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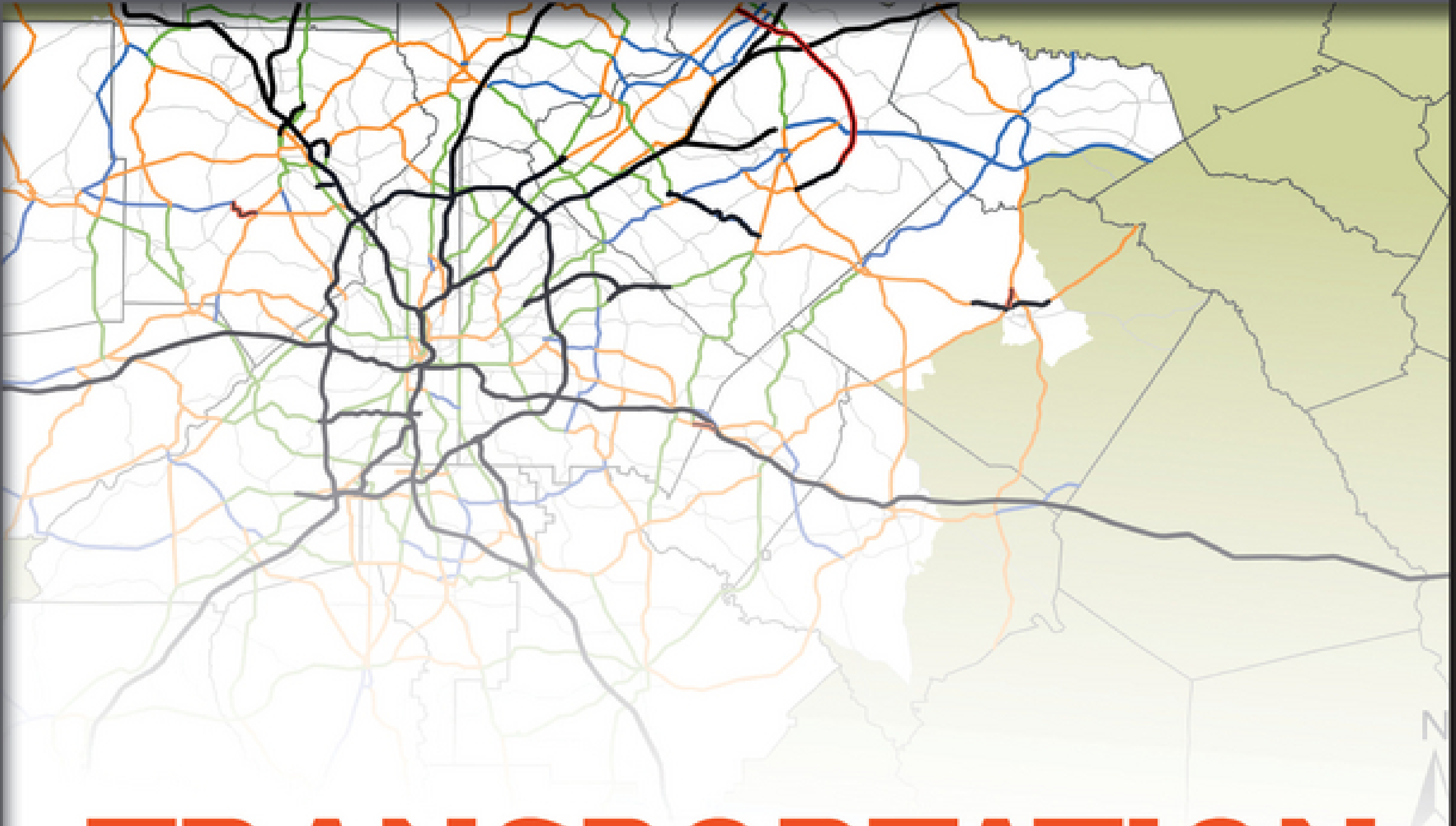

TRANSPORTATION PLANNING HANDBOOK

FOURTH EDITION 4

WILEY

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FOURTH EDITION

Institute of Transportation Engineers

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WILEY

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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

Richard A. Retting

Donald R. Samdahl

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KC Yellapu

Jiguang ZhaoAmit Armstrong

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

Anne E. Dunning

Leon Goodman

Jane Hayse

Susan Herbel

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Jerome Lutin

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Matthew Ridgway

Jerry B. Schutz

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.

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.

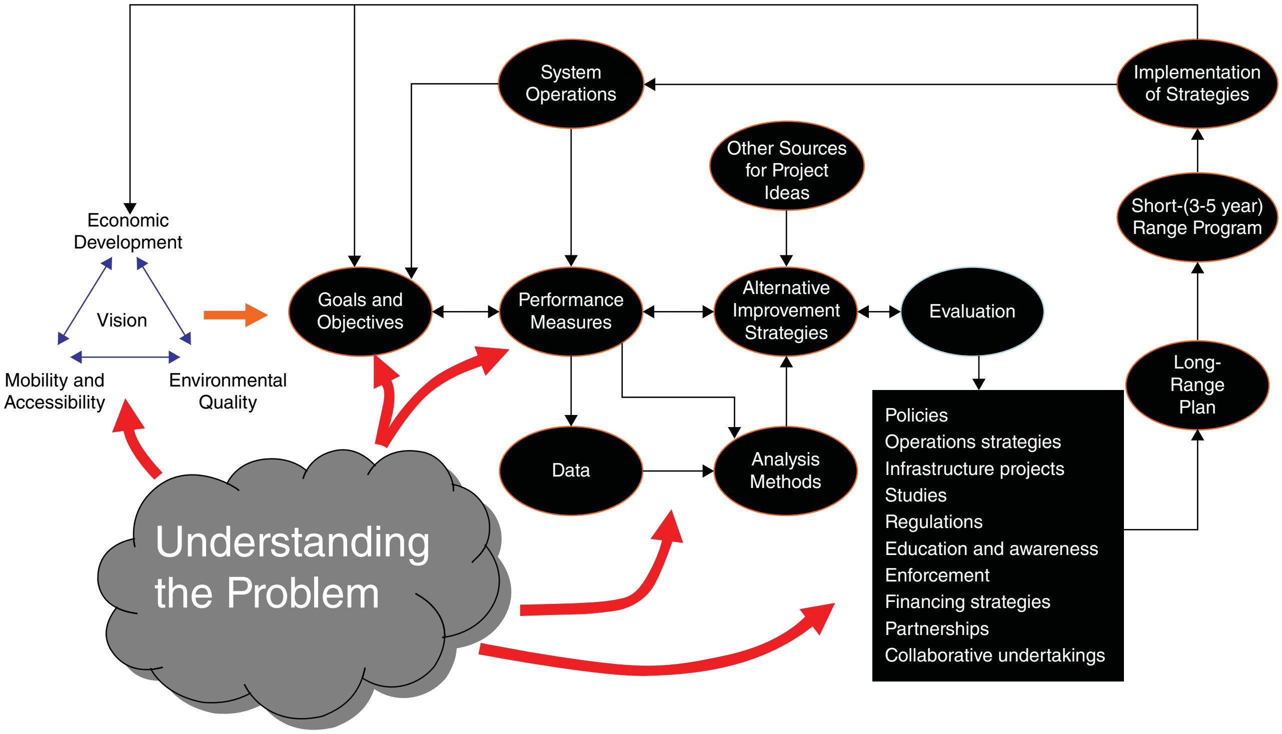
In addition, given the importance of performance measures in today's transportation planning, instead of discussing their definition and role in one chapter, the discussion of performance measures is found in each chapter where appropriate. In this way, performance measures can be discussed with specific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

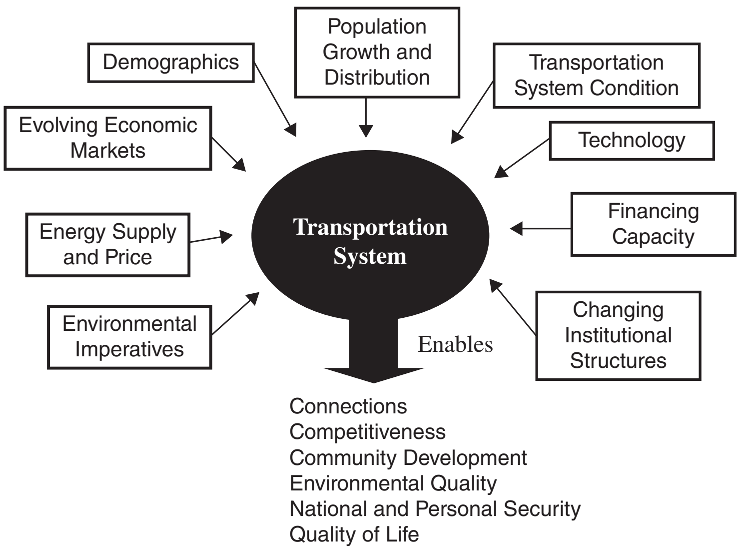
IV. CHANGING CONTEXT FOR TRANSPORTATION PLANNING

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

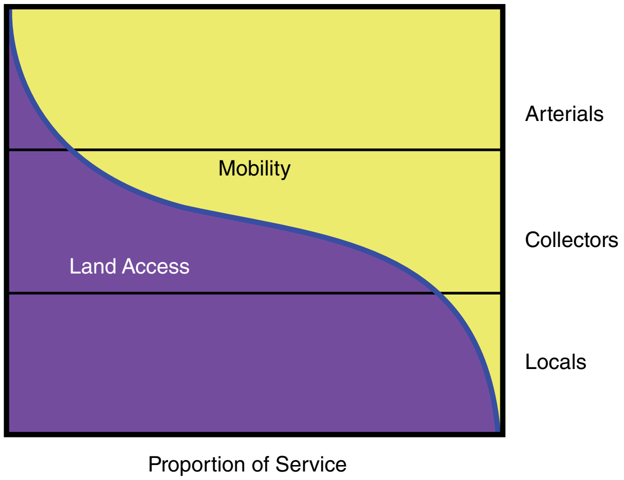
Transportation system data are categorized in a variety of ways to allow transportation professionals to understand the performance of different components of the system for which they are responsible. System-level measures, such as crash rates, pavement condition levels and average travel time, provide 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.

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

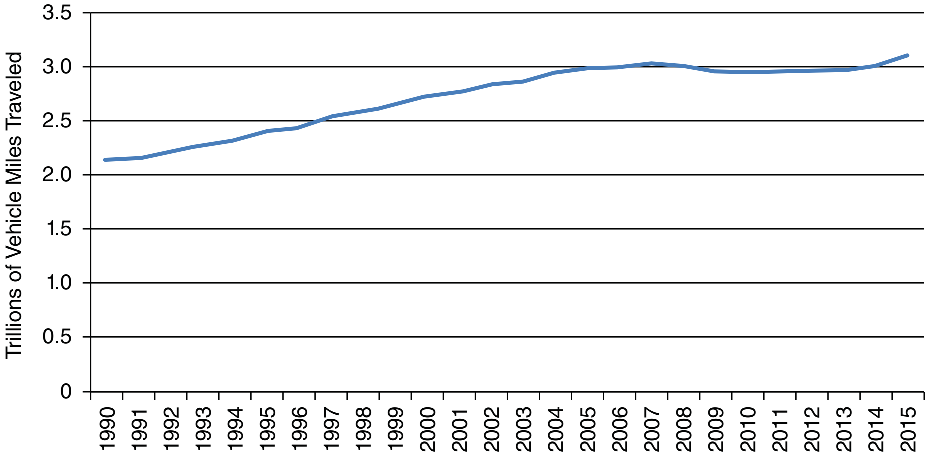
[a]Includes 561 miles of the U.S. Class I freight railroad system owned by Canadian railroads.

[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

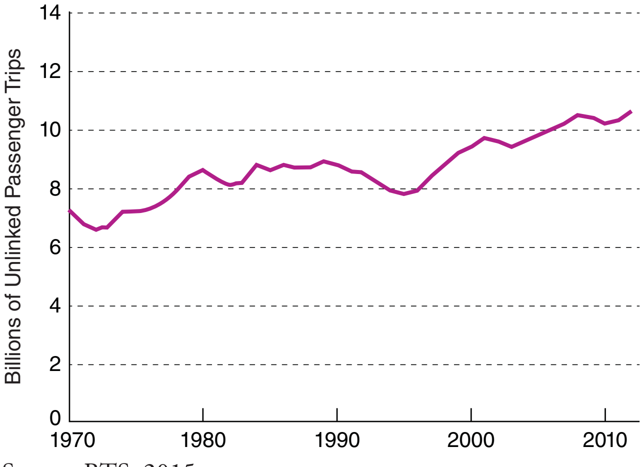
C. System Use

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.

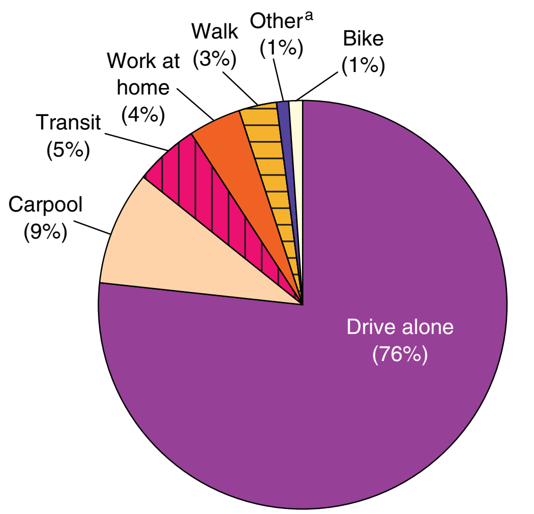
Figure 2-3. Unlinked Passenger Transit Trips, United States, 1970–2012



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.

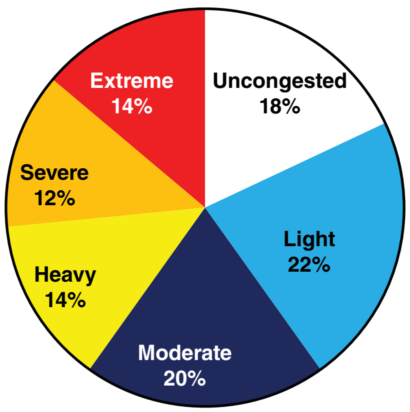
1. Mobility

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.

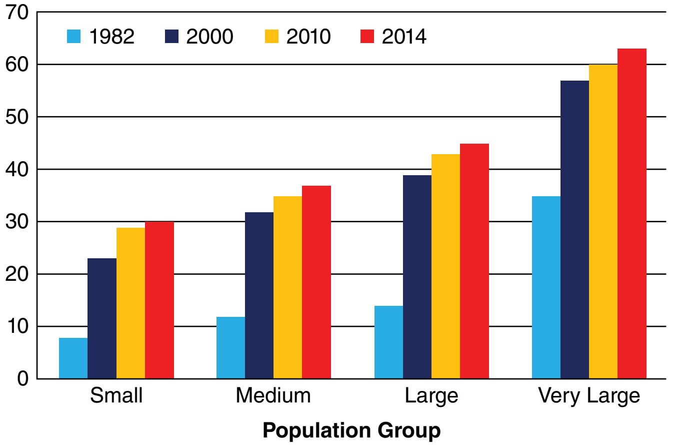
Figure 2-5. Vehicle Travel in Congestion Conditions, United States, 2014



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

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, 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



Small = less than 500,000 Large = 1 million to 3 million
Medium = 500,000 to 1 million Very Large = more than 3 million

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.

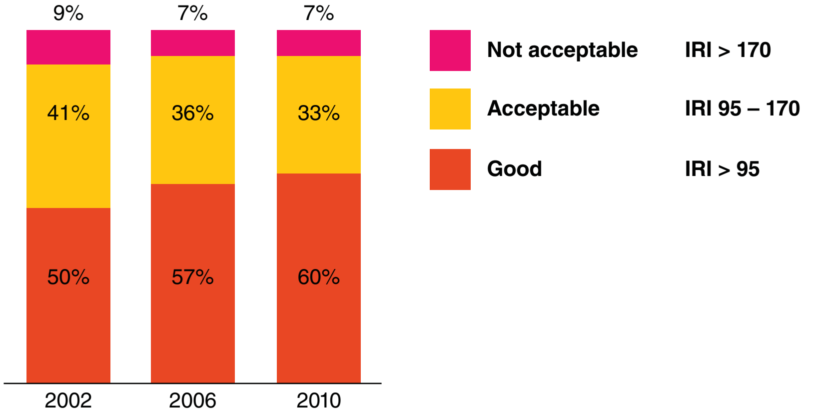
Other Countries. Countries with different legal requirements and enforcement strategies have a very different safety record than the United States. Countries like Australia, Denmark, England, and Sweden have applied very aggressive enforcement strategies and as a result have reduced their fatality levels 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.

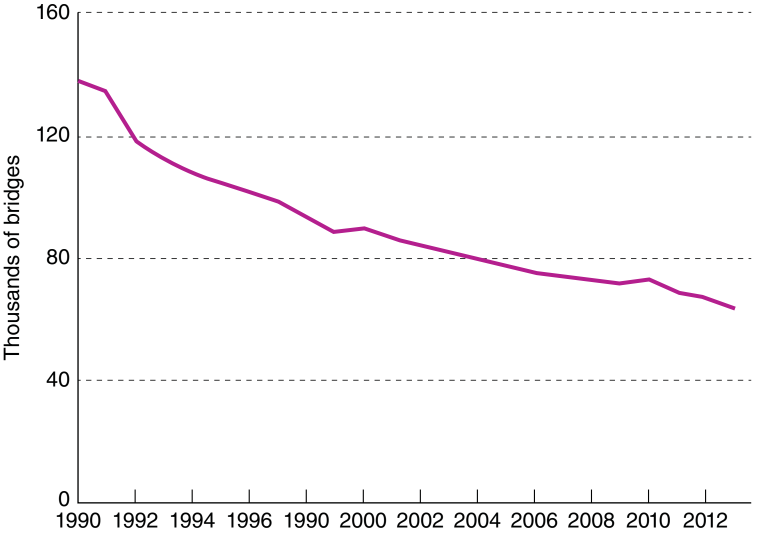
Figure 2-7. Pavement Condition on the National Highway System, United States, 2002–2010



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 inter-relationships 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.

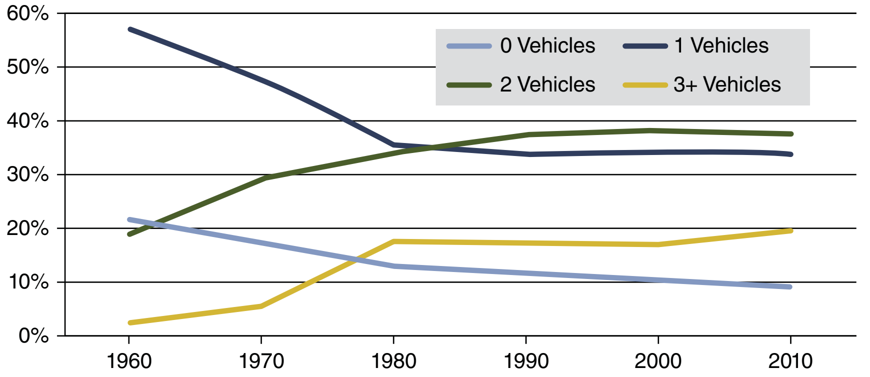
2. Household Characteristics and Vehicle Availability

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.

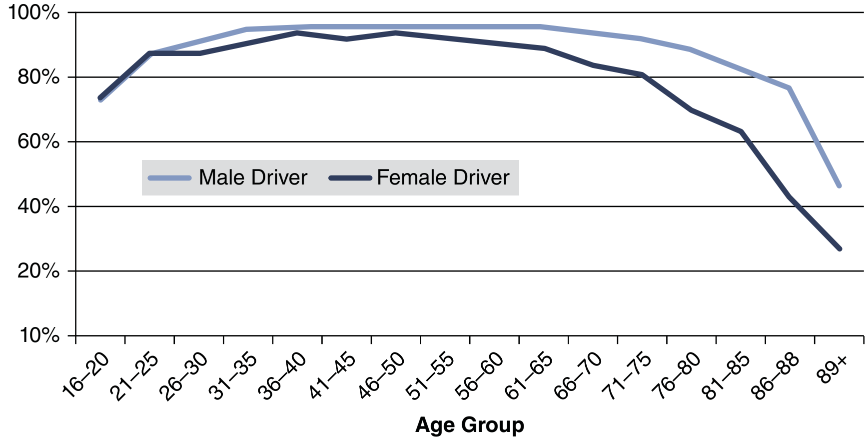
Figure 2-10 illustrates two characteristics of the U.S. population that have an important influence on mode choice. First, the percentage of older Americans having a driver's license has historically been much lower than that for those younger. This, however, is likely to change over time as the younger 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.

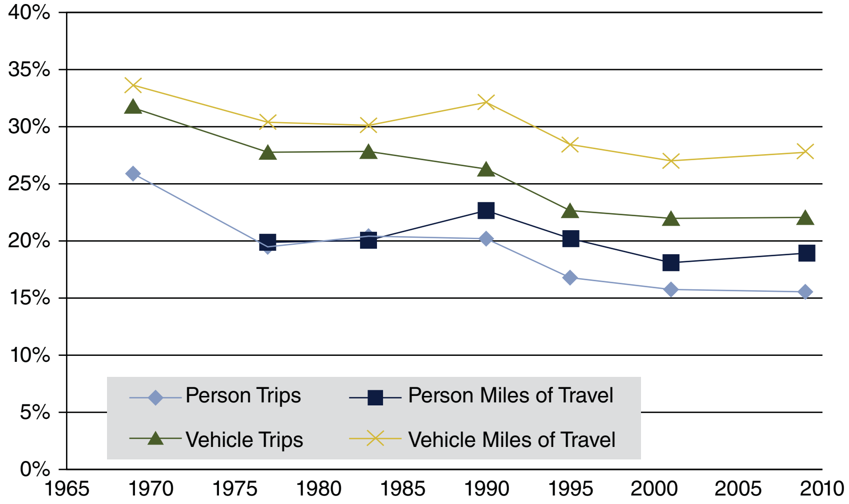
1. Trip Purpose

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:

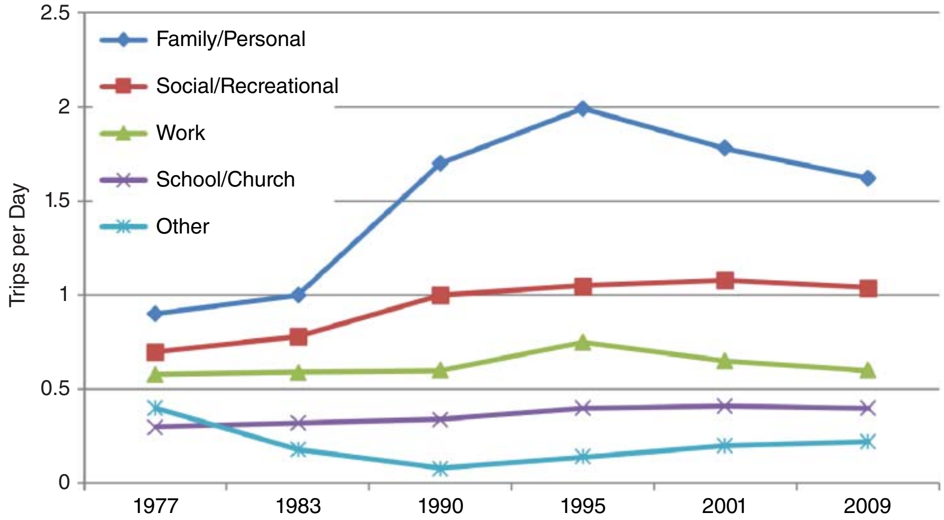
- Trips to work with stops are increasing, both in number of workers making stops and number of stops per worker.
- Persons with stops take longer in miles and minutes than they did in 1995 and are longer than those not making any stops.
- People who make stops tend to be those that live a greater distance 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

City	% Trips by Type			Daily Trip Rate per Person			Daily Trip Rate per Household		
	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.

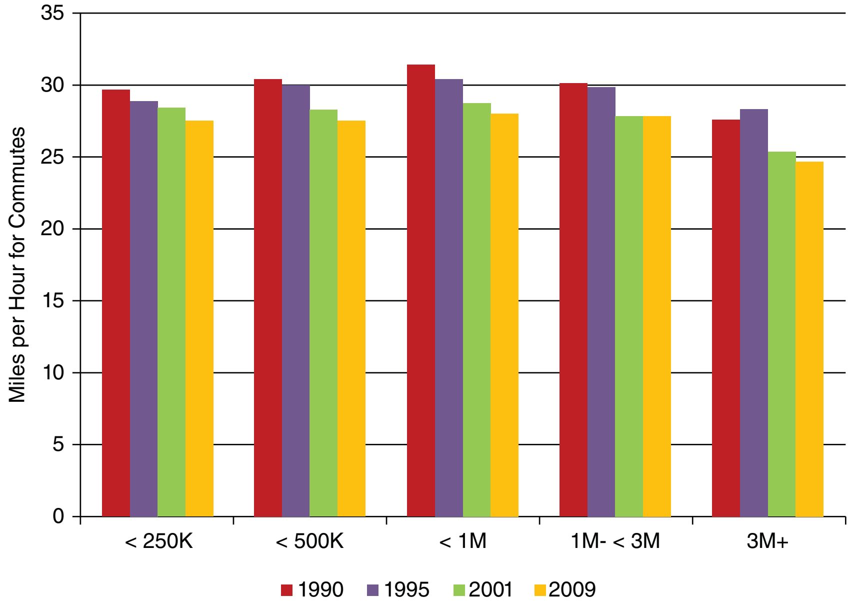
The percentage of the commute trips destined outside of the worker's home county is another characteristic of the growing trend in inter-suburban trips (note that this statistic will vary in different parts of the United States due to the size of counties). During 2006 to 2010, more than a quarter (27.4 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

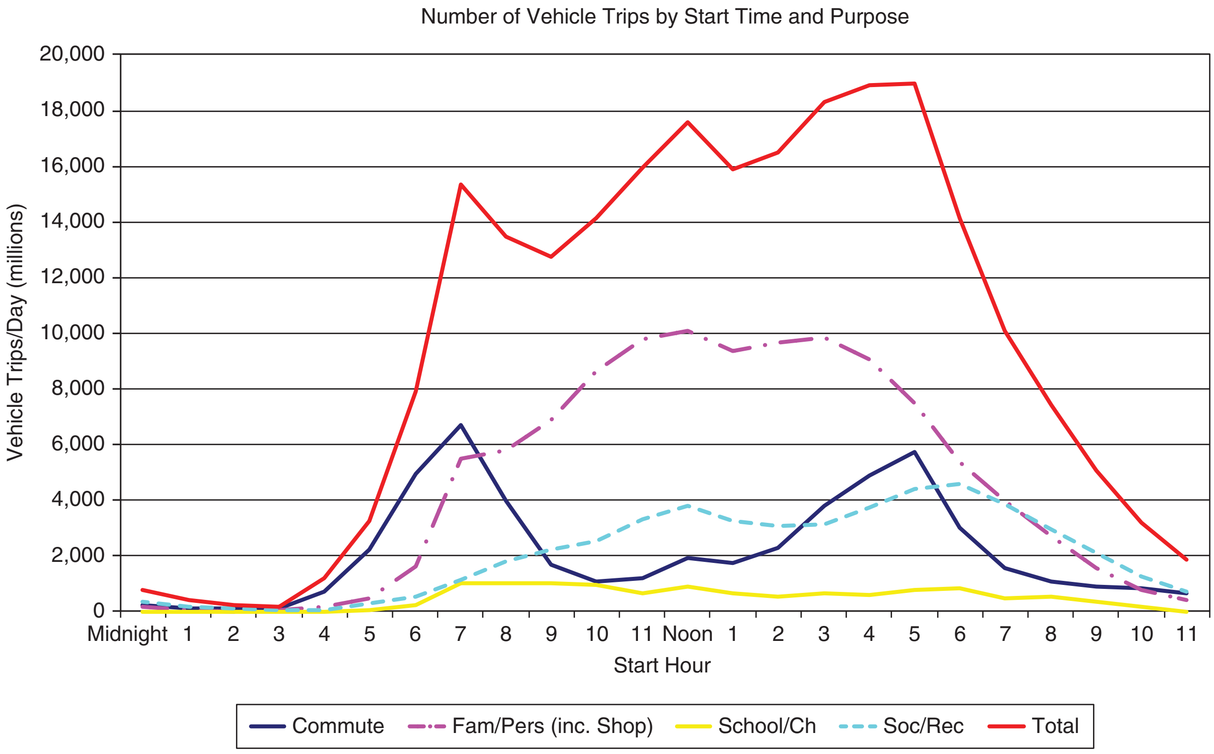
The time of day when trips occur is another important characteristic of urban travel patterns, one that leads to system congestion when many of these trips occur in the same time periods. In most cases, system capacity is available to handle daily trips; if trips were spread evenly over the 12 hours 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.

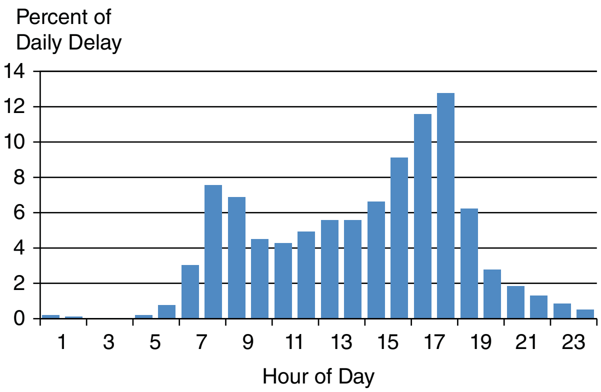
Unlike commuter trips, which generally peak between 7:00 to 9:00 a.m. and 4:00 to 7:00 p.m., truck trips tend to be at their highest levels between 10:00 a.m. and 4:00 p.m.

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:

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

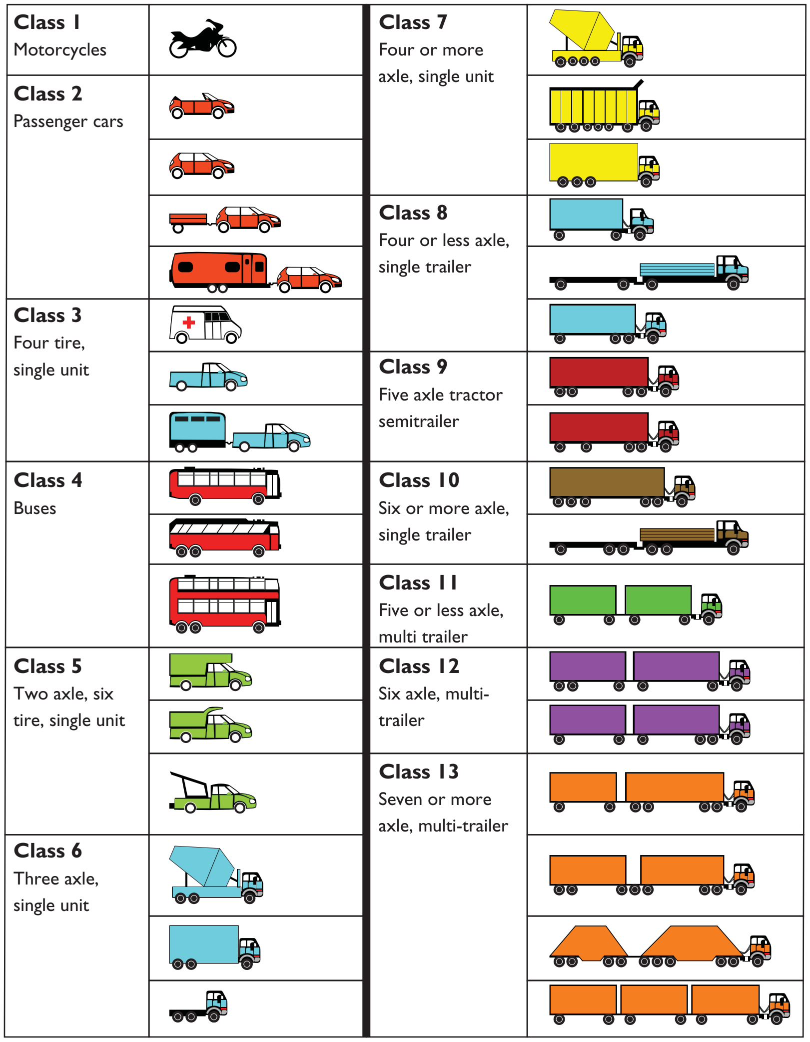
Where:

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.

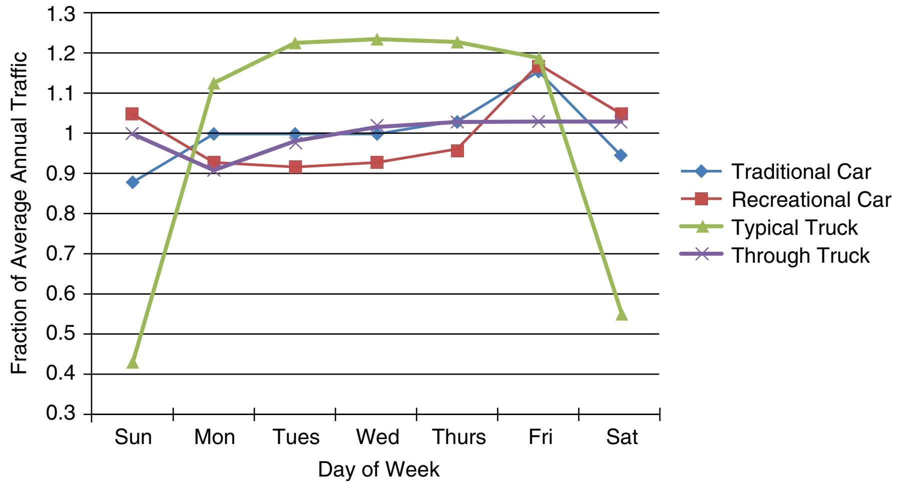
Coverage counts are used to estimate ADTs at many different locations throughout the street network. Major streets are divided into segments with uniform traffic conditions, and a 24-hour, nondirectional count is made in each segment. The count is adjusted using the factors developed from the appropriate 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.

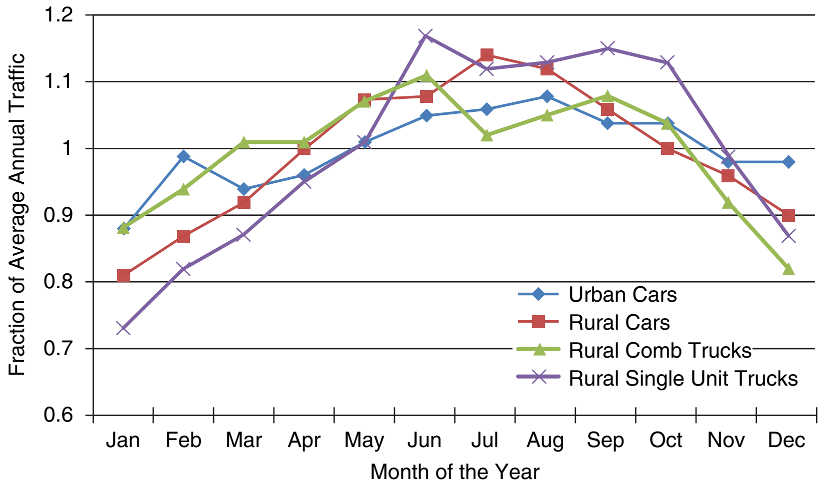
When traffic volume data from coverage counts are maintained at levels of aggregation below that of a daily total, such as by hour and direction, the data have additional uses, such as traffic signal timing, air quality analysis, noise analysis, planning studies, and planning the timing of maintenance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

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

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).

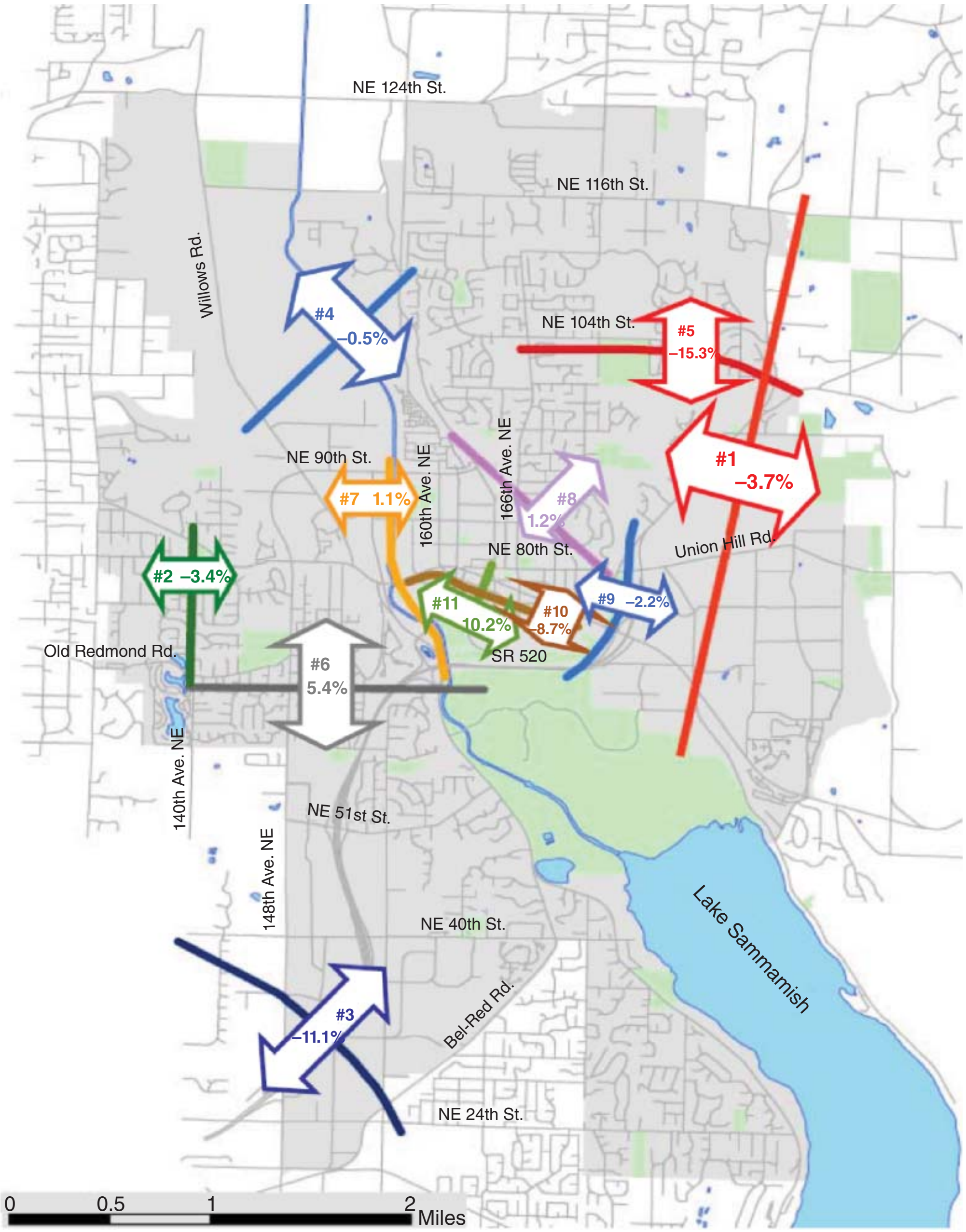
Screenline counts are taken at imaginary lines that bisect a study area or a major facility. The screenline is usually drawn along natural boundaries, such as rivers, escarpments, or railroad rights of way, to minimize the number of vehicular crossings and, therefore, the number of counting stations 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

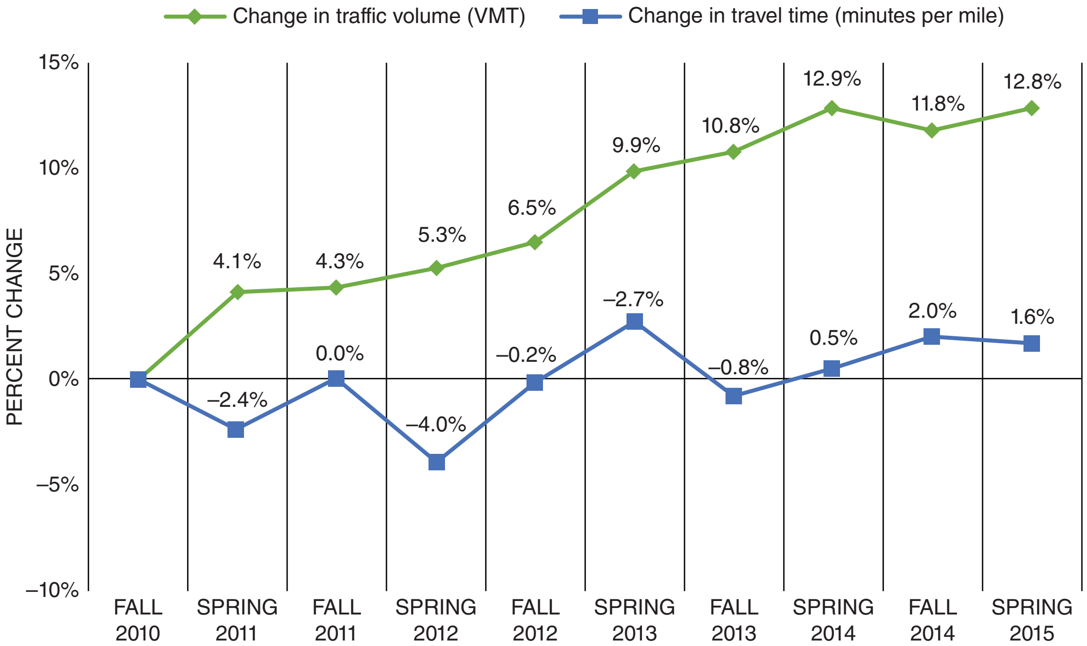


Source: City of Redmond Public Works Department. 2009. Reproduced with permission of the City of Redmond.

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.

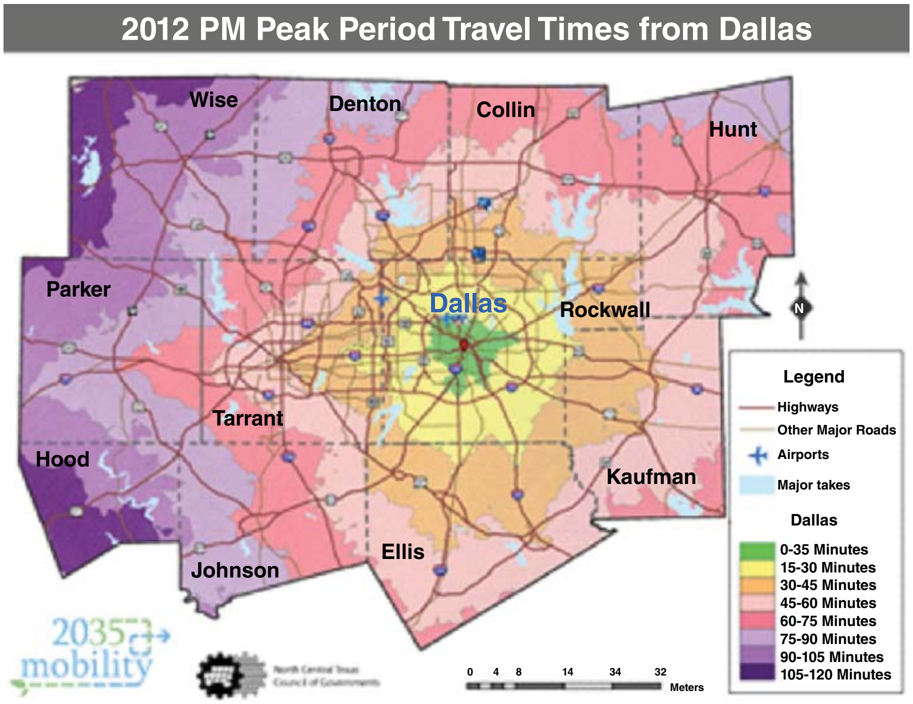
Travel times and delays should be obtained by direct measurement wherever possible. Methods for doing so include test vehicles, license plate matching, aerial photography, interviews, probe vehicles, cell phones, induction loops, sensors, and traffic reporting services. Travel time and delay data can 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

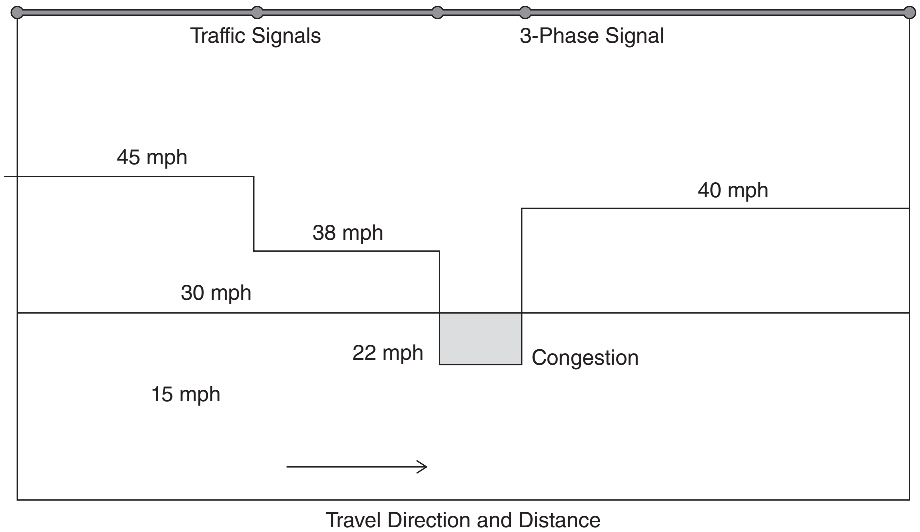
Most of the travel collection techniques discussed previously are designed to collect data at one location over a specified time period. In many ways, these techniques provide a static representation of what is happening on the transportation system. Often in transportation planning it is important to 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



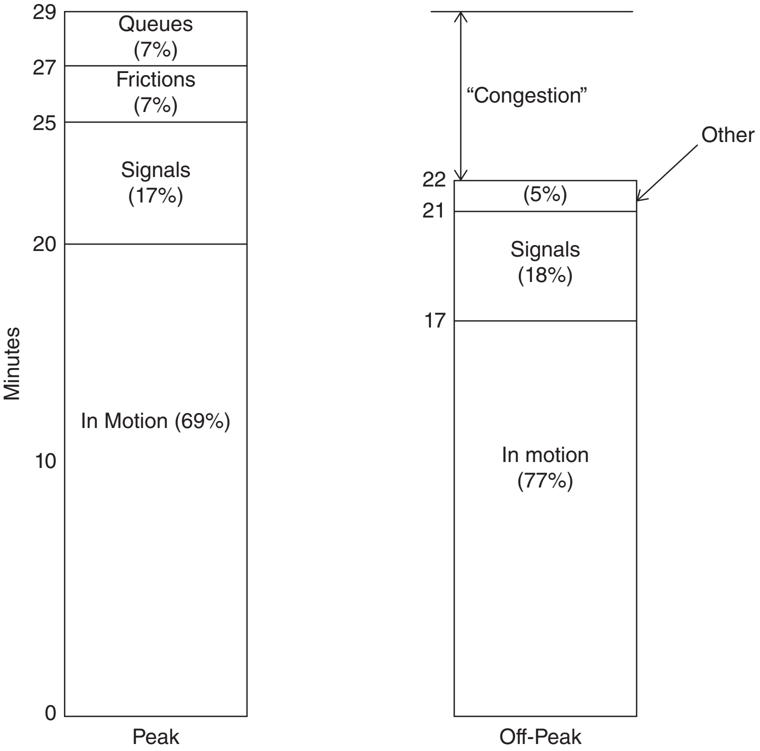
Source: North Central Texas Council of Governments, Accessed Feb. 24, 2016, from, http://www.nctcog.org/trans/data/traveltimes/Dallas.pdf

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.

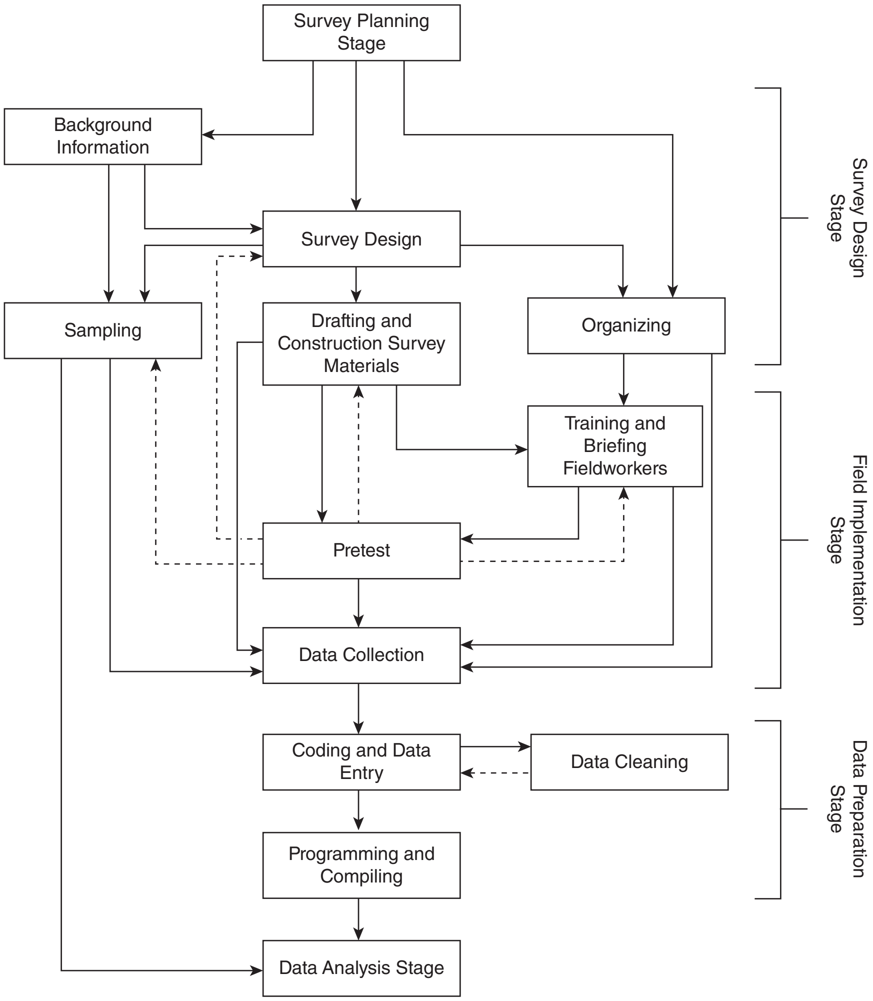
Household Surveys. Household surveys began during the 1940s and became common during the 1950s as part of the comprehensive urban transportation planning process. The initial studies involved home interviews in which respondents were asked to recall the trips made on the previous day. The samples ranged 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

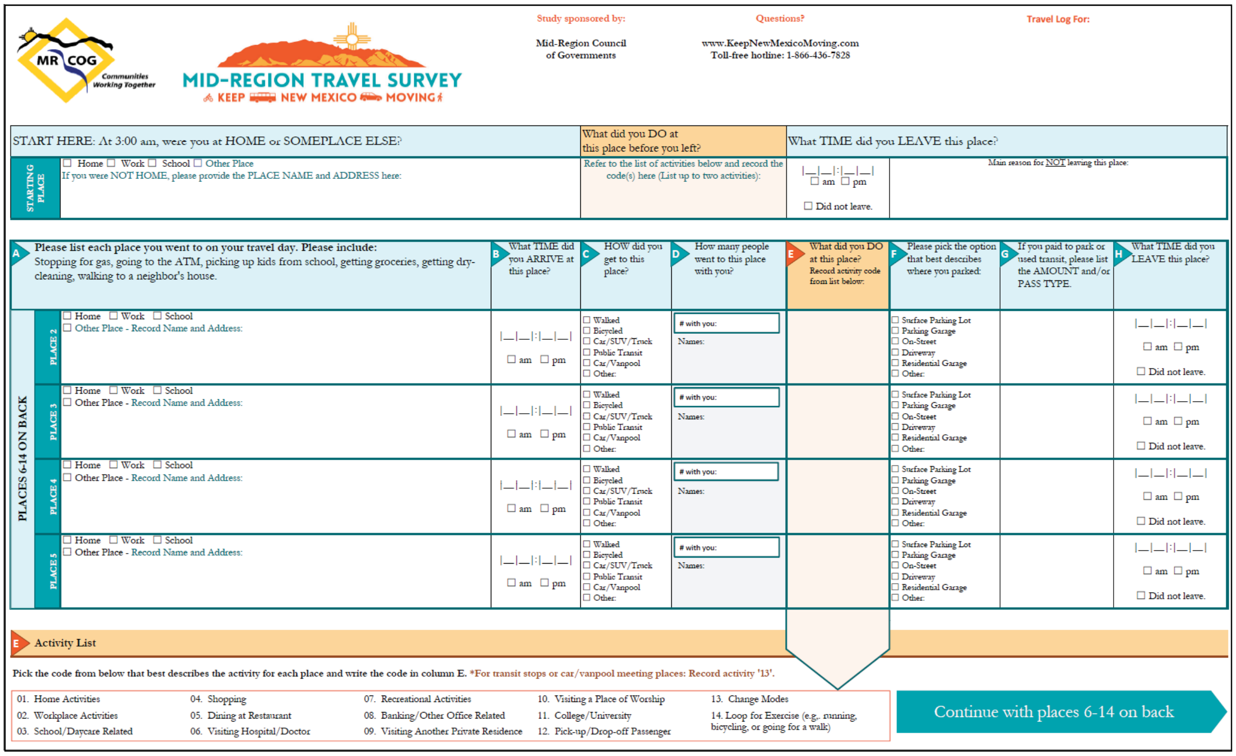


Source: FHWA, 2010

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



MR COG Communities Working Together

MID-REGION TRAVEL SURVEY

KEEP NEW MEXICO MOVING

Study sponsored by: Mid-Region Council of Governments

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

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*)

MR COG Communities Working Together

EXAMPLE for Car Users

MID-REGION TRAVEL SURVEY

KEEP NEW MEXICO MOVING

Study sponsored by: Mid-Region Council of Governments

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: ☒ 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| ☒ am ☐ pm ☐ Did not leave.	Main reason for NOT leaving this place:

PLACES 6-14 ON BACK

	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 ☐ Other Place - Record Name and Address:	|__|8|:|0|4| ☒ am ☐ pm	☐ 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 ☐ Other:	N/A	|__|5|:|1|0| ☐ am ☒ pm ☐ Did not leave.
PLACE 3	☐ Home ☐ Work ☒ School ☐ Other Place - Record Name and Address: Ben's School	|__|5|:|2|9| ☐ am ☒ pm	☐ Walked ☐ Bicycled ☒ 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 ☒ Other: Did Not Park	N/A	|__|5|:|3|5| ☐ am ☒ pm ☐ Did not leave.
PLACE 4	☐ Home ☐ Work ☐ School ☒ Other Place - Record Name and Address: Chipotle Mexican Grill 6810 Menaul Blvd NE, Albuquerque, NM 87110	|__|5|:|5|0| ☐ am ☒ pm	☐ Walked ☐ Bicycled ☒ Car/SUV/Truck ☐ Public Transit ☐ Car/Vanpool ☐ Other:	# with you: 1 Names: Ben	05 Picked up dinner	☐ Surface Parking Lot ☐ Parking Garage ☒ On-Street ☐ Driveway ☐ Residential Garage ☐ Other:	$1.00 (1 hr)	|__|5|:|5|7| ☐ am ☒ pm ☐ Did not leave.
PLACE 5	☒ Home ☐ Work ☐ School ☐ Other Place - Record Name and Address:	|__|6|:|2|1| ☐ am ☒ pm	☐ Walked ☐ Bicycled ☒ 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 ☒ Residential Garage ☐ Other:	N/A	|__|__|:|__|__| ☐ am ☐ pm ☒ Did not leave.

E. **Activity List**

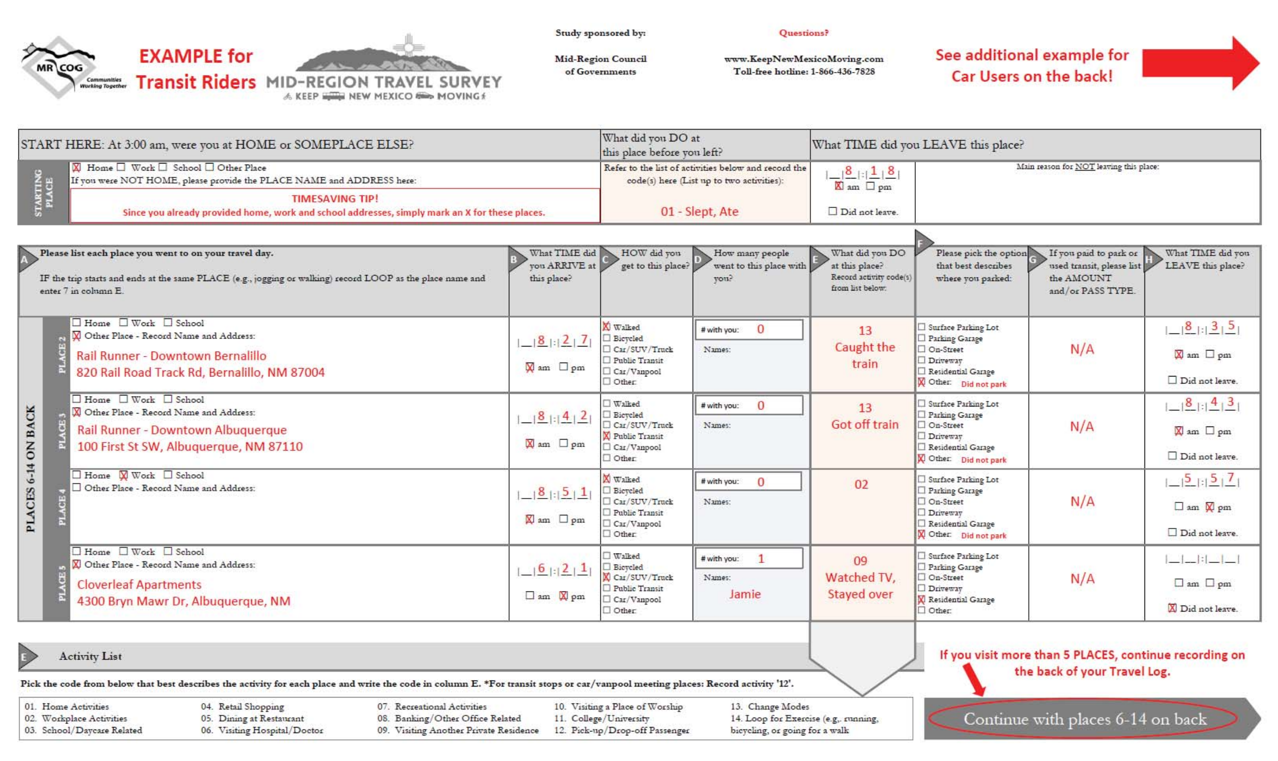
Pick the code from below that best describes the activity for each place and write the code in column E. *For transit stops or car/vanpool meeting places: Record activity '12'.

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 MID-REGION TRAVEL SURVEY — KEEP NEW MEXICO MOVING

Study sponsored by: Mid-Region Council of Governments

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

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: ☒ 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| ☒ 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 ☒ Other Place - Record Name and Address: Rail Runner - Downtown Bernalillo, 820 Rail Road Track Rd, Bernalillo, NM 87004	|__|8|:|2|7| ☒ am ☐ pm	☒ 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 ☒ Other: Did not park	N/A	|__|8|:|3|5| ☒ am ☐ pm ☐ Did not leave.
PLACE 3: ☐ Home ☐ Work ☐ School ☒ Other Place - Record Name and Address: Rail Runner - Downtown Albuquerque, 100 First St SW, Albuquerque, NM 87110	|__|8|:|4|2| ☒ am ☐ pm	☐ Walked ☐ Bicycled ☐ Car/SUV/Truck ☒ Public Transit ☐ Car/Vanpool ☐ Other:	# with you: 0 Names:	13 Got off train	☐ Surface Parking Lot ☐ Parking Garage ☐ On-Street ☐ Driveway ☐ Residential Garage ☒ Other: Did not park	N/A	|__|8|:|4|3| ☒ am ☐ pm ☐ Did not leave.
PLACE 4: ☐ Home ☒ Work ☐ School ☐ Other Place - Record Name and Address:	|__|8|:|5|1| ☒ am ☐ pm	☒ 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 ☒ Other: Did not park	N/A	|__|5|:|5|7| ☐ am ☒ pm ☐ Did not leave.
PLACE 5: ☐ Home ☐ Work ☐ School ☒ Other Place - Record Name and Address: Cloverleaf Apartments, 4300 Bryn Mawr Dr, Albuquerque, NM	|__|6|:|2|1| ☐ am ☒ pm	☐ Walked ☐ Bicycled ☒ 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 ☒ Residential Garage ☐ Other:	N/A	|__|__|:|__|__| ☐ 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 '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 do not 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

BICYCLING IN THE AMES AREA

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

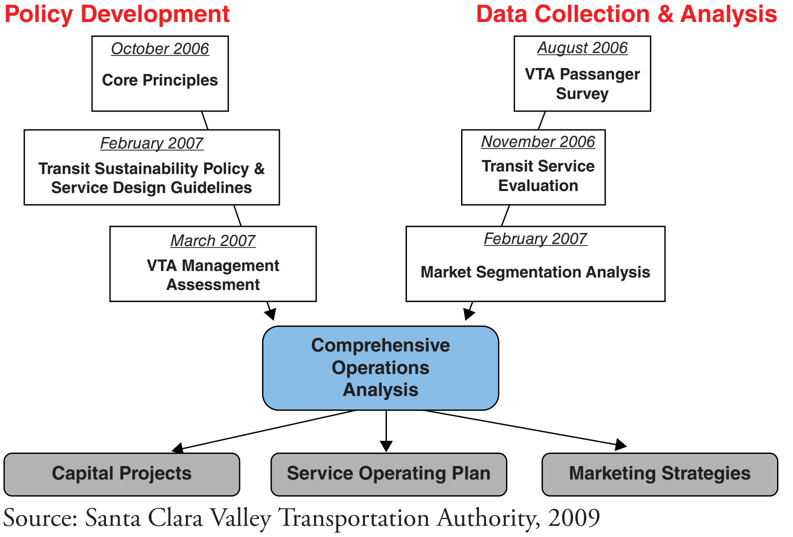
Transportation planning often focuses on specific modal issues, such as transit service planning, parking studies, pedestrian and bicycle analyses, and freight movement. Each of these topics is covered in more detail in other chapters of this handbook. However, some of the important data collection issues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

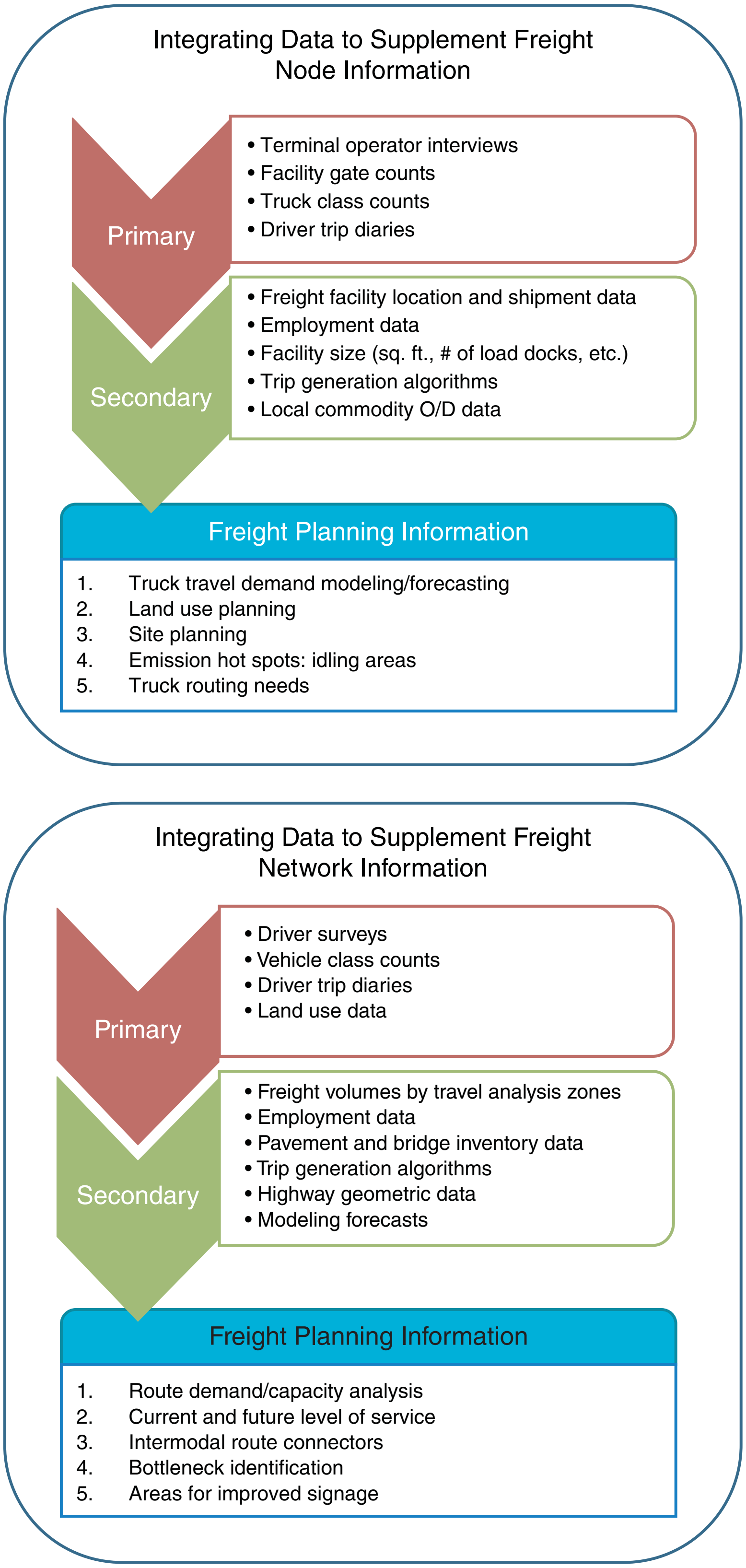
Goods movement involves the collection and distribution of raw materials and finished products. Freight is handled by truck, train, ship, and pipeline with small amounts of high-value cargo going by air. The scale, types, and patterns of goods movement vary widely; studies should be keyed to specific 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

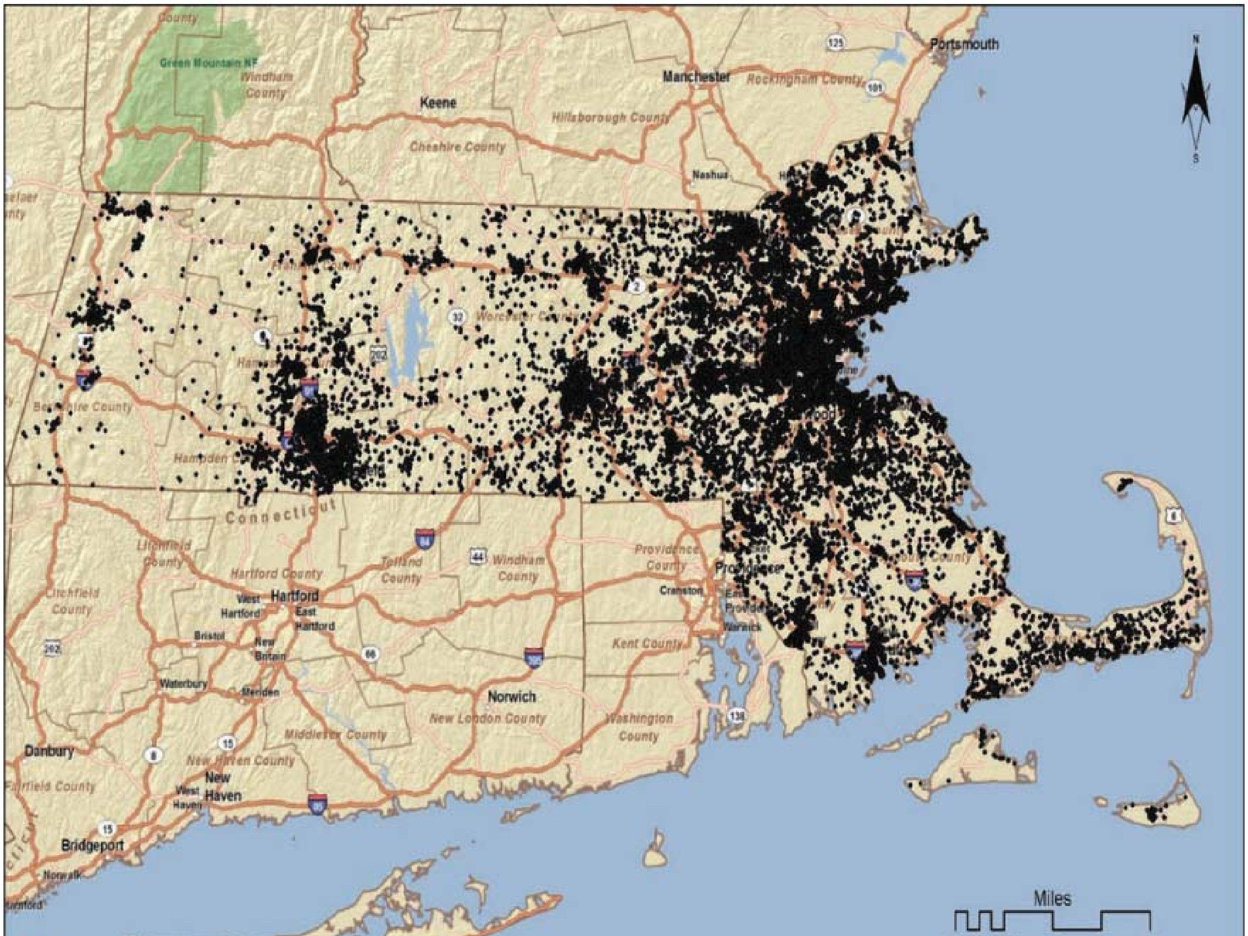
[2] This section was written by William Bachman, Westat, Inc.

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.

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.

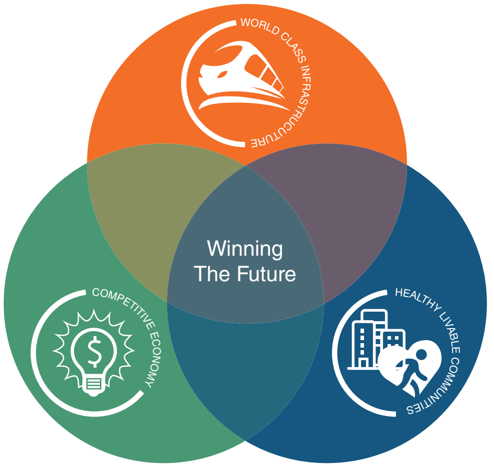
> *"Our vision for the future advances the ideals of our people, our prosperity, and our planet. As we work toward achieving the region's vision, we must protect the environment, support and create vibrant, livable, and healthy communities, offer economic opportunities for all, provide safe and efficient 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).

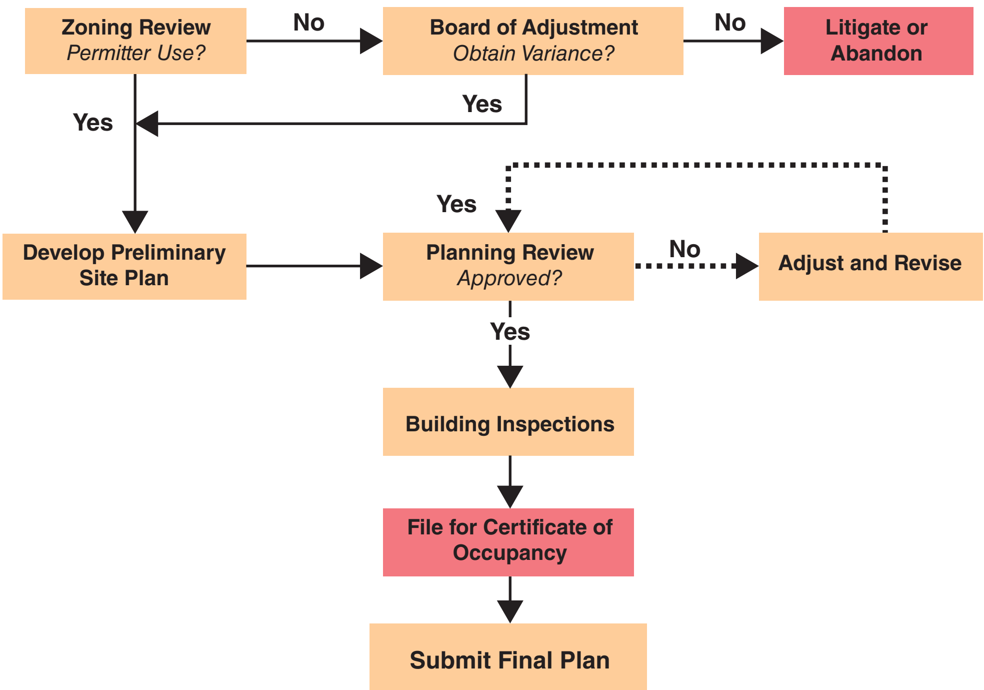
5. Development or Site Plan Review Process

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.

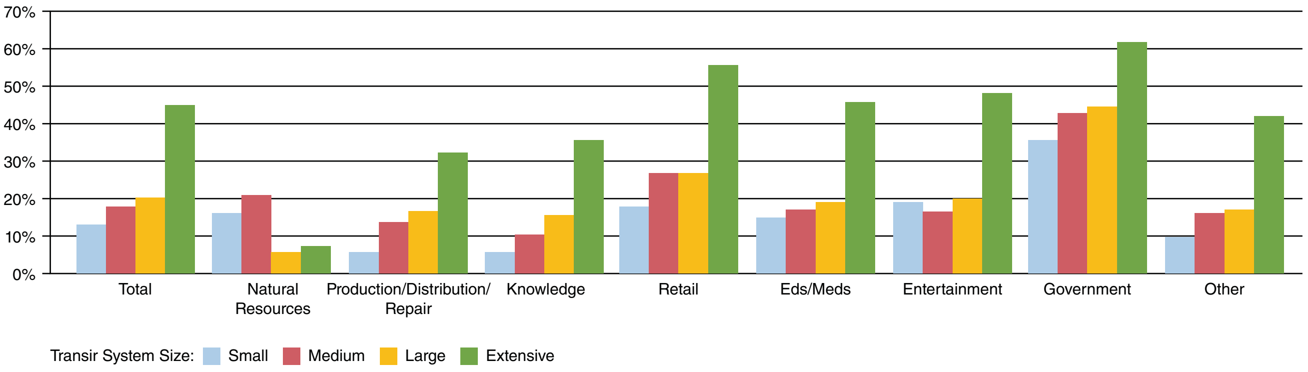
Demographics are promising for TOD: Aging Baby Boomers and young urban professionals are population groups attracted to TOD, and both groups are growing in the United States. In particular, these groups tend to desire "walkable" urban lifestyles.

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.

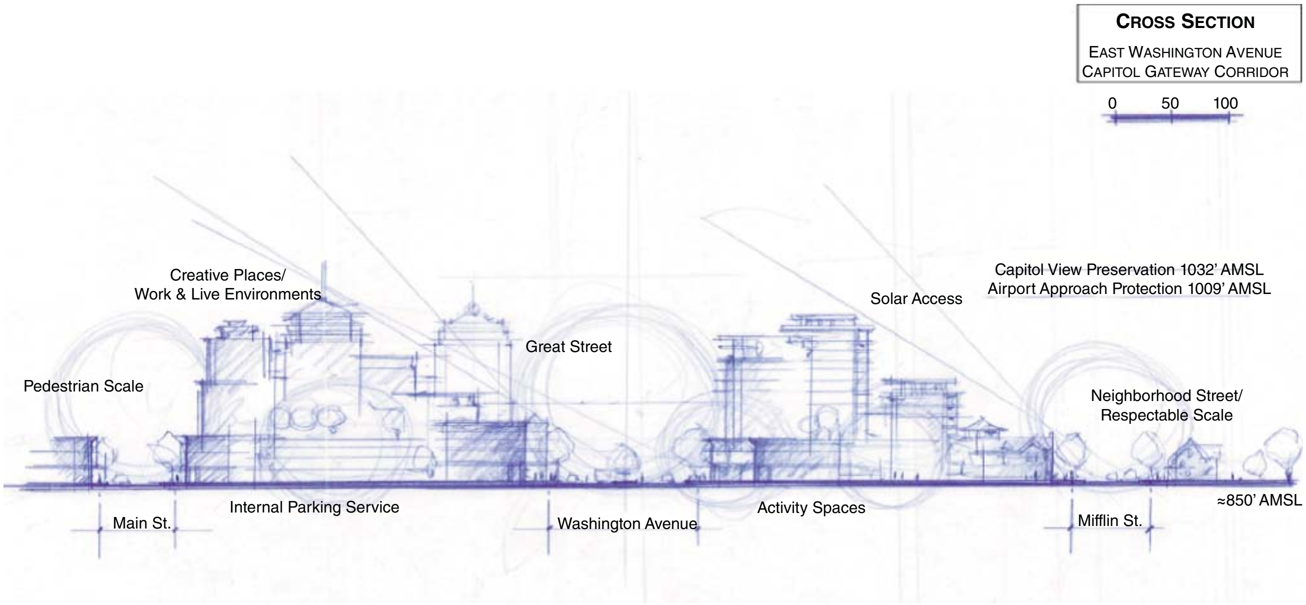
In other cases, urban design guidance takes the form of narrative descriptions of the principles and actions that should guide the "look" and "feel" of community places. [Eitler et al., 2013] For example, the Milwaukee, Wisconsin,

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:

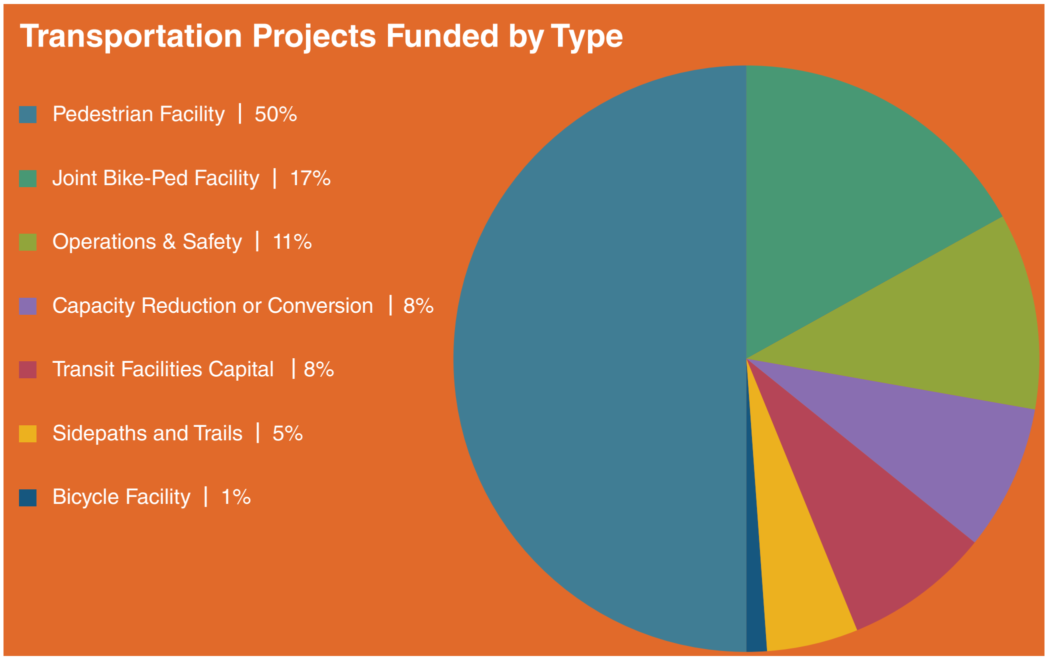
- Consider street variations as a last resort to preserve the network of city streets and arterials.
- Integrate and/or reuse historic pavement materials for streets and sidewalk reconstruction, where appropriate.
- Reduce street widths for safe and convenient pedestrian crossing by adding medians, boulevards, 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.

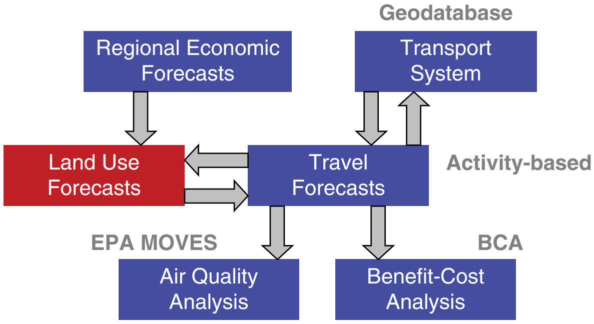
As an example of population forecasts for a large metropolitan area, the ARC notes that its process was "a multi-year effort, benchmarking and culminating into region plan updates. Several forecasting models are used and evaluated. In addition, several advisory meetings are held with local economists, 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

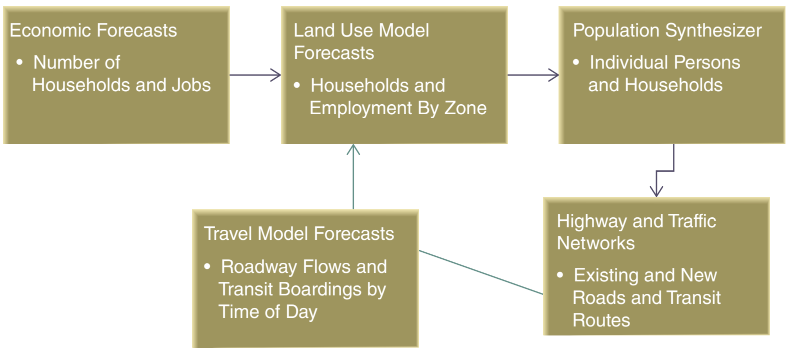
Second, the land-use model has an exogenous input representing regional economic forecasts. In this case, a model other than the land-use model is used to forecast overall population and employment in the study area.

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 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.

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



Source: Denver Regional Council of Governments, 2010

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.

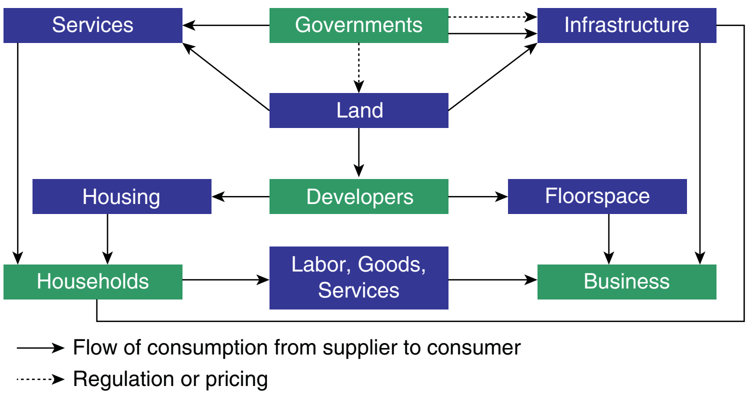
Of the various first generation models, the Lowry model has had by far the most enduring impact on the field. [Lowry, 1964] It is a heuristic model that iteratively allocates households to residential locations and retail or population-serving workers to employment locations, based on an exogenously 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.

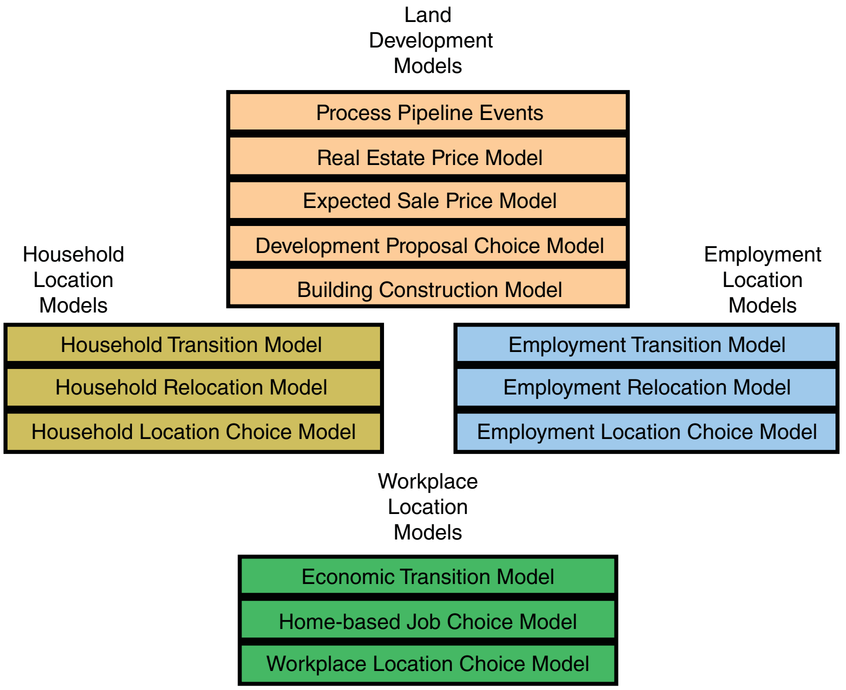
- Households make a cluster of interdependent long-term lifestyle choices, including when to move, neighborhoods to locate within, the type of housing to rent or purchase, and the number of vehicles to own. Individuals within households choose their labor force and educational status, their job mobility 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:

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

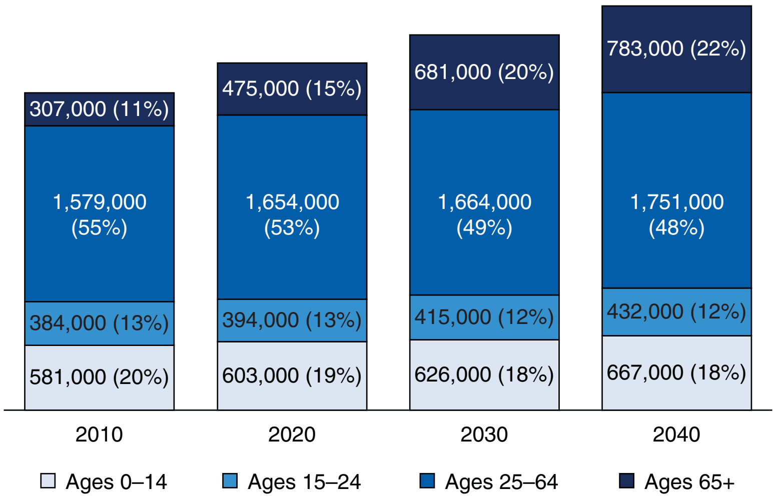
where,

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.

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



Source: Metropolitan Council, 2015a

- 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.
- 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]