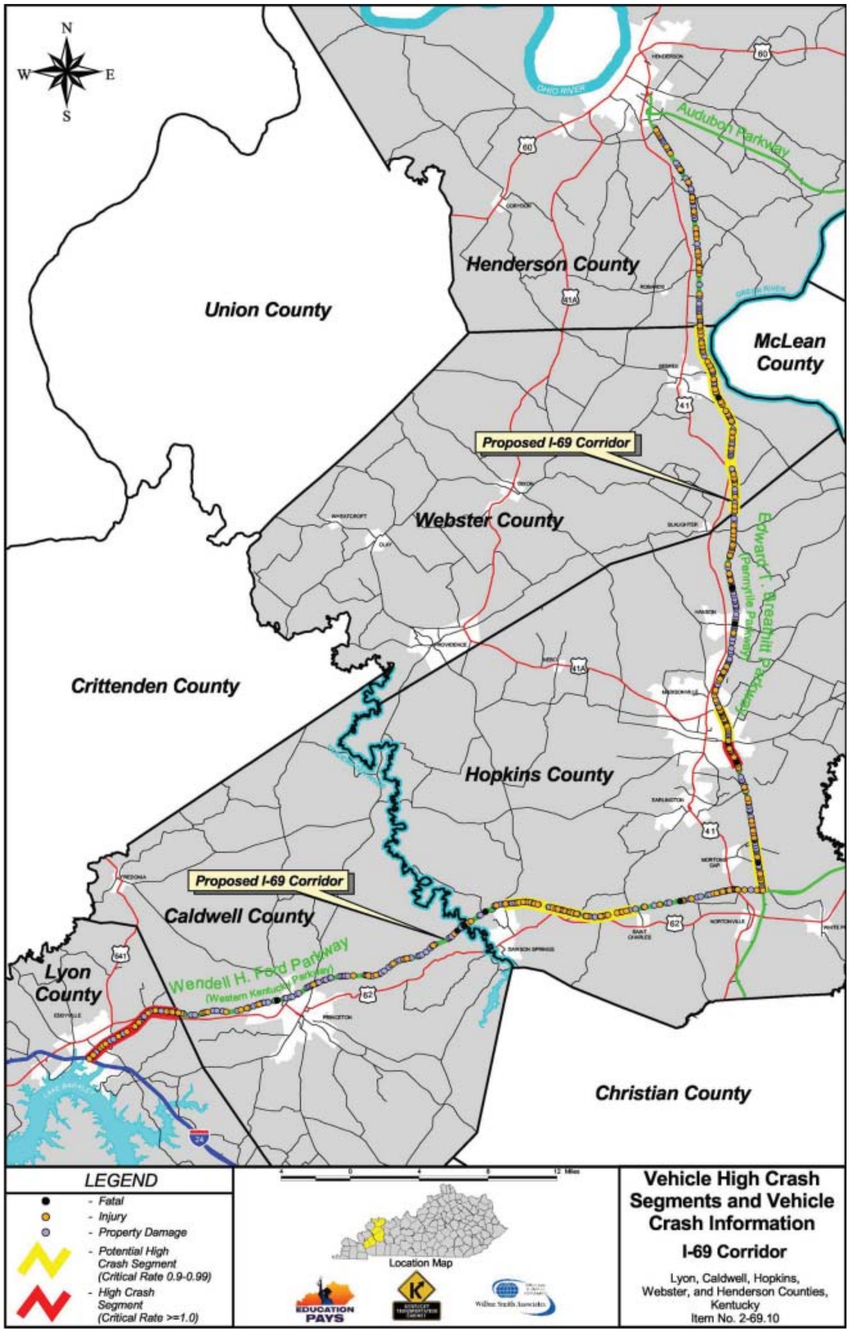
E. Analyze and Evaluate Transportation Safety

1. Identify Safety Countermeasures or Projects

Safety projects can be standalone projects that are undertaken specifically to “fix” a safety problem (for which there are several federal and state funding programs), or more commonly, safety-oriented actions can be taken as part of any project to enhance its safety characteristics. Safe movement of people and vehicles is the most important criterion for facility design, and every design manual used by transportation engineers begins by talking about safety. A large number of projects are eligible for federal funding. For example, the following types of projects are eligible for Highway Safety Improvement Program (HSIP) funding from the U.S. federal government:

- Intersection safety improvements.
- Pavement and shoulder widening.
- Installation of rumble strips or other warning devices.
- Improving user awareness of and compliance with intersection and interchange traffic control devices.

Figure 23-10. Crash Types for High- and Potentially High-Crash Segments, I-69, Kentucky



Source: Kentucky Transportation Cabinet, undated

- Pedestrian and bicyclist safety improvements.
- Safety improvements for people with disabilities.
- Rail-roadway grade crossing safety improvements.
- Traffic calming features.
- Roadside hazard elimination.
- Installation, replacement, and improvement of highway signage and pavement markings.
- Emergency vehicle priority control.

Table 23-9. Information and Data to Include in Purpose and Needs Statements for Safety-Focused Projects	
Type of Information	**Example Information to Consider for Inclusion**
Roadway performance	Comparison of roadway crash rates to expected crashes for similar facility types given traffic volumes to identify the existence of a safety problem (see *Highway Safety Manual* for analysis techniques). Crash rates for multiple types of road users.
Contributing crash factors	Analysis of crash history to indicate predominance of certain crash types.
Multimodal safety issues	Safety issues for specific types of road users, including pedestrians, bicyclists, freight vehicles, and transit vehicles.
Public perceptions	Safety issues raised by the public as being of concern.
Results of road safety audits (RSAs)	RSA results indicating any findings regarding deficiencies/opportunities for improving safety performance.

- Installation of traffic control or other warning devices at high-crash locations.
- Transportation safety planning.
- Work zone safety.
- Installation of guardrails, barriers, and crash attenuators.
- Improvements for high-risk rural roads.
- Roadway geometric improvements.
- Road safety audits.
- Truck parking facilities.
- Any systemic safety improvements.

For transit, most safety measures focus on making the design of rider/vehicle interfaces safe as well as the operating strategies. Thus, one can find in the literature great attention to how one safely designs the movement of pedestrians near transit lines (see [Korve et al., 2001; Cleghorn et al., 2009; Fitzpatrick et al., 2015; and Roberts et al., 2015]).

It is beyond the scope of this chapter to describe all of the safety actions that can be considered as part of the transportation planning process. Every state has an SHSP, which provides a description of the types of engineering and behavioral actions the state is taking to reduce crashes. In addition, the following references are useful for providing some sense of what types of projects and actions can be considered to improve transportation safety.

Federal Highway Administration. 2010. *Transportation Planners Safety Desk Copy* See http://tsp.trb.org/assets/FR1_SafetyDeskReference_FINAL.pdf.

Federal Highway Administration. Website, "Transportation Safety Planning (TSP)."See http://safety.fhwa.dot.gov/tsp/#pub.

FHWA. 2008. "Guidance Memorandum on the Consideration and Implementation of Proven Safety Countermeasures." See http://safety.fhwa.dot.gov/legislationandpolicy/policy/memo071008/.

Governors' Highway Safety Administration, 2013. *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices*. See http://www.ghsa.org/html/publications/countermeasures.html.

Insurance Institute for Highway Safety, Website. "Highway Safety Topics." See http://www.iihs.org/iihs/topics.

National Highway Traffic Safety Administration (NHTSA). Website. "Bicycles" (http://www.nhtsa.gov/Bicycles) and "Pedestrians" (http://www.nhtsa.gov/Pedestrians).

Transportation Research Board. 2004–2006. NCHRP Report 500 series: *Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*. Washington, DC: Transportation Research Board.

Useful examples from states and MPOs:

Cheyenne, WY. *Transportation Safety Plan*. See http://www.plancheyenne.org/wp-content/uploads/2012/12/CheyenneTransportationSafetyManagementPlan.pdf.

Hampton Roads Regional Safety Study, PART II: *Crash Countermeasures*. See http://www.hrtpo.org/uploads/docs/HR%20Regional%20Safety%20Study%202013-2014%20PART%20II%20Final%20Report.pdf.

New Jersey DOT. 2014. *Pedestrian Safety Action Plan Toolbox*. See http://www.dvrpc.org/transportation/safety/pdf/NJ_PedestrianSafetyActionPlan-Toolbox.pdf.

2. Analysis

The use of analysis tools for assessing the consequences of different actions is the core technical component of the transportation planning process. However, analyzing the relative effectiveness of alternative safety strategies is challenging because of the difficulties associated with crash data, as discussed in the preceding section. In addition, many of the strategies that target changing driver behavior do not have much evidence of their effectiveness in actually changing behavior. It is difficult, therefore, to estimate the benefits of specific actions. The literature does provide some guidance on the effectiveness of several of the safety strategies that planners and safety officials might want to consider. Specifically, the NCHRP 500 report series of guidebooks [Transportation Research Board, 2004–2006] and the Governors' Highway Safety Association's (GHSA) *Countermeasures that Work* [2013] provide approaches for estimating the effectiveness of different countermeasures. Research is currently under way to develop crash modification factors (CMFs) for engineering and behavioral strategies. [Bonneson and Zimmerman, 2006; Harkey et al., 2008] The FHWA supports a website that introduces crash modification factors (http://safety.fhwa.dot.gov/tools/crf/resources/cmfs/), as well as a crash modification factor clearinghouse website (http://safety.fhwa.dot.gov/tools/crf/resources/).

Currently, the most common approach to analyzing the safety benefits of road projects is to estimate the decrease in the number of crashes (by type) that will occur because of the countermeasure, and then use benefit/cost analysis to determine the relative desirability among the alternatives being considered (see chapter 7 on evaluation techniques). Two methods are used to estimate crash reduction. The first uses safety performance functions (SPFs) that have been developed based on historical data and their correlation to road characteristics. An example of a safety performance function for freeways in Virginia is Equation 23-1: [Hampton Roads Transportation Planning Organization, 2014]

$$\text{Predicted crash frequency per year per direction} = e^{\alpha}\, x\, (\textit{One Direction AADT})^{\beta} \times \textit{Segment Length} \tag{23-1}$$

The values of α and β are estimated based on historical data on crashes on freeways in the Commonwealth of Virginia. In this case the crash frequency can be estimated as a function of the AADT and segment length.

Another example of a safety performance function from the *Highway Safety Manual* [AASHTO, 2010] focusing on vehicle-pedestrian crash frequency per year is shown in Equation 23-2. In this case,

$$\begin{aligned}\textit{Predicted vehicle-pedestrian crash frequency per year}\\ = \exp[\mathrm{a} + (\mathrm{b}\,x\,\ln(\textit{Total AADT}))\\ + \left(\mathrm{c}\,x\,\ln\left(\frac{\textit{Minor AADT}}{\textit{Major AADT}}\right)\right) + (\mathrm{d}\,x\,\ln(\textit{PedVol}))\\ + (\mathrm{e}\,x\,n_{lanes})]\end{aligned} \tag{23-2}$$

Total AADT is the sum of the major and minor road AADT; PedVol is the total daily number of pedestrians crossing the intersection, and n_{lanes} is the maximum number of lanes a pedestrian would have to cross the intersection. The coefficients, that is, a, b, c, d, and e, are found in the *Highway Safety Manual.*

The second method for estimating crash reduction uses Crash Modification Factors (CMFs). A CMF is "a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site." For example, a CMF of 0.70 means 70 percent of the existing crashes will result from implementing a countermeasure. For many high-crash locations, more than one treatment may be implemented at the same time. Table 23-10 shows an example of crash reduction factors used by the Denver Regional Council of Governments (DRCOG) for determining the benefits of projects to be considered for the regional transportation improvement program (TIP).

Table 23-10. Crash Reduction Factors, Denver Regional Council of Governments		
Improvement Characteristics	**Percentage Reduction in Relevant Crashes (if applicable crash locations)**	**Example Relevant Crash Types**
Intersections		
New traffic signal	20%	Right-angle, turns
Upgrade traffic signal (heads)	20%	Rear-end, red light run
Add new approach turn lanes (either left or right)	25%	Rear-end
Add accel/decel lane	25%	Rear-end, sideswipe
Convert to roundabout	40%	Right-angle
Convert to interchange	40%	Right-angle
Increase turn radii	15%	Turn crashes
Railroad		
Automatic gate	75%	Vehicle-train
Grade separation	100%	Vehicle-train, rear-end
Roadside/Bridges		
Guardrail-install/upgrade	60% fatal, 40% injury	Run off road
Shoulder widening/addition	20%	Run off road, overtake ped/bike
Bridge widening	40%	Bridge
Remove fixed objects	50% fatal, 15% injury	Fixed object
Separated bicycle/pedestrian path	80%	Overtake ped/bike
Roadways		
Curve reconstruction	50%	Run off road, head-on
Vertical realignment	45%	Head-on, limited sight
Median barriers	60% fatal, 10% injury	Head-on
Raised median	40%	Turn crashes, turn-related rear-ends
Climbing/passing lane	15%	Passing, rear-end
Lane widening	20%	Sideswipe (multilane)
Ramp geometric reconstruction	25%	Ramp
Widen from 2-lane to 4-lane road	30%	Rear-end, head-on
Continuous center-left turn lane	30%	Rear-end
Shoulder rumble strips	80%	Run off road
Centerline rumble strips	25%	Head-on, sideswipe
Pave shoulder to full width	10%	Run off road
Other		
Lighting improvement	90%	Night-time crashes
Close median opening	30%	Turn crashes

Notes:

[1]Crash reduction factors are for TIP project scoring guidance only.

[2]The factors are not meant to imply precise predictions of eliminated crashes.

[3]Rates should be applied only to specific applicable sites within the project area.

[4]Rates should only be applied to relevant crash types and crash directions addressed by the improvement.

[5]Do not double-count similar improvement types or eliminated crashes.

[6]Crash reduction factors may be applied to improvement and crash types not shown on this table; however, applicant must provide justifying documentation.

Source: DRCOG, 2015

In addition to the simple reduction factors and performance functions described, many other analysis tools can be used for conducting a safety study. Some tools are oriented toward hot spots that are more specific than corridor-based models and can be used to analyze the impact of geometric deficiencies. Many of these have been developed for use in project design, but could also be used for planning purposes. Some of these tools include interactive- design software packages that allow project designers to modify designs for improved safety purposes (such as the Interactive Highway Safety Design Model [IHSDM], the Roadside Safety Analysis Program, SafeNET, and SafetyAnalyst). Others represent expert systems that provide a data analysis capability and lead the user to identify possible countermeasures, such as the Pedestrian and Bicycle Accident Analysis Tool (PBCAT) and the Pedestrian Safety Guide and Countermeasures (PEDSAFE). All of these tools are described in greater detail in Washington et al. [2006] and Booz, Allen, and Hamilton [2013].

With respect to safety analysis for transit, the FTA has developed uniform guidance on how safety performance and analysis should be undertaken. Since the passage of MAP-21, FTA has been encouraging transit agencies to develop a safety management system (SMS). An SMS is defined as "an organized approach to managing safety, including the necessary organizational structures, safety goals and performance targets, responsibilities and authorities, accountabilities, policies, and procedures for integrating safety into day-to-day operations." [Ahmed, 2011] It is a process that heavily depends on the use of performance measures. With respect to construction of major facilities receiving federal funds, a recipient agency must develop a Safety and Security Management Plan (SSMP) that addresses such things as: (1) project management commitment and philosophy toward safety and security, (2) integration of safety and security into the project development process, (3) assignment of organizational safety and security responsibilities for the project, (4) safety and security analysis and hazard and vulnerability management processes, (5) development of safety and security design criteria, (6) a process for ensuring qualified operations and maintenance personnel, and (7) construction safety and security management activities.

Ideally, all of the analysis tools described in this section would work hand in hand with travel demand forecasting models and be able to forecast future safety characteristics of the transportation system. However, such tools are only now becoming available. NCHRP Report 546 describes one of the first attempts to develop a traffic analysis zone-based prediction tool for use with a travel demand model. The ITS Deployment Analysis System (IDAS) developed for FHWA provides sketch planning-level forecasts of the safety benefits of various ITS and operational deployments. [FHWA, 2013b] It is hoped that these emerging tools will one day enable safety to be considered explicitly in the outputs of the transportation forecasting process. [Washington et al., 2006]

Evaluation synthesizes the results of an analysis to determine the overall benefits and costs of each alternative. Evaluation leads to identifying the most cost-effective set of projects and strategies prioritized based on measures that indicate which factors are most important when implementing a safety program. Evaluation can also lead to other planning outcomes, such as further studies, proposed regulations, and additional policies that affect traveler behavior. For safety to be considered seriously as part of the decision-making process, safety-oriented criteria must be part of the evaluation criteria used to assess the relative benefits and costs of various actions.

F. Make Safety a Decision Factor

Safety should receive strong consideration when developing STIPs and metropolitan-level TIPs. As illustrated in the following material, several methods are available for doing so. [Park et al., 2016] One of the largest challenges is to prioritize funding for noninfrastructure projects that are not part of the TIP or STIP, such as projects for enforcement and safety education. Often, these are found in separate safety programs.

There are many examples of how safety can be incorporated into the evaluation and prioritization process. The two most common approaches include conducting a benefit/cost analysis and assigning points to each project according to the safety benefits that are likely to accrue. The benefit/cost analysis is straightforward and simply evaluates each project by assigning monetary value to the reduction in crashes expected due to the implementation of countermeasures (the benefits) as compared to the expected capital costs of the project. Chapter 7 describes how this analysis is conducted correctly.

The second approach entails assigning points, out of a total sum of points available to a project, for the project's safety benefits. For example, each project might earn 100 points corresponding to how well it achieves the different planning goals. Of these 100 points, a maximum of 20 points could be allocated for safety benefits. Each project being considered for the TIP could have a maximum of 20 percent of its ranking due to safety benefits. The following examples illustrate the range in approaches available for establishing project priorities that include safety.

In Denver, DRCOG uses the information from its analysis to assign points to each safety project. Table 23-11 shows the number of points that can be allocated to roadway operational improvement and roadway widening projects, and the possible points for safety benefits. A similar set of criteria was used for new bicycle and pedestrian facilities, although the safety factor was estimated differently (see Table 23-12).

Table 23-11. Assigning Safety Points for Highway Projects, Denver, Colorado

Roadway Operational Improvements		
Evaluation Criteria	**Points**	**Scoring**
Congestion	0–12	Up to 12 points based on the current degree of congestion (V/C ratio) on the existing roadway.
RTP Emphasis Corridors	0–3	3 points to projects on emphasized freeways or major regional arterials. 2 points to projects on emphasized principal arterial segments.
Crash Reduction (Safety)	0–5	Based on the project's estimated crash reduction and weighted crash rate, up to 5 points will be awarded.
Delay reduction	0–12	Based on the project's current estimated vehicle hours of travel (VHT) reduced during the AM peak hour plus the PM peak hour, 12 points will be awarded to projects reducing 200 VHT or more during the two peak hours; 0 points to projects reducing 20 VHT or less.
Cost-effectiveness	0–10	Based on the project's current estimated cost per vehicle hour of travel (VHT) reduced during the AM peak hour plus PM peak hour: 10 points will be awarded to projects with a cost per VHT reduced of $10,000 or less.
Transportation system management	0–5	1 point will be awarded for such things as provision of raised, depressed, or barrier medians for the entire length of the project; access consolidation (driveways, side streets); signal interconnection; provision of ITS infrastructure; provision of infrastructure that implements an approved incident management plan.
Multimodal connectivity	0–15	Various points for such things as considering transit, pedestrians, bicyclists, and multimodal facilities.
Environmental justice	0–3	3 points will be awarded if 75% or more of the project length is located within an RTP-defined environmental justice area.
Overmatch	0–9	Based on providing above the minimum 20 percent local funding match: 9 points will be awarded to projects with local match of 47 percent or more, 0 points to projects with the minimum 20 percent local match, with straight line interpolation between.
Project-related Metro Vision implementation and strategic corridor focus	0–18	Up to 18 points.
Sponsor-related Metro Vision implementation	0–8	Up to 8 points will be awarded for sponsor actions implementing Metro Vision.
Total	100	

Safety Points for Roadway Widening Projects			
	Estimated # of Crashes Eliminated per Mile (3 Years)		
Weighted Crash Rate	**0–5**	**6–15**	**16+**
0–0.99	0 points	2 points	3 points
1.0–2.99	1	3	4
3.00 +	2	3	5

Source: DRCOG, 2015

Table 23-12. Assigning Safety Points for New Pedestrian/Bicycle Projects, Denver, Colorado		
Evaluation Criterion	**Points**	**Scoring**
Safety	0–10 (out of 100)	Projects will be evaluated on the anticipated improvement of existing safety problems to be made by building new facilities for nonmotorized travel. Three measures of safety improvement will be awarded: *Relevant crash history* Based on the number of documented injury accidents created by the interaction between motorized and nonmotorized traffic in the area to be affected by the proposed new facility; and occurring over the last 3-year period for which data is available. 1 point will be awarded for each applicable injury accident, up to a maximum of 5. *Conflict factor* If the existing facilities are roadways that allow interaction between motorized and nonmotorized traffic, and if the project will build new facilities for the nonmotorized traffic that eliminate or reduce the conflict factor, the project will earn safety points. Based on the speed limit on the existing facilities, up to 4 points will be awarded as follows: 1 point will be awarded if the existing speed limit is 30 MPH or less. 2 points will be awarded if the existing speed limit is 35 MPH. 3 points will be awarded if the existing speed limit is 40 MPH. 4 points will be awarded if the existing speed limit is 45 MPH or above. *Facility lighting* 1 point will be awarded to projects that will provide ADA/AASHTO-compliant lighting to facilitate nonmotorized travel on the planned facilities, if no lighting is currently available on the existing roadway.

Source: DRCOG, 2015

A process-oriented approach to prioritization is illustrated by an example from Minnesota. The Minnesota DOT (MnDOT) established numerous task teams whose job was to focus on the many different types of safety challenges facing the state and to consider different types of countermeasures. The teams identified 153 strategies that could potentially provide safety benefits to the state. The teams were asked to assign priorities to these 153 strategies; the rankings were tabulated, and the 153 strategies were pared down to 69 high-priority strategies. MnDOT then held a state workshop that included numerous safety stakeholders, who also voted on priority strategies. This resulted in further reducing the list to 52 strategies. These 52 strategies were presented to the top management team in MnDOT, which selected 15 strategies to implement the first year.

The approach adopted to evaluate and prioritize strategies will likely vary from location to location, depending on the availability of tools and history of using the approaches (see [Metropolitan Planning Council, undated] for a good overview of prioritization practices in the United States). Chapter 7 provides a more detailed discussion on evaluation approaches, including benefit/cost analysis, which is commonly used in safety planning.

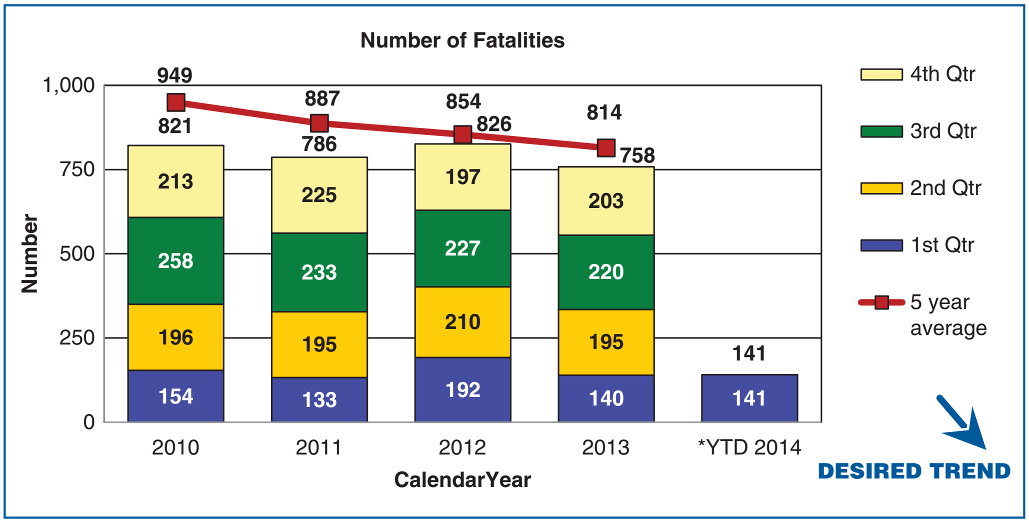
G. Include Safety in Planning Programs and Documents

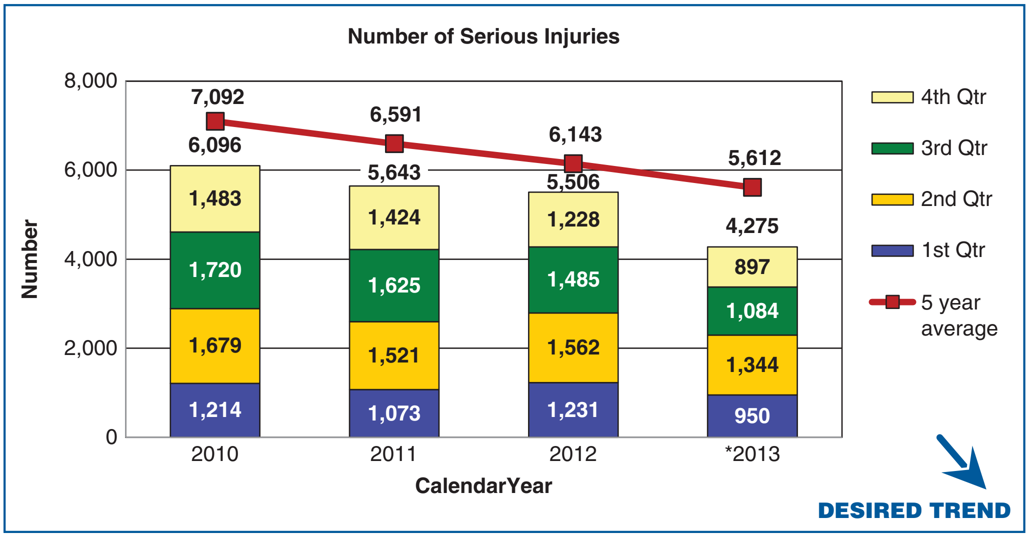
Ongoing monitoring of the performance and condition of the transportation system feeds back into goals, objectives, and performance measures (see Figure 1-1 in chapter 1). The feedback loop becomes an important input into the next cycle of safety planning, as it not only provides a snapshot of performance at that particular point in time but can also inform decision makers about the experience with previously implemented actions. Monitoring should include the trends and absolute magnitudes of the transportation system safety characteristics.

When practicable, before-and-after studies should be conducted on implemented countermeasures for which very little benefit information is available (see, for example, [VicRoads, 2015]). Hauer [2002] provides a detailed methodology that defines target crashes to which the before-after study can be applied. The book also provides guidance on various versions of a before-after study, including the *naïve before-after study*, the *comparison group* method, the *multivariate* method, and the most advanced *Bayesian before-after method*. Such studies are critically important for developing a knowledge base that can be used in future consideration of different countermeasures. It is not clear at this point if the safety community would benefit from a single, consolidated knowledge base, or whether it will be adequate to tie together existing research sponsored by federal and state sources as well as independent organizations such as the Institute of Transportation Engineers and Society of Automotive Engineers.

Finally, safety should be included in agency efforts to adopt dashboard or tracking programs that present high-level agency performance measures designed for decision makers and the public. The programs are relatively new and are designed to both measure performance across the agency and communicate information on agency performance to the public. The challenge is to find meaningful measures of progress that are easy for the layperson to understand. Figure 23-11 shows a graphic from the Missouri DOT's tracker report that addresses recent trends in traffic fatalities and disabling injuries. Dedicating one to two pages of graphs to various safety measures enables agencies to quickly and effectively inform the public and decision makers about transportation safety trends and to put these trends in perspective.

Figure 23-11. Missouri DOT "Tracker" Report on Fatalities and Disabling Injuries





Source: MoDOT, 2014

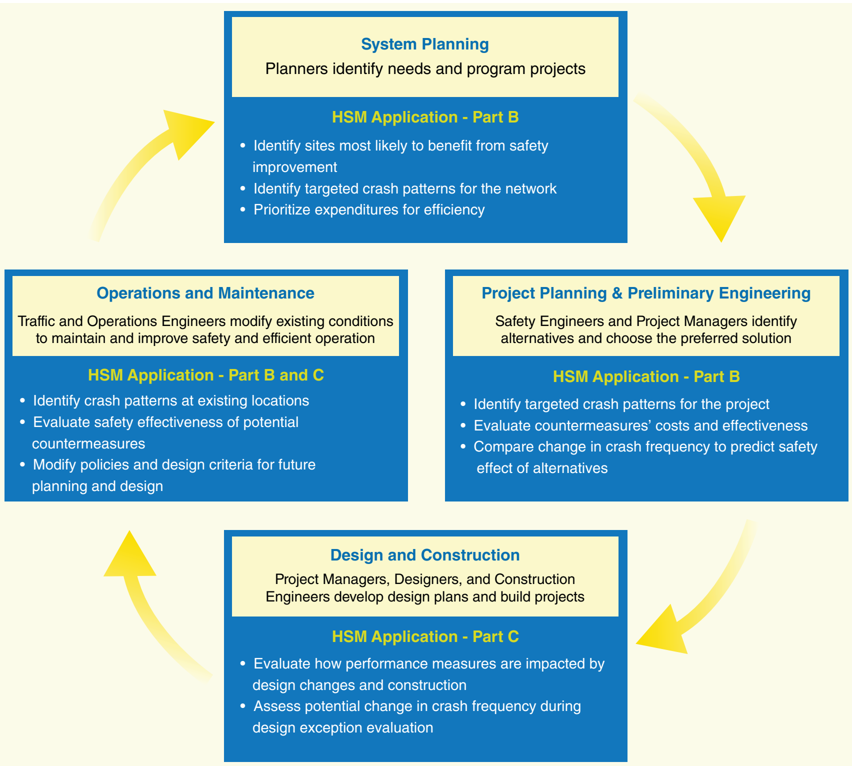
VI. THE *HIGHWAY SAFETY MANUAL* (HSM)

The transportation engineering profession has relied on the *Highway Capacity Manual* for decades as one of the definitive manuals on best practice. In 2010, the American Association of State Highway and Transportation Officials (AASHTO) produced the *Highway Safety Manual* (HSM), the first-of-its-kind manual for identifying and analyzing safety problems. [AASHTO, 2010, 2014] The uses of the HSM include:

- Identify sites with the most potential for crash frequency or severity reduction.
- Identify factors contributing to crashes, and associated potential countermeasures to address these issues.
- Evaluate the crash reduction benefits of implemented treatments.
- Conduct economic appraisals of improvements to prioritize projects.
- Calculate the effect of various design alternatives on crash frequency and severity.
- Estimate potential crash frequency and severity on highway networks, and the potential effects of transportation decisions on crashes. [FHWA, 2014]

It is beyond the scope of this chapter to replicate the material found in the HSM. However, Figure 23-12 shows how the manual is organized and logically flows from safety considerations in system planning to project planning and preliminary engineering to design and construction to operations and management. In the planning phase, the manual focuses on the procedures and approaches for identifying sites where safety countermeasures should be considered and prioritization of such countermeasures. At the project planning level, the manual presents approaches for identifying crash patterns for a particular project and methods to predict safety impacts of implemented countermeasures. Transportation planners should be fully aware of the methods and analysis approaches that are found in this important manual.

Figure 23-12. Organization of the *Highway Safety Manual*



Source: FHWA, *HSM Fact Sheet*, http://safety.fhwa.dot.gov/hsm/factsheet/

VII. RELATIONSHIP BETWEEN TRANSPORTATION SAFETY PLANNING AND STRATEGIC HIGHWAY SAFETY PLANNING

Given the requirement for states to develop an SHSP, it is worthwhile to examine the relationship between this effort and the TSP process described in the previous sections. Both processes are based on a collaborative effort that (1) includes representatives from many different disciplines and interests, (2) uses data to identify high-crash locations, (3) analyzes and selects programs and projects that will improve the safety of the transportation system, (4) evaluates outcomes, and (5) is comprehensive and addresses the 4Es of safety—engineering, education, enforcement, and emergency medical services or emergency response.

TSP ensures that the major transportation planning products—the long-range plan, TIP, and STIP—explicitly address safety in the recommended policies, programs, and projects. Through the collaboration required in developing the SHSP, the TSP will hopefully influence the planning cultures of the other agencies as well. Safety considerations in the STIPs and TIPs become part of the SHSP along with the Highway Safety Plan, the HSIP, and the Motor Carrier Safety Plan. The idea is for the SHSP to serve as the umbrella document, and all other plans are expected to draw from it for their safety analyses and strategies.

Meanwhile, the SHSP provides a building block for the long-range transportation plan and, at the same time, safety policies contained in the plan are compatible with those in the SHSP. The SHSP will provide the information necessary to meet the transportation plan's safety goal, and safety-oriented projects/programs will be included in both the long-range plans and the STIPs/TIPs. In other words, transportation plans will build on and incorporate components of the SHSP and implement transportation planning priorities.

Some issues remain unclear—for example, whether SHSPs will address multimodal and systemwide planning issues, or whether they will focus simply on the road network. If they are initially focused on the roadway network, they may link to the transportation planning process only at the beginning stages, or they may also link to the process later at the project/program selection stage. Many states are focusing the SHSPs on multimodal, systemwide approaches, which is the intent of the requirement.

VIII. LESSONS FROM THE INTERNATIONAL COMMUNITY

European and Australian safety programs have led the world in reducing the number of fatalities on the road network. Sweden, the Netherlands, and the United Kingdom have the lowest road crash death rates per capita in the world. Australia is not far behind and provides "a useful benchmark for America, partly because it is also a federation, but mostly because it is part of the 'new world' where urban form, regional development, and road transport developed more or less contemporaneously." [Washington et al., 2006] A case study from Victoria, Australia, shows what can be accomplished by focusing significant attention and resources on safety. From 1995 to 2004, "the number of persons killed in road crashes in the United States has increased by 2 percent in the last 10 years. In contrast, the number of persons killed decreased in Australia by more than 20 percent in the same period, with improvements in the rates of traffic safety two to three times greater than achieved in America." [Washington et al., 2006] The steps identified in this report that were necessary for developing a successful road safety program included:

- Find a "champion"—an individual or a group—who can help create political and community saliency.
- Introduce new measures of traffic safety performance. Total reliance upon deaths per unit road use is suboptimal. It implies that improvement in this rate is a sufficient goal and accepts that there is a "price" to be paid for mobility and that the greater the road use, the higher that price will be in total.
- Develop an evidence-based strategic plan with objective targets and effective accountability mechanisms.
- Harness all the key players and implement the plan in an integrated, effective manner. The issues to be addressed and the range of acceptable measures will require a partnership among many organizations.

Both the Europeans and Australians have targeted their safety strategies at changing driver behavior—for example, aggressive DUI programs, speed monitoring, and driver education. European research indicates, however, that further reductions in crash levels will require a change in the focus from driver behavior initiatives to actions that make it more difficult for a driver to have a crash in the first place—more specifically, prevention-oriented strategies through TSP.

Much of the transportation safety planning that occurs in other countries follows the same concepts and uses the same analysis approaches that are described in this chapter. For example, Table 23-13 from VicRoads in Australia, the transportation agency for the State of Victoria, shows the types of performance measures that are used by this agency to monitor progress toward safety goals. As seen, many of these measures are similar to what is found in any U.S. state. It is interesting to note some measures that are hardly ever seen in the United States. For example, "the number of people taking risks" and "the percent of people who feel safer" are two measures that are not found in U.S. practice.

Table 23-13. Safety Performance Measures Used in Victoria, Australia

Indicator	Measures	Data Context
Casualty crash rating	• Risk using exposure, crash reduction factors, ANRAM or "Safe System" compliance. • Frequency of conflict points.	Information Access
Fire risk	• Fire risk rating (fuel load).	Project specific
Frequency of casualty crashes	• Number of casualty crashes by location (intersection or road length). • Number of casualty crashes by type (intersection, run off road, rollover). • Number of casualty crashes by user (pedestrian, heavy vehicle, public transport). • Number of casualty crashes per 100 million vehicle kms travelled.	Road Crash Information System (RCIS)/ Information Access
Frequency of people taking risks	• Number of people taking risks (visual count).	Project specific
Incident/hazard response times	• Average response time in minutes. • Percent incidents attended or cleared within 15 minutes. • Percent hazards managed within Road Management Plan response times.	Road operations Project specific
Local trips made by walking and cycling	• Percent local trips made by walking and cycling. • Number of road crossings within 20 meters of crossing facility.	Information Access Project specific
Occupational Health and Safety risk	• Level of risk assessed using Safe Work Methods Statements.	Project specific
Patronage of rest areas	• Number of spaces at rest areas utilized by heavy vehicles during specified times.	Project specific
People feel safer	• Percent of people who feel safer. • Percent of people using the crossing facility of the total crossing within 20 meters of facility. • Safety complaints received.	Project specific
Risk of harm (non-crash)	• Level of water pollution (oil, heavy metals, and other chemicals). • Number of complaints regarding water pollution.	Project specific
Severity of casualty crashes	• Number of fatality crashes and serious injury crashes by location (intersection or road length). • Number of fatality crashes and serious injury crashes by types (intersection, run off the road, or rollover). • Number of fatality crashes and serious injury crashes by user (pedestrian, heavy vehicle, public transport).	Road Crash Information System (RCIS)/Information Access (for vehicle kilometers travelled)
Severity of crash rating	• Risk using exposure, crash reduction factors, ANRAM, or "Safe System" compliance. • Frequency of conflict points.	Project specific

Source: VicRoads, 2015

IX. SUMMARY

Transportation safety is consistently listed as the most important goal of transportation agencies around the world. Yet, roadway-related fatalities in many countries continue to rise, and crashes involving drivers, passengers, pedestrians, and bicyclists remain one of the major causes of death in the world. Many countries, such as Australia, the United Kingdom, Sweden, and the Netherlands, have successfully reduced the number of fatalities and the incidence of crashes by means of aggressive enforcement, driver training, and education policies. In the United States, government programs have been in place for many years to focus resources on this serious problem, but much of this effort has focused on safety-specific programs rather than on ways to include safety in traditional transportation planning.

Transportation planners have a critical role to play in a state or region's safety program. They are involved in the initial steps for planning capital improvement programs at all levels (for example, state and MPO plans). Safety should be an explicit goal of the transportation planning process; thus, transportation planners need to strongly advocate examining safety from many different perspectives. Working with the safety community, integrating safety into the planning documents, and engaging planners in the development and implementation of the SHSP increases the likelihood that planners will encourage local officials to consider safety equally with other competing infrastructure projects and priorities.

Finally, planners have important expertise that can be applied to safety analysis. Planners routinely collect and analyze data, develop alternative solutions, evaluate the benefits and trade-offs among the proposed solutions, identify the most effective and efficient alternatives, evaluate project and program outcomes, and provide feedback to the ongoing planning process. Planners also bring expertise in public participation that can be used to engage a wider range of participants in the process, such as nonprofit safety organizations, the media, and the public. These skills bring great value to the safety planning process and to safety stakeholders, many of whom are not trained or experienced in the planning discipline.

Several keys lead to successful safety integration into the planning process:

- The safety community needs to become a stakeholder in the transportation planning process. Transportation agency safety experts and emergency response and law enforcement personnel are among those who must be at the table as funding criteria are set and projects approved. Achieving transportation safety goals is better served with the participation of safety personnel. Similarly, safety personnel must understand the approval process for transportation program dollars and know that many of these funds can be used to address their concerns.
- Improved analysis tools and processes are needed to analyze safety problems and document the benefits of safety improvements. Efforts are under way to varying degrees throughout the data chain, from collection of data in the field to data storage and processing at DOTs and MPOs, to the development of crash forecasting methodologies, to the integration of safety analysis into travel demand forecasting and simulation models.
- Institutional changes that bring safety concerns into all aspects of transportation planning and project development will likely be needed. These may involve organizational structure changes that bring planning and safety staff closer together or better education and training across agencies.

The ultimate goal is to make the transportation system safer and reduce the unacceptable number of deaths and injuries that occur annually. Policy makers have acknowledged through federal legislation that integration of safety into the planning process can help make this happen. However, it is the combined efforts of the transportation, safety, education, enforcement, and emergency services communities that will ultimately determine whether this goal will be achieved. There are no "silver bullets." The future requires bold, innovative, and comprehensive strategies designed and implemented through collaborative efforts among transportation planners, engineers, law enforcement, safety professionals and practitioners, and others. To make progress, it will be necessary in some cases to restructure organizational priorities and approaches.

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Public Participation and Engagement[1]

I. INTRODUCTION

Including public concerns in transportation planning has a long history in the United States and in many other countries. In the United States, many see the dawn of public engagement as the late 1960s, when there was significant public opposition to the construction of urban freeways in many cities (often called the "highway revolt"). With the increasing desire of public groups to be included in policy decisions affecting their lives, governments at all levels passed legislation to provide opportunities for public participation in planning and project development. The most noteworthy law in the United States was the National Environmental Policy Act (NEPA) of 1969 that required, among other things, public hearings for projects undergoing environmental impact analysis and review. Today, a substantial legislative history serves as the legal and regulatory foundation for citizen participation in transportation planning. Transportation planners need to understand these legal requirements to make sure the planning process and the products of that process satisfy legal requirements.

In addition to the legal perspective, however, providing opportunities for public participation in government-sponsored planning and infrastructure decision making simply makes sense in a democracy. This idea is well stated in the preamble to the Mid-America Regional Council (MARC) (Kansas City metropolitan area) Public Participation Plan.

> *"Public participation is based on the belief that people whose lives are affected by transportation planning and investment decisions have a right to be involved in the decision-making process and influence choices that are made. Directly engaging citizens in this process promotes successful problem solving, yields diverse voices and new ideas, and gives the public a sense of ownership of the developed solutions."*
>
> *[MARC, 2013]*

Public engagement is a two-way street. Not only do citizens learn about what is being planned for their community, but people also have the opportunity to influence these plans. This has never been more evident than in today's world where social media provides an ever-increasing variety of opportunities to stay in touch with what is happening in a community.

A definition of public participation is offered in the next section. The following section then reviews the U.S. federal laws and regulations that require public engagement in transportation planning and project development. The description of a public participation plan (PPP) is described next with attention given to PPP goals and objectives and the large number of strategies and tools that are available to transportation planners. This is followed by a section that looks at public engagement at the project development level. The final sections examine ways of assessing the effectiveness of public participation programs, and provide some "words of wisdom" to those wanting to improve the effectiveness of their program.

II. WHAT IS THE PUBLIC PARTICIPATION PROCESS?

Every metropolitan planning organization (MPO) and state department of transportation (DOT) in the United States must have a public participation plan (PPP) that outlines the opportunities for public input in the development of the transportation plan as well as other mandated planning and project development processes (for example, an eminent

[1] This chapter was written by Michael D. Meyer, WSP/ Parsons Brinckerhoff

Transportation Planning Handbook: Institute of Transportation Engineers, Fourth Edition, Michael D. Meyer

domain property taking to facilitate a municipal roadway project). (Note: some use the term "*public involvement plan* (PIP);" for purposes of this chapter the term public participation plan (PPP) will be used). Some definitions of public participation offered by state DOTs and MPOs include (see also, http://www.iap2.org):

> *"Public participation is the process by which interested and affected individuals, organizations, agencies, and government entities are consulted and included in the decision-making process."*
>
> *[DVRPC, 2007]*

> *"Public input provides transportation decision makers with community insights that illuminate the issues being considered. Community input is an important consideration along with technical data, analysis, and professional expertise in helping decision makers reach an informed decision."*
>
> *[Washington County Department of Land Use and Transportation, 2015]*

> *"The Broward MPO's policy on public participation is to create opportunities for all segments of the public to learn and provide feedback about issues and proposals under consideration, particularly those affected by the outcomes and/or those with special needs. This policy lays the foundation to ensure the public is a key participant in the planning and decision-making process."*
>
> *[Broward County MPO, 2015]*

> *"The Montana Department of Transportation will: 1) provide useful, timely information to the public throughout the development of projects, from planning, programming, and preliminary engineering approval through construction, operation, and maintenance; 2) proactively seek public comment and involvement in planning and project development, 3) facilitate open discussion of controversial issues, 4) respond to comments and suggestions, and 5) ensure public comments are fully considered so that useful ideas are incorporated into projects given availability of resources, policy constraints, and as appropriate."*
>
> *[Montana Department of Transportation, undated]*

> *"The importance of public involvement (to the Colorado Department of Transportation--CDOT) during the planning and programming processes is that it: 1) allows the public to provide valuable information to CDOT to help guide the planning and decision-making processes, 2) builds an ongoing relationship between CDOT and the public based on mutual trust, 3) increases community knowledge by providing citizens with new information, 4) encourages stakeholders to become actively involved in plan or program development, 5) provides feedback which helps CDOT understand areas where additional information is required or where misunderstandings exist, 6) identifies potential problems or plans that require an extra level of sensitivity and public education and 7) provides comments to better inform others who are not participating."*
>
> *[Colorado DOT, 2015]*

One of the best descriptions of public participation comes from the Metropolitan Transportation Commission (MTC) in the San Francisco Bay area, which adopted the following guiding principles for its public participation program. [MTC, 2015] The words emphasized (by the author) are found in many definitions of public participation.

- Public participation is a *dynamic* activity that requires *teamwork and commitment* at all levels of the MTC organization.
- One size does not fit all—input from *diverse perspectives* enhances the process.
- Effective public outreach and involvement requires *relationship building*—with local governments, stakeholders, and advisory groups.
- *Engaging interested persons* in "regional" transportation issues is challenging, yet possible, by making it *relevant*, *removing barriers* to participation, and *saying it simply*.
- An *open and transparent public participation process* empowers all communities to participate in the decision making that affects them. All communities matter!

For purposes of this chapter, public participation is defined as a process that openly and transparently provides opportunities for diverse perspectives in the planning and decision-making processes. Because it deals with human behavior, the process is necessarily dynamic and flexible. It relies on building relationships with key stakeholder groups in the community, as well as those often underrepresented in transportation decision making. Planners offer relevant and worthwhile opportunities for the public to voice their opinions, influence decisions, and be informed of how their input has been considered.

A. Legislative and Regulatory Requirements

In the United States, federal and many state laws require public participation opportunities in transportation planning and decision making. Transportation planners need to be aware of all of the legal requirements that apply to public participation/outreach efforts in their jurisdiction. Many states and smaller locales have replicated federal public participation requirements in their own laws. Below is a discussion of the more relevant federal laws and regulations pertaining to public participation and engagement. Note these laws are relevant for both planning and project level planning, and typically become more relevant if the planning or project area context includes a population that may be protected by these laws.

1. Transportation Laws and Executive Orders

Fixing America's Surface Transportation (FAST) Act. This law, passed in 2015, reaffirmed all previous transportation laws in requiring opportunities for the public and other stakeholders to participate in the transportation planning process. In particular, the law added public ports and certain private providers of transportation, including intercity bus operators and employer-based commuting programs, to the list of interested parties that an MPO must provide with reasonable opportunity to comment on the transportation plan.

Moving Ahead for Progress in the 21st Century (MAP-21). This law, passed in 2012, contained specific language outlining federal requirements for public participation processes and procedures. MAP-21 required MPOs to provide everyone with a reasonable opportunity to comment on the transportation plan. Examples of people and groups who should be included in the public participation process are: citizens, affected public agencies, public transportation agency employees, freight shippers and carriers, private transportation providers, public transit riders, pedestrians, bicyclists, the disabled, and other interested parties.

Civil Rights Act, Title VI. Title VI of the Civil Rights Act of 1964 prohibits federal agencies and subrecipients of federal funds from discriminating on the basis of race, color, or national origin. Subsequent laws and Presidential Executive Orders have added handicap, sex, age, and income status to the nondiscrimination criteria.

Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. This executive order directed federal agencies to identify and address disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority and low-income populations. It also stipulated the need to provide these populations with access to public information and opportunities for public participation in matters relating to human health or the environment.

Executive Order 13166: Improving Access to Services for Persons with Limited English Proficiency. This Executive Order requires federal agencies to examine the services they provide, identify any need for services to those with limited English proficiency (LEP), and develop and implement a system to provide those services so LEP persons can have meaningful access, such as language assistance. LEP refers to a limited ability to read, speak, write, or understand English. The Executive Order also requires that federal agencies work to ensure that recipients of federal financial assistance provide meaningful access to their LEP applicants and beneficiaries.

2. Non-Transportation Laws

Americans With Disabilities Act (ADA). The Americans with Disabilities Act (ADA) of 1990 requires equal planning participation opportunities for disabled persons, especially for paratransit plans. These requirements relate to outreach (developing contacts, mailing lists, and other means of notification), consultation with individuals with disabilities, opportunities for public comment, accessible formats (for example, an ASL sign language interpreter), public hearings, summaries of significant issues raised during the public comment period, and on-going efforts to involve disabled people.

National Environmental Policy Act (NEPA). As noted earlier, NEPA is by far the most important law from the perspective of project-level planning. Under NEPA and Federal Highway Administration (FHWA) requirements, state public participation/public hearing procedures must provide for:

- Coordination of public participation activities and public hearings as part of the entire NEPA process.
- Early and continuing opportunities during project development for the public to be involved in the identification of social, economic, and environmental impacts, as well as impacts associated with the relocation of individuals, groups, or institutions.
- One or more public hearings or the opportunity for hearing(s) to be held by the state highway agency at a convenient time and place for any federal-aid project which requires significant amounts of right-of-way acquisition, substantially changes the layout or functions of connecting roadways, has a substantial adverse impact on abutting property, otherwise has a significant social, economic, environmental, or other effect, or for which the FHWA determines that a public hearing is in the public interest.
- Reasonable notice to the public of either a public hearing or the opportunity for a public hearing. Such notice will indicate the availability of explanatory information (such as plans available for viewing at a local library). The notice shall also provide information required to comply with public participation requirements of other laws, Executive Orders, and regulations. [FHWA, undated]

National Historic Preservation Act. Section 106 of this law requires agency consultation with Tribal Nations regarding religious and/or cultural significance to historic properties that may be affected by a transportation project.

3. Transportation Planning Requirements

Whenever legislation becomes law, federal agencies may interpret the new legal requirements by incorporating key requirements into the Code of Federal Regulations (CFR), where Title 23 relates to highways). The federal rules and regulations correspond to actions that planners take in their planning efforts.

- 23 CFR 450.210 (a)(1)(ii): Provide reasonable public access to technical and policy information used in the development of the long-range statewide transportation plan and the Statewide Transportation Improvement Program.
- 23 CFR 450.210 (a)(1)(iii): Provide adequate public notice of public involvement activities and time for public review and comment at key decision points, including but not limited to a reasonable opportunity to comment on the proposed long-range statewide transportation plan and Statewide Transportation Improvement Program.
- 23 CFR 450.210 (a)(1)(iv): To the maximum extent practicable, ensure that public meetings are held at convenient and accessible locations and times.
- 23 CFR 450.210 (a)(1)(v): To the maximum extent practicable, use visualization techniques to describe the proposed long-range statewide transportation plan and supporting studies.
- 23 CFR 450.210 (a)(1)(vi): To the maximum extent practicable, make public information available in electronically accessible format and means, such as the World Wide Web, as appropriate to afford reasonable opportunity for consideration of public information.
- 23 CFR 450.210 (a)(1)(vii): Demonstrate explicit consideration and response to public input during the development of the long-range statewide transportation plan and Statewide Transportation Improvement Program.
- 23 CFR 450.210 (a)(1)(viii): Include a process for seeking out and considering the needs of those traditionally underserved by existing transportation systems, such as low-income and minority households, who may face challenges accessing employment and other services.
- 23 CFR 450.210 (a)(1)(ix): Provide for the periodic review of the effectiveness of the public involvement process to ensure that the process provides full and open access to all interested parties and revise the process, as appropriate.

4. *Project Participation Requirements in NEPA Studies*

- 23 CFR 771.111(a)(1): Provide early coordination with appropriate agencies and the public to aid in determining the type of environmental review documents an action requires, the scope of the document, the level of analysis, and related environmental requirements. This involves the exchange of information from the inception of a proposal for action to preparation of the environmental review documents.

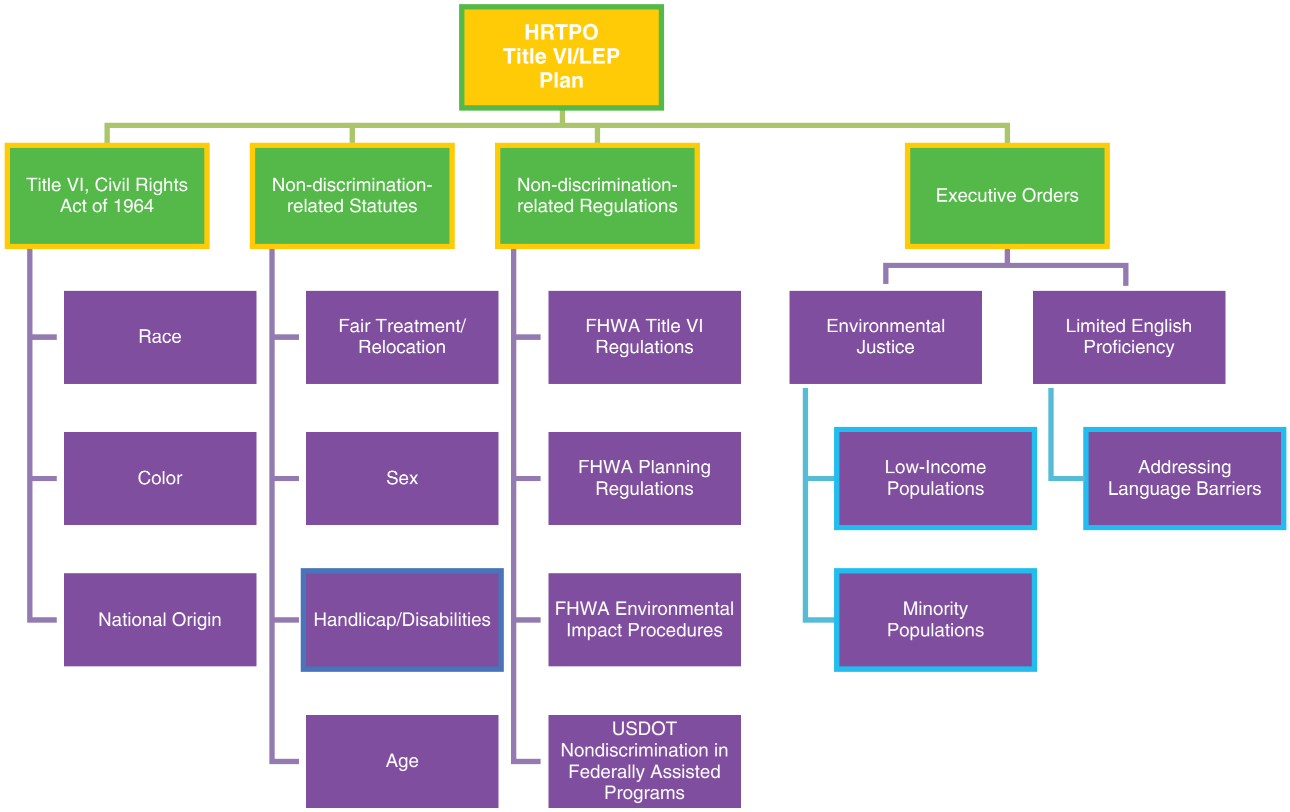
- 23 CFR 771.111(h)(2): State public involvement/public hearing procedures must provide for:
  - i. Coordination of public involvement activities and public hearings with the entire NEPA process.
  - ii. Early and continuing opportunities during project development for the public to be involved in the identification of social, economic, and environmental impacts, as well as impacts associated with relocation of individuals, groups, or institutions.
  - iii. One or more public hearings or the opportunity for hearing(s) to be held by the state highway agency at a convenient time and place for any federal-aid project which requires significant amounts of right-of-way, substantially changes the layout or functions of connecting roadways or of the facility being improved, has a substantial adverse impact on abutting property, otherwise has a significant social, economic, environmental or other effect, or for which the FHWA determines that a public hearing is in the public interest.
  - iv. Reasonable notice to the public of either a public hearing or the opportunity for a public hearing. Such notice will indicate the availability of explanatory information. The notice shall also provide information required to comply with public involvement requirements of other laws, executive orders, and regulations.
  - v. Explanation at the public hearing of the following information, as appropriate:
    - A. The project's purpose, need, and consistency with the goals and objectives of any local urban planning
    - B. The project's alternatives, and major design features
    - C. The social, economic, environmental, and other impacts of the project
    - D. The relocation assistance program and the right-of-way acquisition process
    - E. The State highway agency's procedures for receiving both oral and written statements from the public
  - vi. Submission to the FHWA of a transcript of each public hearing and a certification that a required hearing or hearing opportunity was offered. The transcript will be accompanied by copies of all written statements from the public, both submitted at the public hearing or during an announced period after the public hearing.
  - vii. An opportunity for public involvement in defining the purpose and need and the range of alternatives, for any action subject to the project development procedures in 23 U.S.C. 139.
  - viii. Public notice and an opportunity for public review and comment on a Section 4(f) *de minimis* impact finding, in accordance with 49 U.S.C. 303(d).

- 23 CFR 771.111(h)(4)(i): Applicants for capital assistance in the FTA program:

  1. Achieve public participation on proposed projects through activities that engage the public, including public hearings, town meetings, and charettes, and seeking input from the public through the scoping process for environmental review documents. Project milestones may be announced to the public using electronic or paper media (for example, newsletters, note cards, or emails) pursuant to 40 CFR 1506.6. For projects requiring EISs, an early opportunity for public involvement in defining the purpose and need for action and the range of alternatives must be provided, and a public hearing will be held during the circulation period of the draft EIS. For other projects that substantially affect the community or its public transportation service, an adequate opportunity for public review and comment must be provided.

  2. Are encouraged to post and distribute materials related to the environmental review process, including but not limited to, NEPA documents, public meeting announcements, and minutes, through publicly accessible electronic means, including project websites. Applicants are encouraged to keep these materials available to the public electronically until the project is constructed and open for operations.

Figure 24-1. Laws and Regulations Concerning Participation of Minorities and Those with Limited English Proficiency, Hampton Roads MPO, Virginia



Source: HRTPO, 2013

Figure 24-1 shows how the MPO in Hampton Roads, Virginia, identifies the important legal and regulatory requirements that feed into its plan for public participation.

III. KNOW YOUR PUBLIC AND STAKEHOLDERS

Before discussing specific approaches and strategies for public participation, it is first necessary to ask the question, "Who should be involved in the transportation planning process?" The persons that planners need to reach include: the public, stakeholders, interested parties, and specific target populations. Stakeholders can be defined as "any individual, group of individuals, organizations, or political entity with a stake in the outcome of a decision." [IAP2, undated] These participants in the planning and decision-making processes will likely be identified primarily based on the geographic area of the study.

In some cases, laws and regulations dictate who must be provided an opportunity to participate in planning and decision making (see discussion above on MAP-21). In other situations, it is up to the planning agency or the planner to determine who the key participants should be. The task of identifying stakeholders has been dramatically changed by technology and internet search capability. In addition, some software programs (for example, SalesForce) has allowed a more effective tracking and sorting of people by interest area, organization, and zip code. It has also enabled a more strategic perspective on levels of engagement. The Metropolitan Council in the Twin Cities, Minnesota, for example, defines stakeholders as people, groups, or organizations who care about or might be affected by a Council action. [MetCouncil, 2010] The Hernando/Citrus MPO in Florida identified the following key stakeholders:

- Elected officials.
- Local government staff.
- Transportation agencies (port, airports, transit, etc.).

- Law enforcement and emergency services management, emergency operations centers, chambers of commerce, and economic development agencies.
- Local media (TV, radio, print, etc.).
- Homeowners associations.
- Civic groups.
- Special interest groups (other interested parties).
- Libraries (for public display).
- Federal, state, and local agencies responsible for land use management, natural resources, environmental protection, conservation and historic preservation, and other environmental issues.
- Other parties that would have an interest in the planning and development of the transportation network, including affected public agencies in the transportation planning area.
- Native American Tribal Council.
- Private freight shippers.
- Representatives of public transportation employees.
- Providers of freight transportation services.
- Private providers of transportation.
- Representatives of users of public transportation.
- Representatives of users of pedestrian walkways.
- Representatives of users of bicycle transportation facilities.
- Representatives of the disabled. [Hernando/Citrus MPO, 2014]

Other key organizations could include health authorities, colleges and universities, school districts, major employers, and recreation providers. For instance, a similar list for the Hillsborough County MPO (Tampa, Florida) also included the general public, schools, parent teacher associations (PTAs), community development corporations, chambers of commerce, professional organizations, other business entities, emergency service providers, caregivers for the elderly and for children and persons with disabilities, low income individuals, and LEP persons.

The Colorado DOT identified numerous ways to add to their list of stakeholders (shown in Figure 24-2): user surveys, responding to new requirements from state and federal laws, and reaching out to homeowners' associations, neighborhood groups, outdoor enthusiast/environmental groups, the business community, agencies serving senior citizens, educational institutions, and agencies serving the disabled. The key observation here is that the Colorado DOT is proactively seeking new participants for its planning processes.

Figure 24-3 shows the targeted populations that transit agencies often seek for their public participation activities. As shown, a majority of the transit agencies (over 50 percent) target existing riders, occasional riders, persons with disabilities, and seniors. Table 24-1 shows the reported sources of information that 45 surveyed transit agencies use to identify potential participants in transit planning activities.

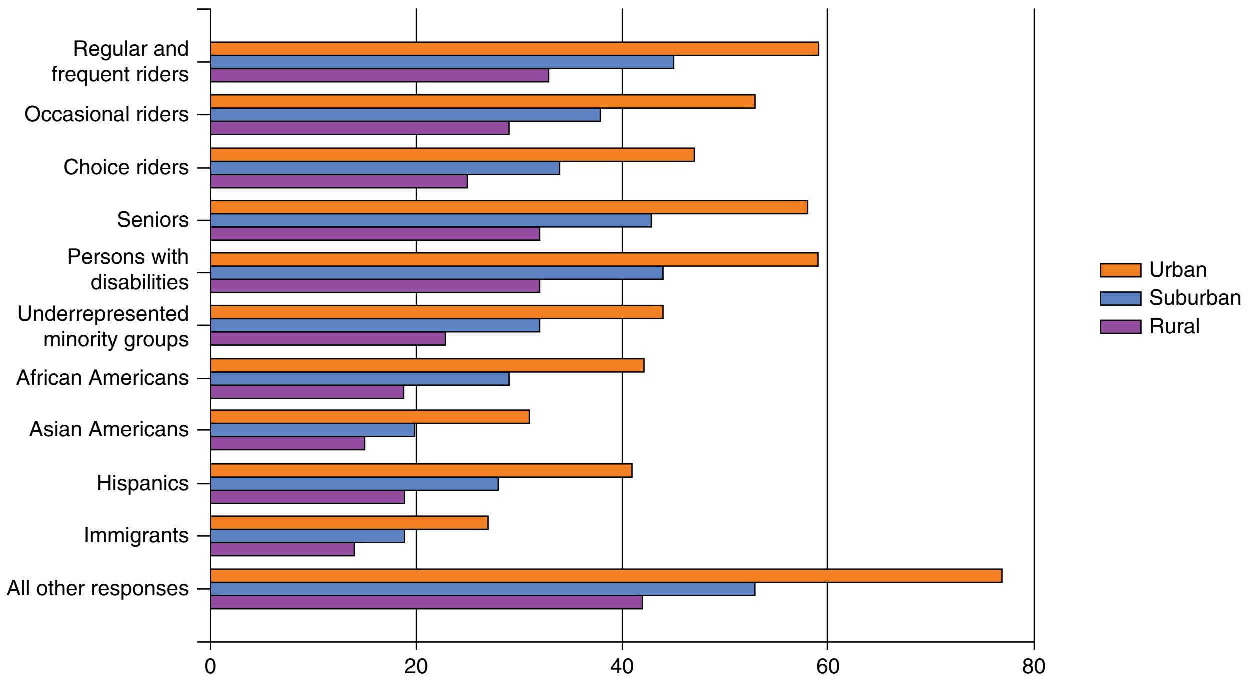
Knowing whom to invite to participate in the planning process is an important first step. However, it is also important to know what motivates participation, and what perceived barriers may exist. A public participation survey from the Mid-America Regional Council (Kansas City, Missouri) identified six reasons why people chose to not become involved in transportation issues, summarized in Table 24-2.

In today's social media world, it is also important to understand how people get their information, and how this information is interpreted. Table 24-3 shows statistics from a recent study of how cell phones were used by different population groups. This type of information can be useful when developing a strategy for reaching out to the different publics in a study area.

Figure 24-2. Colorado DOT's Stakeholders

Source: Colorado DOT, 2015

Figure 24-3. Target Audiences for Public Participation Efforts, Percent Transit Agencies (71 Agencies)



Source: Simon and Simon, 2014, Reproduced with permission of the Transportation Research Board.

Table 24-1. Information Sources Transit Providers Use to Identify Target Audiences	
Information Sources	**Number of Agencies (45 total)**
Customer surveys	27
Ridership statistics	25
Planning studies	22
Human service agencies	19
Historical data	16
Census data	15
Focus groups	9
Fare box data	8

Source: Giering, 2011, Reproduced with permission of the Transportation Research Board.

Table 24-2. Reasons for Not Participating in Public Participation Activities, Kansas City	
Rank	**Choices**
1	I do not know how or when to get involved.
2	I think decisions are being made behind closed doors.
3	I do not think my input will matter.
4	The meeting locations or times are not convenient for me.
5	I do not understand the issues.
6	I do not feel the issues will have an impact on me personally.

Source: MARC, 2013

Table 24-3. Use of Mobile Data Applications by Population Group, 2010				
Activity	**All Adults**	**White, Non-Hispanic**	**African American, Non-Hispanic**	**Hispanic, English-Speaking**
Own a cell phone	82%	80%	87%	87%
Take a picture	76%	75%	76%	83%
Send/receive text messages	72%	68%	79%	83%
Access the internet	38%	33%	46%	51%
Send/receive e-mail	34%	30%	41%	47%
Play a game	34%	29%	51%	46%
Record a video	34%	29%	48%	45%
Play music	33%	26%	52%	49%
Send/receive instant messages	30%	23%	44%	49%
Use a social networking site	23%	19%	33%	36%
Watch a video	20%	15%	27%	33%
Post a photo or video online	15%	13%	20%	25%
Purchase a product	11%	10%	13%	18%
Use a status update service	10%	8%	13%	15%
Mean number of cell phone activities	4.3	3.8	5.4	5.8

Source: Smith, 2010

IV. PUBLIC PARTICIPATION PLAN

As noted earlier, every MPO and state DOT must have a public participation plan (PPP), sometimes called a public involvement plan. The PPP must describe the agency's overall strategy to provide public participation opportunities in the transportation planning process. Most of these plans describe the legal and regulatory foundations for participation, the schedule of planning deliverables (for example, the long-range plan, transportation improvement program (TIP), and the Unified Planning Work Program (UPWP)), as well as the timing of public participation opportunities. The reference list at the end of this chapter has many excellent examples of how a PPP is organized. There are other common elements to the PPP that are also important. These are discussed below.

A. Public Participation Goals and Objectives

The PPP should articulate the goals and objectives for the public participation process. Goals reflect the desired result, while objectives reflect the detailed statements of how the goals will be accomplished. There are numerous examples of PPP goals and objectives, most of which offer similar desired outcomes. For example, the following list of goals and objectives comes from Washington County, Oregon:

1) Provide general information about our transportation system, programs, and projects that is understandable, timely, and broadly distributed.
2) Help residents understand the transportation system planning, project selection, project development, design, and construction processes and how they can stay informed or become involved.
3) Help taxpayers understand the relationship between their taxes and the county's various transportation programs and projects.
4) Encourage and provide stakeholders and the public with opportunities for meaningful input concerning the transportation system, project design features, and the mitigation of potential community impacts.
5) Provide all potentially impacted stakeholders equitable access to pertinent information. This may involve providing information through verbal or written language translation or other alternative formats, and/or collaborating with community-based organizations to involve historically underserved communities.
6) Provide program and project-specific information, which may include project needs, goals, and constraints; scope of work; schedule; funding source(s); land use application and other permit status (if applicable); and construction impacts (if applicable).
7) Provide adequate advance notice of pertinent public hearings, public meetings, open houses, and comment periods. Public hearings typically have existing notification requirements that are applicable. Some programs may have existing notification requirements that are applicable. In instances without prescribed notice requirements, a 30-day notice is preferable and a 15-day notice should be considered a minimum.
8) Provide adequate time for public comment periods. For other transportation programs or processes where a formal request for public comments is made, a 30-day comment period is preferable and a 15-day comment period should be considered a minimum.
9) Ensure that public input is documented and provided to decision makers in summary form (and verbatim, if requested) for consideration prior to key decisions. [Washington County Department of Land Use & Transportation, 2015]

Table 24-4 shows how the goals statements from several MPOs relate to different generic goals categories. For example, "awareness" means a public participation program aims to increase public awareness of transportation planning or of a specific transportation plan. "Diversity" means encouraging the participation of a range of population groups, in particular, underrepresented communities. All of the MPOs in the table have a stated goal of increasing public awareness on transportation issues facing their communities and of the planning programs themselves. Other goals reflect various agencies' assigned importance to each goal.

One should be careful interpreting Table 24-4. Just because a goal is missing from a particular category, one should not infer that the MPO is unaware of or unconcerned about that aspect of public participation. It simply means that the goal category was not part of the overall goals statement of the MPO's PPP. The table provides a snapshot of the different types of goals that can be considered as part of the PPP process.

Table 24-4. Example Public Participation Goals by Category, Selected MPOs

	San Diego, SANDAG [2011]	Atlanta, ARC [2015]	Kansas City, MARC [2013]	Northern New Jersey, NJTPA [2007]	Broward (FL) MPO [2015]	Wilmington, DE, WILMAPCO [2010]
Awareness	Raise awareness of the 2050 RTP as the region's updated blueprint for a transportation system that enhances our quality of life and meets our mobility needs for the future.	Be highly visible in efforts to engage the public to participate and in sharing the results of the project with planners, policy makers, and elected officials.	Inform and educate the public.	Provide adequate opportunities to engage in meaningful two-way discussions between the NJTPA and the public about transportation planning issues.	Inform the public of transportation meetings, issues and other relevant events. The public needs to be aware of their role in the transportation planning and decision-making process.	Widely disseminate, clear, complete, and timely information to residents, affected agencies, and interested parties.
Public Input	Provide the public with opportunities to offer input on the 2050 RTP and its SCS, a new feature of the 2050 RTP required by state climate change legislation.	Be accountable to participants by reporting back to them at regular intervals, and provide a means for all interested individuals to stay informed and involved with the plan.				Create an open and ongoing two-way public participation process that ensures full resident, agency, and interested party participation in, and input into, regional transportation planning.
Dialogue	Stimulate dialogue about the transportation challenges facing the San Diego region.	Design a community engagement strategy that incorporates a complementary mix of smaller, community-based forums, large-scale public forums and online opportunities for engagement.	Engage the public and encourage continued participation.	Use a range of tools that promote timely, innovative and informative two-way education between the NJTPA and the public.		Achieve early and continuous participation of the public in the development of transportation plans, projects, and programs.
Diversity	Develop and incorporate into the plan realistic solutions that address the diverse mobility needs of the region's residents, visitors, and business people.	Partner with other organizations and agencies to maximize participation, with an emphasis on reaching groups that are typically underrepresented in planning processes.	Reach out and build connections.	Make continuous efforts to engage a diverse and wide-ranging representation of those who live, work and travel within northern and central New Jersey.	Include all communities in the planning area to inform and involve, with special emphasis on those communities with people who have been underrepresented and/or underserved.	

Table 24-4. (*Continued*)

	San Diego, SANDAG [2011]	**Atlanta, ARC [2015]**	**Kansas City, MARC [2013]**	**Northern New Jersey, NJTPA [2007]**	**Broward (FL) MPO [2015]**	**Wilmington, DE, WILMAPCO [2010]**
Influence on Outcomes	Build public support for transportation improvements outlined in the 2050 RTP.		Use input to shape policies, plans and programs.	Promote more direct dialogue between the Trustees and the public-at-large to enhance the public's influence on regional transportation planning and decision making.		
Evaluation		Evaluate the effectiveness of activities, modifying the plan as necessary to achieve desired outcomes.	Evaluate public participation strategies.	Evaluate and upgrade, on a periodic basis, the public participation efforts of the NJTPA to ensure that public participation has a demonstrable impact on the transportation planning and decision-making process in the region.	Improve the public participation process by identifying and incorporating new tools and strategies.	
Compliance				Maintain both the letter and spirit of federal and state laws, regulations, and guidelines regarding public participation responsibilities of MPOs.		

An example of a goals and objectives statement comes from the Wilmington, Delaware MPO (WILMAPCO), which identified its first goal as, "widely disseminated, clear, complete, and timely information to residents, affected agencies, and interested parties." [WILMAPCO, 2010] This was followed by several more specific objectives:

- *Objective 1*—WILMAPCO will identify organizations and individuals representing a broad spectrum of community interests and encourage their participation in transportation planning processes.
- *Objective 2*—WILMAPCO will develop relationships and form partnerships with organizations in the communities WILMAPCO serves and use these partnerships to develop a better understanding of WILMAPCO's mission and activities among their members and constituents.
- *Objective 3*—Coordinate public involvement activities with other similar programs to make best use of staff and resources while minimizing public time demands.
- *Objective 4*—Information will be disseminated through a variety of media.
- *Objective 5*—Transportation planning information will be conveyed in language and in a context that is understandable to the lay citizen.

Another common component of a PPP is a statement of the desirable characteristics of a public participation process. For example, the Colorado DOT public participation plan listed the following "principles" representing desired characteristics of its public participation process:

- Early and continuous participation.
- Timely and accurate information.
- Information accessibility in a variety of forms, including visual/print, electronic, and verbal information.
- Involvement with traditionally underserved communities.
- Reasonable access to meetings.
- Diversified approach, providing communication flexibility and innovation.
- Adequate and timely notice.
- Enhanced stakeholder relationships.
- Incorporation of public comments.
- Timely responses.
- Process review on the effectiveness of the public participation process and any proposed changes.

Good examples of public participation goals and objectives can be found in [WILMAPCO, 2010; MARC, 2013; Hillsborough County MPO, 2014a; Hernando/Citrus MPO, 2014; and Boston Region MPO, 2014]. Please refer to the References section of this chapter for the corresponding web addresses.

V. PUBLIC PARTICIPATION METHODS AND APPROACHES

A major purpose of the PPP is to identify the types of strategies, methods, tools, and approaches the agency will use to provide opportunities for public participation in the transportation planning process. Not only is it important to identify what types of strategies will be used, but also in what contexts and target audiences they are best applied. Table 24-5, for example, shows the key planning activities for the Denver Regional Council of Governments (DRCOG) and the types of opportunities and methods provided for each activity. This is not to say that these would be the only methods used. Rather, it identifies the major types of public participation methods the DRCOG finds appropriate for planning activities.

Part of the process of conducting an effective public participation process is understanding which types of strategies and methods are likely to be the most effective. To make such a determination, some MPOs conduct surveys of their

Table 24-5. Key Planning Activities and Public Participation Methods, Denver		
Activity	**Responsibility**	**Opportunities and Methods**
Metro Vision Plan and Metro Vision Regional Transportation Plan	DRCOG	Public interest forums at key points throughout the development process: DRCOG committee review and recommendation; public hearing and comment period before adoption and amendment; staff outreach to communities and organizations using workshops, presentations, questionnaires, website techniques, etc.
Transit Element & Pedestrian/Bicycle Element	DRCOG	Ad hoc committees or work groups; DRCOG committee review and recommendation; solicitation of comments and input announced via website and e-mail notification; public hearing and comment period before adoption.
Strategic Plan or Topical Programming Documents	DRCOG	Stakeholder and practitioner work groups; DRCOG committee review and recommendation; posting of draft documents on website prior to committee discussion and Board action.
Transportation Improvement Program	DRCOG, Local Governments, Colorado DOT (CDOT) and Regional Transportation District (RTD)	Project sponsor conducts public outreach in communities regarding specific projects; DRCOG committee review and recommendation; public hearing before adoption of new TIP or a TIP amendment requiring conformity finding; posting of all amendments on website prior to committee discussion and Board action.
Major Corridor/ Subarea Studies	CDOT, RTD, DRCOG, Local Governments	Task forces/committees and public meetings in the study area; meetings conducted in affected neighborhoods; other outreach efforts (for example, newsletter, website, comment forms).
Project Development	Implementing Jurisdiction	Task forces/committees and/or public meetings in the project locale at key decision points.
Conformity of the RTP and the TIP	DRCOG	DRCOG committee review and recommendation; public hearing on the draft conformity finding.
Unified Planning Work Program	DRCOG, CDOT, RTD	Periodic transportation forums to identify key planning tasks; DRCOG committee review and recommendation.

Source: DRCOG, 2010

study area residents. These surveys asked questions about the public's participation in public participation activities and about which types of information resources are the most or least effective. Tables 24-6 and 24-7 are examples of the types of information gathered in such surveys. This survey was undertaken by the Mid-America Regional Council in Kansas City, Missouri, and was designed as part of the formal evaluation process of the MARC PPP (see later section).

Many different strategies and methods can be considered for a public participation program. The following references are excellent sources of information for such methods: [Context Sensitive Solutions.org, 2005; Morris and Fragala, 2010; National Center for Mobility Management, undated; and FHWA, undated]. A particularly useful guide comes from the Hillsborough County MPO [2012]; tables from this guide are found in the appendix to this chapter.

The following common strategies and methods are presented alphabetically, not indicating priority with respect to use for public outreach. In addition, social media techniques are discussed in the next section and are excluded from this list outright. Importantly, partnering with local governments and other agencies can help identify effective methods of outreach. The International Association for Public Participation (IAP2) has developed a detailed tools matrix [IAP2, undated] and the FHWA has produced a publication, *Public Involvement in Transportation Decision-making*, that provides a useful compendium of tools. [FHWA, undated]

Advisory Groups. A local or regional group appointed by the transportation agency to provide input into the planning process. These groups are also sometimes referred to as advisory committees or councils; task forces; local or regional coordinating councils; or other similar names. An example is the DVRPC Public Participation Task Force in Philadelphia composed of appointed members as well as members-at-large. The mission of the task force is to provide ongoing access to the regional planning and decision-making process, review current issues, serve as a conduit for DVRPC information to organizations and communities across

Table 24-6. What is the Best Way to Engage You in Regional Transportation Issues? Kansas City		
Rank	Choices	% of Responses
1	Written survey sent to my home	50%
2	Internet discussion forums	19%
3	Informal meeting in my neighborhood or church	18%
4	Public meeting at city hall	7%
5	Other	7%

Source: MARC, 2013

Table 24-7. What Are the Best Ways to Communicate with You about Regional Transportation Issues and Ways You Can Get Involved? Kansas City		
Rank	Choices	Other
1	E-mail	Word of mouth, City government sites, schools, internet sites for transit agency, CNN, and others
2	Kansas City newspaper	
3	Mailings	
4	Television	
5	Radio	
6	Internet sites	
7	City or neighborhood newsletter	
8	Other local newspaper	
9	Mid-America Regional Council	
10	Phone calls	
11	Other	

Source: MARC, 2013

the region, and assist the commission in implementing public outreach strategies. Member cities and counties represented on the DVRPC board appoint members to the task force.

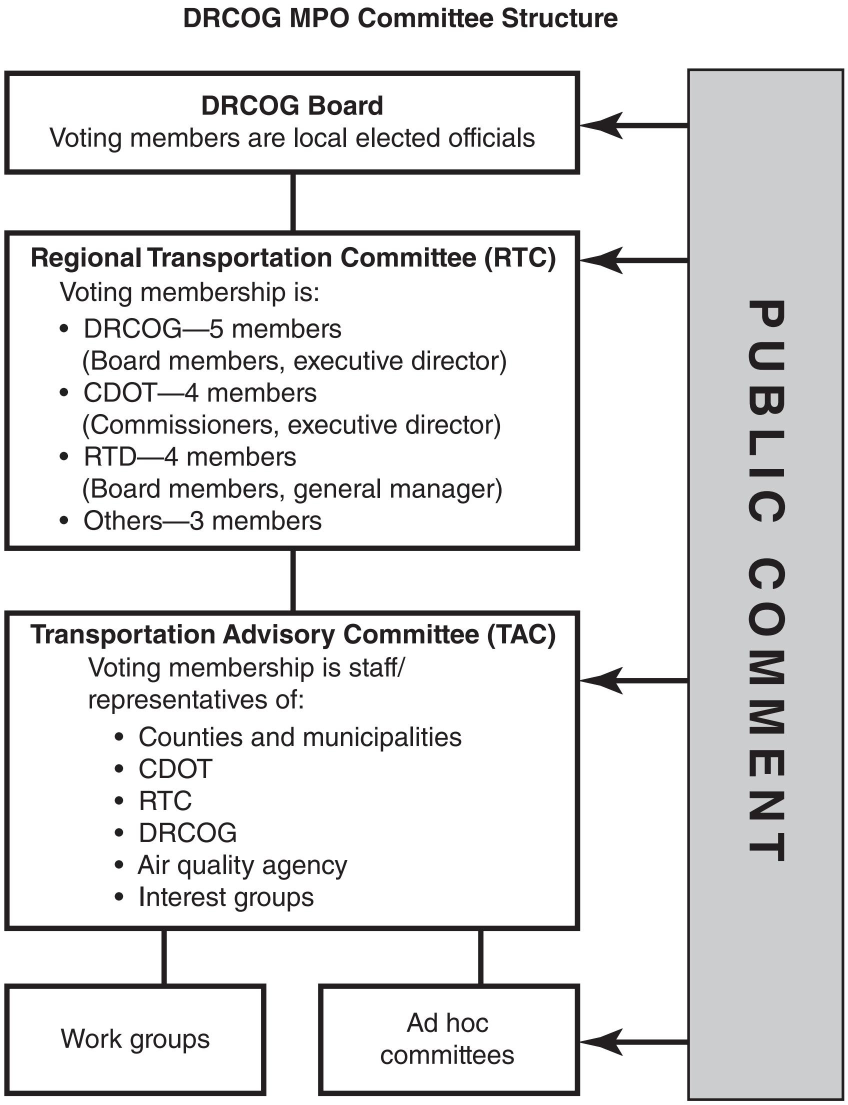
Another example of an advisory committee and how it fits institutionally into an MPO's governance structure is shown in Figure 24-4. This figure shows the Transportation Advisory Committee (TAC) for the DRCOG in Denver. There are 29 members of the TAC representing local counties and municipalities, the Colorado DOT, the Regional Transit District (RTD), the Regional Air Quality Council (RAQC), environmental interests, freight interests, transportation demand management (TDM) and between (TDM) and nonmotorized transportation interests, aging community interests, non-RTD transit interests, aviation interests, business/economic development interests, and ex officio FHWA/FTA representatives.

Community-based Outreach. A relationship between a transportation agency and community organizations to engage existing community organizations in disseminating planning information and hosting forums. A good example of this is in San Diego where SANDAG, the region's MPO, has provided funding to eight community groups to conduct outreach, especially in communities that traditionally are not involved in regional public policy planning. The types of involved groups included a disabled advocacy group, faith groups, Hispanic neighborhood collaboratives, adult health-care centers, and a business association.

Community Engagement Teams. Teams consisting of local representatives and relevant transportation agencies acting as advisors focusing on specific issues or interests.

Community Involvement Roundtable. A form of a citizen advisory group acting as a sounding board for public opinion. Roundtables often formally review plans and make recommendations to the MPO. An example is the Community Involvement Roundtable (CIR) in Broward County, Florida, which is a 45-member citizen advisory group to the MPO whose membership is determined by the Board.

Figure 24-4. Transportation Advisory Committee, Denver



Source: DRCOG, 2010

Community Outreach. Providing information and/or staff presence at gathering places/community festivals to disseminate project information and engage with the general public. This approach is very useful for engaging a diverse audience.

Fact Sheets. Papers or brochures providing summary information on MPO policy, programs, and projects. Fact sheets can be distributed as part of community outreach (see Community Outreach, above).

Focus Groups. A randomly selected group of individuals that represents the sociodemographic profile of the study area. Said individuals are asked targeted questions on issues of importance to the transportation agency. Usually, representatives from the agency observe the process and submit questions to the group while in session. Typical focus groups range from approximately 8 to 15 people, include enough representation to garner a cross section of opinions, while not so many people that some attendees are unable to make themselves heard.

Interactive Voting. Electronic polling devices used to solicit answers to a series of questions on a variety of transportation issues. Electronic keypads register participants' responses and project them graphically on a screen providing the opportunity for discussion and instantaneously capturing public opinions. Smart phone apps and cell phone texting can also be used for instant polling and voting.

Interdisciplinary Teams. A team formed including different types of skills and expertise needed for a particular study. These teams are sometimes called multidisciplinary teams.

"*Invite Us Over*." Asking transportation advocacy groups, professional organizations, transportation-equity organizations, and other such groups to invite staff to attend regularly scheduled meetings to discuss transportation issues that are important to them. This has been used in Boston where MPO staff attends local meetings and makes presentations, answers questions, and gathers comments.

Key Stakeholder Interviews. Interviewing key individuals or groups in a study using a predetermined, standard set of questions. Similar questions are asked of each participant so as to compare answers.

Limited English Proficiency Aides. Interpreters and translating services made available to serve the needs of population groups not proficient in English. Areas where residents that predominantly speak other languages are identified through a Modern Language Association (MLA) Language Map and by geographic mapping data available through the U.S. Census.

Local Coordinating Boards. Members appointed by the transportation agency to act as an official representative of specific groups such as the aging, child welfare, veterans' affairs, and schools. In Florida, for example, the Florida Commission for the Transportation Disadvantaged (FCTD) coordinates transportation services for persons who because of physical or mental disability, income status, or age are unable to transport themselves or purchase transportation to access health care, employment, education, shopping, social activities, or other life-sustaining activities. This assistance is advised by Local Coordinating Boards (LCB).

Local Media Contacts. Establishing contacts with local media. Several strategies can be used to get the local media interested in a study, including news releases, inviting reporters to news briefings, meeting with editorial staff, writing opinion pieces/commentaries, displaying ads, using minority media outlets for news releases, placing speakers on radio/TV talk shows, and using public service announcements on the radio and TV. A media kit is a way to disseminate facts and information about the project to numerous reporters. The kit may contain a map or visualization of the proposed project and fact sheets including unique or interesting aspects that make the project news worthy. The kit can be printed or electronic. Media kits are a quick and convenient reference tool for reporters to use verbatim, thus avoiding potential misinformation.

Mailings/Flyers. Materials prepared specifically addressing the study and offering information on the current status and providing information on how residents can become engaged in the process. Transportation agencies often work with community-based organizations to distribute flyers or to e-mail targeted database lists.

Meeting in a Box. Local citizens or community leaders host a meeting for groups within their communities with meeting materials prepared as a stand-alone kit. The meeting in a box provides everything that is needed for the meeting. The host is responsible for inviting attendees and for securing the meeting location, which may be a school, private residence, or other place of assembly. The host is also responsible for returning the results of the meeting and any comments or notes [Colorado DOT, 2015].

Mobile Participation Sites. Roving information centers, usually some form of vehicle (for example, a bus), provide meeting and interaction space to different parts of the region. The Indian Nations Council of Governments (INCOG) in Tulsa, Oklahoma, is a good example of an organization that successfully utilizes this strategy. As part of a transit planning study, INCOG planners traveled by bus to visit 117 stops in 12 different jurisdictions over a four-month period. BC (British Columbia) Transit's Transit Future Bus is similarly used to invite comments at community events and key transit nodes.

Newsletters. Either in printed and/or electronic form, periodic newsletters sent to a targeted mailing list can provide the latest information to study stakeholders. One could also take all or portions of the newsletter and submit articles for publication in community/corporate newsletters.

Polls/Surveys. Telephone, mail-back, web-based or in-person surveys to gather information on a wide range of issues. The credibility of this data source depends on the sampling strategy and the quality control associated with data collection (see chapter 2).

Public Hearings. Formal legal proceedings required as part of project development, and other meetings subject to hearing requirements. In project development, public hearings are usually required for projects that meet NEPA-defined criteria, such as the completion of a draft environmental impact statement (EIS). The hearings may include descriptive presentations, and they all must afford the public the opportunity to comment on the project/proposed action. Comments for the public record are recorded at the hearing by a court reporter or recording device. Comments for the public record are also usually collected during the pre- or post-hearing comment period, which must last for a standard, predetermined number of days.

Public Meetings. Meetings or a series of meetings not subject to legal procedural protocols, but meant to disseminate plan information and garner public input. These meetings can be held anywhere in the affected region, as deemed necessary. The MPO in Kansas City found that citizens are more willing to participate in transportation discussions when the discussions are part of an organization's meeting (for example, YMCA, neighborhood association, and the Rotary Club). If practical, the transportation agency should consider co-sponsorship of such meetings to maximize potential participation.

Scenario Tools. A tool that allows users to experiment with various choices, view the implications and results, and provide input on their preferences. Scenario testing can be done either online or at meetings. This provides the public with a better understanding of how difficult choices are made (namely, based on balancing the overall benefits and costs of various plan elements). In San Diego, an interactive web-based visualization tool was used following the release of the draft regional transportation plan that visually demonstrated the priorities, investments, transportation system, and other key elements and concepts in the draft plan. The tool also included a web-based form in English and Spanish for members of the public to submit comments.

Speakers Bureau. Individuals trained to deliver a standard presentation and skilled in responding to questions. These speakers are invited to attend community meetings or other groups where the study is on the agenda. The project team may need to "pitch" the presentation to groups and not wait for invitations. This might occur by identifying community groups and contacting them with the offer to present.

Technical Advisory Committee. An advisory committee with representatives from the technical staff of non-MPO/DOT agencies. An example is the Complete Streets Technical Advisory Committee in Broward County, Florida, which provides technical assistance and resources to local agencies. Membership includes staff from local municipalities, Broward County government, Florida Department of Transportation, as well as nontraditional transportation agencies like the Broward Regional Health Planning Council, Smart Growth Partnerships, Broward YMCA, and Florida Department of Health.

Telephone Town Halls. A "town hall" using telephone call-ins to poll a large number of participants on transportation improvements or other issues. As used by the Colorado DOT, the telephone town hall allows participants to ask questions of DOT staff over the phone.

Trusted Advocates. Individuals having strong connections to their communities, a background in community engagement, and the ability to advocate and educate within their communities. Trusted leaders could also be called opinion leaders or champions. Methods of engagement include one-on-one interviews, going door-to-door, tabling (staffing a table at a heavily trafficked location or event), kitchen table meetings/home visits, small-group meetings, and community gatherings. This strategy has been used with great success in the Twin Cities, Minnesota, and Seattle, Washington.

Video. Videos produced to educate the public and disseminate information on transportation, such as describing the steps in a planning process. These videos are often placed on social media sites.

Visualization. Interactive maps, pictures and/or displays that lead to improved understandings of existing or proposed transportation plans and programs.

Workshops. A meeting with a set agenda, usually including participation of workshop attendees. The workshops focus on particular issues (for example, scenario planning for the region) and are usually facilitated by a trained moderator. They offer customized presentations to existing groups and organizations and can be co-hosted with community groups, business associations, etc. The types of tools used in a workshop format can be open houses, question-and-answer sessions, break-out sessions for smaller group discussions on multiple topics, interactive exercises, poster sessions, and charrettes. Workshops use visualization techniques to motivate participant interaction, such as maps; charts, illustrations, and photographs; table-top displays and models; web content and interactive games; electronic voting; and PowerPoint slide shows.

As mentioned earlier, transportation agencies usually develop targeted programs to attract minorities, the elderly, and disabled persons to the planning process. These are particularly challenging groups to involve in planning for a variety of reasons. Table 24-8 depicts example data from the Colorado DOT with respect to reported barriers often

Table 24-8. Identified Barriers to Public Participation, Colorado DOT		
Barrier	**Methods**	**How CDOT Addresses the Barrier**
Cultural	Research culture, customs, language, and community styles. Identify employees of diverse cultural backgrounds that can help improve outreach and communication. Identify and reach out to local community organizations and leaders.	Working actively with CDOT's Center for Equal Opportunity, cultural barriers are reduced through cultural training for staff and connecting with local community leaders.
Language	Identify community bilingual speakers. Ensure materials are in languages representative of where the meeting or outreach is taking place. Provide interpreters.	Working actively with CDOT's Center for Equal Opportunity, to the extent possible, solicit in-house interpreters to assist in dealing with language barriers in the planning process in accordance with Executive Order 13166, "Improving Access to Services for Persons with Limited English Proficiency." Specifically, CDOT has made improvements in providing web pages and major documents in Spanish.
Mobility (and other) Disabilities	Ensure facilities are accessible. Provide materials in large print format or Braille for those vision-impaired. Use sign language interpreters. At meetings offer hearing aid amplifiers and other hearing assistance devices. Use telecommunication device for communication via telephone with hearing impaired.	CDOT staff is attentive to any calls or other forms of communication where individuals request assistance to participate in the planning and programming processes. This includes, but is not limited to, meeting access (in compliance with the Americans with Disabilities Act, as amended) or meeting materials in Braille or large print.
Economic/Income	Schedule meetings or face-to-face interactions at convenient times and locations. Provide snacks by using local community members or local catering. Provide child care. Provide financial incentives for meeting attendance.	CDOT considers meeting locations in terms of multimodal accessibility and meeting times that help to not only provide participant convenience, but snacks and child care where appropriate.

Source: CDOT, 2015

faced by these groups. Many of the strategies described above are relevant means of getting these groups involved in transportation planning, as long as group-specific assistance is also available, such as translators, barrier-free meeting locations, travel provision to the meeting sites, and the like.

Simon and Simon [2014] conducted a study for the Transportation Research Board on the types of arrangements transportation agencies can make to encourage those with disabilities, the elderly, and minority groups to participate in the planning process. They found transit agencies used the following primary techniques for the audiences:

People with Disabilities—Advisory committees, outreach to advocacy organizations and disability organizations, and formal membership on transit agency advisory committees.

African Americans—Outreach to community and neighborhood organizations, church and community leaders, and outreach to targeted transit centers.

Hispanics—Outreach to community and neighborhood organizations, use of the media, bilingual staff, and outreach at transit centers.

Asian Americans—Outreach to community and neighborhood organizations and outreach at targeted transit centers.

Limited English Proficiency (LEP) Groups—Outreach to community and neighborhood organizations, bilingual staff, minority media outlets, and translated materials. Techniques for involving other immigrants included outreach to community organizations, use of advocacy organizations, and reaching out to social service agencies.

The report also suggested that special care is needed to prepare a meeting environment conducive to participation by these groups. Such elements includes hands-on presentations, multilingual translators, sign language interpreters, ADA-compliant locations without physical barriers, child care, refreshments, accessibility via public transportation, and feedback to the participants in a format and medium they can understand.

VI. EVOLVING ROLE OF TECHNOLOGY AND SOCIAL MEDIA

New technologies have dramatically influenced the approaches and strategies for public engagement:

- Every state DOT and MPO has a website with information on transportation plans, programs, and projects.
- Near instantaneous communications and information portals provide agencies with the means of disseminating information quickly and in attractive, cost-effective ways.
- New visualization technologies provide planners with the ability to illustrate and explain concepts that serve as the foundation of proposed plans and project designs.

Social networking/media is defined as any current electronic form of communication such as chat messaging, text messaging, and social networking sites. Giering [2011] noted that "as social media increases in importance as a public participation tool, practitioners are seeking direction on what to use, when, and how. This is a rapidly evolving field that needs a thoughtful approach to study the benefits of social media, adaptable concepts for its use, the legal and privacy issues surrounding it, and whether or not it improves the overall outcome of public participation efforts."

An example of a new technology-based approach is crowdsourcing. Crowdsourcing is a problem-solving approach in which a sponsor (the one who "crowd sources") seeks input online from those having expertise or interests on particular topics. Participants provide ideas and thoughts that can be shared and refined by others (again, online), which provides the crowd sourcer with a set of strategies or actions that have been vetted by those most knowledgeable about the topic. [Gazillo et al., 2013] For example, crowdsourcing outreach for a planned subdivision could ask community members about the amenities most desired. Following that line of questioning, the online survey could be tailored to refine the top answers and add new choices, based on input received to date. Crowdsourcing is essentially a dynamic survey that changes based on feedback and input from the public.

Bregman [2012] conducted a survey of 35 transit agencies to identify the most commonly used social media platforms. The survey found the most common platforms were:

- Blogs or web logs, where individuals or organizations post commentary or news, frequently on a particular topic, and often invite comments and feedback.
- Social and professional networking sites that encourage members to connect with one another, such as Facebook, LinkedIn, and GovLoop.
- Micro-blogging sites, primarily Twitter, which allow users to post comments and web links.
- Media- and document-sharing sites where members post and share video clips (YouTube), documents (Scribd), and photographs (Flickr).
- Geolocation applications, such as Foursquare, which enable users to share their location with other members of their social network and to earn virtual "badges" for checking into sites.

Several other interesting findings from the survey include:

- Staff availability was the greatest barrier to adopting social media.
- As the line between private and professional communications blurs, public- and private-sector agencies are having to address employee use of social media (perhaps inappropriate use).
- Concern that social media would increase criticism from frustrated riders and disgruntled employees.
- Although internet access for people with disabilities has improved substantially over the past few years, social media applications have lagged, and their heavy reliance on graphics, videos, and user-generated content has created accessibility challenges.
- Concerns about cyber threats and user privacy.

Tables 24-9 to 24-11 show some of the other results from this survey.

An example from MARC in Table 24-12 shows how social media is being used for its transportation planning process as of 2013. As shown, MARC uses primarily Facebook and Twitter for its social media outreach efforts.

State DOTs have also been aggressively pursuing new technologies for public participation efforts. The latest survey (2014) of state DOTs by the American Association of State Highway and Transportation Officials (AASHTO) showed only one state reported not using social media technologies in its social media program. [AASHTO, 2014] Facebook and Twitter were the two highest ranked media, with video- and photo-sharing programs seeing a significant increase in use. In 2014, state DOTs had on average 16 individuals dedicated to their communications teams.

It is important to note that social media platforms evolve so rapidly that the major technology applications used today could be superseded by new and more advanced applications in the future. Transportation planners thus need to be aware of the newest and most-used means of interaction via the internet. Readers are encouraged to access the Pew

Table 24-9. Type of Information Provided and Social Media Application Used, U.S. Transit Agencies

Platform	Twitter	Facebook	Blog	YouTube	LinkedIn
Agency news	86%	80%	37%	23%	3%
Service alerts	77	49	9	3	0
Contests and promotions	69	77	23	17	0
Meeting and event notices	66	71	31	3	3
Service info	63	69	29	20	9
Press releases and statements	63	60	23	9	3
Other news	57	63	31	14	3
Feature stories	31	57	40	29	0
Job listings	20	23	3	0	14
Public hearing comments	11	26	20	9	0
Other	11	17	6	14	3

Multiple responses allowed. Responses expressed as percentage of total responding agencies ($n = 35$)

Source: Bregman, 2012, Reproduced with permission of the Transportation Research Board.

Table 24-10. Importance of Social Media Goals, U.S. Transit Agencies

Goal	No.	Not Important	Slightly Important	Important	Very Important	Average
Communicate with current riders	33	0%	0%	3%	97%	4.0
Improve customer satisfaction	33	0%	6%	9%	85%	3.8
Improve agency image	33	0%	6%	18%	76%	3.7
Reach potential riders	32	0%	9%	22%	69%	3.6
Distribute real-time service info.	32	3%	13%	19%	66%	3.5
Strengthen community support	33	0%	12%	21%	67%	3.5
Distribute general service info.	33	3%	6%	45%	45%	3.3
Increase ridership	33	3%	15%	30%	52%	3.3
Obtain feedback on projects	32	3%	19%	31%	47%	3.2
Save money	29	17%	31%	24%	28%	2.6
Recruit and keep staff	29	38%	41%	17%	3%	1.9

Percentage is based on number of agencies responding to question. Weighted average was calculated from responses using a four-point scale.

Source: Bregman, 2012, Reproduced with permission of the Transportation Research Board.

Table 24-11. Effectiveness of Social Media for Reaching Constituencies, U.S. Transit Agencies

Goal	No.	Not Effective	Slightly Effective	Effective	Very Effective	Average
Everyday riders	31	0%	10%	55%	35%	3.3
Young adults	29	0%	14%	48%	38%	3.2
Students	30	0%	20%	40%	40%	3.2
External stakeholders	26	0%	27%	50%	23%	3.0
Agency employees	16	0%	25%	63%	13%	2.9
Minorities	18	0%	33%	61%	6%	2.7
People with disabilities	21	5%	33%	57%	5%	2.6
Low-income communities	18	0%	61%	28%	11%	2.5
Seniors/older Americans	23	17%	48%	30%	4%	2.2

Percentage is based on number of agencies responding to question. Weighted average was calculated from responses using a four-point scale.

Source: Bregman, 2012, Reproduced with permission of the Transportation Research Board.

Table 24-12. Social Media Platforms and Information Disseminated, Kansas City

Social media platform	Account Name/Handle	Content
Facebook	www.facebook.com/MARCKCMetro	General MARC content including transportation related updates and notices.
	www.facebook.com/rideshareKC	Rideshare program information, alerts, etc.
	www.facebook.com/airQKC	Air Quality program updates, alerts, and occasional transportation information.
Twitter	www.twitter.com/MARCKCMetro@ MARCMetroKC	General MARC content including transportation-related updates and notices.
	www.twitter.com/MARCKCMetro@MARCKCTrans	General MARC transportation related updates and notices.
	www.twitter.com/KCSmartMoves@KCSmartMoves	Regional transit activities, project updates, and meeting notices.
	www.twitter.com/AirQKC@AirQKC	Air Quality Program updates, alerts, and occasional transportation information.

Source: MARC, 2013

Research Center program on social media for the latest information on social media use (http://www.pewresearch.org/topics/social-media/2015). For example, some of the information available at this site (as of 2015) include:

- Overall, 85 percent of adults are internet users and 67 percent are smartphone users.
- Thirty-six percent of smartphone owners report using messaging apps such as WhatsApp, Kik, or iMessage, and 17 percent use apps that automatically delete sent messages such as Snapchat or Wickr.
- Half (49 percent) of smartphone owners ages 18 to 29 use messaging apps.
- The proportion of Instagram, Pinterest, and LinkedIn users who use each respective site daily increased significantly from September 2014 to April 2015. Fully 59 percent of Instagram users, 27 percent of Pinterest users, and 22 percent of LinkedIn users visit these platforms daily.
- Facebook remains the most popular social media site—72 percent of online adults are Facebook users, amounting to 62 percent of all American adults. Approximately 82 percent of online adults ages 18 to 29 use Facebook, along with 79 percent of those ages 30 to 49, 64 percent of those ages 50 to 64, and 48 percent of those 65 and older. Facebook continues to have the most engaged users—70 percent log on daily, including 43 percent who do so several times a day.

- Instagram continues to be popular with nonwhites and young adults: 55 percent of online adults ages 18 to 29 use Instagram, as do 47 percent of African Americans and 38 percent of Hispanics. Additionally, online women continue to be more likely than online men to be Instagram users (31 percent vs. 24 percent).
- LinkedIn is the only major social media platform for which usage rates are higher among 30- to 49-year-olds than among 18- to 29-year-olds. Fully 46 percent of online adults who have graduated from college are LinkedIn users, compared with just 9 percent of online adults with a high school diploma or less. [Pew Research Center, 2015]

As additional social media technologies come online, state DOTs and MPOs will have to continually explore how the new capabilities can be used effectively in the transportation planning process. Some useful references include: [Brabham 2013; Barron et al., 2013]; and www.nepaandsocialmedia.com.

VII. PUBLIC PARTICIPATION AND PROJECT DEVELOPMENT

Public participation activities for project planning and development use very similar strategies and tools as described above. However, there are two major differences. First, motivating individuals to help develop a plan with a 25-year timeframe is challenging; many potential participants do not see the long term plan's relevance to their everyday lives. However, a project development process with public participation regulated under NEPA and other federal and state law, especially one that is going through an environmental analysis, will usually focus on very specific concepts and impacts that individuals can relate to. They know where the road or transit alignments are being proposed; they know the neighborhoods that will be affected; and they understand the likely benefits that could occur with the project. It is thus often easier to attract public interest to specific project planning and project development efforts, although the interaction could be more contentious. Second, in cases where the proposed project is significant enough to warrant environmental analysis, federal and state laws will often require formal public hearings, which have legal implications on how the agency responds to public comments.

Some examples of project-level public participation efforts are presented below. Note that the local context, degree of impact, and other factors will influence the selection of tools in each case.

Warm Springs BART Extension, Bay Area, California

This project will add 5.4-miles of new track from an existing station south to a new station in the Warm Springs district of the city of Fremont, extending BART's service to southern Alameda County. [BART, 2015] The public participation activities in this study included:

- Five outreach events held in the Warm Springs catchment area and in San Francisco.
- Input from BART's Title VI & Environmental Justice (Title VI/EJ) Advisory Committee.
- Surveys of residents of Warm Springs as well as current riders.
- A multilingual flyer/mailer in English, Spanish, Vietnamese, and Hindi (including reference to the availability of translation services for meetings).
- An oversized copy of the multilingual flyer displayed at BART stations.
- BART website announcements and posted draft Title VI Equity Analysis.
- BART social media announcements (Twitter).
- BART Passenger Bulletin in English (with standard taglines for more information in Spanish, Vietnamese, Chinese, and Korean) at BART stations.
- Announcement broadcasted up to 7,500 times per day on the BART Destination Sign System (DSS) at all BART stations throughout the District, as well as targeted messages at selected stations.
- Advertisements in local print ethnic media.
- E-mail notice to more than 400 local community-based groups and civic organizations.
- E-mail notice to approximately 5,200 recipients on the Warm Springs Project e-mail subscriber list through GovDelivery.

Virginia Beach Extension Transit Study, Hampton Roads Transit Authority, Virginia
The Hampton Roads Transit Authority was studying transit improvements in a corridor serving the downtown area of Virginia Beach, Virginia. The study looked at multiple transit improvement scenarios: developing a light rail line extension, a bus rapid transit line, enhanced bus service, or doing nothing [HRT, 2010]. The public participation activities for this project included:

- Newsletters.
- E-mail project updates.
- Press releases and news articles.
- Twitter tweets of major project news and meetings.
- Facebook page.
- Community and business organization presentations.
- Public access cable channel presentations.
- Public meetings and hearings.
- Station area workshops.
- Stakeholder interviews.
- Community advisory committee.

Public Participation Tools for Project Development, Washington County, Oregon
The Washington County Department of Land Use & Transportation [2015] in Oregon has developed a set of guidelines for public participation on projects going through the project development process. Public participation tools and strategies for project development may include the following:

- An eSubscription (e-mail list) and/or Interested Parties list to keep interested parties informed.
- Print and e-mail project updates to interested parties list (may include postcards).
- Citizen Participation Organization (CPO) and other community meetings.
- Print and electronic newsletters (county and CPO newsletters).
- Project information signs at project site.
- Project website featuring pertinent documents.
- Social media updates.
- Media releases at major project milestones.
- Open houses.
- Citizen Participation Organization (CPO) and other community meetings.
- Project Focus Group or Community Advisory Committee for select projects with significant community impacts.

For major projects, the Department requires the adoption of a public participation plan with all of the steps presented in earlier sections of this chapter.

VIII. HOW TO MEASURE EFFECTIVENESS

In his synthesis of transit industry experience with public participation strategies, Giering [2011] observed, "one of the most difficult aspects of synthesizing public participation across the agencies that participated in this effort is defining "success." There is a need and a desire among agencies to quantify public participation outputs and outcomes in a way that can be used in a benefit-cost analysis. However, no consistent methods emerged." One way of defining success is identifying early in the process specific targets for individual public participation strategies. An example of this are the following metrics for evaluating the public participation plan for a recent San Diego project:

- Increase hits on project website by 10 percent from the baseline of 2,380 hits.
- Display project information at five high-traffic locations in the corridor.
- Make 30 presentations through the speakers bureau program.
- Distribute three issues of Mid-Coast eBlast.
- Participate in three community events.
- Issue three news releases.
- Conduct 15 stakeholder briefings.
- Conduct three meetings of the Mid-Coast Corridor Transit Project Working Group.
- Conduct five scoping meetings during the scoping period.
- Conduct four public hearings/meetings during the Draft Supplemental Environmental Impact Study/Subsequent Environmental Impact Report (SEIS/SEIR) public review period. [SANDAG, 2010]

However, it is important to distinguish quantity from quality. Making 30 presentations with the speakers' bureau says nothing about how effective these presentations were in informing, educating, motivating, or encouraging those in the audience.

To some extent the North Jersey Transportation Planning Authority (NJTPA) [2007] recognized this in its PPP when it identified desired outcomes for different public participation strategies. For example, its goal "Provide adequate opportunities to engage in meaningful two-way discussions between the NJTPA and the public about transportation planning issues," and the strategies of having public meetings, disseminating information via the internet, and interacting with the media were associated with the following outcomes:

1) More engaged members of the public, elected officials, and other stakeholders in the NJTPA planning process.
2) A Central Staff and Board of Trustees more fully engaged with the public.
3) More understanding by the public of the importance of the NJTPA's work, with more trust and credibility in the transportation decision-making process by the public.
4) A better chance to build consensus around tough decisions for the region.

These are laudable outcomes, but they rely solely on relative or qualitative statements with no description provided on how each strategy would be evaluated for success.

A key challenge to PPP evaluation is developing a systematic evaluation framework that examines all aspects of the agency's efforts. Thus, for example, the evaluation should clearly identify the stated goals of the public participation program and how the PPP efforts have helped achieve these goals. Planners should assess the effectiveness of individual tools and techniques in the context of the plan or project study, as well as identify where improvements can be made. Figures 24-5 and 24-6 show an effort to assess systematically the components of a PPP process. A common approach for evaluating public participation efforts is a self-assessment template that consists of a series of questions relating to the implementation of the PPP and the use of the information disseminated to the participants. This yields a standardized, useful evaluation tool that combines the qualitative with the quantitative.

Figure 24-5. Matching Evaluation Measures to Public Involvement Goals

Evaluating Public Involvement

QUESTIONS TO ASK

Evaluation Principle 1: Evaluation Measures Match Goals

A. Define goals and success criteria during PI planning

Evaluation begins with understanding what public involvement or public information needs to accomplish in your project. Set goals and success criteria during PI planning.

Ask yourself and your project team:

- What are our PI goals?
- What are our definitions of success?
- How will we know when we have fulfilled our goals or reached success?

Each UDOT region takes a slightly different approach to PI. In addition to project-specific goals, ask yourself and your project team questions based on desired PI outcomes of your region. The table below provides an overview of each region's PI approach.

UDOT Region	Overall PI Approach	Questions to Consider Based on Region's Vision of PI Success
Region 1	Customer-friendly Partnering	• Did we provide pro-active information? • Did we create a sense of stakeholder ownership in the project? • Did we coordinate with the appropriate stakeholders?
Region 2	Creation to Completion PI	• Did we consider public involvement or information at every project stage? • Did we inform and engage relevant stakeholders? • Did we build understanding through participation?
Region 3	Strategic Involvement	• Did we coordinate with the appropriate communities? • Did we meet stakeholders' needs? • Did we meet project needs for public input? • Did we effectively communicate with stakeholders?
Region 4	Communicate and Build Relationships	• Did PI support the decision-making process? • Did PI help build relationships with stakeholders? • Did PI help build trust with the public? • Did our approach match community values?

B. Rephrase goals as questions

As shown above, goals and success criteria can be rephrased as questions. Ask yourself and your project team yes/no questions as well as questions that get at *how* and *why* the goal was or was not met.

C. Set measurable goals

Set target measurements during PI planning as benchmarks or expectations. Identify ways to measure goals including documenting numbers, cost-effectiveness, evaluating quality and effectiveness, behavior tracking, message retention, and qualitative or quantitative research methods.

Source: Reprinted with permission of Eileen Barron.

Figure 24-6. Balance Quantitative and Qualitative Measures for Evaluating Public Engagement Programs

Evaluating Public Involvement

TOOL KIT & EVALUATION IDEAS

Evaluation Principle 2: Balance Quantitative and Qualitative

Numbers only tell part of the story. Numbers are effective to document PI activities and track trends over time. Ask yourself and your team how PI contributed to the project as part of evaluating PI effectiveness. The list below provides some ideas for tools and methods of evaluation.

By the Numbers

Number of comments

Attendance at meeting or activity

(*Caution*, low attendance does not always indicate failure)

Number of requests for information

Number of Web site hits

Number of new participants

Number of repeat participants

Number of media stories

Cost-benefit Analysis

Set realistic assumptions (contacts made, readers reached)

Consider ongoing benefits to the project

Look at specific tools

Look at PI plan as a whole

Include value of media coverage (inches of print, minutes of broadcast time)

Quality and Effectiveness

Rephrase goals as questions (see "Questions to Ask" handout)

Identify how PI contributed to the project

Hold a Lessons Learned Meeting

Use a project evaluation form

Compile a PI evaluation report

Gather consultant or contractor feedback

Conduct a Public Involvement Plan post analysis

Evaluate the accuracy of media stories

Track the tone of media stories (positive, negative or neutral)

Figure 24-6. (*Continued*)

Evaluate whether public comments show project understanding

Interview targeted stakeholders

Interview public officials

Conduct random interviews with stakeholders

Include PI in provisions for contractor incentive awards

Invite stakeholder committees to evaluate committee process

Behavior Tracking

Public satisfaction pre- and post-analysis

Number of phone calls or comments

Tone of comments (negative, positive, neutral)

Leverage appropriate level of quantitative or qualitative research

Quantitative or Qualitative Research

Public opinion surveys

Questionnaires

Internal surveys

Customer surveys (before and after a project or activity)

Informal surveys at public meetings

Focus groups

Source: Reprinted with permission of Eileen Barron.

A common approach for evaluating public participation efforts is a self-assessment template consisting of a series of questions relating to the implementation of the PPP and the use of the information disseminated to the participants. The following questions form part of the Colorado DOT's efforts to evaluate its PPP program.

Meetings and outreach

- How many individuals were identified as stakeholders at the beginning of the planning process?
- How many people did staff speak to?
- Were meetings held in previously unreached geographic areas of the state?
- Did the number of participants increase from previous long-range planning efforts?
- Was the overall turnout/response rate higher than past efforts?
- Was the information gathered used in the regional and statewide plans?

Website and electronic media

- How many visitors did the web page receive?
- Was the website updated in a timely manner with the most current information? (i.e., within a day or two of the information being finalized for the Web)

- How many subscribers are there to distribution lists, news feeds, and other electronic interactive media?
- How many times was a document downloaded from the website?
- How many comments were posted on a website?
- How many comments received electronically were addressed in the long-range plan document?

Outreach method evaluation

- What outreach method was the most effective and why?
- Was the use of news and/or electronic media increased from previous efforts? Did it result in increased participation?

Printed materials

- Were informational documents (brochures, fact sheets, studies, white papers) made available?
- How many newspaper articles were written covering the planning or programming process? [CDOT, 2015]

Table 24-13 is another example from the Washington County (Oregon) Department of Land Use and Transportation.

IX. WORDS OF WISDOM

Many MPO and state DOT PPPs have identified lessons learned from prior experience with public participation efforts, which suggest guidance on future activities. These are summarized below simply to provide a snapshot of what others have learned about what makes a public participation effort successful. The PPPs that most contributed to this list come from the Boston MPO [2014], Colorado DOT [2015], Hillsborough County MPO [2014a], and the MTC [2015] in the San Francisco Bay Area.

- *Understand Your Public*—There is no one-size-fits-all approach to public participation. Census data can help identify the socioeconomic characteristics of each community; however, it is important to talk to people to really understand their issues and concerns.
- *Be Cognizant of Participants and Their Different Levels of Technical Expertise*—Organize meetings and other events to appeal to the issues and concerns of those who are likely to participate. Informational materials should be clear and available in sufficient detail to allow citizens to form and express their independent views. Make great use of visualization techniques to enhance understanding.
- *Provide a Predictable Process*—The planning process should be understandable and known well in advance. This consistency in the planning process will allow staff, citizens, and officials to plan their time and effectively apply their resources.
- *Be Creative and Flexible in How You Communicate*—The direction and effectiveness of the program should be reviewed periodically to ensure it meets the needs of the public and the transportation agency. This program should continue to evolve and include new avenues of communication to augment the agency's public outreach efforts.
- *Early Engagement Is Best*—Per the MTC, major planning initiatives and funding decisions to provide meaningful opportunities to help shape outcomes are provided throughout the planning process. However, because MTC's Regional Transportation Plan (RTP) is the blueprint for new policies and investments for the Bay Area, updates to the RTP are one of the best places for interested persons to get involved.
- *Access to All*—Participants, regardless of disabilities or language barriers, should feel welcome at public engagement meetings. Respect the views offered by members of the public, and utilize their opinions, and other information offered.
- *Let People Know What Happened with Their Input*—The transportation agency should make sure meeting minutes reflect public comments and document how comments are considered in agency decisions.

Table 24-13. Self-Assessment for the Public Participation Plan, Washington County, Oregon		
Evaluation Criteria	**√**	**Metric**
Gather input by providing meaningful opportunities to participate		Were efforts made to engage those most affected by the program, project, or service?
		Were community organizations engaged and offered materials to share with their networks?
		If decision-making process, were people invited to share input in advance of decision-making milestone? And, was that input shared directly with decision-makers at meetings?
		How many people visited the project website?
		Were website referrals received from partners, stakeholders or community organizations?
		How many people subscribed to the newsletter
		How many people unsubscribed from the newsletter?
		Did your "interested parties" database grow after the public engagement period began?
		How many people clicked through project e-mails to the website or survey, if applicable?
		How many people opened the e-mail or survey, if applicable?
		How many @ replies, mentions, or comments on social media were received?
		How many people attended a public meeting or open house?
		Were online opportunities to participate also available in other formats?
		Were in-person opportunities to participate held at accessible locations? At various times? And supplemented by online opportunities?
		How many comments were received?
		What types of comments were made?
		What was the demographic make-up of participants?
		Did public involvement activities help build the capacity of people to participate in future public processes?
		Would people provide input in the future?
		Did public input result in modifications or changes to the project?
Involve underserved communities such as those with limited English proficiency, diverse cultural backgrounds, low-income, disability, seniors, and youth.		Was a demographic analysis of the program, project, or service area completed in order to identify race, language proficiency, and income levels?
		Was a four-factor LEP analysis completed to assist in determining an approach to language assistance?
		Was material translated and/or provided to communities that have a limited ability to speak English?
		Were translation services made available upon request?
		Was project information made available at accessible locations such as health care clinics, local and ethnic markets, community centers, and schools?
		How many comments were received in languages other than English?
		Did meeting materials include LUT's non-discrimination and language assistance notice?
		Did meeting materials include an ADA notice?
		Was material provided in alternative formats upon request?
		Were meeting locations accessible and barrier free?
		Were community organizations that serve low-income communities, communities of color, people with limited English proficiency, youth, or persons with disabilities engaged?

Table 24-13. (*Continued*)		
Evaluation Criteria	**√**	**Metric**
Communicate complete, accurate, understandable, and timely information		Was the information to be shared tested for clarity by people not involved in the program, project, or service?
		Was the information reviewed for accuracy?
		Were documents deemed "vital" translated into other languages?
		Were people made aware of the availability of information through e-mail, web, or partner networks?
		Were meetings, workshops, surveys, and other opportunities to participate clearly advertised on the project website and e-mailed to the interested persons list?
		Were project-sponsored meetings advertised on the project website at least two weeks in advance?
		Were people given advance notice of project briefings at community meetings such as neighborhood associations?
		Were formal public comment periods advertised with adequate notice (30 days preferred, 15 days minimum)?
		Did people feel their involvement was considered/acted upon?
		Was information clearly advertised on Twitter, Facebook, and other social media sites?
		What type of news or media coverage did the project receive?
		Was information available at least one week in advance of any decisions based on that information?

Source: Washington County, 2015

- *Coordinate with Partner Agencies and Their Outreach Activities*—Jointly held meetings, especially those that have a strong community presence, are a good way of expanding the potential audience. Potential partners include other municipal agencies (such as local villages) as well as community organizations (such as chambers of commerce, PTAs, and civic associations).
- *Embrace, as Feasible, New Technologies with which to Engage the Public in an Interactive Way*—Stay abreast of evolving social media and new technologies as they emerge.
- *Make Engagement Meaningful*—Credibility and trust are established over time when the public perceives the agency is not just "going through the motions or doing the minimum required by the laws and regulations that govern them," but are demonstrating a genuine commitment to collaborative decision making.
- *Train Staff Conducting Public Participation*—Proper skills and training are critical to successfully engaging the public. For example, staff should have solid verbal and written communication skills, be intimately familiar with the project (and thus able to answer questions), and be able to be direct without being "pushy" when requesting feedback.

X. SUMMARY

Public participation is a continuous effort of every transportation planning and project development process. For legislative and regulatory reasons, transportation planners need to be aware of the expectations of an effective and successful program. From a decision-making perspective, the decision-making process needs input from a broad array of stakeholders and the public to generate the best decisions for the region. Public participation involves building long-term working relationships and providing meaningful opportunities to influence decisions before they are made and finalized. These relationships will likely be with the more traditional transportation agencies and other groups who have participated in the planning process for decades, but also with community-based organizations, faith-based organizations, citizen advisory committees, and similar types of organizations to broaden the range of opportunities for participation.

Many different types of strategies and tools can be used by planners to reach out to the public and key stakeholders. Capturing the public's interest takes effort and continual attention. In today's world, this includes social media technology platforms that allow transportation agencies to reach citizens. The capacity to create and utilize visualizations, videos, the internet, intranets, and social networking will continue to change the way we communicate with one another. The basic concept of the public participation plan is that it articulates a strategy for using appropriate strategies and tools to obtain the most effective public participation process possible. Continual monitoring an evaluation of this process allows planners to adjust the PPP, modifying the plan when strategies are no longer appropriate or where new technologies have offered new capabilities.

A recent overview of public participation in transportation by the TRB Committee on Public Involvement identified four key lessons learned from the past decade. [Gazillo et al., 2013] First, efforts to promote transparency through public participation are becoming the norm, but practitioners should never assume public participation will happen on its own and should never become complacent about outreach efforts. Second, increasing diversity in participation requires greater public participation efforts to embrace these populations as well as improve and implement cross-cultural training, if appropriate. Third, practitioners need to be mindful of the balance between encouraging positive public participation and preventing the process to be used for personal gain. Finally, public participation practitioners need to be trained in the skills required to effectively implement successful programs and projects.

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Appendix A. Public Involvement Strategies and Tools, Hillsborough County MPO, Florida [Hillsborough County MPO. 2012]

Strategies & Tools	PPP Goals Supported 1 Visibility	2 Engagement	3 Notification	4 Responsiveness	5 Communication	6 Resourcefulness	7 User-Friendly	8 Proactive	9 Accessible	10 Compliant	Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?
Advisory Committees		■		■	■			■	■	■	Make recommendations on projects, plans and policies to assist the MPO board in making informed decisions from the seven standing committees composed of experts, citizens & special interest groups. The make-up of citizen-based groups should reflect the community's demographic composition.
Alternative Media	■	■	■		■	■	■	■	■		Use nontraditional means such as: automated voicemail, interactive information kiosks, computer graphic presentations, cell phones, podcasts in English and Spanish, etc.
Banners	■		■					■	■		Position logo banners inside and outside MPO events. The public can easily find event locations and news media will capture the banners to reinforce MPO brand recognition in news clips and photographs taken.
Banner Ad & Wraps	■		■		■		■				Highly visible form of advertising an event or plan in general newspapers, community news, and student newspapers.
Bicycle Suitability Map	■				■	■	■	■			Reinforces the relevance of the bicycle, pedestrian, and safety planning; a great public relations collateral piece distributed through bicycle shops and other locations throughout Hillsborough County.
Business Briefings	■	■		■		■		■		■	Information is brought to a location where members of the business community gather in order to present background, goals, issues, & status of a project with ample opportunity for attendee response.
Celebrity Media	■					■			■		Create excitement & appeal to a broader market than might normally take interest in transportation planning by creating PSA spots, videos, etc. with celebrity spokes-persons or by having a celebrity attend public workshops to bolster attendance.
Chambers of Commerce	■	■		■	■	■		■	■		Being active in area Chambers of Commerce, including specialized Chambers, raises MPO recognition and provides a variety of opportunities to make presentations to various working groups and transportation committees that ideally represent a broad cross-section of the local business community.

(*continued*)

Appendix A. (*Continued*)

Strategies & Tools	PPP Goals Supported 1 Visibility	2 Engagement	3 Notification	4 Responsiveness	5 Communication	6 Resourcefulness	7 User-Friendly	8 Proactive	9 Accessible	10 Compliant	Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?
Charrettes		■		■		■		■		■	A meeting format designed to define issues, analyze problems and alternative solutions in a short, intense time frame to reach consensus on approaches to be taken, usually involving local experts and targeted stakeholders defining values and expectations in the process.
Citizens Guide	■	■	■	■	■	■	■	■	■	■	Produced and distributed in conjunction with the PPP to provide a concise informative tool for citizens on the various ways they can be involved in transportation planning and LRTP updates.
Community Outreach Coordinators		■		■	■	■		■	■		Professionals or volunteers who have extensive knowledge of EJ populations being targeted, relationships with community leaders within that community, and the cultural and linguistic competency in order to engage EJ communities in MPO planning or project management team.
Contests & Games	■					■		■			Intensify community interest and increase community involvement through a game, gimmick or activity created to get the public's involvement in an idea, proposal or project.
Discussion Facilitation	■	■	■	■	■	■	■	■	■	■	Group problem-solving guided by a trained facilitator who is neutral to the issues that focuses on a specific project or issue. Discussion is structured without controlling content in order to keep the process open with the full spectrum of opinions receiving due consideration, with the facilitator moving the discussion toward consensus and conclusion.
Event Hotline (24-Hour)	■	■	■	■		■		■	■	■	A dedicated and publicized local telephone number available 24 hours a day as an automated system to inform of upcoming public involvement opportunities and to collect recorded comments and/or get information for follow-up.
Exhibits & Kiosks	■	■	■					■	■		Inform the community of project activities and opportunities to watch and/or attend in-person meetings or workshops.
Field Reviews					■						On-site visit to facilitate understanding of existing conditions and to communicate proposed activities from an existing conditions viewpoint.

Appendix A. (*Continued*)

Strategies & Tools	1 Visibility	2 Engagement	3 Notification	4 Responsiveness	5 Communication	6 Resourcefulness	7 User-Friendly	8 Proactive	9 Accessible	10 Compliant	Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?
	PPP Goals Supported										
Flexible Database		■		■		■		■	■	■	• A computer database in which participants, stakeholders, and agencies information is entered in a manner that is easily and efficiently sorted and retrieved based on a variety of criteria. • Provide a means to track responses and to provide effective & timely responses. • An efficient means to achieve contact with the community through targeted mailing lists.
Flyers			■		■		■				Printed announcements of upcoming public meetings or events that are posted and handed out in communities affected by MPO plans.
Focus Groups	■	■	■	■		■	■	■	■	■	A meeting with a defined agenda where a set of questions is posed to participants which guides discussion so that public opinion can be more closely gauged. A facilitator is necessary and the number of participants is normally limited.
Growth & Transportation Options Visioning Tool	■	■	■	■	■	■	■	■	■	■	An interactive visioning tool Flash-based program using GIS data, developed in conjunction with Tampa Digital for the Planning Commission to help people better understand the relationship between transportation and land use. It allows users to allocate growth and types of development to building land use scenarios using information on available, developable land, environmentally sensitive land, and population. Users can see instantly the impact it has on transportation choices. This tool has applications in live workshops, at free-standing kiosks and with online participants with easily downloadable results.
HCTV22 & Cable TV	■	■	■	■	■	■	■	■	■		• Broadcast spots that inform the community about events, meetings & other public participation opportunities. • Live and rebroadcasts of all MPO meetings in HTV22 with reference to MPO website on banner. The schedule is available from HTV at 813/272-5362.

(*continued*)

Appendix A. (*Continued*)

Strategies & Tools	PPP Goals Supported										Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?
	1	2	3	4	5	6	7	8	9	10	
	Visibility	Engagement	Notification	Responsiveness	Communication	Resourcefulness	User-Friendly	Proactive	Accessible	Compliant	
"Home Games"	■	■	■	■	■	■	■	■	■	■	A method most recently used for the *MPO Transit Study's* Transit Scenarios Workshops providing the ultimate in proactive participation techniques by providing at home workshops for neighborhood or other stakeholder groups to participate at a time and place most convenient, allowing people to participate who may never have attended a public workshop, having a significant impact on overall number of participants.
Informational Brochures	■	■	■		■	■	■	■	■	■	Develop & distribute informational brochures regarding current transportation issues. Recent & upcoming brochures include a one-page fold-out map depicting LRTP projects, the Ride Guide, Citizens Guide, Transit Concept for 2050 brochure and a Bicycle Suitability Map. Brochures are made available at public events, through public libraries and in the public area of The Planning Commission offices.
Interactive Displays	■	■		■	■	■	■	■	■	■	The electronic display of information, which includes computer graphics, photo mosaics, GIS systems, video brochures, simulations, and visualization tools that can be enhanced with interaction, making complex concepts more easily understood.
Leadership Meetings	■	■	■	■		■	■	■		■	Meetings where the public receives the latest project information in an atmosphere where community leaders can respond to current information, assess leadership concerns and needs and rally support for project goals and upcoming activities.
Advertisements	■	■	■		■		■	■	■	■	Advertise public meetings, public hearings, and required public comment and review periods. See the Notices section.
Logos	■	■	■		■		■	■	■	■	Using the MPO Logo or special study logos to create brand recognition through every phase of projects, plans, programs, and documentation.
Media Kits & Briefing Packages	■		■			■	■	■	■	■	An informational package to provide general project data to media outlets that will be able to disseminate accurate information to interested audiences in a people-friendly format.

Appendix A. (*Continued*)

Strategies & Tools	PPP Goals Supported 1 Visibility	2 Engagement	3 Notification	4 Responsiveness	5 Communication	6 Resourcefulness	7 User-Friendly	8 Proactive	9 Accessible	10 Compliant	Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?
Media (non-traditional)	■	■	■		■			■	■	■	Includes newspapers aimed at ethnic groups, broadcast media serving non-English speakers.
Meeting Notices & Agendas		■	■		■	■					Mailed electronically or in hard-copy to all citizens who request them in addition to MPO members and Committee members. Posted on the MPO website. See the Notices section.
Mobile Devices	■	■	■		■	■		■	■	■	Electronic forms of communication can leverage technology through means such as text messaging, email blasts, and Twitter to broadcast alerts and public notices to mobile devices and smart phones.
Mobile Exhibits	■	■	■	■	■	■	■	■	■	■	A portable, stationary or interactive display of project background and current information that can be moved community sites or special events to improve awareness and response collection by stakeholders.
Money Game		■		■	■	■	■	■			An active participant form of surveying used to demonstrate how the public would like to see their tax dollars spent. At the onset of a meeting, participants are given $100 in play money and asked to distribute the money into boxes representing various modes of travel.
Newsgroups	■	■	■	■	■	■	■	■	■	■	Available 24 hours a day for interested and informed stakeholders.
Newspapers	■	■	■	■	■	■	■	■	■	■	An article, advertisement, or announcement generates attention, intended to reach a wide audience to announce a project or meeting and/or stimulate interest community interest. Building relationships with reporters to cover relevant transportation planning activities is key. See the Notices section.
Online Communities, i.e., MySpace, Facebook, Yahoo	■	■	■	■	■	■	■	■	■	■	Setting up an online community can generate a new level of interest, particularly with the younger generation who may not typically be interested in long range transportation planning. This can be a good discussion forum, as well as a way to broaden notice opportunities.

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Appendix A. (*Continued*)

Strategies & Tools	PPP Goals Supported 1 Visibility	2 Engagement	3 Notification	4 Responsiveness	5 Communication	6 Resourcefulness	7 User-Friendly	8 Proactive	9 Accessible	10 Compliant	Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?
Open House	■	■	■	■	■	■	■	■	■	■	An informal gathering that provides a forum where questions can be asked or submitted and answered in a comfortable atmosphere that encourages open discussion focusing on issues rather than positions, often tailored to specific area needs. Complex projects can be broken down into smaller components for easier understanding.
Participatory Budgeting		■		■		■		■			A democratic form of budget-making for all or part of a municipal or state budget, in which volunteer delegates selected from districts or thematic groups (e.g., health, education, transportation) identify projects, the costs of which are estimated by professional staff. The delegates then review and prioritize projects against available funding and present them to elected officials for final approval.
Partnering with Community Organizations	■	■			■	■	■	■			Reaching out to partner with community-based organizations and leaders to promote and hold meetings, facilitate discussions, and obtain feedback on MPO plans.
Personal Interview		■		■					■	■	Face-to-face discussion about project specific topics and issues with key community stakeholders, community and opinion leaders, agency representatives and other interested parties who represent broader community opinions for the purpose of gathering information and opinions early in the planning process or prior to decision-making.
Photo Inventory		■				■		■			• Assign citizen volunteers to photograph what they like and do not like about their community. • Photos are compiled and organized into an inventory of community problems and assets. • Smart phones can be used to take photos, transmit them and geo-tag locations for easy mapping later on.

Appendix A. (*Continued*)

Strategies & Tools	1 Visibility	2 Engagement	3 Notification	4 Responsiveness	5 Communication	6 Resourcefulness	7 User-Friendly	8 Proactive	9 Accessible	10 Compliant	Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?
	PPP Goals Supported										
Plain Language		■			■		■		■		MPO plans and presentations should always strive to be clear, concise, free of technical jargon, understandable and inviting to citizens.
Plan Documents	■				■		■			■	Published by the MPO at regular intervals and include the LRTP, TIP and other plans and reports and disseminated according to the guidelines outlined in this PPP.
Postage Paid Comment Cards		■		■		■				■	Accompany the distribution, preferable as an attachment, with all plan documents in order to solicit immediate feedback from the public. Tear-off versions of the card are included in all publications printed for widespread distribution.
PowerPoint Presentations	■	■	■		■	■	■	■	■	■	An excellent tool for reaching out to other agencies and community groups and for presentations to the MPO and its advisory committees, helping to tell our story and explain plans and projects using visuals and allowing for Q&A or discussions.
Press Releases	■	■	■		■	■	■	■	■	■	Press releases are free and can often generate print, television and radio coverage going beyond purchased legal and display ads to encourage participation at MPO activities and events and to help keep people who cannot attend involved and aware.
Project Teams—Citizens Leadership Technical	■	■	■	■	■	■	■	■	■	■	Used most recently for the *MPO Transit Study*, this was a great avenue to involve citizens, leaders and technical advisors for a specific project to generate excitement, improve communication, and bolster the effectiveness of public participation goal.
Public Hearings	■	■	■	■	■			■	■	■	Advertised meetings held by the MPO to consider the adoption of the plan or program being presented at which public input is encouraged. All comments, whether written or oral, are formally recorded.

(*continued*)

Appendix A. (*Continued*)

Strategies & Tools	PPP Goals Supported 1 Visibility	2 Engagement	3 Notification	4 Responsiveness	5 Communication	6 Resourcefulness	7 User-Friendly	8 Proactive	9 Accessible	10 Compliant	Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?
Public Participation Workshops	■	■	■	■	■	■	■	■	■	■	• Interactive meetings held throughout a defined community to which all community members are invited, information is shared, project questions are asked and answered and awareness is increased. • Provide information to the community in a forum that allows people to feel comfortable & encouraged to contribute meaningful feedback to the project team in a non-threatening atmosphere. • Held prior to decision-making points in the MPO process.
Periodic Newsletter	■	■	■	■	■	■	■	■	■	■	Produce & distribute a periodic newsletter concerning transportation issues in the county that promotes best planning practices to neighborhood associations, business groups, professional associations, social clubs, chambers of commerce, interest groups, churches, schools and other groups and associations of those traditionally under served by existing transportation systems. Hundreds of copies are also distributed through the Hillsborough County Public Library system.
Radio & PSAs	■	■	■		■	■	■	■	■	■	• News releases will be made available to all local radio media. • Broadcast spots that inform the community about an event. • Inform the community of project activities and opportunities to become more involved. • Partner with radio personalities like WFLA's Jack Harris, who has consistently supported transit and a better transportation network. • Target community reporters at public radio stations such as WMNF and WUSF.

Appendix A. (*Continued*)

Strategies & Tools	1 Visibility	2 Engagement	3 Notification	4 Responsiveness	5 Communication	6 Resourcefulness	7 User-Friendly	8 Proactive	9 Accessible	10 Compliant	Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?
	PPP Goals Supported										
Relationship Building	■	■		■	■	■	■	■	■	■	Building relationships with interagency partners, community leaders, civic groups, faith-based organizations, media, etc. will ensure understanding by the MPO and support all of the public participation goals.
Report Public Comments & Results		■	■	■	■			■		■	Each MPO report developed will include a public and interagency comment section summarizing comments received and any changes made to plans as a result of the comments.
Ride Guide	■	■	■	■	■	■	■	■	■	■	A highly informative, user-friendly collateral piece distributed though human services and transportation agencies throughout Hillsborough County. Printed in large font for the elderly market, it is an excellent tool for the transportation disadvantaged and caregivers.
Scenario Workshops	■	■	■	■	■	■	■	■	■	■	Planners, citizens, technical specialists, community leaders, elected officials doing hands-on planning in a visualization format. Used most recently for the *MPO Transit Study* with a "Home Game" version.
Signage	■		■		■		■				Making the public aware of public meetings and events by posting signs in the affected areas.
Speakers Bureau					■					■	A presentation to interested groups to provide background information and discuss current issues, allowing ample time for interactive feedback. Upon request, the MPO will give presentations to public, private or citizen groups concerning the MPO plans and activities.
Student Newspapers	■	■	■		■						Articles and notices pertinent to specific school, college and university populations are a good way to engage what can be a hard to reach segment of the community.
Surveys & Comment Cards	■	■	■	■	■	■	■	■	■	■	Can be used at community events, following presentations, in the newspaper, in the MPO newsletters, accompanying MPO plan documents or direct-mailed to solicit general input from the public or a target audience, or to generate specific technical data. Can also be distributed at the end of MPO events to get feedback on the event itself.

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Appendix A. (*Continued*)

Strategies & Tools	PPP Goals Supported: 1 Visibility	2 Engagement	3 Notification	4 Responsiveness	5 Communication	6 Resourcefulness	7 User-Friendly	8 Proactive	9 Accessible	10 Compliant	Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?
Talking Points	■	■	■		■	■	■				Provides an accurate, uniform message for the MPO and staff to use to address public or media inquiries or when making presentations.
Technical Memos					■						For long-term projects like the LRTP, the MPO staff and/or project consultants prepare technical memoranda concerning the technical and policy issues. Specifically, these document issues methodologically used and data developed as part of the planning process.
Teleconferencing	■	■		■				■	■	■	A telephone or visual communication meeting between interested parties in two or more locations allowing distance-disadvantaged community participants to be involved in the exchange of ideas and discussions, saving time, gas, and travel inconveniences.
Telephone Polling		■		■		■		■		■	Telephone interviews with a randomly generated community cross-section or specific sub-section of the community will provide a current sense of community awareness and particular project issues.
The Planning Commission Library	■				■		■			■	A central depository for MPO publications and other transportation related materials. It is open to the public and is located at: The Planning Commission County Center Building, 18th Floor 601 East Kennedy Boulevard Tampa, FL 33602
Town Call Meetings	■	■	■	■	■	■	■	■	■	■	Town Hall style meetings held as a live telephone conference call providing an opportunity to share information, answer questions and poll thousands of participants. Celebrity host & panelists may be used.
Town Hall Meetings	■	■	■	■	■	■	■	■	■	■	Displaying at events like the BOCC Town Hall Meetings supports all of the PPP goals in various communities throughout Hillsborough County and minimizes costs by partnering with the County's event format.

Appendix A. (*Continued*)											
	PPP Goals Supported										**Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Strategies & Tools	**Visibility**	**Engagement**	**Notification**	**Responsiveness**	**Communication**	**Resourcefulness**	**User-Friendly**	**Proactive**	**Accessible**	**Compliant**	
Translation into Other Languages	■	■	■	■	■	■	■	■	■	■	Speaking the language the people speak to enhance their ability to not only understand the plans, but actually participate in the transportation planning process. Opportunities may exist in more than one language, including sign language, depending on the targeted group or stakeholders in the planning area and may be applied to publications, website, advertisements, hot-line information, customer assistance and presentations. See Accessibility for more information and Appendix E for the MPO's *Limited English Proficiency Plan*.
Transportation Fairs	■	■	■	■	■	■	■	■	■	■	An event used to create public interest in a transportation project or program usually of one-day duration. The event is actively promoted across multi-media and involves visual displays or technology demonstrations; thus, encouraging community interest in a program or study, keeping the public interested and informed while allowing for casual input and formal feedback opportunities.
twitter	■	■	■	■	■	■	■	■	■	■	Used as a rapid news source feed to provide information about all MPO plans, programs and events as well as a tool to providing information about other relevant meetings, events and resources. Also, an interactive tool providing two-way communication for feedback.
Videos	■				■	■	■	■	■		Recorded visual and audio messages for presentation to the community that is easy to understand and visually appealing with the advantage of being used for consistent presentations that can go beyond the capabilities of live presentations or when a live speaker is not available.
Visioning		■		■		■		■		■	A series of meetings focused on long-range issues involving a broad spectrum of people to generate ideas, set goals and priorities and to assist in the formulation of policy direction. Determines parameters of short-range planning activities. Provides a venue for the input of a wide range of ideas and potential solutions.

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Appendix A. (*Continued*)											
	PPP Goals Supported										**Strategy or Tool Description: How Does This Strategy or Tool Work? Could This Strategy or Tool Work for Us in the Future?**
	1	2	3	4	5	6	7	8	9	10	
Strategies & Tools	Visibility	Engagement	Notification	Responsiveness	Communication	Resourcefulness	User-Friendly	Proactive	Accessible	Compliant	
VISSIM Software	■	■	■	■	■	■	■	■	■	■	Powerful 3-D multi-modal tool applied to simulate future vehicular flows, bicycle and pedestrian traffic, transit operations and conditions at rail stations. Used to model movement and behavior from small surface roads to complex, large-scale transit systems and generate before and after aerial animations of future transportation projects based on existing and future traffic conditions.
Visualization Software Programs	■	■	■	■	■	■	■	■	■	■	Samples of visualization techniques range from photo, PowerPoint or video presentations, brainstorming sketches and visual preference surveys to scale models, renderings, maps, aerials, 3-D imagery, and other computer-aided visualization.
Walking Tours & "Walkshops"											Organized group walking tours through a project site or corridor to enable community members to see and or point out problems, assets and resources important to the community. "Walkshops" are mobile workshops geared around group activities, such as photo inventorying and mapping.
Web 2.0 Technology & Crowdsourcing		■		■		■	■				Web 2.0 refers to new Internet programs designed to foster collaboration between users. Crowdsourcing is a form of distributed problem-solving. Internet-based tools, such as Wikis, webcasts, and online dialogues, can allow users to develop documents collaboratively, for example, corridor plans drafted with direct input from community representatives.
Websites	■	■	■	■	■	■	■	■	■	■	24-hour accessible online site with web address http://www.hillsboroughmpo.org where the community can immediately access calendars, agendas, members, interactive maps, links to related sites, general study information and most MPO publications with the opportunity to participate in a survey or email feedback. Visits to the site are tracked. www.mpo2035.org created in conjunction with the 2035 Plan.

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