NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 446

A Guidebook for Performance-Based Transportation Planning

CAMBRIDGE SYSTEMATICS, INC.
Cambridge, MA
Oakland, CA
and
Washington, DC

SUBJECT AREAS
Planning, Administration, and Environment • Public Transit • Rail • Freight Transportation

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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NOTICE

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

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A GUIDEBOOK FOR PERFORMANCE-BASED TRANSPORTATION PLANNING

PREFACE

Research Project 8-32(2)A is one of five related projects undertaken by NCHRP to improve the practice of multimodal transportation planning through research and dissemination of findings. The other four projects in the 8-32 series dealt specifically with best practices, land use/transportation interaction, public-private partnerships, and data issues in multimodal planning. Project 8-32(2)A focused on how to use performance measurement and monitoring in the multimodal transportation planning process.

This two-phase research project began in April, 1994, and produced several interim products, including a Phase I final report (dated August 1996), and *NCHRP Research Results Digest 226,* summarizing the Phase I results and proposed Phase II work plan (published in July 1998). The second phase of work resulted in an Interim Report (dated February 1998), a preliminary draft Final Report (dated February 1999), and a preliminary draft of this performance-based planning manual (also dated February 1999).

This guidebook establishes the rationale for performance-based planning and provides practical guidance for a wide range of potential applications. The Performance Measures Library (Appendix B to this manual) is a comprehensive, structured inventory of performance measures identified through literature reviews, case studies of applications, and field visits with client agencies and organizations. The separately bound Final Report offers more complete documentation of the study process and case study findings—it is available as *NCHRP Web Document 26.*

The research for Project 8-32(2)A was conducted in two phases. The first phase involved a detailed search of literature from the public and private sector, from within the transportation industry and without. This search was undertaken with several objectives in mind: to ascertain the degree to which the concepts of performance-based planning were taking hold in the public transportation planning process, to identify use of the concepts in private transportation sectors, and to identify any transferable concepts or lessons from non-transportation fields, such as health care and education. This literature review was followed by performance of 10 detailed case studies of various transportation planning and project implementation efforts, ranging from long-range multimodal plan development to public-private project implementation partnerships. A third area of investigation was data collection and analysis issues, where current practices were assessed relative to the data needs of performance-based planning. The results of

Phase I were documented in several interim technical reports that described a framework for integrating performance-based planning into ongoing multimodal transportation planning activities. A final Phase I report was produced in August of 1996 and summarized in *NCHRP Research Results Digest 226* (*1*).

The second phase of research focused on refining the framework and identifying specific methods and practices that would be useful to a broad range of agencies and organizations undertaking performance-based planning. Eleven in-depth case studies were conducted to identify such practices and evaluate the effectiveness of performance-based planning at the state and regional level, as well as among transportation operators. Some care was taken to ensure that these case studies represented a spectrum of applications (e.g., urban and rural, highway- and transit-dominant, freight- and passenger-oriented, public and private sector). The results of these investigations, documented in the Final Report, were used to develop much of the material offered in this guidebook.

FOREWORD

By Staff
Transportation Research Board

This report contains the results of research into the development of a framework for performance-based transportation planning. It is intended to provide transportation organizations, planning practitioners, and transportation decision makers with practical tools and guidance for considering system performance in the multimodal transportation planning and decision-making process. It is also expected to support transportation investment decisions tailored to the specific conditions and performance needs of major transportation systems. Presented as a guidebook, it brings together lessons learned from different regions of the country and establishes a rationale for performance-based transportation planning and provides guidance for a wide range of applications having different scopes and levels of complexity. This guidebook provides a structured approach to monitoring, evaluating, and considering transportation system performance in various components of the planning process. It also includes a "Performance Measures Library" (Appendix B) that catalogs measures currently being applied throughout the country. This guidebook should be especially valuable to planning practitioners in state departments of transportation (DOTs), metropolitan planning organizations (MPOs), and local transportation agencies, as well as other practitioners concerned with planning, programming, and implementing multimodal transportation projects. It should also be a useful educational resource on the concepts, tools, and procedures currently employed for establishing system performance as a basis for transportation planning and decision making.

Federal transportation policy, as embodied in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21), places a high priority on transportation decision making that is based on transportation system performance and reflects the specific needs of the area and public served. This new emphasis represents a shift from predetermined modal decisions toward a broader consideration of tailored multimodal solutions within the context of transportation performance expectations and investment commitments. As such, this emphasis is intended to result in transportation plans, programs, and decisions driven by the needs of the specific area, rather than by the modal restrictions on funding sources or support programs.

Practitioners and decision makers need help in employing performance expectations and objectives in developing plans and making investment decisions. Specifically, research was required in order to design planning approaches and procedures that use performance as a foundation for planning decisions and to identify relevant performance measures and supporting data to achieve that end. There are many planning environments and transportation conditions to which performance-based planning can be applied. These environments and situations differ in terms of adopted policy, available resources, character of the built environment, and size and complexity of the metropolitan area or state. Approaches for employing performance objectives must be flexible enough to serve these different conditions and applications.

Under Project 8-32(2)A, "Multimodal Transportation: Development of a Performance-Based Planning Process," Cambridge Systematics, Inc., of Oakland, California, developed guidance for use by planning practitioners and other decision makers to design, manage, and carry out multimodal transportation planning that reflects performance objectives. Although this guidebook addresses many of the fundamental activities included in effective performance-based planning studies, the emphasis is not solely on the process. Rather, the emphasis is on how to organize and employ systematic, effective performance measures to support planning analyses and decisions. The principles and procedures are intended as guidance to practitioners, to be applied in a way that is tailored to the decisions being made. Although this guidebook focuses on the planning-level decisions, it emphasizes the importance of integrating planning and project development so that decision making is, in effect, seamless and objective. In addition, this guidebook includes a comprehensive catalog of performance measures in use in the United States today. This catalog is provided in Appendix B.

The project also resulted in a research project final report. *Multimodal Transportation: Development of a Performance-Based Planning Process* presents, in detail, the results of the entire project, including more detailed documentation of the case studies that serve as the foundation for the project results. This report can be found on the NCHRP home page (www4.nas.edu/trb/crp.nsf) as *NCHRP Web Document 26.*

CHAPTER 1

OVERVIEW

This purpose of this guidebook is to help organizations improve the development, implementation, and management of their transportation plans and programs. By adding an element of performance measurement and monitoring to existing transportation planning processes, agencies can obtain better information about the performance of their existing programs and services. Performance-based planning provides a process and tools to identify and assess alternative programs, projects, and services with respect to overall transportation plan goals and objectives.

MOTIVATING FACTORS

NCHRP Research Project 8-32(2)A, *Multimodal Transportation—Development of a Performance-Based Planning Process*, is intended to support a new era of transportation planning efforts at the federal, state, and regional levels. The impetus for these planning efforts is a group of factors that have increased awareness of a more broad range of goals and objectives for transportation, and that have helped identify the diverse set of customers that the system must serve. These factors include

- The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) legislation with its emphasis on multimodal solutions and its long-range planning, financial planning, management system, and flexible funding provisions;
- Heightened concern about the most effective use of scarce resources in an era where traditional transportation funding sources are not generating sufficient revenue to meet perceived needs;
- Increased awareness and concern about the role of transportation in supporting economic competitiveness as changes in the national and global economies place new demands on the transportation system, especially for freight and goods movement, and international trade agreements open new markets;
- Environmental laws and regulations, particularly the Clean Air Act (CAA) and Energy Efficiency Act;
- Social and equity concerns reflected in legislation such as the Americans with Disabilities Act of 1990 (ADA) and further supported through the Transportation Equity Act for the 21st Century (TEA-21);
- Growth management, congestion management, and transportation/land use laws and regulations; and
- Various new technologies offering a wider range of transportation solutions, including Intelligent Transportation Systems (ITS), alternative fuel vehicles, and high-speed rail.

While performance measurement and monitoring is an important component of a successful multimodal planning process, it alone is not sufficient. Performance-based planning must be integrated with a comprehensive planning process that includes public outreach and participation, strategic visioning, competent analysis, and periodic incorporation of results into the process.

Despite the funding boost from TEA-21, many states and regions may still face major financial needs. While the condition of the infrastructure is considerably better than before passage of ISTEA in 1991, spending for maintenance and rehabilitation continues to be the dominant funding priority for states and regions. Given that vehicle travel is increasing at a faster rate than population or employment in many regions, the emphasis on maintenance means that we may not be increasing transportation system capacity as rapidly as demand is growing. As a result, congestion levels on surface arterials and highways will continue to rise, and transit systems may not be expanded to serve the growing populations. These trends have implications for air quality standards attainment, land use, and customer satisfaction or quality of life. Given that freight movement by truck continues to increase on most urban roads, both congestion and infrastructure deterioration rates will grow also. The effect of congestion on the reliability and cost of goods movement will also be more apparent. Safety problems are likely to grow with increased levels of congestion.

INTENDED USERS

Amid this backdrop, state and local transportation planning and operating agencies are likely to be further pushed—either by governing bodies, the public, special interest groups, or by their own desire for excellence—to continue to search for better methods and information to help manage operations, to improve accountability for resources spent, and to anticipate or mitigate the effect of external forces.

Candidates for this type of process include any agency or organization that makes planning and programming decisions that cut across different transportation modes and user markets. Such agencies often draw on different sources of funding (with different levels of certainty and flexibility) and must address different policy directives, regulatory requirements, or political priorities. Examples of agencies and organizations that might find this process useful include

- State departments of transportation (DOTs);
- Metropolitan planning organizations (MPOs);
- County and municipal governments, their transportation departments or planning commissions;
- Transit agencies;
- Congestion/transportation management agencies; and
- Special transportation commissions or policy boards.

Certain characteristics and conditions may make some of these organizations more likely to benefit from an investment in performance-based planning. Such characteristics and conditions include

- Rapid growth areas,
- Highly urbanized and congested areas,
- Areas with demonstrated support for multimodal transportation solutions and investments,
- Areas with serious financial constraints or major infrastructure upkeep needs or both,
- Areas that are in conflict over growth or investment policies or choices, and
- Areas that are having difficulty meeting air quality attainment goals.

POTENTIAL BENEFITS

The benefits to be gained from performance-based planning could be substantial. One of these is the ability to better direct resources to those programs and projects that provide the best return on investment, as measured by progress toward the goals of the local transportation plan or other relevant policy plans and documents. Though the passage of ISTEA in 1991 was a compelling impetus for this research, more recent events, trends, and conditions in the transportation sector are also conducive to the adoption of performance-based planning methods and objectives. The passage of TEA-21 in 1998 opened up substantial new financial resources to the transportation sector. In contrast with ISTEA, however, a much larger percentage of these resources will go out to states and regions to spend with greater latitude. Although significant new funds are likely to be available for agencies to program, in many cases, these agencies cannot add the internal staff resources or capabilities at a pace that ensures that the planning and programming processes can keep up with this funding.

Although the overall goals of performance-based planning are to improve decision making and to increase the link between planning goals and investment decisions, agencies can expect to derive several incremental benefits such as

- Improved correlation between agency goals and those desired by the users and general public;
- Improved internal understanding and management of programs and services;
- Improved internal strategic planning and analysis;
- Improved accountability and reporting on performance and results to external or higher level entities;
- More informed decision making by governing boards or bodies; and
- Periodic refinement of programs or services. (Such refinement will be guided by better understanding of the effects of alternative courses of action and the tradeoffs among those alternatives.)

TYPES OF GUIDANCE OFFERED

One of the findings of this research is that different organizations have different needs and, thus, will need to tailor and adapt any guidance to their needs and capabilities. By providing flexible, widely applicable guidance, this guidebook will assist agencies to undertake one or more actions to implement a performance-based approach to transportation planning. This guidebook will provide agencies with guidance and assistance as they

- Identify their needs and priorities, articulate key issues, and translate all of these into specific goals and quantifiable objectives;
- Decide on a framework for the planning process that more directly links these priorities and the actual decision making;
- Determine (by evaluating different performance measures with respect to goals and the availability of supporting data) how best to measure the performance of the programs, systems, and services that the agencies supply;
- Develop data collection and management systems to generate performance data and to support application and use of such data;
- Identify, develop, and apply analytical methods to generate useable, credible performance information and bring that information to bear on transportation decisions.

There has been a special effort to investigate the use of performance measures in non-transportation fields and in non-governmental sectors to identify concepts and lessons that are of value in the public transportation field. We have conducted a thorough review of public agency transportation planning efforts as documented in management system plans, regional transportation plans, and statewide plans. We have searched for examples of application of performance-based planning and management in the private-sector freight transportation industry. Outside of the transportation arena, we have looked into private-sector applications, such as the power generation industry and the services industry, as well as public-sector applications, including social services, education, and more. A series of case studies was conducted to observe application of elements of performance-based planning in practice. Finally, several workshops were held with regional and national audiences to hear about their needs and experiences and to test the various concepts that emerged from the research.

ORGANIZATION OF THE GUIDEBOOK

This guidebook establishes the rationale for performance-based planning and provides practical guidance for a wide range of potential applications. Chapter 2 introduces basic principles of performance-based planning, including an overall framework for structuring transportation planning elements into a performance-based process. Chapter 2 also discusses crosscutting issues that were identified as common features of successful performance-based applications. Chapter 3 presents an eight-step process for undertaking performance-based planning at a variety of application levels; it includes a series of agency examples and key points that illustrate the principles introduced in the eight steps. Chapter 4 identifies potential sources and approaches in the area of data resources and analytical tools for various multimodal and intermodal applications.

There are three appendixes to this guidebook. Appendix A (*Summary of Case Studies*) provides a brief overview of 11 case studies of performance-based planning applications. These case studies, which were conducted between April 1997 and February 1998, included state DOTs, MPOs, service providers, and a private-sector firm specializing in goods transportation. Appendix B (*Performance Measures Library*) provides a comprehensive and structured inventory of performance measures identified through literature reviews, case studies, and field visits with client agencies and organizations. Appendix C (*ITS Data for Performance-Based Planning*) provides additional information about ITS data sources, features of the data, and potential applications to performance-based planning.

CHAPTER 2

BASIC PRINCIPLES

INTRODUCTION

Although performance measurements may be applied in numerous contexts, generally, motivations for applying measurements may be divided into those in which the motivation for using performance measurements is internal to an agency and those in which the motivation is external. In the first category, performance measures are used primarily for decision making within an agency or organization. Ranking capital investment alternatives, evaluating programs, and allocating resources within an agency are the types of internal decision making for which performance measures may be used. Typical activities include long-range strategic planning, near-term project programming, and even alternative evaluation at the corridor or facility level.

Externally motivated applications of performance measures generally involve evaluation of a program or agency by someone outside the organization. Such external evaluations are often peer comparisons that measure the efficiency of one agency or program to others of its kind. These efforts attempt to improve performance by identifying comparable-agency "benchmarks," which an agency is then asked to meet or exceed. Performance-based budgeting is often an external application that attempts to set budgets for agencies based on desired program outcomes. In addition to these planning activities, performance measurement is used to evaluate agency performance and efficiency, to allocate budgets, and for other organizational matters.

This guidebook focuses primarily on how to apply performance measurement to internal decision making regarding transportation plan development and implementation. However, some of the lessons learned from the external "audit" or "benchmarking" context apply here and have been included where appropriate.

A FRAMEWORK FOR PERFORMANCE-BASED PLANNING

A general framework for applying principles of performance measurement and evaluation to the planning process is depicted in Figure 1. Planning includes identifying goals and quantifiable objectives; defining measures that relate to those goals and objectives; identifying the analytical methods and data required to generate the performance measures; and applying the measures in a process of alternatives evaluation, decision support, and ongoing monitoring.

The U.S. Government Performance and Results Act of 1993 provides a good example of the basic principles and elements that should be part of any performance-based planning application. The Act requires each federal agency to develop strategic plans that include the following components:

- A comprehensive mission statement for the agency;
- General goals and objectives, including outcome-related goals and objectives;
- More specific performance objectives expressed in an objective, quantifiable, and measurable form;
- Identification of performance measures or indicators to be used in measuring or assessing the relevant outputs, service levels, and outcomes of each program activity;
- A description of how performance measures relate to the goals and objectives;
- A reporting method for comparing actual program results with the established goals;
- Identification of those factors beyond the agency's control that could affect the agency's performance; and
- A description of the resources required to achieve the performance goals.

The provisions set out in the Act show that the federal government is using performance measures to inform, rather than to dictate, budget making. Performance-based planning methods are being implemented in a measured and flexible fashion and may be modified or done away with if the pilot studies do not produce good results. If goals are not met, agencies must explain why, including situations where goals turn out to be infeasible. This approach is appropriate, given that performance-based planning methods have not been tested in most public agencies, and is advisable in implementation of performance-based planning in public transportation.

OBSERVATIONS ABOUT PERFORMANCE-BASED PLANNING

Research of written materials, discussions with practitioners, and numerous case studies of performance-based planning

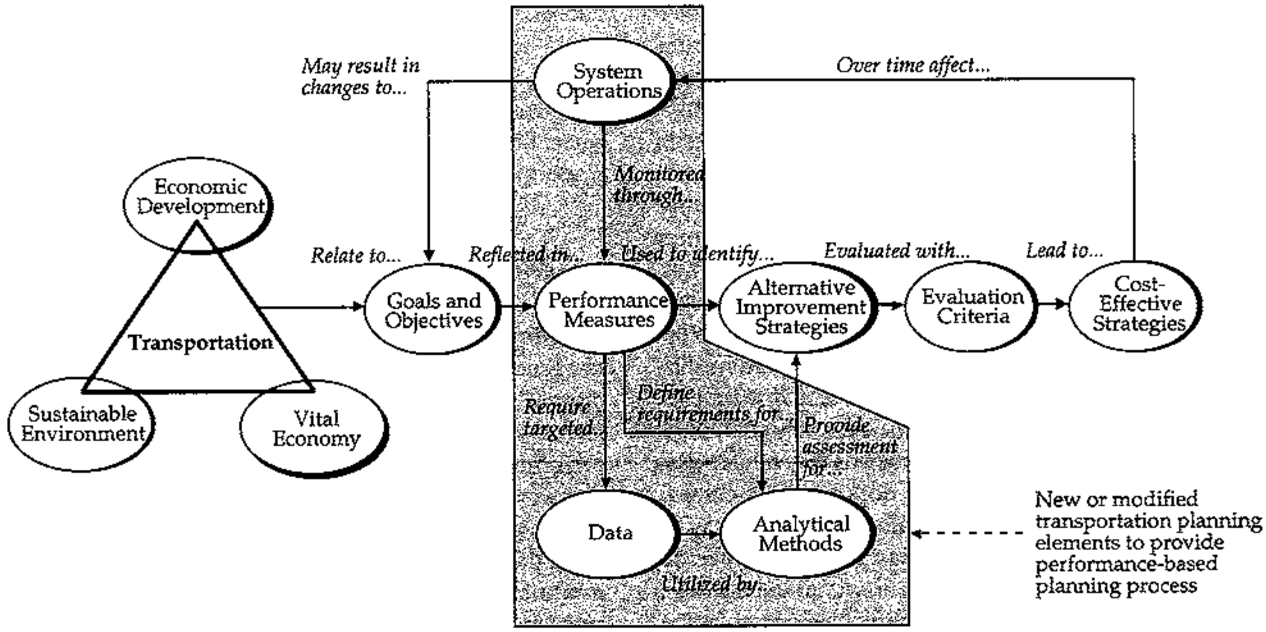

Figure 1. Elements of a performance-based planning process.

applications (including those summarized in Appendix A) have resulted in many useful observations. The following are of particular note:

- **Remember that performance-based planning is an incremental process.** Application of performance-based planning methods over a significant period will be required to alter the existing processes by which transportation investments are planned and decisions are made. Translating analyses into policies and decision making has been methodical, rather than radical, and the actual effect of performance measurement on the decision-making process has been limited to date. Progress has been made, nonetheless, and practitioners have found that more clearly articulating transportation goals and objectives has been beneficial.
- **Be aware that different terminology or nomenclature abounds.** A working definition of the terms that make up a performance-based planning framework is helpful. Suggesting common definitions of terms such as "policies," "goals," "objectives," "standards," "strategies," and "recommendations," would be useful in broadening understanding and speeding adoption and implementation of the concepts. Many agencies want to avoid undue requirements for conformity; so, it is not surprising that some have resisted consistent terminology.
- **Start with a structured, simplified system.** In order to develop an approach and methodology that will help an agency manage a potentially overwhelming number of issues and specific performance measures, it is useful to define broadly acceptable **goal categories** and **selection criteria** to help select and organize performance measures in a way that improves their clarity and meaning of the performance measure. This structured system and its various definitions and conventions then needs to be communicated to a broad audience to facilitate refinement and implementation of the concepts. The goal categories, selection criteria, and dimensions of performance measures suggested in this guidebook should be helpful to agencies.
- **Ensure that the approach fits the situation.** A package of performance measures should be sensitive to the probable range of system improvements or programs that are to be evaluated.
- **Focus on primary strategic objectives.** Only those performance measures that provide useful information for the planning, implementation, and/or management of key agency functions and activities should be used. Because collecting and reporting data can be expensive, it may be impractical to provide performance data for every agency activity.
- **Ensure that those who will be accountable participate.** Managers should help develop and select performance measures. Managers should not be held accountable for program performance if they are not involved with setting and monitoring performance goals and objectives. The selected measures should be limited to as small a number as will meet the information needs of those involved.
- **Be clear about causality.** Agencies that want to implement performance-based planning processes need to isolate and account for external factors that affect outcome (results) on the agencies' systems. The array of performance measures needs to be selected so as to minimize the likelihood that those external factors not measured by

the methodology are, in fact, responsible for the noted changes in performance. Good examples of this problem can be drawn from the environmental goal category. Many factors external to the transportation system affect outcome as evaluated by measures such as "number of non-attainment days." Measures that are more specific to the transportation system, such as "mobile source emissions" (e.g., tons by pollutant category and time period) should also be used to help better gauge the system's contribution to outcome. Similar cautions apply to goal categories such as safety and economic development, where much of the total outcome is determined by factors other than transportation system investments. This does not imply that such measures should not be used. In fact, it can be very instructive for an agency to measure effects that the agency does not fully control, such as accidents or pollution. Such measures may be useful for better understanding just how responsive the system performance is to decisions within the agency's control and may also help to identify other causal factors that need to be addressed through partnership with other agencies or organizations.

GOALS

Setting clear, concise, and achievable goals and objectives is part of the critical foundation of any successful planning effort. There has been significant movement toward better integration of performance criteria and project evaluation. ISTEA regulations have stipulated that there be consistency among all elements of the transportation plan, as well as between the plan and the projects selected for implementation. This explicit link has prompted many agencies to give more careful thought to the issues raised in their transportation plan goals and objectives and to define objective measures or criteria by which progress toward these goals and objectives can be tracked.

It is now typical to see multimodal performance criteria used in project evaluations to assess effect on overall goals. The common practice, however, has too often been to deemphasize or abandon these goals and objectives once an agency starts programming and implementation of specific transportation projects. There are several possible reasons for this, but certainly among these reasons is a lack of a clear link between goals and performance measures. Often an agency simply does not have the data or analytical resources to reliably measure progress toward a goal or objective. The chosen performance measures reflect these data or analytical constraints and, as a result, decisions about investment in programs or projects do not clearly relate to the underlying planning goals and objectives.

Making goals **operational** will help improve tracking between plans and implementation decisions. A goal that can be unambiguously compared with an existing situation is operational. For example, "reform criminals" is a non-operational goal; "double the rate of inmate participation in prison programs" is operational and can be more clearly linked to specific measures and more effectively tracked with those measures. Plan goals need to be tested to ensure that they can be made operational and linked to specific measures of progress.

PERFORMANCE MEASURES

Defining objective performance measures that relate clearly to agency or program goals and objectives is central to the process. How an agency measures system or facility performance will affect the types of projects selected to enhance performance and attain goals. For example, as many state highway departments evolved into multimodal transportation agencies in the ISTEA era, there has been much concern about the use of roadway level of service (LOS) as a primary measure of system performance or mobility. Projects that enhance LOS might be given priority by virtue of this definition of system performance. In the view of some, this creates an inherent bias toward highway capacity enhancement and modernization projects.

Many agencies have attempted to avoid this problem by defining several measures to evaluate system performance in any one goal category. The ISTEA management systems effort contributed to a trend toward broader and more numerous measures of system performance. For example, an agency may elect to define performance in the "mobility" category through measures of travel time, transit load factors, delay, person-hours of travel, and a congestion index, in addition to roadway LOS. Other agencies are following this trend, but are, of necessity, introducing a "tiered" approach in which more "innovative" measures will be phased in as data collection and analysis capabilities catch up with the demands of the performance measures.

It is also important to measure the **outcome** of system investments and project decisions, in addition to the **output** of an agency. Research into other sectors, particularly those with a strong customer-service orientation, revealed numerous examples of this. Output is, generally, a measure of the level of activity of an agency, department, or program (e.g., the number of cracks sealed or number of lane miles plowed). These are useful measures in tracking overall activity and efficiency, at least in the sense of measuring how much activity a particular budget level generates. Outcome measures, on the other hand, provide a better indication of the **effectiveness** of a given level of budget or activity. For example, "average length of hospital stay" is an output measure for the health care industry; "readmission rate" or "mortality" rate is a measure of outcome and effectiveness of the service. A transportation analogy might be "number of ice-related accidents" rather than "tons of salt applied." The former measures the outcome or effect of an effort or investment; the latter measures only the output of the crew.

DIMENSIONS OF TRANSPORTATION PERFORMANCE MEASURES

Performance measures may be identified that describe dimensions or market segments. These many dimensions make performance-based planning more challenging in the transportation arena than it might be in a more narrowly focused industry. For example, performance measures may be related to broad goal categories such as mobility, safety, or economic development.

Indeed, part of the difficulty in identifying a finite set of performance measures for use in the public transportation sector is the overly wide range of roles or "public goods" that are expected from the transportation system. The main strategic business area (i.e., movement of people and goods) must share the stage with other roles (e.g., redressing economic inequities imposed by society, managing environmental effects, or providing for the economic health of a region). While many private businesses have always had to externalize certain costs and effects, now the publicly provided transportation system increasingly must account for and address such externalities and even the undesirable side effects of non-transportation activities. All of this makes selecting a manageable set of measures that address an acceptably broad set of issues more complicated.

Performance measures may also be classified according to whether they are multimodal or mode-specific, by whether the measures apply to freight or passenger transportation or both, by the system level to which they apply (e.g., systemwide, corridor, or facility), or by the planning jurisdiction to which they are most relevant. Finally, they may be classified by perspective, that is, whether the measure describes performance in the eyes of the user, the general public, or that of the planning agency or system owner/operator.

It is useful to consider these dimensions in selecting and implementing a set of performance measures to suit any particular planning process. Not only may it help reduce analytical effort by eliminating some irrelevant performance measures, but it will also ensure that adequate breadth is instilled in the planning process so that all relevant issues are addressed. The Performance Measures Library (Appendix B to this guidebook) uses several of these dimensions to help catalog numerous performance measures suggested and/or used by various public and private transportation agencies.

SELECTION CRITERIA FOR PERFORMANCE MEASURES

Several previous studies consulted in this research identified criteria for selecting performance measures. These selection criteria help an agency to consider their particular needs and capabilities and the intended use of the measures. Chapter 3 of this guidebook includes a list of frequently cited criteria for selecting performance measures and a discussion of each. This list can serve as a starting point to help planners select performance measures and balance the sometimes-conflicting needs and limitations of decision makers and analysts. The most appropriate selection criteria may vary from one agency to the next, depending on need, resources, and capabilities. Each agency should learn to apply these selection criteria in a framework that suits the agency's particular need and situation (2).

PERFORMANCE INDEXES

Performance indexes are measures that combine and distill various measures, potentially covering multiple dimensions or goal areas, into a single measure. Performance measures are of interest to planners and decision makers because such indexes can be used to reduce the complexity and volume of performance-related data that must be regularly monitored or factored into a specific decision. An analogy is the Consumer Price Index, which is a single number reflecting the cost of a broad "market basket" of goods and services regularly purchased by the typical consumer.

The interest in defining a common performance index seems particularly strong for goal categories such as "mobility" and "accessibility." For example, definitions of mobility vary widely. Agencies have debated how broadly to cast the net to encompass the various factors that make up mobility for the traveler. Lacking a single most important descriptor of mobility, a composite index seems attractive.

The performance index concept is still under discussion and development at several different levels. The attempt to address various factors on a common scale is the first step toward developing a more effective way to evaluate and reconcile difficult trade-off decisions.

CUSTOMER ORIENTATION, PERCEPTION, AND SATISFACTION

Many agencies, public and private, transportation or other, recognize the need to improve customer service and develop user-oriented systems of planning and management. State and metropolitan transportation agencies, in particular, have embraced more of a customer service orientation in the ISTEA era. Many statewide and regional transportation plans strive to involve "transportation system customers" in the planning process and make concerted efforts to assess customer satisfaction and perception of system performance. Innovative programs have been developed that emphasize customer survey data during the planning and evaluation processes.

This customer orientation is a key aspect of the success of private-sector service industries and organizations. Performance measures are used to address mismatches between what the organization measures and what its customers see as important. In the service sector, the performance measurement process must start by defining precisely the services that the organization promises to provide, including the **quality** or level or service (e.g., timeliness or product reliability) to be delivered. The process must provide information to managers about how well such services are being provided.

A key difference between performance measurement in the service sector and performance measurement in transportation is that the overriding motive in the private sector is profit. In transportation planning, on the other hand, the process is seldom guided by a profit motive alone, but must consider numerous other motives such as equity and external effects. These differences aside, there are some parallels between the service and transportation sectors, from which emerge these considerations for development of a performance-based methodology:

- Performance measures should reflect the satisfaction of the transportation service user, in addition to the concerns of the system owner or operator.
- Measuring performance before, during, and after the delivery of a transportation service can profoundly affect the organization's ability to diagnose problems and develop solutions.
- An understanding of the relationship between internal performance measures (e.g., crew sizes and overtime hours worked) and external performance measures (e.g., vehicle hours of delay due to incidents and transit ridership) is another key to improving the outcome of a given level of effort.
- Given the significant involvement of human resources (people) in the transportation service delivery process, performance measures must accommodate variations in individual skills, productivity, and quality.
- There are good opportunities for collecting feedback from system users in "real time," because the transportation service is often "consumed" at the same time it is "produced" (i.e., the transit rider consumes a transit trip while the transit vehicle is producing the trip).
- Although "soft" measures, such as customer perceptions of safety, may be more difficult to interpret than "hard" measures, such as number of highway accidents, transportation agencies should not neglect soft measures.
- The performance measurement process should balance long- and short-term system needs and should recognize the periodic need to balance short-term results and long-term benefits.
- The performance measurement process must start with defining the services that the organization promises to provide. In planning, this means defining carefully the goals and objectives in statements that can be made operational. Through monitoring performance measures that are clearly linked to the service objectives, the process should inform transportation decision makers about how well those services are being provided.

CHAPTER 3

DEVELOPMENT PROCESS

No two performance-based planning processes will be exactly alike. Agencies across the country have different organizational needs to satisfy, different resources to draw on, and unique local and regional issues to consider. Therefore, although your process and products will probably draw on the successes and failures of other agencies, your process should be unique to your agency. Your process will not be perfect, especially during early stages of development and testing. As you move on, you will discover much about your organization and about performance-based planning. The process is incremental and evolutionary; however, with sufficient review, feedback, and adjustment, you will develop a highly effective process.

STEP 1: GETTING STARTED

You should begin by assembling the organizational resources necessary to initiate and then manage the development process through to its conclusion. Staff and management changes during the development process will severely affect the quality and timeliness of the project. There is a tendency to underestimate the levels of staff resources and management commitment required to implement this kind of process. Executive management must show considerable support for the concept at the outset; otherwise, the resources may run out before the work is done and any products are in place.

Although the following formula for developing a project team is generic, it is still good to follow. At the very least, your project team needs a **project manager**, who will orchestrate and manage daily activities. This can easily be a full-time job when an agency is starting the process from the ground up. Those with experience suggest that the best candidate for this is the highest-level **non-appointed** (i.e., civil service) staff member that the agency can afford to devote to the project. A **senior executive** should be identified whose most important function is to communicate project progress and value to other senior managers and directors. At least one **project planner** should be available to assist the project manager, particularly when it is time to address technical details such as the location of data and generation of baseline performance measures. Depending on the complexity and desired pace for the project, additional staff and/or outside consultants may be necessary. (Participation of other internal and external stakeholders is discussed in Step 3.)

Once the project team is in place, it is useful to come to agreement on why you are embarking on the project and what you plan to get out of it. Some agencies have even written "mission statements" documenting where they are headed and why. This will pay off significantly when the project runs into doubt or opposition. An initial outline of the intended products (e.g., clear goal and objective statements, a short list of near-term performance measures, baseline data for those measures, a future data collection plan, and proposed reporting mechanisms) should be developed. Although these documents will be revised during development, it is important to have a basic plan and clear goals.

Finally, you should develop a budget and schedule for the various steps in the development process, based on the staff resources that will be allocated, the need for outside contract employees or consultants, and so forth.

STEP 1 OUTPUT:

- **Project team**
- **List of desired outcomes of the process and "mission statement"**
- **Budget and schedule**

STEP 2: SELECT APPLICATION

The next step is to establish clarity and consensus about which of your agency's activities and processes you will be applying performance-based planning to. Setting and measuring performance objectives may be used for a myriad of different planning and management activities. Indeed, many of the most instructive lessons in the performance management field have been learned from experiences in other industries such as electric utilities, air shipping, and theme parks. Within a transportation planning agency, there is still a range of potential applications, and experience suggests that it is important to be as clear and focused as possible at this early stage about the intended applications. This focused planning will reduce the complexity of each step of the process, such as identification of goals and measures, and will help establish a framework for implementation within the agency. Common applications at the state DOT and MPO levels include

- Regional and statewide transportation plans;
- Transportation improvement programs (TIPs) used in project selection and programming; and
- Corridor studies, major investment studies (MIS), or other efforts that focus analysis and evaluation on more specific, targeted areas where significant problems or opportunities exist.

Other applications include

- Transit system route planning and operations (transit agencies);
- Strategic and business planning; and
- Transportation system performance audits.

Some agencies have been more focused in their intended application (e.g., application of performance measurement to help specifically with development of a regional plan update). Others have had a broader focus, bringing certain aspects of long- and short-range planning and programming efforts together under one performance-based framework. Either approach is acceptable—the approach chosen should reflect the agency's needs and aspirations. It is important, nonetheless, to be as clear as possible about this from the start. Examples of how different agencies have selected an application are provided in Examples 1, 2, and 3, which follow.

Example 1: East-West Gateway Coordinating Council (EWGCC) (St. Louis, MO)

EWGCC is the designated MPO for the St. Louis, Missouri, region of 2.4 million people. The Council has been exploring the use of performance-based planning throughout its planning activities for more than 4 years. The foundation of this effort is the long-range transportation plan, *Transportation Redefined: A Plan for the Region's Future*, adopted in 1994. A recent supplemental effort further stratified the performance-based planning approach according to three essential planning activities: the long-range plan, the transportation improvement program, and specific corridor analyses. Measures were selected that were appropriate to each of the applications, but that could all be related to broad transportation goals and objectives common to each application and included in the long-range plan.

Example 2: Miami Valley Regional Transit Authority (MVRTA) (Dayton, OH)

MVRTA is the transit operator for the Dayton, Ohio, metropolitan area. One of MVRTA's major efforts in the last decade has been to integrate itself into the power and decision-making structures in Dayton. MVRTA went about this integration by adopting principles of performance-based planning, and, more specifically, through intensive outreach to the community. Through this process, the Authority solidified its standing and financial position in the area and changed its route system and operating structure to better reflect the needs (and demands) of a broad base of users and financial partners.

Example 3: Florida Department of Transportation (FDOT)

FDOT integrates performance-based planning in both the long-range and short-range components of the Florida Transportation Plan (FTP) and throughout the planning and project development process. In addition to statewide and corridor planning, FDOT uses performance-based planning for its intermodal management system and for budgeting.

STEP 2 OUTPUT:

- **Selected application(s)**

STEP 3: DEVELOP A WORKING GROUP

The next key step is to develop a working group of stakeholders to involve in the process. While the organization's internal project team will form the core of this group, the active participation of others who will be affected by and/or responsible for implementing the resulting performance-based planning system is critical. Often, the support of one or more outside agencies or organizations is critical to success, even if they are not playing a direct role in implementation. This is particularly true for agencies dealing with **multimodal** planning solutions that involve different agencies and funding partners.

Who to involve depends on your own political and operating environments. The most effective processes include a broad, yet manageable, group of individuals who will actively participate in all essential activities. There is a tradeoff between breadth of representation and consistency of participation. Although it is important that your working group try to include and represent a broad section of potentially affected internal and external stakeholders, it is perhaps even more important that the same agencies and individuals are involved over the course of the process design and roll-out. A reasonable strategy is to start with a relatively small group that has a consistent perspective about the **purpose** of the undertaking. Participation may then be broadened once there has been fundamental agreement on directions and approach and the discussion turns to more specific content and methodology questions.

In our research, we have found that organizations have included representatives from the following types of agencies and groups. You should consider these participants when you develop your own working group.

- The state DOT;
- The MPO;
- Regional federal agency representatives (e.g., FTA, FHWA);
- Local county(ies);

- Local city(ies);
- Transit agency(ies);
- Business group(s) or representatives of specific relevant industries (e.g., retail trade and manufacturers);
- Shipping and trucking industry members or representatives(s);
- Community group(s);
- Special interest groups; and
- Technical consultants and/or process facilitators.

Within an agency such as a large DOT, the selection of participants also depends on the motivation for performance-based planning and the expected applications. Generally speaking, the planning groups will be represented and often are leading the charge. Other participants come from programming (e.g., the STIP manager) finance, information systems, and similar "administrative" units. Depending on the application, groups such as maintenance and design probably will be involved. The objective is to involve the smallest number of units or individuals necessary to adequately represent the breadth of concerns likely to be subjected to the performance measurement process.

External participants from the above list should be chosen based on the likelihood that resulting performance-based planning process will be improved as a result. The more that a performance-based process focuses on broad, multimodal transportation issues, the more likely that participation from outside agencies and groups will be useful. These representatives will raise issues that might be de-emphasized by internal staff and will tend to have a different perspective on what is important to the system user.

As with preparation of a statewide or regional long-range plan, it may be useful to establish distinct working groups to focus on more specific issue areas, such as mobility and economic development. This approach allows broader participation and input, without creating an unduly large steering committee. The tradeoff is the staff or consultant time required to organize, chair, and manage multiple committees.

Examples 4, 5, 6, and 7 illustrate how different agencies have approached development of a working group.

Example 4: MVRTA (Dayton, OH)

In the early 1990s, new leadership at MVRTA considered community credibility to the most crucial issue facing the organization. They immediately convened the RTA in 2000 Committee (RTA/2) to provide an external review of what the community expected from its transit agency. The Committee was charged with determining the social, economic, and environmental role, as well as level of service, that the community will require from a transit system in the Year 2000. This committee's work formed the basis of the performance-based planning approach used by the agency today.

Example 5: Colorado DOT (CDOT)

In developing its performance-based *Investment Strategy*, the Colorado Department of Transportation (CDOT) made a special effort to involve persons outside the agency in the development of performance goals and measures. These external stakeholders were particularly evident in the discussion and debate of mobility issues, one of five key areas that CDOT targeted for strategic evaluation and investment. "Mobility" as a program or investment area is unusual in that there are no widely accepted definitions as to what constitutes mobility, how it should be measured, what necessarily constitutes success, and so forth. Unlike safety or system maintenance, for example, where most DOTs have a history of collecting and analyzing performance data, mobility is a relatively recent concern and data are limited both in variety and history. At CDOT, the external stakeholders provided a progressive and challenging definition of mobility. Mobility itself was defined as comprising several desirable attributes (e.g., movement, access, and reliability) embracing the traveler's or system user's point of view rather than the DOT's alone. Measures were defined that extended beyond the state highway system to include performance on regional transit and other modes that work together to provide multimodal mobility in the state.

Example 6: Met Council (Twin Cities, MN)

Met Council, the Minneapolis/St. Paul's MPO, with the state DOT and regional transit agency, worked to respond to the Minnesota State Legislature's request for a transportation system audit. A consulting team was selected to work closely with and report to a Management Team composed of representatives of the Met Council, Mn/DOT, and Metro Transit. The process consisted of initial joint sessions during which key issues and data resources were related to the study team, followed by development of a framework for conducting the evaluation, specification of measures, and conduct of the analysis. The early involvement of high-level staff at these three agencies helped to provide the credibility needed to address the Legislature's request.

Example 7: Amtrak

In December of 1993, Amtrak chartered the Customer Attitudes Shall be Heard (CASH) Team to prepare and recommend a plan for collecting and communicating customer data to Amtrak management. The Team consisted of individuals from throughout Amtrak's management and worked closely with three customer survey vendors. All of Amtrak's business units and all levels of management were included in this process, which became the foundation of an ongoing, performance-based service planning and evaluation process.

STEP 3 OUTPUT:

- **Working Group, possibly including special-purpose advisory committees or panels**

STEP 4: DEVELOP GOALS AND OBJECTIVES

The development of goals and objectives is one of the more time-consuming steps in the process. Although most agencies have already developed goals and objectives for their various planning activities, performance-based planning usually requires agencies to take a closer look at their goals and objectives and refine or clarify them for use in a more quantitative, methodical process.

Goals and objectives relate to system performance in that they reflect different perceptions of what the transportation system should be achieving. These goals and objectives are often developed through extensive public outreach efforts and thus incorporate a broad community perspective on what elements of system performance are important. Understanding different goals and objectives is critical to identifying the different types of performance measures that might be incorporated into the planning process. Most agencies will find that they need to become more disciplined in defining goals and objectives in order to make them more operational and less ambiguous.

The composition of goals and objectives, as well as the terminology (e.g., "policies," "goals," "objectives," "strategies," and "recommendations") used to describe them vary widely across the country. Typically, however, the planning documents contain broad goals related to one or more policy areas, followed by more specific goals or objectives. The following excerpts from recent statewide transportation plans illustrate this point:

- **Manage, maintain, and expand system capacity.**
  - Expand system capacity to relieve congestion and to facilitate interregional travel and commerce.
  - Make cost-effective transportation investment decisions through the use of transportation management information systems (*3*).
- **Goal #4: Transportation Safety and Convenience.**
  - Policy Statement B—Reduce injuries and property damage at Ohio's rail-highway grade crossings.
  - *Initiative*: Upgrade Ohio's 3,700 existing passively protected rail-highway grade crossings" (*4*)

Definitions

You can see that some of these goals can be unambiguously evaluated and compared more readily than others. The following definitions should facilitate generation of operational goal and objective statements and should promote understanding of the important nuances between performance-based planning and more traditional planning processes:

- **A goal is a general statement of a desired state or ideal function of a transportation system. For example**
  - "Promote economic development." (*5*)
  - "Improve the safety of the state highway system"
  - "Protect the public's investment in transportation." (*6*)
- **An objective is a concrete step toward achieving a goal, stated in measurable terms. For example**
  - "Reduce the number of commercial vehicles that exceed legal weight limits on the State Highway System." (*6*)
  - "Reduce the number of alcohol-related traffic fatalities."
  - "Reduce the number of at-grade railroad crossings." (*7*)
- **Objectives may have specific performance standards, which set out in clear, numerical terms a desired or required degree of achievement. For example**
  - "Provide transit service in all urban areas/corridors with more than nnn population."
  - "Travel times in urban areas/corridors should not deteriorate below 1994 levels." (*8*)

Performance Standards

Not all agencies that have embarked on performance-based planning have identified performance standards. In some cases, agencies may believe they do not have enough experience dealing with the measure in question to establish a reasonable, non-arbitrary target or standard. This is especially understandable when an agency enters new territory—for example, tackling measures of accessibility or equity for the first time, where there does not exist a base of historical data and trends to draw on. In these cases, it may be necessary and sufficient to simply attempt to improve the current situation or hold the line, as indicated by the example objectives above.

On the other hand, some practitioners believe that a performance standard should be established for every objective and measure. For example, if the objective is to reduce the number of passively protected rail crossings, and the measure is the number or percent of remaining such crossings, then a performance standard might require that a number or percentage of such crossings are eliminated per year or by a certain date. Without an unambiguous standard, there may be insufficient incentive or mandate for an agency to take action.

In either case, as an agency accumulates experience with its performance on a particular measure, it may become clearer where to "set the bar" in terms of desired future performance. Thus, agencies can retroactively instate performance standards or update them to reflect current realities and priorities. Some of the published data resources identified in Chapter 4 may be used to establish initial or interim standards or to validate an agency's choice of a particular standard.

Categories of Goals and Objectives

The breadth and depth of issues identified by transportation planning agencies produce challenges for decision-makers. Even if adequate information is provided for each issue identified, trade-off decisions become increasingly complex as the volume of information increases. It is useful, therefore, to group the issues into broader categories, for which appropriate goal and objective statements can then be formulated. This will in turn keep manageable the number of performance measures adopted and will ensure that the measures and goals can be traced to an identified issue raised during plan development.

Based on an extensive review of planning documents and research into public agency planning processes, the following categories of goals and objectives have been identified and found to provide a solid, broad basis for a performance-based planning process:

- Accessibility,
- Mobility,
- Economic development,
- Quality of life,
- Environmental and resource conservation,
- Safety,
- Operational efficiency, and
- System condition and performance.

Example Goal and Objective Statements by Category

There are many styles in goal and objective statements. One MPO's goal may be another state's objective; some states refer to a performance standard as an objective. This can present a stumbling block for developing a performance-based planning process, because the process begins with goals and objectives, and includes multiple checks and feedback loops to monitor progress toward meeting those goals and objectives. To gauge the breadth of agency approaches and to seek to reconcile contrasting styles, we built on the definitions presented above. We inventoried examples of goal and objective statements currently used in practice and present them in Table 1. In some instances, we moved a stated "goal" into the "objective" category, or vice versa, so that the statements are consistent with our proposed definitions. The examples help to further illustrate the incrementally more specific and quantifiable nature of objectives relative to goals.

STEP 4 OUTPUT:

- **Goals and Objectives, by category**

STEP 5: DEVELOP PERFORMANCE MEASURES

Though many equate performance-based planning with the development of performance measures, you probably see by now that the development of performance measures is one step, albeit a critical one, in a broader performance-based planning process.

How you measure system or facility performance will affect significantly the types of projects that you eventually implement to enhance performance. For example, in its infancy, the California Congestion Management Program (CMP) used roadway level of service (LOS) as the only mandated measure of system performance; projects that enhance roadway LOS would be given priority by virtue of this definition of system performance. (CMPs are prepared by local California governments acting at the county level through a "Congestion Management Agency." California's CMP process is separate from the federal CMS process.)

Most agencies strive to avoid this problem by defining several measures, rather than trying to define system performance through one measure. ISTEA is partly responsible for a rapidly expanding awareness of the value of moving to use of more numerous and broader measures of system performance. For instance, the California Statewide Transportation Plan proposes a number of performance measures aligned with several categories or "desired outcomes": mobility and accessibility, reliability, cost-effectiveness, sustainability, environmental quality, customer satisfaction, economic well-being, safety and security, and equity (*9*). Other agencies have taken this same approach, but are implementing a phased approach in which more "innovative" measures will be integrated as data collection programs are modified to better meet the demand of the performance measures and analytical methods.

Dimensions of Transportation Performance Measures

A better understanding of the many **dimensions** of performance measures is useful in the development process. These many dimensions make the exercise of performance-based planning a challenge. Performance measures may be classified by whether they are multimodal or mode-specific, by whether the measures are applicable to freight or passenger transportation, by the system level to which they apply (e.g., systemwide, corridor, or facility), by the planning jurisdiction to which they are most relevant, and by their perspective. The perspective of a performance measure may be that of the user or that of the agency or operator. In some cases, the perspective has included that of a funding partner who is neither necessarily user or operator.

It is instructive, therefore, to consider these dimensions in developing, selecting, and implementing a set of performance measures in a planning process. Not only may it help reduce analytical effort by eliminating some irrelevant performance

TABLE 1 Example goals and objective statements by category

Category	Goal	Objective
ACCESSIBILITY	To ensure reasonable accessibility to all areas of the city for all citizens. (The Calgary, Alberta, Canada Transportation Plan)	Improve or upgrade and maintain access to ceremonial sites as needed in cooperation with the Cultural Committee. (Hoopa Valley Indian Reservation Transportation Plan, 1996-2001)
MOBILITY	Work with the general public, public agencies, and private-sector organizations to ensure basic mobility for all Michigan citizens by, at a minimum, providing safe, efficient, and economical access to employment, educational opportunities, and essential services. (Michigan Long-Range Plan)	Make public transportation travel time competitive with autos. (Oregon IMS)
ECONOMIC DEVELOPMENT	Address anticipated demand from increase in international trade. (Montana IMS)	Improve access to passenger and freight facilities to serve international markets. (New Jersey's "Transportation Choice 2020")
QUALITY OF LIFE	Ensure that transportation investments are cost-effective, protect the environment, promote energy efficiency and enhance the quality of life. (Southern California Association of Governments (SCAG) Draft 1998 Regional Transportation Plan (RTP))	Provide the opportunity for safe, enjoyable, and low environmental impact water recreation on rivers and streams in the Missoula area, including canoeing, kayaking, inner tubing, rafting, and fishing. (Missoula Non-Motorized Transportation Plan, 1994)
ENVIRONMENTAL AND RESOURCE CONSERVATION	Develop projects that are environmentally acceptable. (Alaska Intermodal Transportation Plan)	Improve air quality in Texas through transportation measures. (Texas Transportation Plan)
SAFETY	Ensure high standards of safety in the transportation system. (Mississippi Statewide Transportation Plan)	Reduce the rate of motor vehicle crashes, fatalities, and injuries, and bicycle and pedestrian fatalities and injuries on highways. (2020 Florida Transportation Plan)
OPERATIONAL EFFICIENCY	Develop strategies that improve the transfer of people and goods between modes, private facilities, and publicly owned systems by reducing delays and minimizing inconvenience, thus providing a more "seamless" transportation system. (Tucson, Arizona IMS)	Utilize economies of scale by providing for joint use of ports by several tenants. (West Virginia Statewide Transportation Plan)
SYSTEM CONDITION AND PERFORMANCE	Preserve the highway infrastructure cost-effectively to protect the public investment. (Washington Statewide Multimodal Transportation Plan)	Improve construction techniques and materials to minimize construction delays and improve service life of transportation improvements. ("Access Ohio," Ohio's Statewide Plan)

measures, but it will also ensure that adequate breadth is instilled in the planning process so that all relevant issues are addressed.

Below are several common dimensions of performance measures and examples of the potential choices within each dimension:

- **Sector**–freight and passenger;
- **Mode**–highway (auto, truck, transit), pipeline, rail, water, intermodal, bicycle, walk, and other non-motorized modes (electronic "modes" were also proposed by some);
- **Perspective**–user versus supplier and performance versus condition;
- **Concern**–economic development, environment, safety, efficiency, system preservation, mobility, equity, and stable funding;
- **Type of Application**–policy, regulatory, programmatic, and implementation;
- **Spatial Concern**–metropolitan (urban versus suburban), rural, intercity/interurban, interstate, and international;
- **Level of Responsibility**–federal, state, regional, and local;
- **Use of Information**–management decision making, diagnostic tool, tracking and monitoring, resource allocation, signaling systems between users and suppliers, and information systems;
- **Time Frame**–present/short-term, future/long-term, point in time versus trend; and
- **Level of Refinement**–data item versus performance measure, primary versus secondary indicator, surrogate versus desired primary indicator, original versus preexisting/secondary choice, and primary versus composite measure.

The categories in the dimensions listed above are flexible. For example, the highway mode could be broken down even further into truck, bus, and auto. Most planning agencies categorize selected or proposed performance measures according to some but not all of the dimensions listed above. For example, the Michigan Transportation Plan classifies proposed performance measures by system level (links versus systemwide trends) and by mode (highway, transit, person). The dimensions shown above are designed to permit any number of classification systems.

Selection Criteria for Performance Measures

Several state, local, and regional transportation plans have laid out criteria for selecting performance measures. These selection criteria are instructive as to agencies' concerns and the intended use of the performance measures. Agencies that use selection criteria usually are particularly concerned with the actual "operationalizing" of the performance measures and with the many different dimensions of performance measures listed in the previous section.

The following list presents common criteria for selecting performance measures and a discussion of each. It is adapted from several different sources, including the Southern California Association of Governments' (SCAG's) Regional Mobility Element, the Santa Clara County (CA) Subregional Deficiency Plan, and FHWA's *Analytical Procedures to Support a Congestion Management System.* Such a list can help planners select performance measures and balance the different needs and preferences of decision makers and analysts.

- **Measurability**–Is it possible to generate the performance measure with the tools and resources we have available? How much would it cost to adequately quantify this measure? What level of accuracy is needed for the measure to be useful? How reliable are the sources of data for this measure? Are needed data available?
- **Forecastability**–Can one realistically compare future alternative projects or strategies using this measure? Is it difficult to define this measure using existing forecasting tools?
- **Measurability**–Is it feasible to collect the necessary data through field measurements, either to monitor ongoing system performance or to calibrate forecasting models?
- **Multimodality**–Does this measure encompass several relevant travel modes?
- **Clarity**–Is this measure understandable to policymakers, transportation professionals, and the public?
- **Usefulness**–Is this measure useful? Is it a direct measure of the issue of concern? Is it primarily an indicator of condition, that is, a "triggering" device that will cause further study or action to occur, or is it capable of diagnosing transportation deficiencies and their causes?
- **Temporal Issues**–Is the measure comparable across time? That is, is it capable of expressing the temporal extent of congestion or other conditions? Is it capable of discriminating between peak-period, off-peak, and daily conditions? Also, does the measure fit well with the time frame of analysis and action? Long-range plan measures may be very different than measures intended to gauge the more immediate effect of near-term program decisions.
- **Geographic Scale**–Is the measure applicable to all areas of the state, region, and/or local area? Can it discriminate between freeways and other surface facilities? Is it useful at a regional, subarea, or corridor level?
- **Multiple Indications of Goals**–How many of the project goals does the measure help to address? Is the measure related to thresholds that indicate how well the system is performing? Is it a measure of supply or demand or both?
- **Control**–Is the characteristic being measured something that can be controlled or corrected by the agency doing the measuring?

- **Relevance**–Is the measure relevant to planning/budgeting processes? Does the reporting of these measures happen often enough to give decision makers the information they need as often as they need it?
- **Ability to diagnose problems**–Is there a logical link between this measure and what actions/phenomena affect it? Is the measure too aggregated—to a level where a "black box" syndrome can occur?

Of course, selection criteria will vary from one agency to the next, depending on need, resources, and capabilities. One common difference is the degree to which agencies are willing or able to support new data collection procedures in order to implement new performance measures. We heard in the workshops and in our case studies that the cost and institutional obstacles to new data collection were an issue for most agencies and a "deal killer" for some.

Therefore, some agencies will be most comfortable and successful with measures that are readily quantifiable with existing data. In most cases, this will mean making do with a rather limited array of measures. Other agencies have already demonstrated a willingness to pursue useful measures of performance that required new data collection efforts or that will be supported by "surrogate" data until new data collections programs can be put in place. Each agency should learn to apply these selection criteria in a framework that suits the particular need and situation and that reflects realistic expectations about the availability of data and analytical support.

Composite Performance Index

The concept of a composite performance index has been suggested as an efficient means to compare multimodal alternatives or to otherwise allow comparison across one or more of the dimensions described earlier. A few agencies are actively pursuing variations of this concept. Among them, SCAG uses index values to assess mobility, the environment, finance, economic development, livable community, safety, and quality of service. SCAG's mobility index, for instance, is a composite value of vehicle-miles of travel (VMT), operating speeds, free-flow speeds, average vehicle occupancy, and population. Example 8 illustrates how one agency has explored using an index.

By establishing a uniform unit of measurement and relying on available data to make the measure operational, the primary advantage of an index approach to measuring performance is that it breaks the deadlock on mobility and moves the process forward. The **range of uses** that could be served by the measures include

- Reporting on performance to the legislature, transportation commissions, other special interest groups, and the general public;
- Allowing agencies to better establish measurable performance standards;
- Tracking changes in performance over time in relation to both policies and actions of the agency, as well as external actions and trends;
- Calculating benefits and costs; and
- Evaluating the effectiveness of alternative policies and transportation facility investments, services, or programs.

Having an index measure represent performance through a single number that has no dimensional units (e.g., dollars

Example 8: Florida's Transportation/Connectivity Index

The state of Florida has been actively exploring the potential for a Transportation/Connectivity Index. The idea of using an index approach for measuring mobility has emerged as a possible way of breaking an impasse on the Department's attempts to begin accounting for mobility.

The strategy behind an index approach to measuring mobility is to try to steer around the many impediments associated with trying to agree on "just the right measure," and return to the objective of trying to measure and be in touch with mobility. In that vein, the index is more of a collection and packaging of mobility attributes, rather than one or a small set of precise individual measures that will raise arguments about realism and comparability. The index would be a roll-up of several mobility attributes into a composite measure, probably with dimensionless units, much like the Consumer Price Index (CPI).

With the CPI, the goal is to have the index represent the level of prices as reflected in goods and services that are relevant to consumers. As the index changes, the consumer has an indicator of how prices are changing. Comparing the changes in the CPI with corresponding trends in salaries and wages tells the consumer whether "buying power" is being increased or decreased. The value and accuracy of the CPI depends on what is included in the "market basket" of representative goods and services and on how those items are proportioned (the weight they are given) in the index. The user of the CPI is neither concerned with how specific commodities in the index are performing, nor with the absolute value of the index, but in its changes from period to period.

The proposed transportation/connectivity index would have similar characteristics. It would include important attributes of mobility that would reflect the degree to which the transportation system is serving the needs of the population and businesses to perform activities efficiently and effectively. It would, in effect, be a market basket of mobility-related commodities that would represent those attributes important to constituents. These items would be weighted into a total value that would constitute the value of the index. Like the CPI, the index number would be dimensionless, with a base value equated to, say, 1.0 or 100. Thereafter, changes in the value of the elements in the mobility market basket would result in a new total, which could be compared against the base value of 1.0 or 100 to assess the **relative change** in mobility conditions.

or travel time) has both advantages and disadvantages. The **advantage** is that, for certain audiences (e.g., non-technical), it would be much easier to understand and grasp than a large collection of individual measures whose meaning requires trained insight and careful thought and analysis. Also, because it is more of a "bottom line" result, it may be less likely to provoke large numbers of questions on individual measures' values or trends and how or why they contribute.

The **disadvantage** of an index is the converse of its advantage. Because it is an aggregate number, it does not provide immediate insight into what aspects of performance are changing **or why**. Since the individual components and relative weights are not identified in general reporting or in an index, it can be difficult to determine quickly the sensitivity of an index to changes in its component measures.

This characteristic of partial obscurity/ambiguity may, however, lead to some other important advantages. First, because the rules for including a given mode or market in the index may not be overly limited by an official formula, it increases the opportunity for all modes and markets to be included. It is believed that there is much more to be gained, strategically, by bringing all participants to the table through the index, than eliminating those for which the measures or data are not as well developed. By virtue of having these other perspectives represented, the index conveys the message that each service is important and elevates the discussion on how best to measure and report performance. This is important dialog to have between modes and sectors because it enhances awareness, broadens perspective, and may lead to new and more comprehensive solutions.

The index concept is still under discussion at different agencies. Although the composite concept may not soon evolve into wide practice, the ongoing debate is positive. The attempt to address a wide variety of issues on a common scale is the first step toward developing a more effective way to evaluate and reconcile difficult trade-off decisions.

Example 9: Mn/DOT's Family of Measures

The Minnesota Department of Transportation (Mn/DOT) began its current Strategic Management Process in 1992 to involve citizens in clarifying transportation issues and needs. As a result of that process, Mn/DOT produced their Family of Measures, an organizational performance measurement framework, in 1995. This document presents the following vision for Mn/DOT: "to pioneer, from the *customer's* (emphasis added) viewpoint, a seamless transportation system that offers more choice, flexibility, and ways of moving people and goods (*11*)."

The Family of Measures also presents some of the valuable core concepts of Mn/DOT's performance measurement philosophy. One concept notes that "a well known principle of measurement states that what is measured gets most of the attention. The right measures, then, provide strong reinforcement of the key results that Mn/DOT wants to achieve." A second provides some criteria for good performance measures. According to Mn/DOT, the best measures are

- Directed at what the customers think is most important,
- Aligned to support organizational priorities and strategies,
- Part of a family that is not too large or too small,
- Not always easy to implement, taking some work,
- Developed by the people closest to the work, and
- Providing frequent feedback to those doing the work leading to improvement.

With the Family of Measures, Mn/DOT has demonstrated an innovative, strategic approach to measure, track, and evaluate whether customer needs and public goals are being met with the most efficient use of resources. Customer satisfaction will be measured, at least in part, through market research surveys that will determine customer perceptions of system performance (e.g., condition, safety, and commute time), public values and issues (e.g., satisfaction with air quality and promises kept on project completion), and organizational performance (e.g., employee satisfaction with diversity efforts and management perception of progress).

Customer Perspective

One of the fastest growing trends in performance-based planning is the increasing focus on customer service and the development of a user-oriented transportation system. Iowa's Transportation Plan, for example, is characterized as a report to Iowa's "transportation customers." In Missouri, "The Long-Range Transportation Plan will ensure that the Missouri Highway and Transportation Department proactively involves its customers from both the public and private sectors in the transportation decision making process (*10*)."

One of the most extensive uses of customer satisfaction measures to date has been undertaken by the Minnesota Department of Transportation where customer surveys provide a significant portion of the data needed to generate performance measures. This is discussed further in Example 9.

Output and Outcome Measures

Another well-established trend in performance-based planning is the increased use of **outcome**-based performance measures, in addition to the traditional use of **output**-based performance measures.

Output measures reflect the quantity of resources used, the scale or scope of activities performed by an organization, and the efficiency in converting those resources into some type of product. Output measures are most often used as indicators of organizational activity or performance, but stop short of identifying results as viewed by intended beneficiaries. Output measures provide necessary information for the proper management of resources and, therefore, are critical in any performance-based approach. In addition, since they are ordinarily driven by data that are more readily accessible and easily measured, such measures are valuable and timely management tools.

Outcome measures, on the other hand, reflect an agency's success in meeting stated goals and objectives and focus on the beneficiaries of the agency's service. Customer satisfaction measures are growing in popularity as outcome-based planning approaches become more widespread. For example, "the number of transit users who rate service as 'excellent'" may be a key outcome measure; "bus down time due to equipment malfunctions" would be a related output measure. Outcome measures are likely to be more meaningful to the general public and representatives from other non-transportation public agencies, since they avoid the technical jargon and detail that are common and necessary in output measures.

Traditionally, outcome measures have received less attention in planning processes, since they are ordinarily more difficult to measure and more difficult to link directly to the actions of the organization. Most agencies that have attempted to develop outcome-based measures would agree on an approach that uses **both** output and outcome measures in planning processes, linking them to build cause-and-effect relationships, and testing that model over time to challenge theorized causal relationships. When output measures are linked to outcome measures (e.g., volume-to-capacity [*V/C*] ratio linked to average travel time), their value increases dramatically.

A sample comparison of potential output and outcome measures in several areas of concern within transportation can be found in Table 2. The first thing one may notice in the table is the subtle difference between the two categories. For instance, both outputs and outcomes appear to have a numeric component to them and seem to be issues that are frequently addressed. A closer look, however, reveals that the output measures tend to be oriented toward management concerns such as resource usage (e.g., salt or funds) and operational conditions (e.g., delay or LOS). The outcome measures are oriented toward the results of some action such as changes in condition, customer service (e.g., complaints, quality, or illnesses), or relative status (e.g., percentages).

Using safety as an example, a traveler's main concern is having a roadway free of ice and snow thereby minimizing the likelihood of getting in an accident. The maintenance engineer for the DOT will also be interested in knowing if the roads are passable; likely bigger concerns for the engineer, however, are how much salt was used and how much remains for the next snowstorm.

As this safety example illustrates, selection and monitoring of an output measure (e.g., salt) can directly affect achievement of an outcome (e.g., accident potential or open roads). Hence, both types of measures are important in transportation, but each are best suited for particular applications; outputs appear best oriented to day-to-day service delivery and management needs, while outcomes may be best for system planning, communicating results with the public, and winning support for large agency initiatives.

Outcome measures have been historically under-represented in the typical state DOT and MPO measurement and evaluation process. Extra effort should be made to develop a better sense of stakeholder needs and how those needs may be translated into outcome measures and objective statements that are outcome-oriented. Examples 10 and 11 illustrate approaches to output and outcome measures.

A Hierarchy of Measures

Planning is made increasingly more complex as additional decision-making levels and interest groups are brought into the process. These various groups have different information needs. The technical details, timeliness, and overall amount of information needed usually vary from group to group. This complexity will affect the design of your performance-based planning system.

Some agencies have addressed this issue by developing a set of "core" performance measures that provide a unified set

TABLE 2 Sample output and outcome measures

Concern Area	Output Measures	Outcome Measures
Safety	Tons of salt applied	Number of ice-related accidents or number of hours of road closure
	Money spent on alcohol education programs	Percent of accidents that are alcohol related
Maintenance	Miles resurfaced	Lane-miles improved to defined surface quality (ride quality)
	Tons of asphalt applied	Number of pothole complaints
Mobility	*V/C* ratio	Change in average travel time
	Delay	Percent of jobs within X minutes of airport
Environment	Number of Transportation Control Measures (TCM) funded	Number of air quality-related illnesses on excedence days.
	VMT	Effluent quality after rainstorms

Example 10: State of Delaware

The Delaware DOT (DelDOT) has adopted a performance-based approach that ties output and outcome performance measures to the goals, objectives, policies, and strategies set forth in the statewide long-range plan. DelDOT has identified three main performance measures in its statewide long-range plan that it is using to ensure that its programs and strategies are having a positive effect in supporting these planning objectives:

Customer Satisfaction: The public's perception of their mobility and changes in mobility, elicited through surveys.

Travel Time: The ability of the transportation system to provide an adequate level of service in a multimodal context (i.e., accounting for different capabilities and expectations with regard to mode, trip purpose, and land use setting). Multiple criteria/analyses are used, including door-to-door travel time, travel rates, total delay and delay rates for all modes obtained through recurrent GPS data collection.

Sustainable Investments: The ability of existing systems or planned improvements to sustain benefits into the future, measured through an advanced form of benefit/cost analysis. DelDOT's approach is to account for the effects of land use and other variables on a sample of existing or planned transportation investments.

Example 11: UPS' "Balanced Scorecard"

The Balanced Scorecard adopted by the United Parcel Service (UPS) is used widely in the private sector. It is an integrated system of leading and lagging performance indicators tied to strategic objectives of the company. In this context, a **lagging indicator** suggests how well a company has done in the past, while a **leading indicator** suggests how well a company is positioned for the future. Successful applications of the balanced scorecard tend to be based on an understanding of the relationship among corporate objectives that are at the core of the measurement system. Therefore, a performance measurement system under the balanced scorecard approach not only requires outcome and output measures, but also performance drivers that indicate how strategic outcomes are to be achieved. In other words, a causal linkage needs to be established from the performance measures to the core goals and objectives.

The four elements of the balanced scorecard at UPS are financial, operations (also known as internal business process), customer, and employee. Performance measures that focus on customers, employee skills and internal business processes are leading indicators of financial objectives (a lagging indicator in and of itself). The balanced scorecard concept is used to develop measures within each operating level and to align measures between levels. The concept underlies performance evaluation at every level in the corporation, with each level having a specific name for its performance evaluation component. UPS Districts use the Balanced Scorecard directly as the performance evaluation component. Therefore, the term Balanced Scorecard refers to both the overall concept of performance measurement at UPS and the specific evaluation component at the District level.

of measures that the various groups all use. Meanwhile, individual groups develop supplemental measures for use in understanding the needs within their own functional area. The core measures may be all that is reported to certain decision makers or stakeholder groups, while the supplemental measures might be more actively used within the different groups of an organization to diagnose and manage their particular system components.

A similar approach is to develop a tiered system of performance measures. Using this approach, an agency uses a common set of goals to develop performance measures at two or more levels of specificity. The type and number of measures, and the level of detail reported at any level, are tailored to the group that will be using the information. As an example, the Colorado DOT has developed preliminary measures for use at two levels: that of overall strategic departmental evaluation and investment and that of the individual program. A third tier of measures, aimed at actual service delivery, is also possible. The number of measures increases as one moves from the investment level to the program and service delivery levels, and the level of detail provided also increases from top to bottom. Yet the measures at any one level are aligned vertically according to common goals, for example, accident reduction, or system preservation. The Florida DOT system of measures is similar in its hierarchy of tiered groups of measures. This approach improves the linkage between actions at the "street level" and trends reported at the top, while helping to prevent information overload among decision or policy makers who must be accountable for a broad array of programs and services. Example 12 illustrates one approach to a hierarchy of measures.

Example 12: "Core" System Performance Measures at Capitol District Transportation Commission (CDTC) (MPO in Albany, NY)

CDTC began the New Visions process in 1993 on the heels of its 1992 Transportation Improvement Program (TIP) update. Based on initial public input, CDTC formed nine task forces to investigate particular subelements of the overall plan. CDTC identified a set of initial issues and then asked the individual task forces to help develop and agree to a set of core performance measures that would guide the work of all task forces. These measures became the foundation for all future work. The core measures are a mixture of monetary, non-monetary, and descriptive qualities.

The task forces then developed supplemental performance measures. These measures allowed each task force to consider measures and criteria that are more common in their specific areas and may be more helpful in making trade-offs. However, the task forces were required to relate their final recommended action in terms of the core performance measures.

Requiring the task forces to contribute and agree to a limited set of core performance measures assured that key stakeholders were "on the same page" for technical analysis and underlying policy assumptions.

Incorporating Freight

Freight movement has become a growing focus of state and local transportation planning in the 1990s, as planners increasingly have understood the size, complexity, and economic significance of goods movement. Freight movement can and should be part of a performance-based planning process.

Although many performance measures account for both passenger and freight movement, freight planning typically has more complex performance assessment needs than passenger-related transportation planning. At the system level, freight in a truck is indistinguishable from people in a car, and trucks can be translated into passenger car equivalents for general analytical purposes. However, effective performance-based planning must consider the major differences between goods movement and person movement (see Table 3). The typical freight trip (via truck) is significantly different from a passenger vehicle trip in a number of key areas.

In view of the differences presented in Table 3, appropriate incorporation of freight into the performance-based planning process usually requires performance information that is distinct from that used in passenger-related planning activities. The Performance Measures Library, presented in Appendix B of this guidebook, specifies performance measures that are applicable for use in freight planning. Example 13 illustrates an approach to incorporating freight.

Example 13: The Eastern Washington Intermodal Transportation Study (EWITS)

EWITS focuses on individual commodities that use the system. EWITS examines the mobility of grain and apples, for instance. In doing so, it first documents the mobility needs of the commodity, from the fields to the grain elevators, from the grain elevators to the barges, from the barges to the milling plants, and so forth.

EWITS created highly disaggregate information that was used to drive its performance-based planning system. The study examined the timing of the harvest of different crops and the nature and timing of the trucking to temporary holding areas. The EWITS data are also used in support of the analysis of facilities, based on an understanding of the characteristics (e.g., weight and seasonality) of the commodities using those facilities. The study was able, for example, to trace the loadings of the paper industry trucks on specific routes and to predict when unusual maintenance needs would occur. Uncovering and understanding more detail about the commodities being moved is an important component of freight planning and is one that distinguishes it from passenger travel planning.

Performance Measures by Category

The Performance Measures Library (Appendix B) contains a list of performance measures associated with the categories listed previously. The list of measures was developed from a number of federal, state, and local planning documents. Although most agencies have developed their processes without the benefit of such a library, you will likely find this source helpful in generating a list of performance measures to consider.

TABLE 3 Differences between freight and person movement

Measure	Goods (Truck)	Person (Car)	Performance-Based Planning Implication
Distance	Approximately 10 miles for local travel, 400 miles for intercity travel	Approximately 10 miles for local travel	Requires analysis of multiple congestion chokepoints and safety hazards; requires multi-jurisdictional cooperation and data exchange
Time sensitivity	Varies with commodity	Varies with purpose (work, social, etc.)	Requires complete performance data on industry logistics patterns by commodity
Linkages	Frequent with rail, water, air	Infrequent; mass transit for local, air for long-distance	Requires knowledge of trips and overall logistics patterns
Temporal distribution of trips	Peak in morning; concentrated on weekdays	Peak in late afternoon; more even throughout day	May require supplemental performance measures to reflect freight movement peaks

STEP 5 OUTPUT:

- **A Structured Group or Groups of Performance Measures**

STEP 6: IDENTIFY DATA NEEDS

The performance measures selected as part of the planning process will generate needs for data collection or synthesis capabilities that an agency may not currently have. It is important to spend some time during the performance measures identification process to consider data needs and costs.

In theory, it is preferable to let the goals determine the performance measures and data needs. This helps ensure that the foundation of the plan–that is, the policies, goals, and objectives–determine what information is reported to planners and policy makers to help them make decisions on projects and other investments. This is in contrast to a situation in which the available data collection and synthesis tools—traffic count programs, travel model forecasts, and so forth—dictate what information is made available to the participants. This inevitably lessens the degree to which anyone can really gauge whether a particular scenario or strategy is better or worse at meeting the plan goals.

In reality, of course, few agencies are in a position to significantly expand or modify data collection and synthesis practices and programs because of constraints on human and financial resources. Most agencies have expressed some degree of concern over the ability to generate more innovative outcome measures, such as those attempting to measure system reliability, accessibility, and economic effect. This is true whether the data are to be collected from primary sources or generated using computer models or other forecasting tools. Further, performance measures must be updated on a periodic basis, thus implying some amount of continuous or periodic data collection and synthesis.

Operations-oriented measures may continue to rely to some extent on traditional data collection programs and techniques, such as traffic counts, travel time studies, and travel demand forecasts. Many output measures are effectively populated with data on agency activities, such as maintenance logs and emergency service responses. More broadly defined outcome measures, however, are likely to require additional types or quantities of data. Reliability measures, for example, need frequently sampled data on travel time or speed. Accessibility measures require spatially allocated travel and socioeconomic information.

Some agencies have dealt with this problem by incrementally adopting more challenging measures as they become able to implement the necessary data collection, synthesis, and analysis tools. One strategy is to begin by identifying the "ideal" measures that relate to a particular goal, then working backward to an "interim" or "surrogate" measure that can be developed using more readily available data. The intent is to migrate to the ideal measure over time, according to the availability of resources, the success with the surrogate measures, and the relative priorities of the agency. Example 14 illustrates how one agency used this approach.

Intelligent transportation systems (ITS) technology is likely to play an important role in future data collection and manipulation strategies. Programs such as advanced traffic monitoring systems are already in place in some locations and capable of generating useful data; the constraint thus far has been in reducing large volumes of data to useful samples for planning applications. Chapter 4 provides additional information on data needs and ITS sources to support performance-based planning.

STEP 7: IDENTIFY ANALYTICAL TOOLS

The analytical methods required to operationalize each type of performance measure will reflect the underlying goals being addressed and the type of data available for input. For example, goals and objectives aimed at improving the flow of vehicles, people, or goods require system- or corridor-level operations measures. Thus, the analytical methods relevant to this type of strategy might include traffic flow simulation models, capacity and delay modeling packages, and network models. Goals and objectives that focus on the relationship between transportation system performance and other societal issues would require tools that relate, for example, mobility and accessibility to user costs and benefits, emissions, and safety effects.

Geographic information systems (GIS) have been used by a number of agencies to analyze changes in accessibility resulting from alternative investment scenarios. These tools are especially well suited to measuring populations or areas affected by changes in system operating characteristics or performance. Portland METRO, for example, has utilized its integrated travel demand modeling and GIS to develop measures of transit and auto accessibility. This has been mea-

Example 14: Short-Term and Future Performance Measures

The Colorado DOT (CDOT) is one of several agencies that have established short-term measures for immediate implementation based on readily available data. These short-term measures are linked to future measures in the same general goal category that will be implemented on a time frame that depends on the success of the program, management support, and future data availability. As an example, a short-term measure of system reliability might be the number or percent of VMT that occur under congested conditions. A more direct measure of reliability would be the actual variation in average trip time for selected origin-destination (O-D) pairs by mode and/or facility type, but this kind of measure will probably not be feasible until automated data collection technologies are deployed.

sured in various ways, including the average number of jobs accessible to each household via auto or transit within an acceptable trip duration during the peak commute period. Variations on the measure address access to retail services, non-motorized access, and other attributes of accessibility of interest to METRO. Although such systems demand significant resources to set up, they are powerful analytical tools that may be used for a wide variety of purposes.

Another analytical methodology of particular interest is that used by the Southern California Association of Governments (SCAG). SCAG has evaluated the distribution of benefits and costs of regional transportation investments on different population groups, using census data and on-board transit survey data to generate disaggregate model results (*12*). Population characteristics of particular interest include household income and ethnic group—SCAG is interested in using these data to evaluate equity aspects of transportation investment. As an example, SCAG has calculated transit and highway accessibility under different plan scenarios, by income and ethnic group, which helps to show the degree to which these different groups would benefit from different plan investments. A companion measure indicates the estimated payments made by these same groups, through sales, gas, and personal income tax. This approach provides some measure of the distribution of costs and benefits of alternative transportation investment scenarios to different groups of society.

Chapter 4 provides information on analytical tool needs to support performance-based planning.

STEP 8: REPORT RESULTS

Measuring performance is of no value unless results are reported to the appropriate audiences in a way that makes the information readily understandable. Some of the problems faced by planning professionals attempting to implement a performance-based planning system are rooted in the absence of clear, concise, and compelling ways to present performance information to decision makers.

One of the most important concepts is to provide information in a quantity and format suitable for the intended user. In many agencies, for example, this will require different reporting methods for commissioners and executive management than for division and program managers. The general public and system users are additional audiences for performance-related data; each has different needs.

As a general rule, the amount of information provided and level of detail of each type of information should **increase** moving down the chain of command from executive decision-makers to hands-on managers. At the highest level, performance reports should summarize the overall trends and conditions of the system elements being measured. Transportation commission members, for example, should not require the detailed explanation or understanding of specific department operations. Program results can be presented in highly aggregate format to help present the overall picture of progress toward plan goals. Such reports could be relatively infrequent, coinciding with decision cycles on program allocations.

At successive levels further into the organization, additional detail is desirable. Reports need to be more disaggregate, and thus the number of reported measures will increase. Reporting frequency can be increased to the level that is consistent with the use of the information. In the case of transportation plan implementation and monitoring, for example, annual reports are common. Transportation service providers, such as trucking companies and rail operators, may calculate and report results much more frequently, since they are dealing with operations data and decisions as much as long-range planning issues.

Most of the agencies studied in this research have developed some form of reporting that is unique to their organizational and management structures. "Executive Report Cards" have been developed that summarize a few key indicators for high-level decision makers, for example. Often these summary reports contain results of customer perception or satisfaction measurements, since it is the higher level decision makers (often appointed or elected) who must most directly answer to the customer.

More detailed and diagnostic reports are made available to managers of "business lines" or programs within an organization. This is the case with operators such as Amtrak and United Parcel Service. The Albany New York CDTC provides summary reports of supplemental performance measures to each of several task forces assigned responsibility for specific areas such as transit or arterial management. The individual measures on these reports will vary according to that task force's area of responsibility, but each of the measures is related to one of the "core" measurement areas (e.g., congestion, safety, or economic costs). In this way, different information is provided to the appropriate audience, but that information is part of an overall structure based on common interests and goal categories. The individual case studies documented in the NCHRP 8-32(2)A Final Report provide examples of this and other reporting mechanisms.

CHAPTER 4

DATA AND ANALYSIS TOOLBOX

As important as having the right people for the task of performance-based planning, practitioners must have the proper data and tools to drive the process into the future. While Chapter 3 touched on where and how these pieces fit into the development process, the following describes these resources in more detail and provides references for more detailed follow-up by the reader.

MULTIMODAL TRANSPORTATION PLANNING DATA

NCHRP Project 8-32(5), *Multimodal Transportation Planning Data*, ran in parallel to the NCHRP project that produced this guidebook (8-32(2)A). The 8-32(5) project produced a wealth of information on data needs and sources for multimodal performance-based planning. Summaries of these findings are included in this section.

Surveys

Surveys provide an opportunity to collect a broad range of data about system condition and system performance and about the traveler's perception about the system, mode, or even individual trip. Although the term "survey" can be applied to just about any kind of data collection effort (e.g., a survey of pavement condition or high-accident locations), the term is used here to denote research that seeks response to specific questions from various individuals or groups, usually established through a statistical sampling method. The results from surveys are often used to develop and refine travel forecasting models, which, in turn, can be very useful analytical tools in a performance-based planning application. In addition to this use, survey data can help establish baseline conditions for various potential performance measures (e.g., "percent of travelers using modes x, y, and z for work-related travel.") With the assistance of statistical methods or other analytical tools, survey data can be used to forecast values of these same measures and to evaluate future performance under multiple scenarios. Surveys can also be used to focus on the customers' perceptions of conditions or satisfaction with the transportation services they consume.

Within the traditional travel demand forecasting framework, the major impetus for conducting surveys has been to supply the data needs for four basic models: (1) trip generation, (2) trip distribution, (3) mode split, and (4) and assignment of trips to a network (usually one containing highway links and transit routes). The passage of the 1990 Clean Air Act Amendments (CAAA) and ISTEA initiated the process of enhancing these models to accommodate the new regulatory requirements. This precipitated the re-evaluation of the surveys that support these models. The most useful types of travel surveys include (*13*)

- Household travel surveys,
- Workplace surveys,
- Stated-preference surveys,
- Longitudinal and panel surveys,
- Transit on-board surveys,
- Commercial vehicle (truck) surveys,
- External station surveys for commercial and/or passenger vehicles, and
- Parking surveys.

Household Travel Surveys. The characteristics and uses of household surveys are numerous. Household surveys provide data on the characteristics of families and individuals, as well as their travel movements, mode choice, and time of travel. Both telephone collection and mail-out/mail-back surveys can be used. Because of the extent of information that can be gathered from a household survey, many of the information needs prompted by the 1990 CAAA and ISTEA will result in an enhancement and/or alteration of the traditional household survey.

The evolution to multimodal planning has created specific information needs that can be addressed by new or revised survey processes. For instance, ISTEA requires analysis of all modes, so the collection of travel data by all modes including non-motorized modes is necessary. It is difficult and/or expensive to obtain the desired level of representation of alternative mode usage from a typical random sample survey, because of the predominance of auto use. Rather than collect a very large random sample, surveyors target or "enrich" the sample to find enough transit users, pedestrians, bicyclists, and so forth to permit accurate estimation of the characteristics of these alternate modes.

The collection of information on specific vehicle-type trips (e.g., auto, van, or pick-up) by trip type is needed for air quality planning, as is information on the physical characteristics of vehicles such as make, model, fuel type, and odometer reading. Likewise, to meet the level of detail regarding emissions and dispersion of pollutants, air quality models need to be supplied with travel estimates by facility, by vehicle type, by hour of the day, and by vehicle operating mode (e.g., cold start).

Furthermore, household travel surveys have typically focused on trips made by household members. Modelers have advocated changing the focus of household surveys from surveys of trips to surveys of activities of household members. The two principal reasons for the shift to activity-based modeling are as follows:

- A "trip" is an abstract term describing movement from one point to another. It is not always well understood by the population being surveyed and can lead to unreported trips. People recall their daily activities much better than the individual trips.
- Activity-based surveys allow for more information to be gathered on the reasons for trip making. In order to properly understand and model that effects of the changing transportation supply and socioeconomic pressures on travel, we need to understand the activities that are performed during a day.

Workplace Surveys. Workplace surveys have been used to gather detailed information, including the attraction purposes (e.g., visitor, customer, or employee) of trips at the location attracting those trips. The surveys provide disaggregate data that can be used to estimate trip attraction rates. Their primary use has been to support the calibration of trip attraction models. Information such as parking cost and walk distance can also be used in other models such as the mode choice model. Workplace surveys have also been a component of Travel Demand Management (TDM) to collect information about employees' individual and aggregate commute behavior. Examples include the South Coast (Southern California) Air Quality Management District "Regulation XV" surveys and the State of Oregon Department of Environmental Quality "ECO" rule surveys. Although workplace surveys can provide detailed data useful for various purposes, they are expensive and difficult to conduct accurately.

Stated-Preference Surveys. In a stated-preference survey, each respondent is asked to make a travel decision for a hypothetical scenario that describes the available travel alternatives and their characteristics. They represent an attempted increase in the volume and variety of data that traditionally have been taken from household and other surveys (revealed preference data). State-preference surveys allow respondents to respond to multiple scenarios, resulting in more useable data for estimating travel behavior and characteristics. They have traditionally been used in long-distance travel demand modeling or for predicting the response to introduction of new modes in a specified market.

Data collected through stated-preference surveys, however, do not reflect actual travel behavior. Rather, people respond in a manner that characterizes how they would prefer to behave. In addition, respondents are provided with more information than is available to a typical traveler. Therefore, models operating off of these data frequently underestimate the level of uncertainty present under actual decision-making conditions.

Longitudinal and Panel Surveys. Longitudinal and panel surveys are characterized by a sample of households that are surveyed over time (2- to 3-year intervals) to determine changes in travel behavior of the same individual households under different socioeconomic and transportation supply conditions. Aspects of travel behavior that are not realized under typical snapshot household surveys, but are potential outputs of a panel study, include understanding the process of information acquisition, experience and learning, and behavioral turnover.

Transit On-Board (TOB) Surveys. Traditionally used by transit operators to gain an understanding of ridership profiles, TOB surveys have also been used by travel demand modelers to develop trip tables for travel model validation and to enhance survey data for development of mode choice models. TOB surveys are typically self-administered and short enough to complete during the transit ride. Results of on-board surveys have been combined with the results of household travel surveys to develop "choice-based" calibration data files for mode choice model estimation. Applications in performance-based planning include assessment of customer perception of transit-ride quality or overall service (e.g., smoothness, reliability, and security).

Commercial Vehicle Surveys. Traditionally, commercial vehicle surveys were used to collect information on truck trips made in a region. Because of the confidentially associated with some commercial trucking information, the difficulty in determining the population to be surveyed, and the incomplete data provided by truck registrations (because of out-state trips), few comprehensive truck surveys have been conducted in recent years.

Recent changes and developments associated with the design and execution of commercial vehicle surveys are as follows:

- Similar to the movement of the household survey toward activity-based modeling, work has been conducted that focuses on the actual movement of commodities, rather than truck trips.
- Studies have recently been conducted using hand-held computers, called Personal Digital Assistants (PDAs), as truck survey instruments rather than the standard paper-and-pencil survey (*14*). The Street Smart Company (Duluth, GA) was contracted by the Federal Highway Administration to conduct origin-destination and commodity surveys using the PDA technology. Several advantages were identified over the course of three case

studies: (1) improved accuracy of data because of the ease with which data could be input and quickly reviewed; (2) reduced collection time primarily resulting from the elimination of re-entering data before processing; and (3) reduced cost of data collection by removing data entry and transfer, as well as eliminating erasers, pencils, clipboards, and the printing of new forms.

- Geographic positioning system (GPS) units are now frequently attached to commercial vehicles (e.g., taxis, rental cars, trucks, and trailers) to help with fleet operations. The data collected through this technique could be valuable for planning applications, but, to date, there are no known widespread applications.

Some types of surveys that may not be applicable to all transportation planning agencies include visitor surveys and parking surveys (*15*). Visitor surveys are sometimes utilized in areas where visitors contribute significantly to the total amount of travel. Many large metropolitan areas and even relatively small areas may host thousands of visitors on a daily basis due to attractions such as businesses, convention centers, sporting complexes, and amusement parks.

Visitor surveys are typically designed to obtain information about the characteristics of the non-residents who are staying in the area (e.g., hotels, motels, and bed-and-breakfasts), as well as the number and type of trips being taken. The data collection can be used in several ways. Trip generation estimates, such as trips generated per occupied hotel room, can be estimated. The data can also be used to estimate the visitor demand for possible new travel modes or services (e.g., added bus service or people movers). In addition, estimates of increased trip generation by visitors because of new development or the addition of a major visitor attraction can also be made.

The two primary methods of conducting visitor surveys involve distributing self-completion surveys and in-person interviews, typically in the hotel lobby. Recent advances in hand-held computers have allowed some interviewers to conduct computer-assisted personal interviews (CAPI). The advantages of CAPI surveys are

- The hand-held computers can be programmed to accept only valid entries, which would reduce field data entry errors.
- The storage capacity allows previous entries to be checked to avoid inconsistencies with other entries.
- The computer automatically guides the interviewer through the questions so none are missed or asked out of order.
- The interviewer can use visual information on the computer screen to better communicate with respondents.

Disadvantages of the CAPI system include

- The computer program for the survey requires a significant amount of time and effort to ensure precision because program corrections are usually not feasible once the interviewers have gone into the field.
- Interviewers must be skilled in using the CAPI system.
- The lack of hardcopy records places greater reliance on the information entered into electronic file storage.

External Station Surveys. External station surveys are used to provide information about trips traveling into, out of, and through a region. Survey techniques include roadside interviews, postcard handout/mailback surveys, and license plate recording/survey mailing. The recording of license plants, matching numbers with vehicle registration, and mailing a survey form has uncovered a host of privacy issues that any agency would need to address prior to embarking on such a survey.

Recent changes and developments associated with the design and execution of external surveys are as follows:

- The methods and technology of roadside collection have been enhanced through microcomputer-based data entry procedures. Through the use of database software and real-time data entry, automatic geocoding of survey responses can be achieved.
- Surveys conducted in large transportation centers (e.g., bus stations, airports, and railroad stations) can provide information similar to that found in an external station survey, but from an individual, rather than vehicle, standpoint. Information on passenger movements, volume, mode choice, and customer perception of the trip and the transportation service can be obtained via these surveys. Computer-aided survey administration and data entry have improved the quality and lowered the cost of data that can be obtained through these surveys.
- Experimentation at these large transportation centers with computer-administered surveys completed by self-selected participants has revealed some of the advantages and disadvantages of such an approach (*16*). The surveys are initiated via touch-screen computers placed in a common area kiosk. One advantage of the computer-administered survey is that, if properly designed, it can minimize the frequency of respondent errors. For example, only certain questions should be answered by particular respondents, depending on their purpose at the location. In the paper-and-pencil survey, the respondent often has to skip one or more questions, whereas in the computer-administered survey, the proper questions are automatically displayed. Additionally, the use of touch screen technology enables maps to be displayed and allows respondents to choose specific locations from the maps for their responses to O-D questions. This significantly advances the use and precision of geocoding (discussed below) as part of the survey process. Finally, computer-administered surveys can be continuous and provide real-time data and larger data sets than the paper-and-pencil surveys. This allows data to be collected during periods when supervised surveys may be costly or difficult to administer and avoids the problems

associated with one-time surveys (e.g., abnormal weather conditions or construction periods).
- Computer-administered surveys do not eliminate the need for facilitator-supervised surveys. Studies have shown that there is a statistical difference between the type of responses received from computer-administered surveys and supervised surveys. To provide control data, as well as survey those who do not typically respond to a touch-screen system, traditional surveys would be needed in some quantity.
- A hybrid survey technique for determining trip characteristics, which was tested at a shopping center in 1993, was able to increase the questionnaire response rate from 11 percent to nearly 30 percent (*17*). The survey utilized techniques from both roadside interviews and postcard handout/mailback. Survey postcards were distributed on parked cars throughout the shopping center. As the drivers exited the center, members of the survey team collected the surveys. Additionally, monetary incentive was provided by promising respondents a $1.00 payment for returning a completed survey.

Parking Surveys. Parking surveys have evolved from being used exclusively to project parking supply, demand, utilization, and turnover to using the data to provide trip generation figures associated with a particular parking area. Pricing information collected during a parking survey can also assist with understanding and predicting price elasticity of parking costs and the effects on travel behavior.

Three methods of collecting parking survey data include

- Interviewing drivers as they enter or exit a parking facility,
- Placing mail-back questionnaires on the windshields of parked cars, and
- Matching parked car license plates with addresses from DMV files and mailing out surveys.

Mail-back surveys tend to be less costly, but the response rate is generally much lower than the interview method. In addition, the accuracy of the cost and duration of the parking stay are more accurate with the interview method. As with any survey involving mail-back cards or questionnaires, care must be taken to minimize and correct for sample response bias.

Travel Survey Methods Resources

The following references may assist transportation planners in evaluating various survey methods for application to performance-based planning:

- Papacostas, C. S. et al. "Computer-Administered Surveys at Honolulu International Airport," *Transportation Research Record 1412: Innovations in Travel Survey Methods,* Transportation Research Board, National Research Council, Washington, DC (1993).
- U.S. Department of Transportation et al., "Travel Survey Manual and Appendices," prepared by Cambridge Systematics, Inc., and Barton Aschman Associates for the Travel Model Improvement Program Track D, *FHWA-PL-96-029 and -030* (1996).
- U.S. Department of Transportation et al., "Scan of Recent Travel Surveys," *DOT Report DOT-T-97-08* (June 1996).
- Lau, Samuel. *Truck Travel Surveys: A Review of the Literature and State-of-the-Art.* Metropolitan Transportation Commission, Oakland, CA (January 1995).

Traffic Monitoring

Aside from surveys, another way to support the generation of performance measures is via traditional traffic monitoring programs. This section describes some of the current methods associated with collection of travel monitoring data, such as speed, travel time, vehicle occupancy, vehicle weight, and vehicle classification and counts.

Traffic count data needs encompass coverage counts, long-term pavement performance (LTPP) counts, project-related counts, special count requests, and data obsolescence counts. Three basic types of traffic counting equipment used in collecting the traffic data include traffic volume, vehicle classifiers, and weigh-in-motion (*18*).

Traditional Traffic Volume Counters. As with all three types of equipment, traffic volume counters may be either portable or permanent in design. They utilize a single-axle sensor and may include time period or cumulative counts recorded on punch tape, printed paper, or electronically. The permanent traffic counters use a single inductive loop that recognizes passing vehicles and records the data on vehicle lengths and speed for a given period. Data can be retrieved through periodic collection of paper tape, downloading the data to computer, or, in the newer systems, telecommunications technology.

Vehicle Classification Recorders. The portable recorders use two-axle sensors, such as road tubes, tape switches, tape-down piezo-electric film, or piezo-electric cable to sort vehicles into 13 FHWA-established categories. The permanent designs utilize two in-pavement inductive loops, two piezo-electric axle sensors, or combinations of two loops and one-axle sensor, or two-axle sensors and one loop. Data recorded can include date and time, axles packing, number of axles per vehicle, and speeds.

Weigh-In-Motion (WIM). Both portable and permanent WIM equipment can collect data on date and time, vehicle lengths, speed, and axle weights and spacing. The portable WIM uses a combination of two loops and a capacitance weigh pad to collect data. Units are available that require no personnel on site. The permanent model uses a combination of one or two inductive loops and one or more axle weight sensors for data collection. As with volume counters, the data can be retrieved through manual collection or telecommunications, depending on the sophistication of the equipment.

(A more detailed discussion of ITS-generated traffic and travel data appears later in this Chapter, as well as in Appendix C.)

Customer Satisfaction and Perception Data

Surveys of customer perception, satisfaction, or other attributes represent a particular subset of multimodal transportation planning data. Chapter 3 presented several considerations about the use of perception and satisfaction data in the development of performance measures. In practice, many of the various survey methodologies discussed immediately above (e.g., household travel surveys, stated-preference surveys, longitudinal panel surveys, and transit on-board surveys) may be used to collect information about the customers' level of satisfaction with the transportation system, their perception and prioritization of important issues, and so forth. A few pointers are useful to note if you want to integrate customer information into the performance-based planning process:

- **Define the term "customer."** In workshops and meetings around the country, transportation planners have debated just who their customers are and which subset of that large group should be surveyed. To some, customers are the *users* of the system, which could include commercial users (e.g., shippers and trucking companies) as well as the private motorist, transit rider, and so forth. To others, the term is more broadly defined to include those who may not be regular users but who are asked to help pay for the system operation, maintenance, and expansion, through sales tax, property tax, or other non-user taxes. Finally, many agencies that are measuring the performance of their own organizations will define customers to include external parties, such as vendors and contractors, as well as internal parties, such as employees. So, be clear about how your organization wants to define "customer" before setting out to measure their perceptions and attitudes.
- **Be prepared to act on the information you receive.** More than one practitioner has cautioned that agencies should only seek the opinions of customers if they are prepared to respond to those opinions and try to address the issues or needs raised by the customers. Otherwise, you may erode credibility with your customers and reduce the usefulness of future surveys. *There are different opinions on this matter, however.* At some agencies, it may be valuable to understand the customers' perceptions of the relative importance of different issues. This information can be used, for example, to help an agency conduct trade-off analyses and prioritize spending among competing programs. While transportation agencies should not (and presumably rarely do) establish priorities based solely on customer needs or desires, it is useful to consider these opinions, along with other information, in the evaluation and decision process. **Customer information may be useful to "calibrate" the process.** In some instances, an agency may need to determine "how much is enough" when providing different levels of service quality. Examples include pavement smoothness, roadside maintenance, and transit vehicle upkeep. Knowing what is an acceptable level of performance or condition to the majority of users may be helpful in setting budgets for these activities.
- **Customer surveys can be used to collect a range of information,** including perception of system performance, issues that are important to the public, and values that they hold that might influence transportation plans and investments. These surveys could be used also to test the public's perception of the *outcome* of transportation system inputs; for example, has an agency's efforts to make urban bus transit more user-friendly been effective, from the riders' point of view?
- **Transportation agencies can survey internal and external customers** to get a sense of organizational performance. How well, for example, does the contracting/purchasing division serve the needs of engineering and design units? How well does the accounting department serve external vendors and contractors? The effectiveness of these units can be measured, in part, through periodic survey of their respective customer groups.

Above all, customer surveys should be designed and conducted only *after* the agency understands its goals, objectives, and relevant performance measures. Survey methods and instruments (i.e., the survey documents or questions themselves and the means by which they are administered) need to be carefully designed and worded to elicit precisely the information sought and to avoid introducing bias into the response. In most cases, agencies are well advised to retain the services of a consultant with survey research expertise to help design the survey. Opinion- or survey-research firms are equipped to administer surveys, whether through telephone, direct interviews, mail-out, and so forth. These same firms, however, may not be as well qualified to design a survey instrument focused on something as specialized as transportation customer opinion and perception. It may then be cost-effective to also seek assistance from outside consultants with expertise in transportation survey design and analysis and with "domain" knowledge (i.e., expertise in transportation planning). In short, survey design and administration have become two distinct sub-specialties, and many firms are optimized to provide one or the other.

Highway Performance Monitoring System (HPMS)

FHWA maintains a national database of highway conditions in each of the states in the form of a computerized database known as the Highway Performance Monitoring System (HPMS). This database uses traffic counts and physical inventories of individual highway segments in each of the states to monitor the conditions on the nation's highway system. Although this is only a sample and not a complete inventory of conditions at the national level, the database is extensive with more than 300,000 records nationwide. Some states have augmented the sample to include a much larger percentage of highway segments in the state, making the HPMS a more valuable tool for statewide planning purposes.

Each state DOT delivers HPMS information to the FHWA by June 15th of each year. The June submittal covers data for the previous calendar year. Thus, the June 1998 submittal consisted of data as of December 31, 1997. This submittal includes the state's certified mileage for the year. This is the DOT's official tally of public mileage and a special letter indicating mileage on Native American Reservations. All mileage is included in some record in the database. The DOT queries all jurisdictions each year to obtain the latest breakdowns of their mileage. The sum is referred to as the state's *universe*. Because it is impractical to collect all data items on the entire universe, the HPMS contains samples. The DOT picks the samples for various functional classes of the universe to give a representation of those classes nationally.

In most cases, the interstates and freeways are completely sampled. Samples on other classes usually have expansion factors. These factors represent the ratio of universe mileage to sample mileage for a category of roads. When the data from samples are expanded, the data provide the DOT the chance to create summaries of data about various road systems. Important data on the samples include traffic, pavement, and inventory data. The data from HPMS are used by Congress and locally to assess the state of the road system. HPMS data are used in the federal aid allocation process.

FHWA gives each state and territory eight spreadsheet templates to complete with the year's summary data. The following is the list of templates:

1. **System Length and Daily Travel.** There are statewide totals for population, net land area, length, and travel. The travel is expressed in daily vehicle-kilometers of travel (dvkt). The state is then broken into three subareas. These are rural, small urban, and urbanized. These areas are delimited by FHWA's transportation urban boundaries. Urbanized areas have populations of 50,000 or more. Small urban is the 5,000 to 50,000 population range. Rural is everything else. Each of these three subareas has totals for population; land area; and then length and dvkt by functional classification.
2. **System Length and Daily Vehicle Travel (Urbanized).** Each urbanized area is detailed on template 2. For instance, Oregon has five urbanized areas. They are Portland-Metro, Salem-Keizer, Eugene-Springfield, Medford-Central Point, and Rainier. The state supplies a population and land area total for each of these areas. They also supply length, travel, and occupancy for each functional classification in each area. The occupancy data are derived from the state's accident records.
3. **System Length and Daily Vehicle Travel National Ambient Air Quality Standards (NAAQS).** The third template is like the second, except that it is for areas not meeting certain standards of the NAAQS.
4. **Minor Collector and Local Functional System Length.** The state estimates length within the local and minor collector classes split among surface types and volume groups.
5. **Fatal and Injury Motor Vehicle Accidents.** For each functional classification, the state tallies length, travel, fatal and injury accidents, fatally injured and injured persons, and fatally injured and injured pedestrians.
6. **Travel Activity by Vehicle Type (Basic Data).** The state estimates percentages of vehicles in each of FHWA's 13 vehicle classes for each functional classification. These estimates are derived from approximately 300 vehicle class counts performed on a 3-year schedule.
7. **Travel Activity by Vehicle Type (Supplemental Data).** This template is used to indicate which days of the week, months of the year, and hours of the day are used for template 6 data. Any other comments on combining classes or special considerations are also reported here. For instance, Oregon DOT uses only weekday counts, mostly March through October. They use 24-hour manual counts or 48-hour machine counts.
8. **U.S. Territory Information.** Only U.S. territories must submit this supplemental information.

The HPMS Analytical Process

To make the HPMS database more useful, FHWA developed the Analytical Process. FHWA, states, MPOs, and local government agencies use the HPMS to assess the physical condition, safety, service, and efficiency of operation of their respective highway systems. In addition to assessing the characteristics of the existing highway systems, the HPMS Analytical Process also is being used to predict the effect that proposed highway programs and policies are likely to have.

The capabilities of the HPMS Analytical Process may be summarized as

- Assess base year conditions and performance,
- Forecast highway system needs,
- Simulate highway system conditions,

- Analyze investment strategies, and
- Estimate user costs.

The HPMS Analytical Process utilizes an analytical method that identifies and prioritizes needed highway improvements according to specified criteria decision rules. It also estimates resulting highway system conditions that can be expected under various levels of funding for identified improvements. This is an important feature of the model because sufficient funds typically are not available to correct all highway system deficiencies. This feature enables an understanding of what kind of performance can be expected when funding is constrained and tradeoffs must be made between different investment programs (e.g., preservation and maintenance versus modernization, that is, new capacity). Examples 15 and 16 illustrate the approach some agencies have used for the HPMS analytical process.

ITS as a Data Resource

Much of the data generated by Intelligent Transportation Systems (ITS) can be of great value to performance-based planning. However, unless ITS operators have made special provisions, data from system surveillance equipment are typically not stored for future use. Because the amount of data is so enormous, it is doubtful that simply saving the raw data would be of use to other stakeholders; some level of aggregation or sampling is required to make the data more meaningful to stakeholders. Further, the National ITS Architecture currently has no specification for a data archival process.

Data needs of many stakeholder groups have been identified in several past studies. In particular, the *ITS As A Data Resource Workshop* held in January, 1998, substantiated stakeholder needs and began the process of matching ITS-generated data with those needs. In addition, an FHWA Office of Highway Information Management report, *ITS as a Data Resource: Preliminary Requirements for a User Service* (April 1998), summarized various data collection methodologies and uses for planning purposes. This section draws heavily on this past work.

Table 4 summarizes some of the typical applications of performance-based planning and contrasts the collection and use of currently available data with that which may be collected with ITS.

Example 15: North Carolina DOT

The North Carolina Department of Transportation (NCDOT) utilized the HPMS Analytical Process to conduct an analysis of highway needs along with an assessment of the future performance and condition effects resulting from alternative policies and funding scenarios. This was accomplished by using the Analytical Process's capabilities to simulate conditions and performance at seven funding levels (i.e., 100, 80, 70, 60, 40, 10, and 0 percent). For each funding level, HPMS outputs regarding safety, service, condition, and composite indices were plotted. Investment/performance analyses were conducted for each functional classification to facilitate evaluations of the future impacts of different funding strategies and improvement programs.

North Carolina also employed the Bridge Needs and Investment Process to conduct a similar investment/performance analysis for bridges.

Example 16: Oregon Highway Plan

The Oregon DOT included estimates of user costs and benefits in developing its 20-year investment plan for the state highway system. There are very significant costs experienced by every user of the system, beyond the agency costs for system construction, operation, and maintenance. For example, roads in poor condition put extra wear and tear on private and commercial vehicles, meaning that the public spends more money on vehicle maintenance and replacement. Travel speed decreases as a result of both poorer roadway condition and increased congestion, resulting in increased costs to private and commercial travelers. These kinds of costs are called "user costs," since they are paid "out of pocket" by highway users.

The Oregon DOT used the Highway Economic Requirements System (HERS) to estimate user cost and user benefits from alternative levels of funding for the highway system. HERS is a companion to the HPMS Analytical Process in that it is designed to estimate highway system needs. It has the added ability to base decisions on benefit/cost analysis of the recommended improvements. The HERS model demonstrated that user benefits in the 20th year of the highway plan would be 20 to 30 times greater than the additional public money spent on modernization, preservation, and safety improvements. These marginal benefits in comparison to marginal costs are much higher than could be achieved with any other private or public investment of the incremental funds.

Uses and Benefits of Archived Data Generated By ITS

For the most part, data generated by ITS are similar to data collected by traditional means (e.g., traffic counts) but ITS-related data are collected continuously and at a very detailed level. Accordingly, a wide range of planning and other stakeholder functions can be supported with data from ITS. For example, roadway surveillance data can be used in many stakeholder applications, including development and calibration of travel demand forecasting and simulation models, congestion monitoring, transit route and schedule planning, intermodal facilities planning, and air quality modeling. In addition to identifying specific applications, several general

TABLE 4 Opportunities for ITS-generated data

		Collection and Use of:	
Application	**Method or Function**	**Current Data**	**ITS-Generated Data**
Congestion Management Systems	Congestion Monitoring	Travel times collected by "floating cars": usually only a few runs (small samples) on selected routes. Speeds and travel times synthesized with analytic methods (e.g., *HCM*, simulation) using limited traffic data (short counts). Effect of incidents missed completely with synthetic methods and minimally covered by floating cars.	Roadway surveillance data (e.g., loop detectors) provide continuous volume counts and speeds. Variability can be directly assessed. Probe vehicles provide same travel times as "floating cars" but greatly increase sample size and areawide coverage. The effect of incidents is embedded in surveillance data and Incident Management Systems provide details on incident conditions.
Long-Range Plan Development	Travel Demand Forecasting Models	Short-duration traffic counts used for model validation. O-D patterns from infrequent travel surveys used to calibrate trip distribution. Link speeds based on speed limits or functional class. Link capacities usually based on functional class. Non-recurring congestion is not considered.	Roadway surveillance data provide continuous volume counts, truck percents, and speeds. Probe vehicles can be used to estimate O-D patterns without the need for a survey. The emerging TDF models (e.g., TRANSIMS) will require detailed data on network characteristics (e.g., signal timing) that can be collected automatically via ITS. Other TDF formulations that account for variability in travel conditions can be calibrated against the continuous volume and speed data.
Corridor Analysis	Traffic Simulation Models	Short-duration traffic counts and turning movements used as model inputs. Other input data to run the models collected through special efforts (e.g., signal timing). Very little performance data available for model calibration (e.g., incidents, speeds, and delay).	Most input data can be collected automatically and models can be directly calibrated to actual conditions.

observations on the uses and benefits of ITS-generated data can be made:

- The continuous nature of most data generated by ITS removes sampling bias from estimates and allows the study of variability.
- The variability of ITS data provides the opportunity to analyze non-recurring congestion issues, causes, and solutions.
- The detailed data needed to meet emerging requirements and for input to new modeling procedures can be provided by ITS.
- Use of data generated by ITS for multiple purposes is a way to stimulate the support of other stakeholders for ITS initiatives.
- Promoting the use of archived data for multiple purposes complements the initiative for integrating ITS in general.
- Because the data are already being collected for ITS control, other uses provide a value-added component to ITS.
- ITS is a rich data source for multiple uses, but not a panacea; traditional sources of data will continue to be important.
- As the focus of transportation policy shifts from large-scale, long-range capital improvements toward better management of existing facilities, **ITS-generated data can support the creation and use of the system performance measures that are required to meet this new paradigm.**

This final point has significant ramifications for performance-based planning. System performance measures provide objective feedback to transportation professionals on the effectiveness of programs and improvements and also provide a common basis for comparing different jurisdictions. This kind of feedback is extremely important as the focus shifts to short-term management strategies. However, data with higher resolution and accuracy than have been traditionally collected are required to support the use of system performance measures.

Help on the Way

Because of the wide range of support among stakeholders represented at the ITS As a Data Resource Workshop, it has been determined that there is a need for a new User Service to be included in the National ITS Architecture: the Archived Data User Service.

Successful implementation will require resolution of many difficult institutional and technical issues. These include

- Development, operation, and maintenance costs;
- System access and ownership;
- Data quality, data management, and data communications standards;
- Liability, privacy concerns, and confidentiality of privately collected data;
- Coordination with other data collection efforts;
- Retrofitting versus new development of systems;
- Data flows not defined by the National ITS Architecture;
- Conformance with metric conversion standards; and
- Training and outreach.

As these barriers are overcome, there are significant opportunities in ITS to generate data to support performance-based planning. Appendix C provides a further summary of ITS data sources and their planning uses.

Freight Data

As mentioned in Chapter 3, accommodating freight issues in performance-based planning typically involves more complex data needs than passenger-related transportation planning. In view of these differences, freight planning for the functions described earlier requires data distinct from those used in passenger-related planning activities (see Table 5).

Current Freight Data Collection Methods

Current methods for collecting these freight data include the following:

- **Manual Traffic and Vehicle Surveillance.** This category includes techniques (e.g., traffic volume and classification counts, spot speed observations, aerial photography, videography, license plate matching, and floating car studies) and national databases such as the Highway Performance Monitoring System (HPMS). These data collection methods are designed to cover all traffic, but provide some data on trucks. The data collected through these methods often are sporadic, with limited information on the temporal and spatial distribution of traffic.
- **Manual Goods Movement Surveillance.** This category includes compilation and analysis of weight measurements, shipment records, fuel consumption reports, travel logs, vehicle registration data, and vehicle inspection reports. It also includes review of truck- and freight-specific databases, such as the Census of Transportation, the Vehicle Inventory and Use Survey, and the Commodity Flow Survey. These data collection methods are complex and involve sampling of truck performance and freight shipment information. Often, the private sector wants to keep data related to a particular company's fleet operations confidential for competitive purposes.
- **User Surveys.** This category includes travel surveys, roadside interviews and origin-destination surveys, travel diaries, focus groups, and customer surveys. User surveys often are expensive to develop and implement and can be subject to bias.

Table 6 highlights the data currently provided by secondary truck-related data sources in the following categories: vehicles/passengers, shipment characteristics, commodity, origin/destination, and facilities.

Despite these and other statistical programs, the current level of knowledge about freight movement is inadequate in many respects. Agencies publish reams of data on the number of intermodal containers landed at ports and the volume and weight of trucks moving over our highways, but it is very difficult to integrate this information in order to determine how these freight systems are linked so as to provide freight shipments for different types of commodities. In addition, data on most regional and local activity–the levels of interest for state and metropolitan freight planning activities–generally are not available. The U.S. DOT, Bureau of Transportation Statistics (BTS) has concluded that the state of knowledge about for-hire trucking activity is acceptable for most facets of national activity, needs improvement at the international and state levels, and is "virtually nonexistent" at the local level (*19*).

Some of the specific deficiencies by planning function include the following:

- **Congestion Management.** State DOTs and MPOs generally have adequate data–road maps, traffic counts, accident records, traffic engineering studies, and so forth–to identify congestion bottlenecks and analyze their causes. What usually is missing for freight planning purposes is information about the number of trucks and types of commodities delayed by traffic congestion.
- **Intermodal Access.** State DOTs and MPOs generally have simple inventories of the major intermodal facilities in their jurisdictions, but often lack time-series data on the truck movements into and out of these facilities. They also may lack information on specific access problems (e.g., intersections and exit ramps that are too small for today's larger trucks), low bridges that force trucks to make long detours, and noise and safety problems when trucks must travel through local neighborhoods.
- **Truck Route Designation and Maintenance.** State DOTs and MPOs typically have limited data on truck

TABLE 5 Public-sector freight data needs for performance-based planning

Function	Data Needs	Support for Performance-Based Planning
Congestion management	• Truck-hours of travel • Average speed or travel rate (hours per mile) for truck • Added truck-hours or truck-hours per mile due to congestion • Truck transport cost (total, or per truck-mile, ton-mile, or dollar value of freight carried) • Added cost due to congestion • Transport time reliability • Types of trucks and commodities caught in congestion • Energy consumption for trucks: total or per truck-mile or ton-mile • Emissions rates for trucks: total or per truck-mile or ton-mile	• Understand impact of congestion on goods movement • Understand contribution of trucks to urban congestion and air quality problems
Intermodal access	• Volumes of trucks entering or exiting an intermodal facility • Variability in demand for, and supply of access to, intermodal facilities • Congestion-related delays on access roads to the facility • Queuing counts related to the capacity of the facility • Accident rates on access roads to the facility • Travel time contours around the facility (e.g., driving distance within 30 minutes) • Number of people living or working within x miles of the facility	• Identify land-side access improvement needs
Truck route designation and maintenance	• Truck traffic volumes • Origin-destination patterns • Truck size and weight data	• Identify high-volume truck routes and corridors • Assess pavement damage and replacement needs
Safety mitigation	• Accident rates • Rail-grade crossings • Low-clearance bridges • Steep grades	• Identify safety hazards and develop mitigation strategies
Economic development	• Truck volumes • Commodity movements • Origin-destination patterns • Shipping costs	• Assess economic benefits and costs of freight transportation investment projects

volumes and patterns. With the exception of a few specialized port agencies, state DOTs and MPOs have even less knowledge of industry supply chains and distribution networks. Data are limited with respect to commodity flows, particularly for interstate or international traffic. Consequently, planners have little sense of the freight trip as a whole–its origin, modes of travel, routes, transfer points, destination, and reliability.

- **Safety Mitigation.** State DOTs and MPOs typically have inventories of rail-grade crossings and low-clearance bridges and may have collected data on intersections with high frequencies of truck-related crashes. They

TABLE 6 Major secondary data sources for truck information

Source	Vehicles/ Drivers	Shipment	Commodity	Origin/ Destination	Facilities
Commodity Flow Survey (U.S. BEA)		✓	✓	✓	
Highway Performance Monitoring System (U.S. DOT)	✓				✓
LTL Commodity and Market Survey (ATA)		✓	✓	✓	
Nationwide Truck Activity and Commodity Survey (Census Bureau)	✓	✓	✓	✓	
North American Truck Survey (AAR)	✓		✓	✓	
Truck Inventory and Use Survey (Census Bureau)	✓		✓		

often lack data on the types of trucks that are involved in accidents or the cost to industry from accident impacts and countermeasures.

- **Economic Development.** Planners have high-level data on the employment or revenue of the trucking industry, but little information is available about (1) the value of freight flowing into or out of most metropolitan areas, (2) shipment costs, and (3) the time-sensitivity of deliveries. Without these data, it is difficult to gauge the impact of congestion on business logistics practices and overall regional economic growth.

Future Opportunities for Freight Data

The information collected and stored by ITS systems offers an opportunity to address some of the deficiencies in freight-related data. Three types of ITS deployment offer potential sources of freight data:

- **Metropolitan Traffic Management Systems.** Under the auspices of the Intelligent Transportation Initiative, major metropolitan areas are planning and deploying freeway management systems, incident management programs, electronic toll collection systems, and related services. The enabling technologies for these services include loop detectors, automatic vehicle classification (AVC) and automatic vehicle identification (AVI) equipment, closed-circuit television cameras (CCTV), and other equipment that more closely can monitor the number, type, and identity of trucks and other vehicles passing through the highway system. Nevertheless, metropolitan ITS traffic management systems are oriented primarily toward passenger cars and, therefore, may not address the unique routing restrictions and service demands faced by freight carriers.
- **Commercial Vehicle Operations (CVO).** The national ITS/CVO program is heavily focused on streamlining state regulatory processes, such as vehicle registration requirements or roadside safety inspections. Through the Commercial Vehicle Information Systems and Networks (CVISN) initiative, FHWA is supporting the development of a national CVO information systems architecture and electronic communication standards, as well as the model deployment of systems for safety information exchange, electronic credentialing, and electronic screening. The public-sector ITS program has not paid much attention to freight movement to date. Nevertheless, roadside CVO systems–such as AVI and weigh-in-motion (WIM) devices–can provide a rich source of freight planning data.
- **Fleet Management Technologies.** In the freight sector, carriers such as trucking companies and railroads have been the early leaders in ITS deployment. These organizations have invested in new technology to reduce the cost and improve the reliability of long-distance freight transportation; ensure the safety of drivers, vehicles, and cargo; and streamline internal business management practices. The number of motor carriers using fleet management systems and other ITS technologies has increased rapidly, with a nearly 50-fold increase between 1987 and 1992 (*20*). In 1987, the TIUS statistics show that less than 0.01 percent of the nation's medium and heavy trucks were equipped with trip recorders, electronic engine controls, automatic vehicle identification transponders, or automatic vehicle location systems. In 1992, TIUS statistics show that just under 4.0 percent of trucks were equipped with more than one of these technologies. Fleet and vehicle management systems include onboard computers, routing and dispatching software, mobile communications, and automatic vehicle location (AVL) systems (see Table 7). The data collected by these systems are proprietary and, in most cases, highly sensitive, but in aggregated form may enhance public-sector planning efforts.

The data collected by these ITS technologies can support each of the major functions of state and metropolitan freight planning (see Table 8).

TABLE 7 **Fleet and vehicle management systems**

System	Applications	Major Users
Electronic Trip Recorders/ Onboard Computers	Automatically monitors and records information on the performance of the vehicle or the driver	Large or private fleets; carriers with national or regional operations
Static Routing and Dispatching Software	Computes the most direct route between an origin and a destination, enabling carriers to maximize fleet efficiency	Carriers operating on fixed routes with the same customers
Dynamic Routing and Dispatching Software	Uses real-time congestion and shipment volume information to determine the most efficient route for a vehicle	Carriers operating large numbers of vehicles over variable routes; national fleets
Communications Systems	Provides driver-to-driver communication and a link between the carrier's terminal, dispatch office, and vehicles	Large fleets, especially those with time-sensitive cargo and variable routes
Cargo Monitoring	Provides real-time tracking of assets and monitoring of cargo conditions	Carriers transporting high-value, perishable, or hazardous material shipments, especially containerized cargo
Automatic Vehicle Location	Enables real-time identification of a vehicle's location relative to a map; assists with package tracking and real-time routing	Truckload carriers operating over long distances

Other Published Data Sources

In addition to the published secondary sources of freight-related data noted in Table 6, the following sources are of potential use in establishing and calibrating measures for a performance-based planning application.

Characteristics of Urban Travel Demand ("CUTD")

The 1988 CUTD Manual is being updated, with a final product expected in 1999. This manual is a compendium of information on urban travel demand characteristics and relationships of relevance to planning, forecasting, and evaluation of transportation system improvements, policies, and programs. The updated manual will include data such as

- Demographic data (e.g., population density, vehicle ownership, and employment);
- Transportation system characteristics (e.g., lane miles and transit system route miles);
- Trip characteristics (e.g., mode, length, vehicle occupancy, total VMT, purpose, and temporal distribution);
- Trip-making and trip generation characteristics (e.g., person trips per household, per vehicle, per person, and by various social and demographic strata); and
- Truck trip characteristics (e.g., length, purpose, and temporal distribution).

While this data source is a compendium of samples and average values from various sources, it is a potentially powerful and convenient "one-stop" location for a great variety of data that can be used to establish default performance standards and check the reasonableness of local estimates and forecasts.

American Travel Survey

The American Travel Survey was conducted by the U.S.DOT BTS in 1995 and provides information on the long-distance travel characteristics of persons living in the United Sates. The ATS focuses on state-to-state travel as well as travel to and from MPOs. Summaries of travel characteristics for states and metropolitan areas include data such as trip mode, purpose, distance, duration, and size of party. The BTS is a good source of aggregate information on trip making and is readily accessible through the World Wide Web at bts.gov.

ANALYTICAL TOOLS

This section, although closely related to the preceding section on data, focuses more specifically on analytical methods

TABLE 8 Freight planning applications of ITS technologies

Technology	ITS Use	Freight Planning Opportunities
Traffic surveillance technologies (loop detectors, infrared sensors, acoustic sensors, radar, CCTV)	• Collect information about the status of the traffic stream (counts, speeds, incidents)	• Provide real-time data on truck travel times and speeds at specific points • Provide detail on types of trucks and commodities
Automatic Vehicle Classification (AVC)	• Vehicle counts and classifications	• Inventory the type and volume of trucks using particular roadways
Dedicated Short-Range Communication (DSRC)/ Automatic Vehicle Identification (AVI)/ Automatic Equipment Identification (AEI)	• Electronic toll collection • Electronic roadside screening • International border clearance • Container identification • Traffic management	• Estimate travel times and speeds on certain corridors or around particular sites • Estimate travel time reliability • Estimate truck and container flows at intermodal facilities • Suggest broad O-D patterns
Smart Cards	• Gate access at terminals • Driver licensing • Electronic toll collection • Electronic fuel purchasing	• Provide information on travel times and speeds, route selection, and O-D patterns
Weigh-in-motion (WIM)	• Truck weighing • Electronic roadside screening	• Determine the weight of trucks using particular roadways • Assess potential pavement damage
Vehicle Navigation Systems	• Locate vehicles and cargo • Estimate time of arrival • Optimize routing and dispatching	• Assess travel times and delivery reliability • Estimate the impact of congestion on business logistics practices

and tools that may be useful in generating and analyzing performance data. Included are travel forecasting models, geographic information systems, benefit-cost models, trade-off analysis methodologies, survey research methods, and so on.

Urban Travel Demand Forecasting Models

Many metropolitan and local transportation agencies now maintain forecasting models for use in preparation of local and regional plans, air quality conformity analyses, and so forth. These models are useful to the performance-based planning process because they allow estimates of data that would otherwise be difficult to measure in the field. This is true not only for forecasts, which of course cannot be confirmed through field observations, but also of current period data such as VMT, person-miles of travel, and average vehicle speed by highway functional class. Such aggregate measures are difficult and expensive to collect in the field with any regularity. If calibrated with occasional survey data, however, travel models can provide reasonably accurate estimates of these kinds of data, which are useful in a planning application.

Entire programs of research and development have been devoted to improvement of the travel forecasting process and do not need to be described here. The U.S. DOT-sponsored Travel Model Improvement Program has generated a number of useful resource documents that are recommended to agencies wishing to use their model systems for more, or more accurate, planning data. Perhaps the most generally useful of these is the report on "Short-Term Travel Model Improvements," *DOT-T-95-05*, October 1994 (*13*). This report summarizes the methods and procedures that MPOs are recommended to implement over a 5- to 10-year time frame to improve urban travel demand modeling systems.

Areas of expected improvement include collection of travel survey data, modeling of non-motorized data, integration of land use components or allocation models, dynamic assignment techniques, improved air quality analysis, and more. One of the benefits of this analysis and review is the identification of improved methods for estimating speed and vehicle emissions from traditional travel demand models and "post processors."

Statewide Travel Models

Unlike the metropolitan planning situation, where travel demand forecasting models are relatively commonplace, many states are rather limited in their ability to generate estimates of existing or future flows on inter-city corridors or statewide networks. As a result, many state DOTs would find it challenging to generate certain systemwide performance measures and forecasts of those measures, such as average trip length on the system or VMT.

A recent conference sponsored by TRB (*21*) focused specifically on the current status and challenges of statewide travel modeling. Several states are starting or upgrading inter-city modeling capabilities—in some cases moving from trend-line or sketch planning techniques to network-based models with distribution, mode choice, and assignment capabilities. In a number of cases, the desire to know more about commercial vehicle freight traffic has been a significant factor in the decision to invest further in these analytical models. Because of the number of states developing truck or commodity flow components to their statewide models, the ability to forecast truck travel should improve substantially in the near term.

FHWA has published a guidebook on statewide travel demand forecasting. While this guidebook will likely be enhanced and updated in coming years, it remains a good reference that describes different types of long-distance travel demand forecasting procedures.

Data sources noted for their potential use in developing statewide travel models may also have value in development of performance measures at the state level. These include national databases such as the National Passenger Transportation Survey (NPTS) and the American Travel Survey.

Quick-Response Freight Manual

The U.S. DOT's Travel Model Improvement Program has resulted in a number of relevant analytical methodologies and data sources. One of these is the *Quick Response Freight Manual* (*22*). This manual provides several kinds of useful information, including

- Information on factors affecting freight demand and movement,
- Available data and freight-related forecasts compiled by others and guidance in how to apply these data,
- Simple techniques and transferable parameters that can be used to develop commercial vehicle trip tables, and
- Techniques for site planning that can be used to anticipate local commercial vehicle traffic caused by new facilities.

In particular, the manual identifies alternative analytical methodologies and data collection techniques that can be used to improve the accuracy of the freight analysis and planning processes.

Travel Survey Manual

The U.S. DOT, in conjunction with several other federal agencies, developed a manual describing current practices and improved techniques to implement the surveys often required for travel model system development. This Travel Survey Manual (*23*) provides detailed procedures for designing, implementing, and processing the following types of travel surveys. While the emphasis of this research is on obtaining the type of survey data necessary for travel demand model development, many of the survey techniques are applicable to performance-based planning approaches requiring either direct information about personal and commercial travel characteristics, or development of improved analytical models. The manual covers

- Household travel and activity surveys,
- Vehicle intercept and external station surveys,
- Transit onboard surveys,
- Commercial vehicle surveys,
- Workplace and establishment surveys,
- Special generator surveys, and
- Parking surveys.

Benefit/Cost Models

The U.S. DOT has funded development of analytical models designed to assess the relative benefits and costs of alternative transportation projects or investment scenarios. Two that have progressed to the point of being available "off the shelf" to interested users include STEAM and IDAS. STEAM, the Surface Transportation Efficiency Analysis Model, is designed to allow comparison of alternative mode capital projects (e.g., a mixed-flow freeway lane, HOV lane, and rail extension). STEAM uses components of standard four-step travel demand models as input and generates various outputs (including user benefits expressed as travel-time savings, externalities such as vehicle emissions, energy costs, benefit/cost ratios, and more).

IDAS, the Intelligent Transportation System Deployment Analysis System, is a sketch-planning analysis tool that estimates the impacts, benefits, and costs resulting from the deployment of ITS components. Like STEAM, it is a post processor to travel demand models and is aimed at MPOs and state DOTs. IDAS incorporates analytical routines such as cost/benefit analysis, sensitivity analysis, risk analysis, and ranking of alternatives. IDAS evaluates a range of benefits for each identified alternative, including

- Travel time and throughput (for persons and vehicles);
- Environmental (emissions and energy consumption);
- Safety (change in the number and severity of accidents); and
- Travel-time reliability.

Using IDAS, one can compare, for example, the relative costs and benefits of a new HOV lane with a new transit line, with and without ITS features such as ramp metering, incident management, and electronic toll collection. Costs estimated include public- and private-sector capital costs and public- and private-sector operating and maintenance costs.

These two analytical tools will soon be available at nominal cost from FHWA. STEAM is available with limited user support. IDAS was scheduled for release in the fall of 1999; details of the user support program are in development.

Incident-Related Effects and Incident Management Strategies

FHWA has undertaken development of a sketch-planning method for estimating the impacts on nonrecurring congestion (incidents) and the effectiveness of strategies to mitigate that congestion. The method provides estimates of change in vehicle hours of travel (VHT) and VMT, as well as queue length, and is intended to be applied for sections of freeways from 2 to 20 miles or more in length (*24*). The beneficial effects of incident management strategies, such as automated incident detection, service patrols, computer-aided dispatch, and shoulder widening, can be estimated.

REFERENCES

1. National Cooperative Highway Research Program, "Multimodal Transportation: Development of a Performance-Based Planning Process," *NCHRP Research Results Digest 226*, Transportation Research Board, National Research Council, Washington, DC (July 1998).
2. Pratt, R. and Lomax, T. "Performance Measures for Multimodal Transportation Systems," presented at the 73rd Annual Meeting of the Transportation Research Board, Washington, DC (January 1994).
3. California Department of Transportation. "California Transportation Plan," Office of the Director, Sacramento, CA (June 1995).
4. Ohio Department of Transportation. "Access Ohio—Ohio Statewide Transportation Plan," Division of Planning, Columbus, OH (October 1993).
5. New Jersey Department of Transportation. "Transportation Choices 2020; Part One, The Policy Framework," Trenton, NJ (December 1994).
6. Florida Department of Transportation. "Connections—Bringing Florida Together, 2020 Florida Transportation Plan," Office of Policy Planning, Tallahassee, FL (1995).
7. Mississippi Department of Transportation. "Mississippi Statewide Transportation Plan—Draft Final," Jackson, MS (November 1994).
8. Texas Department of Transportation. "Mobility and Access Committee Policy Paper, Texas Transportation Plan," Austin, TX (October 1994).
9. California Department of Transportation. "Transportation System Performance Measures, Final Report," Transportation System Information Program, Sacramento, CA (August 1998).
10. Missouri Long-Range Transportation Plan policy document.
11. Minnesota Department of Transportation, "Family of Measures," unpublished office memorandum (February 27, 1995).
12. Southern California Association of Governments, *Draft 1998 Regional Transportation Plan, Technical Appendix* (November 1997).
13. Cambridge Systematics, Inc., "Short-Term Travel Model Improvements: Final Report," *Report No. DOT-T-95-05*, U.S. DOT, Washington, DC (October 1994).
14. Lau, Samuel. *Truck Travel Surveys: A Review of the Literature and State-of-the-Art*, Metropolitan Transportation Commission, Oakland, CA (January 1995).
15. *Travel Survey Manual (Draft)*. Prepared by Cambridge Systematics for the Travel Model Improvement Program (DOT, FHWA, FTA, EPA), Track D (1995).
16. Papacostas, C.S. et al. "Computer-Administered Surveys at Honolulu International Airport," *Transportation Research Record 1412: Innovations in Travel Survey Methods*. Transportation Research Board, National Research Council, Washington, DC (1993).
17. Landis, Bruce W. "Improved Sampling Techniques To Determine Trip Characteristics for Traffic Impact Analyses," *Transportation Research Record 1400: Planning and Programming, Land Use, Public Participation, and Computer Technology in Transportation* (1993).
18. *Guidelines for Traffic Data Programs*. American Association of State Highway and Transportation Officials (AASHTO), Washington, DC (1992).
19. Transportation Statistics Annual Report, p. 181.
20. U.S. Department of Commerce, Bureau of the Census. *Truck Inventory and Use Survey for 1987 and 1992*.
21. Statewide Travel Demand Forecasting Workshop, Irvine, California, December 1998, sponsored by the Transportation Research Board.
22. U.S. Department of Transportation et. al., *Quick Response Freight Manual*, Final Report (September 1996).
23. U.S. DOT and others, "Travel Survey Manual and Appendices," *Reports FHWA PL 96-029* and *-030* (July 1996).
24. FHWA, *Sketch Methods for Estimating Incident-related Impacts*, DTFH-61-95-C-00060, TO-21 (December 1998).

APPENDIX A

SUMMARY OF CASE STUDIES

Following is a summary of the numerous case studies conducted for this research project. More complete documentation of the case studies is contained in the project Final Report.

SUMMARY OF CASE STUDIES

The case studies conducted for Phase II of this research project reflected public and private experiences with performance-based planning. The cases were chosen because of specific characteristics that allowed the project team to generalize from this experience to other contexts. These case studies included state departments of transportation, metropolitan planning organizations, service providers, and a private firm specializing in goods transportation. In each case, field visits provided an in-depth review of the institutional and technical foundations for performance-based planning. The results of these case studies provide important insights into the challenges and opportunities associated with such planning. These case studies were conducted during the period April 1997 through February 1998. Most of these agencies have continued to develop and refine their systems since that time, and these case study summaries do not reflect the changes and improvements that may have been made.

Capital District Transportation Commission (Albany, New York)

The Capital District Transportation Commission (CDTC) was one of the earliest metropolitan planning organizations to use performance measures in a comprehensive way. As part of an update to the long-range regional transportation plan, the CDTC adopted a set of "core performance measures" that reflected a total cost-accounting perspective on transportation system impacts. This cost accounting, as reflected in the performance measures, includes both monetized and non-pecuniary costs.

Nine task forces were established to provide focus in key planning areas, with each task force developing supplemental performance measures that linked directly to the core performance measure and could be used for tradeoff analysis of specific plan options. This process was successful in linking broad system performance measures to criteria for evaluating cost-effective strategies in individual applications.

Two of the task forces regarded the performance-based approach as particularly well suited to the types of options they considered, but case study participants did not find that the approach had much influence on the overall plan structure. The minimal impact on ultimate decisions is likely to be true for any transportation investment decision process where tradeoffs must be made. In addition, a backlog of TIP projects meant that new projects that surfaced from the performance-based planning approach would have to compete with projects that had already received political approval. The specific lessons learned from the Albany case study were

- Adoption of performance-based planning for a planning process will be evolutionary, that is, there will be a period before the new approach begins to have an impact.
- Developing a set of core performance measures to which everyone agreed assured consistency as planning proceeded toward recommended policy and strategies.
- Performance-based planning is perhaps more participatory than traditional models, implying that efforts to "open" the process to a broad range of participants and making it understandable to these participants are needed.
- Long-term commitments for data collection and analysis are necessary for performance-based planning to work.

East-West Gateway Coordinating Council (St. Louis, Missouri)

The East-West Gateway Coordinating Council has been exploring the use of performance measures in planning since the early 1990s. The long-range transportation plan identified outcome-based performance measures that related to the social, economic, and environmental vitality of the region. These measures were used in three planning initiatives, with varying levels of success.

The first initiative was a major investment study (MIS) in which performance measures were used to compare and rank modal investments. Measures were identified as part of the evaluation process, but the selected measures did not seem related to project-specific impacts nor the availability of data. A second effort in the MIS to incorporate performance measures resulted in 50 measures being identified. Due to the large number of measures, lack of data to support them, and an unclear causal linkage, the exercise was considered unsuccessful.

The second initiative was to use performance measures in project prioritization for the TIP. Projects were ranked by their relation to regional goals (and hence performance measures) and their cost-effectiveness. However, the selected performance measures were not viewed as adequate for measuring progress toward overall goals.

The third and most successful initiative involved incorporating performance measures into a regional freight planning study and subsequent "report card." A list of 28 performance measures related to regional freight objectives was identified through a process in which industry participants played an active role. The recommended measures were chosen based on ease of data collection and relationship to regional significance, thus reflecting a strong level of implementation feasibility. The specific lessons learned from the St. Louis case study were

- Focusing on a few good performance measures provides more targeted information to decision-makers.
- Any set of performance measures that results in an overwhelming data collection requirement will be quickly abandoned.
- As in the Albany example, the freight "report card" illustrates the need for incorporating stakeholders and system users into measure definition and having adequate in-house technical capacity to use performance measures.

Metro (Portland, Oregon)

Metro, the MPO for Portland, Oregon, has a higher degree of legislative and statutory strength behind its planning activities relative to many other MPOs. Oregon's "Transportation Planning Rule" requires the quantification of goals and objectives as part of the process. The Regional Transportation Plan (RTP) is framed by the more comprehensive "2040 Growth Concept," which calls for emphasis on access to the central city, regional centers, intermodal facilities, and industrial areas.

Metro has a relatively larger amount of resources dedicated to transportation analysis and is known for innovations in development and application of analytical models. In particular, Metro has developed measures of accessibility that are fairly advanced and based upon a set of spatially referenced tools. The advantages of this approach include providing measures of access to opportunities that are relatively mode-neutral. Specific lessons from the Portland case study include

- Planners should anticipate that implementation of performance-based approaches will increase the time required to evaluate and reach decisions, not decrease it.
- Public values cannot be accurately gauged without thorough public involvement, but this involvement will not be successful without meaningful feedback.
- Metro has gone further than most agencies in devising and implementing quantitative measures of mobility and accessibility that are computationally complex but are still relatively intuitive to the user. It may be challenging for many regions to develop the analytic capabilities needed to address the equity aspects of mobility and accessibility.

Metropolitan Council (Minneapolis/St. Paul, Minnesota)

The Minnesota State Legislature required the Metropolitan Council to perform an audit of the region's transportation system in order to provide public accountability for the resources that were being allocated to the system. A review of recently completed policy statements and plans provided an overview of the regional goals and objectives guiding transportation investment. The evaluation framework for the audit focused on three levels, starting first with transportation system performance, then leading to economic growth and competitiveness, and finally to quality of life. For audit purposes, performance measurement was related to data, including benchmarks, peer comparison, and performance standards. Results of transportation system customer satisfaction surveys from households and businesses were included in this assessment.

The Twin Cities case study reflects a growing use of performance-based planning—providing accountability for public resources expended. The concept of an audit targets the relationship between these expenditures and system performance. Of great interest in the Twin Cities was the broadening of the outcome measures to include economic growth/competitiveness and quality of life, thus providing a direct link to stated regional goals and objectives. The specific lessons learned from the Twin Cities case include

- Performance measurement over time is meaningful when related to changes that occur and that reflect some datum of reference such as the change from the last measurement cycle, peer comparison, use of performance standards, or benchmarks.
- Customer orientation is an important element of measuring system performance. Not only does this relate to the original definition of appropriate measures, but also to the actual determination of system performance relative to customer expectations.

Florida Department of Transportation

The Florida Transportation Plan explicitly uses performance measures to establish and revise goals and objectives, with indicators of progress used to measure progress toward these long-range objectives. The Short-Range Component of the Plan is the basis for an annual performance report on the level of achievement of the 15 short-range objectives.

The Florida DOT was one of the first DOTs to develop a comprehensive intermodal management system (IMS). The original concept of the IMS was for the focus to be systemwide with emphasis on both transfer facilities and quality of access. As this effort evolved, the focus became solely access characteristics to the state's highway network. This new focus further evolved into a process whereby points were assigned to empirical observations that could be used to establish priorities for specific improvements within each district. After a 2-year test period, an internal evaluation of the IMS concluded that no district had used the information for establishing priorities.

A key conclusion from Florida is that participants very carefully distinguish between *performance measures* and *indicators of conditions*. Indicators provide information on what is happening to key system characteristics, but they do not necessarily relate directly to a causal linkage with agency action. Nonetheless, an ability to track key system characteristics became a component of the agency's commitment to improve its actual performance. At another level, performance measures were used as triggering devices to indicate when further study was warranted and to integrate performance considerations with existing planning processes. Other observations that come from Florida include

- Establishing causality between program investment and performance measures is an important technical and political issue.
- The process of monitoring system performance was considered as important as the actual performance measures.
- A concern was expressed about the danger of decision-makers "chasing" the performance measures. This means that once it is known how "success" will be measured, those actions that most quickly and easily achieve this success will tend to be selected, even though the root cause of the problem might suggest different actions.

Oregon Department of Transportation

Along with Florida, Oregon was one of the earliest states to devote considerable resources to the development of a statewide intermodal management system (IMS). The early phase of IMS development included inventorying intermodal facilities, defining a set of general performance measures, and identifying corresponding data requirements. Once the sheer scale of such an IMS became known, the concept was refined to focus on access quality into and out of major points of transfer. This new focus reflected extensive input from transportation system stakeholders who identified capacity, accessibility, connectivity, time delay, and safety as critical performance dimensions. Attention was given to establishing thresholds of acceptable performance and to using this information for prioritizing projects; this use for prioritization continues to be debated.

Specific observations that come from the Oregon case study include

- Performance measures were refined to reflect only those elements of the transportation system under control of the agency.
- Efforts to supplant (or at least perceptions of such efforts) the political process associated with prioritization were not well received.
- Extensive stakeholder involvement was considered essential in successfully defining an IMS that would have an important role in the transportation planning process.
- There was great hesitation in refining performance measures to ever finer quantification. The measures were viewed as input into planning, not as replacing the planning process itself.

Washington State Department of Transportation

The Eastern Washington Intermodal Transportation Study was undertaken to study the mobility needs of agricultural stakeholders. An important feature of this study was the focus on the "trip" of a commodity from origin to destination through a logistics-chain database, rather than on aggregate flows across a transportation network. So, for example, the study examined the timing of harvests, the demands for transportation, and the resulting impacts on the network. Although the perspective adopted in this study was very much oriented toward transportation system users, the performance measures targeted those system components under state DOT control. As in Florida and Oregon, Washington State used the concept of indicators to represent phenomena that are not causally linked to agency action.

A similar effort has been occurring in Seattle. The Puget Sound Regional Council (PSRC) has developed an analysis process for freight planning that is commodity-based, rather than the traditional reliance on land use characteristics. The PSRC has developed a monitoring program consisting of 26 critical segments of the region's road network, mainly measuring conditions experienced by trucks. In the near term, these measures are to be used to report trends, but are viewed as the basis for a more systematic planning process aimed at freight movement in the region.

The specific observations that result from this case study include

- Performance-based planning efforts become quite meaningful when the appropriate stakeholders are included in the process.
- Both system-based and user-based performance measures should be included in performance-based plan-

ning, with the level of disaggregation related directly to the type of information desired and the types of decisions that need to be made.
- A market group focus for performance measures draws a strong linkage between economic productivity and the performance of the transportation system.
- This case also illustrates the concern with having performance measures replace political decision making in establishing priorities.

Vermont Agency of Transportation

The Vermont Agency of Transportation (AOT) has set in motion a program to monitor the performance of the programs aimed at improving the quality of transportation in the state. The program is based on both the commitment of the agency and legislative mandate to undertake a program of monitoring and feedback in the planning process. Senior managers at the agency reported satisfaction with the development of a program to monitor the outputs of the agency's work, but are now wrestling with the transition to the use of outcomes.

Managers believe that certain departments have made major strides in reorienting their work to incorporate performance-based evaluation. For example, high-level managers believe that the pavement program has evolved from a list of specific projects to a *system* that can be described, evaluated, and understood. The biggest challenge facing managers is to develop a meaningful monitoring program in the maintenance department that will include a new telephone log system to capture customer requests, a mechanism to annually survey district customers, and a numerical index to rate maintenance conditions for road sections. These examples show how the agency has augmented or modified their data collection and manipulation systems to better suit the information demands of the performance-based approach.

Amtrak

As part of its strategy to attract customers, Amtrak management instituted a Customer Satisfaction Tracking System (CSTS) as input into operations and capital decisions. In 1994, Amtrak sponsored a survey of more than 10,000 customers to determine the most important customer satisfaction factors. Customers on each Amtrak product line were then surveyed on a regular basis, with a 3-month rolling average used to track customer satisfaction trends. A composite Customer Satisfaction Index (CSI) was developed and became the major indicator of customer satisfaction as reported to the Board of Directors. Study participants suggested that some managers were also using the CSTS database to make decisions at their level.

Specific observations that come from the Amtrak case study include

- Study participants suggested that management and employee "buy-in" is needed with customer satisfaction measures to motivate staff and influence operations; including staff in measure and tool development was suggested as one way to accomplish this.
- Customer-oriented product delivery requires a good understanding of the desired service characteristics and of the status of those characteristics in actual service delivery. Surveys are a crucial element in gathering this customer information.

Miami Valley Regional Transit Authority (Dayton, Ohio)

In the early 1990s, the Miami Valley Regional Transit Authority (MVRTA) was perceived as being isolated from the community that it was trying to serve. To address this credibility problem, MVRTA leaders established an independent committee of civic, business, and constituency leaders to develop a strategic direction for the agency. This strategic direction included a service standards process whereby service performance could be monitored and new service requests could be evaluated in terms that were understandable to the community. Four service standards were defined by the Authority—passengers per platform hour, vehicle load factors, on-time performance, and community-based service needs. The last standard is a qualitative assessment of how a service relates to fundamental community needs such as access to key employment, commercial, or medical facilities. A wide-ranging data collection effort supports the monitoring of system performance. Organizational changes have occurred that further implement the system performance orientation of MVRTA. For example, the planning staff has been given responsibility for scheduling and is expected to field customer complaints twice per month. This provides a direct link between customer perceptions on service provision and actual provision of service.

Specific observations that come from the MVRTA case study include

- The implementation of performance-based planning is an evolutionary process with important "developmental" phases along the way.
- Periodic system measurement provides feedback to customers and stakeholders that benefits are accruing for their investment and involvement with the planning process.
- Credibility in the process also means having the resources and willingness to address problems that surface from the performance-based planning process.

United Parcel Service

United Parcel Service's (UPS's) measurement systems have traditionally focused on productivity, efficiency, and finance. Early performance measures in support of these goals included volume growth, revenue growth, time-in-transit, and cost per package. In recent years, profit has become a more explicit concern with the realization that revenue and volume growth does not necessarily equate to profit growth.

Within the last 5 to 15 years, UPS managers have concluded that an exclusive focus on efficiency and finances, particularly volume growth, was creating long-term negative implications, especially for fixed asset requirements. For example, new service offerings brought about by competition could not be assessed (and serviced) in same way as traditional ground service. Many forces have come together to compel UPS to take a broader approach to performance measurement. UPS's current approach is centered on the "Balanced Scorecard" concept; this approach acts as an alignment mechanism for data collection and analysis from the Board of Directors through front-line managers. Other observations on the use of performance-based planning at UPS include

- Participants stated that a performance measurement system should be applied in both top-bottom and bottom-up fashions. However, it should be established top-down, with key corporate goals used as the driver and alignment mechanism for all measures.
- UPS has underestimated both the cost of maintaining information technology and the additional costs that are incurred just by virtue of having data available.
- Timeliness of information is more critical than quantity of information at all levels.
- Undue concerns about the long-term stability of measurement systems and specific measures may paralyze agencies and prevent them from responding to changing internal and external forces.
- Different kinds of measures may be needed to track performance with respect to strategic objectives, as opposed to measures, which are better diagnostics of the problems and effective solutions.
- Feedback and evaluation, particularly in terms of customer satisfaction, are needed to identify effective performance drivers.
- UPS is trying to measure, interpret, and predict financial performance in a broader context that incorporates customer- and employee-oriented measures.
- The availability of "unlimited" information creates new problems of putting it all together or of "creating information out of data."

APPENDIX B
PERFORMANCE MEASURES LIBRARY

The following material is a comprehensive catalog of many of the performance measures in use in the United States today.

TABLE OF CONTENTS

INTRODUCTION

The purpose of this Performance Measures Library is to provide practitioners of performance-based planning with a concise look-up guide cataloging many of the measures in use around the United States today. The Library is a companion to *A Guidebook for Performance-Based Transportation Planning*. By using these resources in tandem, users will find guidance on the **process** of performance-based planning as well as an organized list of **specific performance measures** that are being used or have been considered for use at state DOTs, MPOs, and other transportation organizations around the country.

Performance measures from a wide variety of sources and transportation organizations have been included. The intent is that practitioners will benefit from having access to a number of variations and alternative measures. The following section describes the organizing framework and how to use the Performance Measures Library.

Organization of the Library

To facilitate the use of this library, we have organized performance measures into eight major goal categories consistent with many agencies' categorization of goals and measures. These are as follows:

1. Accessibility,
2. Mobility,
3. Economic Development,
4. Quality of Life,
5. Environmental and Resource Conservation,
6. Safety,
7. Operational Efficiency, and
8. System Condition and Performance.

The intent of this organizing structure is that users can easily scan the table of contents and readily locate measures pertinent to their categories of interest. The remainder of this document consists of a series of sections, one for each category listed above.

Within each section, the performance measures are further divided into subcategories to make navigating the long lists of measures easier. Rather than develop a universal organizational scheme for all eight goal categories, we created subcategories that best fit each of the individual categories. Each section has an "index tree" giving an overview of the subcategories. These index trees should give practitioners a quick way of identifying the set of performance measures best suited for their particular needs.

Within the tables, those measures that appear to be used more frequently or are cited more often are ***italicized***. Some of the performance measures in this library appear in more than one of the eight goal categories. Section 9.0 contains an alphabetical index of all the measures contained in this library. In particular, the index notes those measures that occur in multiple goal categories, providing the user with an indication of which measures cut across various goals.

References

References are provided for each of the performance measures in this library. In the tables, the code shown to the right of each measure refers to the references listed below:

1. Cambridge Systematics. "*Multimodal Transportation Planning—Development of a Performance-Based Planning Process, Phase I Final Report.*" National Cooperative Highway Research Program. Transportation Research Board, National Research Council, Washington, DC (August 1996).
2. The Citizen League Research Institute. *Regional Benchmarking: A Resource for Community Dialogue* (June 1997).
3. Department of Geography, New Mexico State University. *The Use of Intermodal Performance Measures by State Depart-*

ments of Transportation. U.S. Department of Transportation (June 1996).
4. Cambridge Systematics. *Performance Measures Used by State Agencies and MPOs.* Unpublished list of performance measures.
5. *State Transportation Plan Review: NTS Framework/U.S. DOT Restructuring Progress, Interim Submission* (February 1996).
6. Michael D. Meyer. "Alternative Performance Measures for Transportation Planning: Evolution Toward Multimodal Planning." U.S. Department of Transportation, *Report FTA-GA-26-7000* (December 1995).
7. Cambridge Systematics. *Performance Measures Overview for Michigan Department of Transportation* (May 1994).
8. *Transportation Planning and Performance Measurement in Washington State.*
9. Cambridge Systematics. *Suggested Performance Measures for Texas Transportation Plan* (August 1994).
10. Texas Department of Transportation. *Texas Department of Transportation Established Transportation System Performance Measures.*
11. Cambridge Systematics. "National Transportation System Performance Measures, Final Report." For Office of the Secretary, U.S. Department of Transportation, *Report DOT-T-97-04* (April 1996).
12. Florida Department of Transportation. *Measures for Performance-Based Program Budgeting as Stated in the General Appropriations Act for FY 1997–1998* (October 1997).
13. National Cooperative Highway Research Program. "Performance Measurement in State Departments of Transportation." *NCHRP Synthesis of Highway Practice 238.* Transportation Research Board, National Research Council, Washington, DC (1997).

1.0 ACCESSIBILITY

Providing accessibility to jobs, recreation, shopping, intermodal transfer points, and other land uses is one of the primary purposes of any transportation system. Measures of accessibility should reflect the ability of people and goods to access services, use different modes, and reach different destinations. Measures of accessibility also often capture the density of transportation service or land uses within a given area. Accessibility is frequently measured from the **user's perspective.**

A concept closely related to accessibility is connectivity. Connectivity refers to the completeness of a given transportation system or subsystem. A lack of connectivity often impedes accessibility. For example, the lack of a pedestrian overpass over a freeway may severely restrict the accessibility of a commercial district to pedestrians. Or, a bridge weight restriction may limit the accessibility of a region for industrial purposes. Thus, a number of measures associated with accessibility actually measure connectivity.

The accessibility measures are first divided into a set applicable to both passenger or freight movement, a second set specifically addressing freight movement, and finally, a third set specifically addressing passenger movement. Each of these subcategories is then divided into finer subcategories.

Of the measures applicable to passenger or freight movement, the most often cited accessibility measures monitor trip time/distance and mode shares. Trip time is typically estimated with travel models, but can also be determined with field measurements. Trip distance information is typically stored in GIS databases. Mode share is often established by surveys done at specific geographic locations.

Two types of frequently cited freight-specific accessibility measures assess the ability of the roadway to handle heavy freight traffic and the capacity of specific intermodal facilities. Weight, height, and turning radius data for roadways are maintained by the DOT in most States, and by the highway patrol in others. Information on specific intermodal facilities can be gathered from the operators of these facilities.

Often cited passenger-specific accessibility measures include those dealing with the ease of access to the transportation system and the ease of connecting at transfer facilities. Some ease of access measures can be calculated using GIS and census information, but often, these kinds of measures require detailed surveys. Connecting times and distances at transfer facilities can be determined with field data or passenger surveys. See Figure 1 and Tables 1.1 through 1.21 for more information.

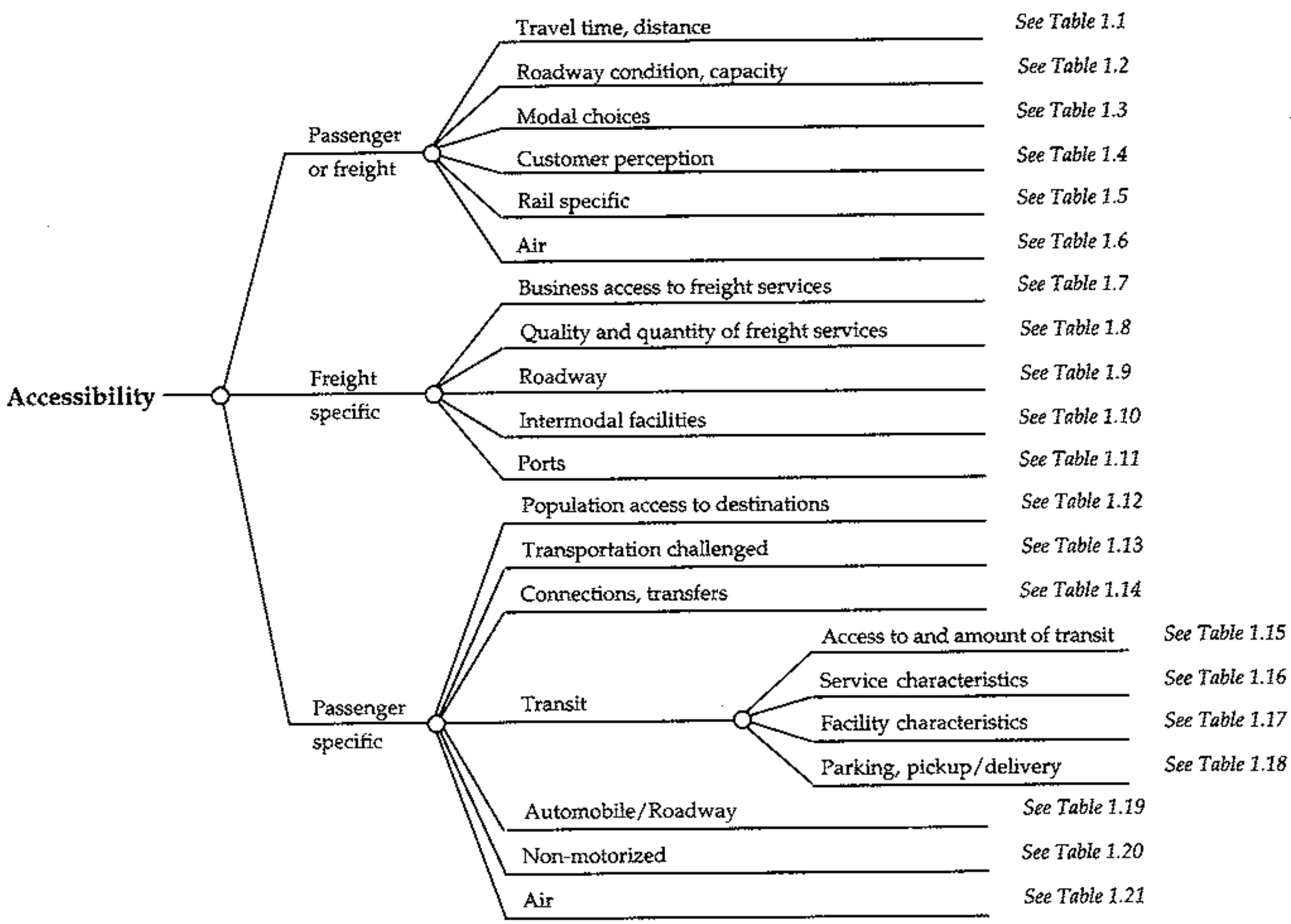

Figure 1. Accessibility measures.

TABLE 1.1 Accessibility
Passenger or Freight
Travel Time, Distance

Performance Measure	Reference
Average travel time from facility to destination (by mode)	*3, 8*
Average travel time from facility to major highway network	3
Average trip length	*4, 6, 11*
Number of projects (area and population) accessible to designated development centers	5
Accessibility index	4

TABLE 1.2 Accessibility
Passenger or Freight
Roadway Condition, Capacity

Performance Measure	Reference
Total freeway lane-miles (or per capita or per measure of regional business volume or per square mile or truck VMT)	2, 11
Number of Trunk System lane miles planned vs. completed	8
Total freeway lane-miles in acceptable condition (or per capita or per measure of regional business volume or per square mile or truck VMT)	11
Number of miles with intelligent transportation service	13
Number of new rest areas constructed vs. planned	8

TABLE 1.3 Accessibility
Passenger or Freight
Modal Choices

Performance Measure	Reference
Percent of users with option of more than one modal choice	5
Overall mode split	3
Mode split by facility or route	3
Percent of change in mode splits	3

TABLE 1.4 Accessibility
Passenger or Freight
Customer Perception

Performance Measure	Reference
Perceived deficiencies	3
User identification of access issues	3
Percent of State residents aware of intermodal opportunities	3

TABLE 1.5 Accessibility
Passenger or Freight
Rail Specific

Performance Measure	Reference
Miles of track in operation (by FRA rating)	*3, 4, 8, 11*
Existence of railroad electrification	3

TABLE 1.6 Accessibility
Passenger or Freight
Air

Performance Measure	Reference
Air transportation capacity	2
Amount of scheduled service between major cities	8
Number of cities over one million population served directly by nonstop commercial airline flights from airports in state	13
Airport improvement and cost scheduled at airports	3
Airports within a 30-minute drive of agricultural centers capable of supporting twin-engine piston-powered aircraft	3
Percent of aviation community reached through aviation service programs	10
Percent of general aviation needs funded	3

TABLE 1.7 Accessibility
Freight Specific
Business Access to Freight Services

Performance Measure	Reference
Percent of wholesale and retail sales in the significant economic centers served by unrestricted (10-ton) market artery routes	5
Percent of manufacturing industries within 30 miles of interstate or four-lane highway	11

TABLE 1.8 Accessibility
Freight Specific
Quality and Quantity of Freight Services

Performance Measure	Reference
Number of shipping establishments per 1,000 businesses	2
Number of package express carriers	11
Capacity of package express carriers	11
Percent of goods moved with option of more than one modal choice	5
Availability of real-time cargo information	3

TABLE 1.9 Accessibility
Freight Specific
Roadway

Performance Measure	Reference
Average circuity for truck trips of selected O-D pattern	11
Number of truck-days of highway closure on major freight routes	8
Number of overload permits rejected due to structural capacity deficiency	8
Number of structures with vertical (or horizontal) clearance less than 'X' ft.	*1, 3, 4, 8*
Bridge weight limits	*3, 4*
Percent of truck VMT or tonnage affected by weight restrictions (or clearance) on bridges	7
Percent of truck highway bridges sufficient in load capacity, vertical and horizontal clearance	5, 7
Percentage of highway system with bridges that are structurally deficient or functionally obsolete	3
Sufficiency rating (percent bridges meeting federal sufficiency rating)	4, 7
Geometrics of connector link	3, 4

TABLE 1.10 Accessibility
Freight Specific
Intermodal Facilities

Performance Measure	Reference
Average distance to intermodal terminals from different community shipping points	4
Number of intermodal facilities	*3, 4, 11*
Capacity of intermodal terminals	11
Average travel time between intermodal facility and rail	3
Amount of turning radius from major highway to intermodal facility	3
Number of T.E.U.'s (10'x 21') (or railroad cars or containers) that can be stored on the premises of the intermodal facility	3, 4
Number of trucks that can be loaded with bulk material per hour of loading time	3
Types of modes handled	3
Freight dock availability	3
Track capacity (size, acreage)	3
Double-stack capacity (or rating)	*3, 4, 11*
Number of intermodal facilities that agency assists in development	3

TABLE 1.11 Accessibility
Freight Specific
Ports

Performance Measure	Reference
Number of ports with railroad connections	13
Lift capacity (annual volume)	3

TABLE 1.12 Accessibility
Passenger Specific
Population Access to Destinations

Performance Measure	Reference
Percent of population within 'X' miles of employment	1
Percent of population that can reach specified services by transit, bicycle, or walk	11
Percent of employers that cite difficulty in accessing desired labor supply due to transportation	11
Employee-related percent of employers who have relocated for transportation reasons	11

TABLE 1.13 Accessibility
Passenger Specific
Transportation Challenged

Performance Measure	Reference
Percent of transit-dependent population served	4
Percent of region's persons who have mobility impairments and who can reach specific activities by public transportation or by walking/wheelchair	11
Percent of persons who are elderly or have disabilities and who have special transit service available	3, 5
Percent of transit demand-response trip requests met	4
Existence of access for persons with disabilities to all areas	3
Percent of transit facilities accessible to persons with disabilities	5, 10

TABLE 1.14 Accessibility
Passenger Specific
Connections, Transfers

Performance Measure	Reference
Percent of transfers between modes to be under 'X' minutes and 'N' feet	3
Transfer distance at passenger facility	3
Flow time in minutes as it compares to the number of connecting transfers	3
Connectivity deficiency	3
Number of intermodal facilities that agency assists in development	3

TABLE 1.15 Accessibility
Passenger Specific
Transit
Access to and Amount of Transit

Performance Measure	Reference
Percent of workforce that can reach worksite in transit within one hour, and with no more than two transfers	11
Percent of population with access to (or within 'X' miles of) transit (or fixed-route transit) service	*3, 4, 5, 8, 11*
Percent of urban and rural areas with direct access to passenger rail and bus service	3
Percent of rural population with access to transit service	3, 4
Number of transit systems in State	5
Number of counties in State with countywide transit systems	5
Access time to passenger facility	3

TABLE 1.16 Accessibility
Passenger Specific
Transit
Service Characteristics

Performance Measure	Reference
Route-miles (or seat-miles or passenger-miles) of transit service (or per capita or per employee or per licensed driver)	11
Frequency of transit service	*1, 3, 4*
Route spacing	4
Percent of total transit trip time spent out of vehicle	11

TABLE 1.17 Accessibility
Passenger Specific
Transit
Facility Characteristics

Performance Measure	Reference
Transfer distance at passenger facility	*3*
Availability of intermodal ticketing and luggage transfer	3
Existence of information services and ticketing	3

TABLE 1.18 Accessibility
Passenger Specific
Transit
Parking, Pickup/Delivery

Performance Measure	Reference
V/C of parking spaces during daily peak hours for bus, rail, park-and-ride, or other passenger terminal lots	3
Percent of rail station parking lots with midday spaces available	3
Parking spaces per passenger	3
Parking spaces available loading/unloading by autos	3
Number of pick-up and discharge areas for passengers	3

TABLE 1.19 Accessibility
Passenger Specific
Automobile/Roadway

Performance Measure	Reference
Percent of population within five miles or 10 minutes of state-aided public roads	5

TABLE 1.20 Accessibility
Passenger Specific
Non-Motorized

Performance Measure	Reference
Number of miles of non-motorized facilities	3
Percent use of walking and bicycling for commute trips (or all trips)	8

TABLE 1.21 Accessibility
Passenger Specific
Air

Performance Measure	Reference
Percent of jobs within 45 minutes of airports	5
Minimum layover times at airports or passenger terminals	3
Access time to passenger facility	3
Transfer distance at passenger facility	3
Existence of information services and ticketing	3
Availability of intermodal ticketing and luggage transfer	3
V/C of parking spaces during daily peak hours for bus, rail, park-and-ride, or other passenger terminal lots	3
Parking spaces per passenger	3
Parking spaces available loading/unloading by autos	3
Number of pick-up and discharge areas for passengers	3

2.0 MOBILITY

Providing mobility is another fundamental function of transportation systems. Unlike accessibility, which reflects the ability of people or goods to reach destinations, mobility incorporates the relative ease or difficulty with which the trip is made. For example, a location may be accessible by transit but, if service is infrequent, transit-dependent travelers may still face restricted mobility. Likewise, congestion often impedes the mobility of private vehicle users who nonetheless enjoy excellent accessibility.

Because mobility is concerned with travel times, speeds, system usage, and system capacities, many of the measures of mobility are from the supplier's perspective. Examples of these include *V/C* ratios and levels of service (LOS) measures. There are a number of measures that better reflect the user's perspective, however. Among these are travel times, delay, and measures of reliability.

The mobility measures are first divided into a set applicable to both passenger or freight movement, a second set specifically addressing freight movement, and finally, a third set specifically addressing passenger movement. Each of these subcategories is then divided into finer subcategories.

The most frequently cited mobility measures fall into six areas: congestion-related (e.g., LOS, *V/C* ratio, and delay time), trip time, amount of travel (e.g., VMT and VHT), mode share, transfer time, and transit performance. Congestion-related, trip time, and amount of travel measures are typically estimated with a travel model, though trip time is sometimes determined with data collected from the field. Mode share is often established by surveys done at specific geographic locations. Connecting times and distances at transfer facilities can be determined with field data or user surveys. Transit data, such as on-time performance and headways, can be directly obtained from transit operators. See Figure 2 and Tables 2.1 through 2.19 for further information.

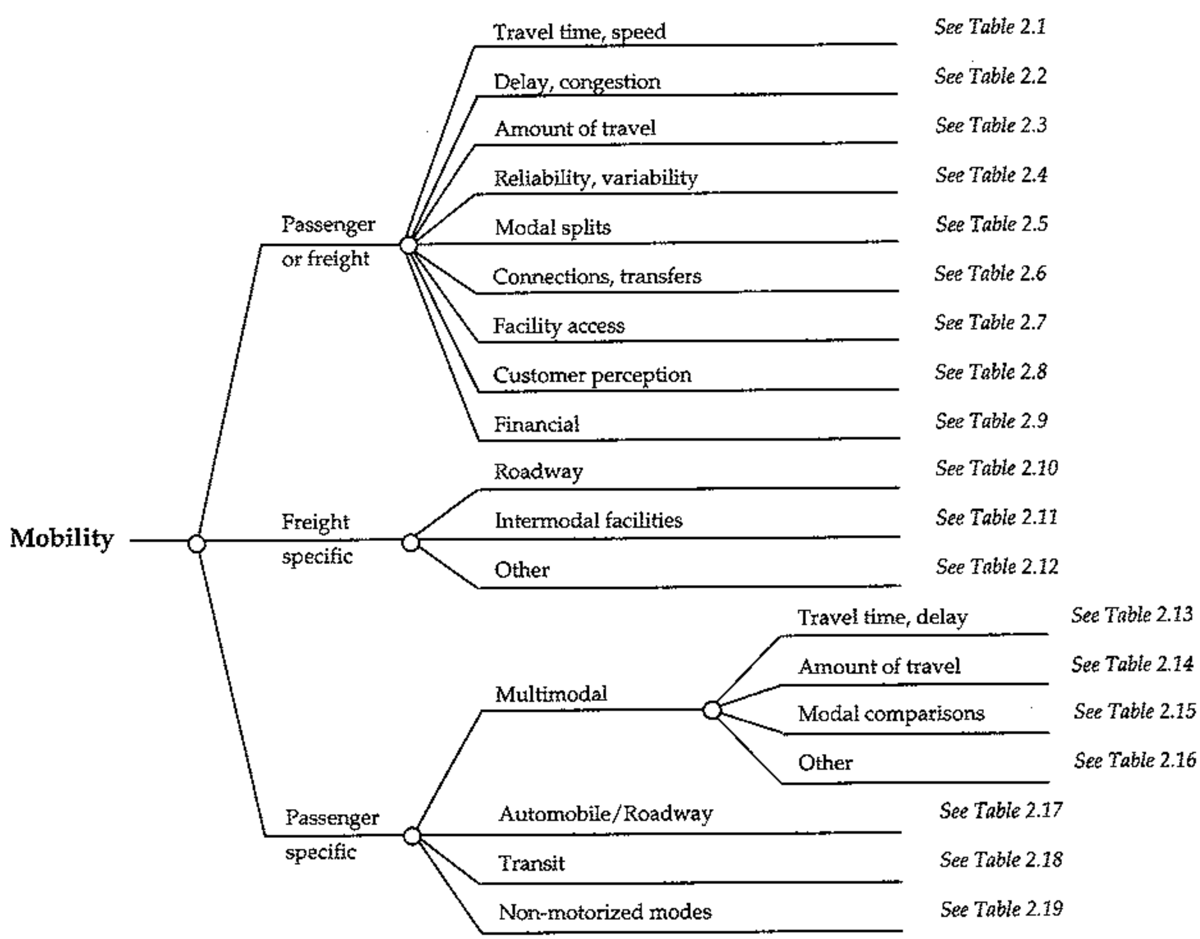

Figure 2. Mobility measures.

TABLE 2.1 Mobility
Passenger or Freight
Travel Time, Speed

Performance Measure	Reference
Origin-destination travel times (by mode)	*3, 4, 5, 7, 8, 11*
Total travel time (by mode)	*3, 4, 5, 7*
Average travel time from facility to destination (by mode)	*3*
Average speed	4

TABLE 2.2 Mobility
Passenger or Freight
Delay, Congestion

Performance Measure	Reference
VMT by congestion level	*5, 7, 8*
Travel time under congested conditions	4, 11
Percent of VMT which occurs on facilities with V/C greater than 'X'	11
Percent of VMT at LOS 'X'	4
Percent of highways not congested during peak hours	13
Number and percent of lane-miles congested	4, 5
Lost time due to congestion	*1, 3, 4*
Delay per VMT (by mode)	*3, 4, 5, 7*
Delay due to incidents	5, 11
Percentage of time average speed is below threshold value	4
Queuing of vehicles (including rail) and its relationship to overall delays	3
LOS	*1, 4, 5, 6*
Intersection LOS	*1, 4, 5, 6*
V/C ratio	*1, 4, 5, 8*
V/C by route	8
Reserve capacity	14
Interference of movement at grade crossings – delay time and speed	3
Delay time at primary commercial airports	3

TABLE 2.3 Mobility
Passenger or Freight
Amount of Travel

Performance Measure	Reference
VHT per capita	4
VHT per employee	4
VMT per capita	*3, 4, 6, 11*
VMT per employee	*3, 4, 6, 11*
Total VMT	11
VMT growth rate relative to population, employment	4
VMT within urban areas	3
Average daily traffic	3
Average daily traffic per freeway lane	2

TABLE 2.4 Mobility
Passenger or Freight
Reliability, Variability

Performance Measure	Reference
Percentage of on-time performance	3
Percentage of scheduled departures that do not leave within a specified time limit	3
Travel time contours	4
Minute variation in trip time	5
Fluctuations in traffic volumes	3

TABLE 2.5 Mobility
Passenger or Freight
Modal Splits

Performance Measure	Reference
Percent of change in mode splits	3
Overall mode split	*3*
Mode split by facility or route	*3*

TABLE 2.6 Mobility
Passenger or Freight
Connections, Transfers

Performance Measure	Reference
Percent of transfers between modes to be under 'X' minutes and 'N' feet	3
Transfer time between modes	*3*
Number of users of intermodal facilities	3

TABLE 2.7 Mobility
Passenger or Freight
Facility Access

Performance Measure	Reference
Time to access intermodal facilities	3
Average travel time from facility to major highway network	*3*
LOS on facility access roads	3
V/C on facility access roads	3
LOS at intersections serving facility	*3, 4*

TABLE 2.8 Mobility
Passenger or Freight
Customer Perception

Performance Measure	Reference
Customer perception of time it takes to travel to places people/goods need to go	5
Customer perception of time it takes to drive through highway construction areas	5
Customer perception of ease of travel through highway construction areas	5
Perceived deficiencies	3

TABLE 2.9 Mobility
Passenger or Freight
Financial

Performance Measure	Reference
Cost/benefit of existing facility vs. new construction	3
Number and dollar value of projects that improve travel time on key routes	5

TABLE 2.10 Mobility
Freight Specific
Roadway

Performance Measure	Reference
Delay per ton-mile traveled (by mode)	*3, 4, 5, 7*
Ton-miles traveled by congestion level	*5, 7, 8*
Line-haul speed	3, 4
Capacity restrictions	3
Miles of freight routes with adequate capacity	5
Percent of lane-miles which are truck priority (or excluded)	11
Tonnage moved on various transportation components (by mode)	*3, 4, 5, 12*
Facility usage by mode (V/C)	3
Freight carrier (or local shippers) appraisal of quality of highway service in terms of travel time/speed, delay, circuity, scheduling convenience	11
Truck VMT by light duty, heavy duty, and through trips	11
Ton-miles of rail freight into/through metropolitan areas	11
Truck delivery and loading interference with street traffic	3, 4

TABLE 2.11 Mobility
Freight Specific
Intermodal Facilities

Performance Measure	Reference
Average transfer time/delays	*3, 4, 5*
Dwell time at intermodal facilities	3
Truck turnaround time at intermodal terminals	3
Average processing time for shipments at intermodal terminals	11
Delay of trucks at facility per VMT	3
Delay of trucks at facility per ton-mile	3
Frequency of delays at intermodal facilities	3
Customs delays	3
Tons of commodity undergoing intermodal transfer	11
Average travel time between intermodal facility and rail	3

TABLE 2.12 Mobility
Freight Specific
Other

Performance Measure	Reference
Average cost (or speed) for a sample of shipments	7, 11
Traffic at border crossings	3
Number of dockage days at seaports	11

TABLE 2.13 Mobility
Passenger Specific
Multimodal
Travel Time, Delay

Performance Measure	Reference
PMT by congestion level	*5, 7, 8*
Origin-destination travel times (by mode)	*3, 4, 5, 7, 8, 11*
In-vehicle travel time	4, 11
Average commuting time for urban population	3, 4
Proportion of persons delayed	4

TABLE 2.14 Mobility
Passenger Specific
Multimodal
Amount of Travel

Performance Measure	Reference
PMT per capita	3, 4
PMT per worker	3, 4
PHT	3, 4
Passenger-trips per household	4, 6
Vehicle-trips per household	4, 6
Number of non-work trips	4, 6

TABLE 2.15 Mobility
Passenger Specific
Multimodal
Modal Comparisons

Performance Measure	Reference
Cost of an intermodal trip as a percent of cost of auto use	3
Origin-destination travel times (by mode)	*3, 4, 5, 7, 8, 11*
Percent of trips with transit advantage	14
Percent of passengers traveling under five miles made by means other than SOV	13
Percent of workers who work at home because of transportation cost or level of service	11
Percent of workers who work at home	11

TABLE 2.16 Mobility
Passenger Specific
Multimodal
Other

Performance Measure	Reference
Mobility index [person-miles (or ton-miles) of travel/vehicle-miles of travel (PMT/VMT) times average speed]	1, 4
Number of people provided service at travel information centers	3

TABLE 2.17 Mobility
Passenger Specific
Automobile/Roadway

Performance Measure	Reference
Percent of lane-miles of recreational routes operating below LOS D	5
Vehicle ownership, demand per licensed driver (or worker)	4, 11

TABLE 2.18 Mobility
Passenger Specific
Transit

Performance Measure	Reference
On-time performance of transit	*3, 5, 8*
Frequency of transit service	*1, 3, 4*
Average wait time to board transit (or between modes)	3
Number of public transportation trips	3, 11
Passengers per capita within urban service area	3
Number of commuters using transit park-and-ride facilities	13
Number of demand-response trip requests	3
Percent of transit demand-response trip requests met	4

TABLE 2.19 Mobility
Passenger Specific
Non-Motorized Modes

Performance Measure	Reference
Percent use of walking and bicycling for commute trips (or all trips)	8
V/C for bicycle and pedestrian facilities	3
Bicycles per boarding	3

3.0 ECONOMIC DEVELOPMENT

Economic development is frequently viewed as the underlying reason for providing transportation infrastructure. While the relationships between transportation investment and economic growth and productivity are complex, transportation systems are an unquestionable prerequisite for economic activity.

The economic development measures are divided into those that measure the transportation system's direct economic impacts (e.g., congestion costs) and those that measure the economic health and vitality that transportation supports (e.g., number of businesses with good transportation service).

The most commonly cited economic development measures address jobs directly supported by transportation and the cost of transportation-related disbenefits. Transportation jobs can be determined by examining employment data from the Bureau of Labor Statistics or the U. S. Census. Assessing the cost of transportation-related disbenefits, such as accidents and lost time, requires, first, determining the amount of disbenefit (e.g., the number of hours lost in delay) and, second, assigning a dollar value to one unit of disbenefit (e.g., the value of one hour in delay). For more information, see Figure 3 and Tables 3.1 through 3.4.

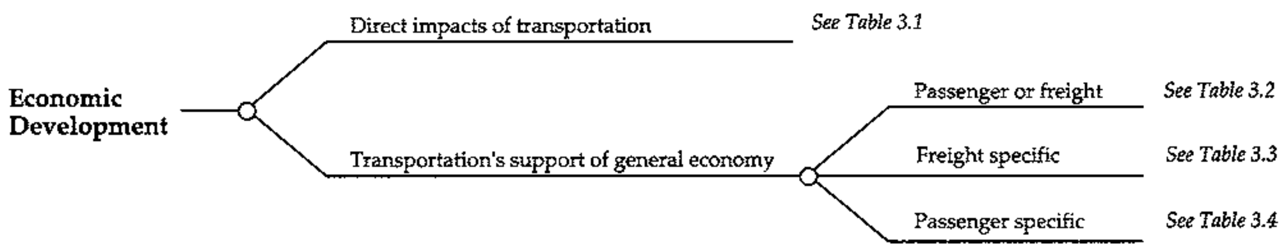

Figure 3. Economic development measures.

TABLE 3.1 Economic Development
Direct Impacts of Transportation

Performance Measure	Reference
Direct jobs supported (or created)	1, 3, 4
Percent of state gross product	3
Economic costs of pollution	1, 3
Economic costs of accidents	1, 3, 4, 5, 8
Economic costs of fatalities	1, 3
Economic costs of lost time	1, 3, 4
Economic costs of congestion	4, 5
Property damage accidents/vehicle miles traveled	5

TABLE 3.2 Economic Development
Transportation's Support of General Economy
Passenger or Freight

Performance Measure	Reference
Indirect jobs supported (or created)	1, 3, 4

TABLE 3.3 Economic Development
Transportation's Support of General Economy
Freight Specific

Performance Measure	Reference
Economic indicator for goods movement	5
Percent of state residents aware of intermodal opportunities	3
Percent of wholesale and retail sales in the significant economic centers served by unrestricted (10-ton) market artery routes	5
Price index for selected local delivery service	11
Percent of manufacturers/shippers who have relocated for transportation purposes	11
Traffic at border crossings	3
Number of shipping establishments per 1,000 businesses	2
Regional truck VMT per unit of regional economic activity/output	11
Tonnage moved on various transportation components (by mode)	*3, 4, 5, 12*
Market share of international or regional trade by mode	3, 8
Percent increase in intermodal facilities use	3
Tonnage originating and terminating	4
Business volume by commodity group	11

TABLE 3.4 Economic Development
Transportation's Support of General Economy
Passenger Specific

Performance Measure	Reference
Economic indicator for people movement	5
Percent of employers that cite difficulty in accessing desired labor supply due to transportation	11
Employee-related percent of employers who have relocated for transportation reasons	11
Percent of region's unemployed or poor who cite transportation access as a principal barrier to seeking employment	11
Number of cruise embarkations	12

4.0 QUALITY OF LIFE

Quality of life is closely related to the first four categories of goals and objectives. Certainly, the enjoyment of accessibility, mobility, and economic prosperity contributes to quality of life. Typically, however, quality of life is associated with those attributes that are more difficult to measure in economic terms. These attributes may include things such as aesthetics, a sense of community, and people's general sense of satisfaction.

The measures are categorized by the aspect of life quality that they affect (e.g., safety, land use, and noise).

Three types of quality-of-life measures are frequently cited: time lost due to delay, the level and rate of accidents, and the amount of air pollution. Time lost is typically estimated by using travel models. Accident data are usually consolidated by and can be obtained from state highway patrols. Information on air pollution is typically collected by regional air quality management districts. For more information, see Figure 4 and Tables 4.1 through 4.8.

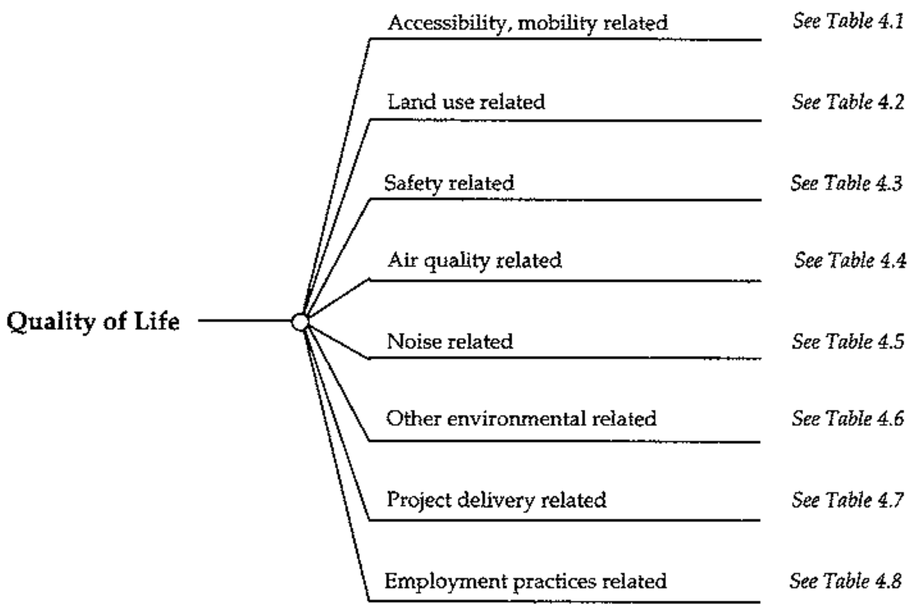

Figure 4. Quality of life measures.

TABLE 4.1 Quality of Life
Accessibility, Mobility Related

Performance Measure	Reference
Percent of population that perceives that its environment has become more 'livable' over the past year with regard to ability to access desired activities	11
Percent of region's unemployed or poor that cite transportation access as a principal barrier to seeking employment	11
Percent of region's persons with mobility impairments who can reach specific activities by public transportation or by walking/wheelchair	11
Customer perception of satisfaction with commute time	5
Customer perception of quality of transit service	11
Lost time due to congestion	*1, 3, 4*
Average number of hours spent traveling	11
Worktrips completed per vehicle hour or commute travel	1

TABLE 4.2 Quality of Life
Land Use Related

Performance Measure	Reference
Sprawl: difference between change in urban household density and suburban household density	2

TABLE 4.3 Quality of Life
Safety Related

Performance Measure	Reference
Accidents (or injuries or fatalities)/VMT	*1, 3, 4, 5, 7, 11*
Accidents (or injuries or fatalities)/PMT	*1, 3, 4, 5, 7, 11*
Customer perception of safety while in travel system	*1, 3, 5*
Percent of population which perceives that response time by police, fire, rescue, or emergency services has become better or worse and whether that is due to transportation factors	11

TABLE 4.4 Quality of Life
Air Quality Related

Performance Measure	Reference
Tons of pollution (or vehicle emissions) generated	*1, 3, 4, 5, 7, 11*
Number of days that Pollution Standard Index is in unhealthful range	2, 11
Number of urban areas (or population in areas) classified as nonattainment status	*3, 4, 5*
Customer perception of satisfaction with air quality	5

TABLE 4.5 Quality of Life
Noise Related

Performance Measure	Reference
Percent of population exposed to levels of highway noise above 60 decibels	11
Number of residences exposed to noise in excess of established thresholds	5
Number of noise receptor sites above threshold	8

TABLE 4.6 Quality of Life
Other Environmental Related

Performance Measure	Reference
Customer perception of satisfaction with transportation decisions which impact the environment	5
Customer perception of amount of salt used on trunk highways	5
Number of archeological and historical sites that are not satisfactorily addressed in project development before construction begins	5

TABLE 4.7 Quality of Life
Project Delivery Related

Performance Measure	Reference
Customer perception of satisfaction with involvement in pre-project planning	5
Customer perception of satisfaction with completed projects	5
Customer perception of promises kept on project completion	5

TABLE 4.8 Quality of Life
Employment Practices Related

Performance Measure	Reference
Compliance with affirmative action goals	5, 10

5.0 ENVIRONMENTAL AND RESOURCE CONSERVATION

The conservation of environmental resources is a desired byproduct of transportation systems. Society wishes to foster mobility, accessibility, economic development, and quality of life through transportation but, at the same time, wishes to minimize undue damage to the environment. Measures of environmental and resource conservation may be given in terms of resources saved (e.g., gallons of fuel conserved) or in terms of resources expended (e.g., tons of pollutants emitted).

The measures are categorized by the type of resource that they affect (e.g., energy or air pollution).

The most commonly cited environmental and resource conservation measures track mode share, air pollution, and fuel usage. Mode share is often established by surveys done at specific geographic locations. Information on air pollution is typically collected by regional air quality management districts. Fuel usage can be determined by multiplying the total amount of travel estimated by a travel model with an estimate of the average fuel usage per vehicle-mile, from the agency responsible for administering the fuel tax in those States with a fuel tax, or from data obtained directly from fuel retailers. For more information, see Figure 5 and Tables 5.1 through 5.8.

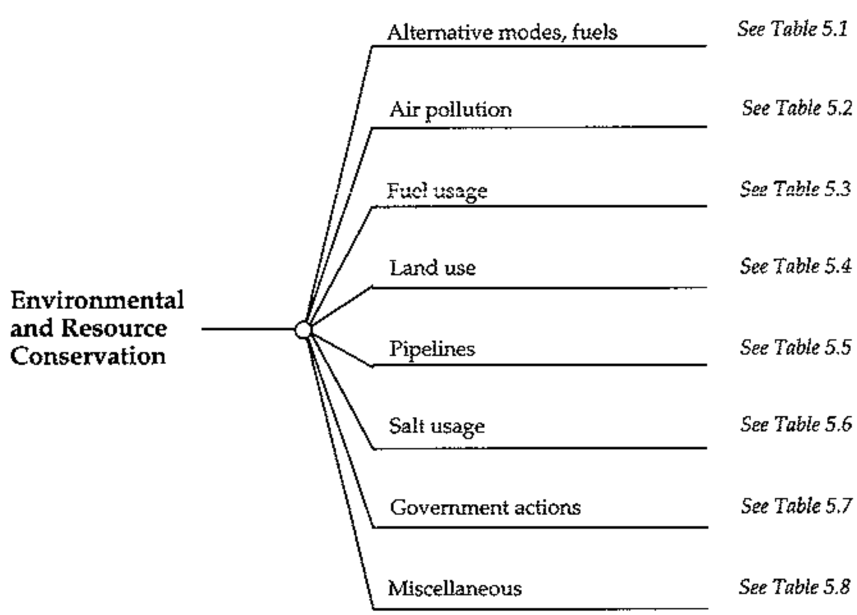

Figure 5. Environmental and resource conservation measures.

TABLE 5.1 Environmental and Resource Conservation
Alternative Modes, Fuels

Performance Measure	Reference
Overall mode split	3
Mode split by facility or route	3
Percent of change in mode splits	3
Public transportation passenger-miles/total vehicle-miles	2
Percent of vehicles using alternative fuels	4, 10
Percent use of walking and bicycling for commute trips (or all trips)	8
Number of miles of non-motorized facilities	3

TABLE 5.2 Environmental and Resource Conservation
Air Pollution

Performance Measure	Reference
Tons of pollution (or vehicle emissions) generated	*1, 3, 4, 5, 7, 11*
Highway emissions levels within non-attainment areas	10
Tons of greenhouse gases generated	1, 3
Air quality rating	5
Number of days that Pollution Standard Index is in unhealthful range	2, 11
Number of urban areas (or population in areas) classified as nonattainment status	*3, 4, 5*
Customer perception of satisfaction with air quality	5

TABLE 5.3 Environmental and Resource Conservation
Fuel Usage

Performance Measure	Reference
Fuel consumption per VMT	11
Fuel consumption per PMT	11
Fuel consumption per ton-mile traveled	11
Average miles per gallon (MPG)	11
Fuel usage	*3, 4, 7*
Average fuel consumption per trip for selected trips (or shipments)	11

TABLE 5.4 Environmental and Resource Conservation
Land Use

Performance Measure	Reference
Sprawl: difference between change in urban household density and suburban household density	2
Percent of region which is developed	2

TABLE 5.5 Environmental and Resource Conservation
Pipelines

Performance Measure	Reference
The degree to which pipeline spills and accidents are minimized	3
Number of pipeline spills	9

TABLE 5.6 Environmental and Resource Conservation
Salt Usage

Performance Measure	Reference
Amount of salt used per VMT or per lane-mile	5
Customer perception of amount of salt used on trunk highways	5

TABLE 5.7 Environmental and Resource Conservation
Government Actions

Performance Measure	Reference
Customer perception of satisfaction with transportation decisions which impact the environment	5
Number of environmental problems to be taken care of with existing commitments	14
Number of transportation control measures (TCMs) accomplished vs. planned	1
Environmentally friendly partnership projects per year	5

TABLE 5.8 Environmental and Resource Conservation
Miscellaneous

Performance Measure	Reference
VMT/speed relationships	4
Constraints to utilization due to noise (hours of operation)	3
Constraints to utilization due to water (dredge fill permits)	3
Number of accidents involving hazardous waste	*3, 5, 11*
Amount of recycled material used in road construction	5
Number and miles of designated scenic routes	5

6.0 SAFETY

Safety is similar to environmental conservation in that it is a state that we wish to enjoy while attaining other goals. Society wishes to remain safe while attaining mobility, productivity, and so forth. The lack of safety has a definite impact on society in the costs of accidents, injuries, and property damage.

The safety measures are first categorized by type of infrastructure (e.g., safety on the roadway network, safety in parking areas, and transit safety). Where appropriate, these categories are divided into finer subcategories.

The most frequently cited type of safety measure deals with the level and rate of accidents. Accident data are usually consolidated by and can be obtained from state highway patrols. Two other frequently cited types of safety measures are incident response time and roadway conditions. Response time data can also be obtained from state highway patrols. For State-controlled and -operated roads, roadway condition data are maintained by the DOT. For local roads, this information is collected by each individual city and municipality. For more information, see Figure 6 and Tables 6.1 through 6.15.

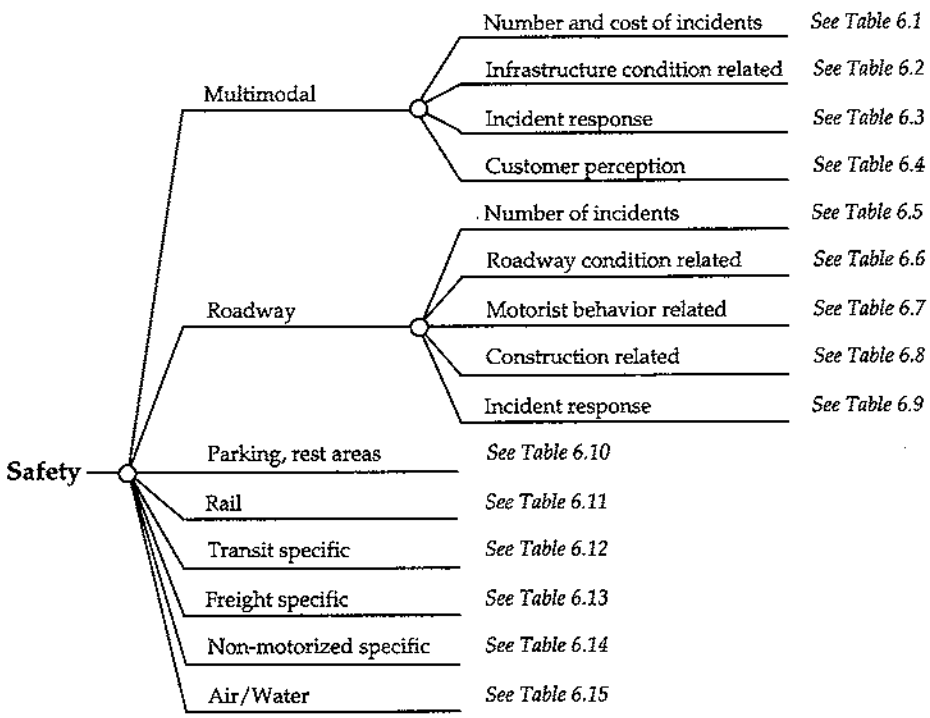

Figure 6. Safety measures.

TABLE 6.1 Safety
Multimodal
Number and Cost of Incidents

Performance Measure	Reference
Number of accidents per VMT	*3, 4, 5*
Number of accidents per year	*3, 4, 5, 11*
Number of accidents per trip	*3, 4, 5, 11*
Number of accidents per capita	*3, 11*
Number of accidents per intermodal movement	*3, 4, 5*
Number of accidents per ton-mile traveled	*3, 4, 5*
Hazard index (calculated based on accidents per VMT by severity)	4, 7
Accident rate, deaths, injury, property loss by type of corridor	1, 4
National rank for accident, injury, fatality rates	4
Average accident cost per trip	3
Fatality (or injury) rate of accidents	3
Alcohol-related fatal accidents/all fatal accidents	3
Accidents (or injuries or fatalities) per 'X' users of intermodal transfer points	3
Dollar value of property loss per 'X' users of intermodal transfer points	3

TABLE 6.2 Safety
Multimodal
Infrastructure Condition Related

Performance Measure	Reference
Number of high-accident (or hazardous) locations	3, 4
Accident risk index ('Safety Index')	4
Number of safety-related improvements	5

TABLE 6.3 Safety
Multimodal
Incident Response

Performance Measure	Reference
Response time to incidents	*1, 5, 11*
Average duration of incidents	5

TABLE 6.4 Safety
Multimodal
Customer Perception

Performance Measure	Reference
Customer perception of safety while in travel system	*1, 3, 5*
Number of safety-related complaints	4
Percent of population which perceives that response time by police, fire, rescue, or emergency services has become better or worse and whether that is due to transportation factors	11

TABLE 6.5 Safety
Roadway
Number of Incidents

Performance Measure	Reference
Accidents (or injuries or fatalities)/VMT	*1, 3, 4, 5, 7, 11*
Accidents (or injuries or fatalities)/PMT	*1, 3, 4, 5, 7, 11*
Number of statewide traffic accidents (or injuries or fatalities)	3
Property damage accidents/vehicle miles traveled	5

TABLE 6.6 Safety
Roadway
Roadway Condition Related

Performance Measure	Reference
Percent of vehicle crashes on highway system where roadway-related conditions were listed as a contributing factor	12
Number of highway miles driven at high-accident locations	13
Percentage of highway mainline pavement (or bridges) rated good or better	*3, 4, 5, 7, 8, 11, 12*
Roadway sections not meeting safety standards	4
Percent of highway miles built to target design and operational standards to handle traffic at a steady 55 mph rate	13
Accidents related to bridge characteristics	7
Customer satisfaction with snow/ice removal	5

TABLE 6.7 Safety
Roadway
Motorist Behavior Related

Performance Measure	Reference
Number of accidents in which speed or traffic violation is a factor	11
Number (or percent) of highway miles driven above speed limit	13
Number (or percent) of motorists driving under the influence of alcohol or drugs	13
Percent of drivers complying with seat belt law	3

TABLE 6.8 Safety
Roadway
Construction Related

Performance Measure	Reference
Construction fatalities/dollars of construction cost (or per 100 highway-related crew)	7, 10
Number of accidents occurring in highway construction zones	13

TABLE 6.9 Safety
Roadway
Incident Response

Performance Measure	Reference
Average response time for emergency services	*1, 5, 11*
Percentage of emergency road calls that get through to state highway agency	10

TABLE 6.10 Safety
Parking, Rest Areas

Performance Measure	Reference
Accidents (or injuries or fatalities) per 1,000 vehicles at park-and-ride lot	3
Percentage of parking areas that are secured	3
Lighting and security staff at parking areas	3
Crime at rest areas and other facilities	3, 10

TABLE 6.11 Safety
Rail

Performance Measure	Reference
Number of fatalities and injuries occurring on the rail system	3
Exposure (AADT and daily trains) factor for rail crossings	4
Accidents at major intermodal crossings	*1, 3, 4, 11*
Railroad/highway at-grade crossings	*3, 4*
Grade crossing safety improvements (MI)	3

TABLE 6.12 Safety
Transit Specific

Performance Measure	Reference
Transit accidents (or injuries or fatalities)/PMT	13
Transit accidents (or injuries or fatalities)/VMT	13
Number of intercity bus and rail accidents	3
Crimes per 1,000 passengers	3
Ratio of number of transit incidents to investment in transit security	5

TABLE 6.13 Safety
Freight Specific

Performance Measure	Reference
Number of commercial vehicles weighed (by fixed and portable scales)	12
Number of commercial vehicle safety inspections performed	12
Percent of commercial vehicles that pass safety inspections	12
Percent of commercial vehicles weighed that are overweight (by fixed and portable scales)	12
Number of accidents involving hazardous waste	*3, 5, 11*
Percentage of state truck highway system rated good or better	5
Percent of traffic on regional highway which is heavy truck	11

TABLE 6.14 Safety
Non-Motorized Specific

Performance Measure	Reference
Bicycle accidents (or injuries or fatalities) per bicycle-mile of travel	*1, 8, 12*
Number of pedestrian accidents (or injuries or fatalities)	3, 8
Use of safety equipment by bicyclists	3
Joint-use bicycle crossings	3

TABLE 6.15 Safety
Air/Water

Performance Measure	Reference
Accidents (or injuries or fatalities) caused by air transportation	3
Percentage of airports that meet federal and state planning and design standards	3
Number of landing areas inspected	5
Number of airports where weather information is collected for dissemination to pilots	5
Number of weather products provided to pilots on computer weather terminals	5
Total annual attendance at pilot safety seminars	5
Accidents (or injuries or fatalities) caused by waterborne transportation	3
Shipping accidents occurring on waterways	3

7.0 OPERATIONAL EFFICIENCY

Operational efficiency refers to the efficiency with which resources are used to produce a given level of transportation output. There are families of measures that reflect, for example, labor productivity or the operating efficiency of transit systems. Again, while operational efficiency is not, in and of itself, a fundamental purpose of transportation systems, it is certainly a desirable characteristic and an area of great concern to many practitioners. Measures of operational efficiency are typically the concern of transportation system **suppliers** and are associated with system **efficiency.**

The operational efficiency measures are first divided into a set applicable to both passenger or freight movement, a second set specifically addressing freight movement, and finally, a third set specifically addressing passenger movement. Where appropriate, these subcategories are further divided into measures of how efficient systems are from a financial point of view, a time point of view, an operational point of view, and the customer's point of view.

The five most frequently cited types of operational efficiency measures are trip time, congestion-related (e.g., V/C ratio and LOS), mode share, transfer time at connecting facilities, and transit cost performance. Trip time and congestion-related measures are typically estimated with a travel model, though trip time is sometimes determined with data collected from the field. Mode share is often established by surveys done at specific geographic locations. Connecting times at transfer facilities can be determined with field data or user surveys. Transit cost data, such as farebox recovery ratio and cost per revenue-mile, can be obtained from FTA Section 15 reports or directly from transit operators. For more information, see Figure 7 and Tables 7.1 through 7.22.

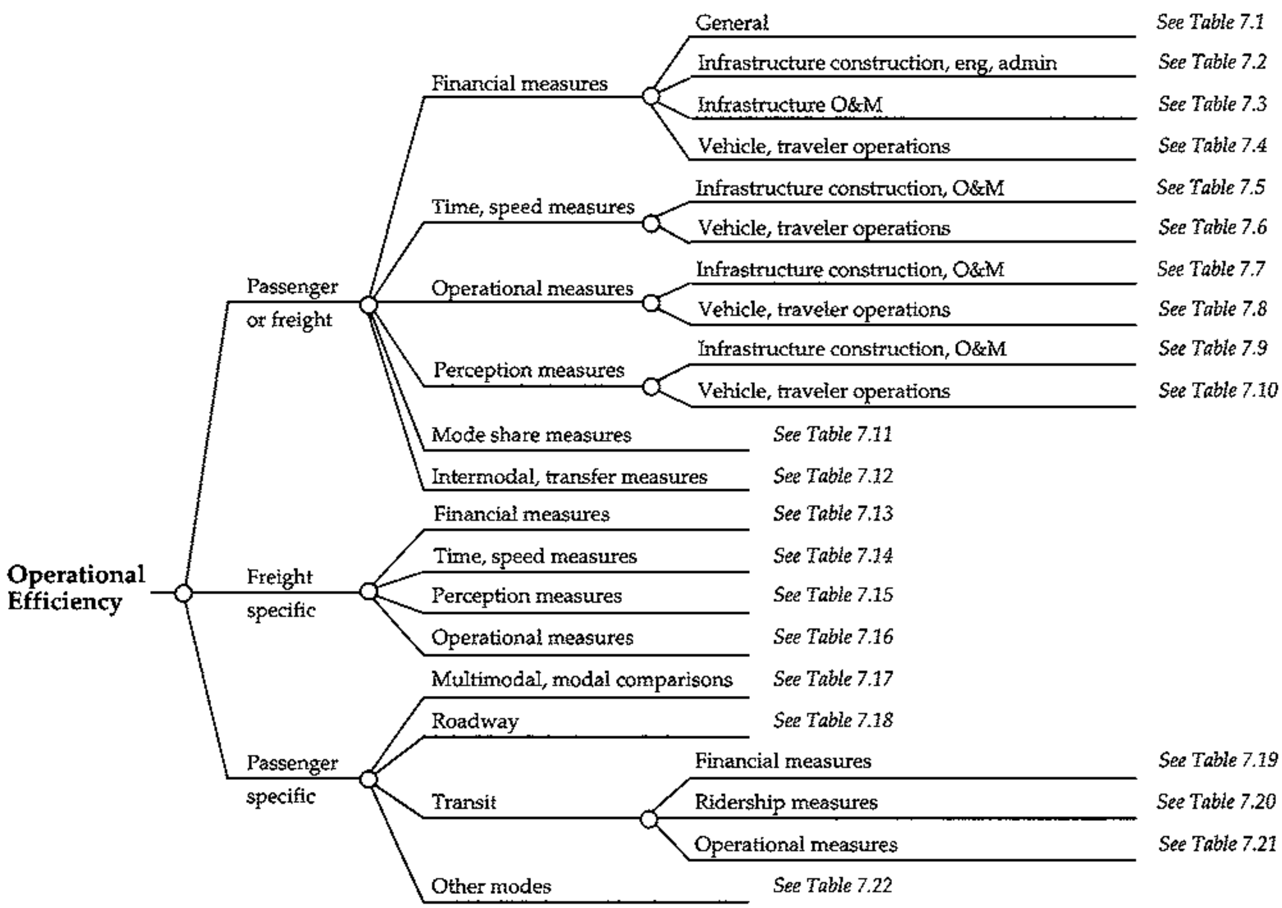

Figure 7. Operational efficiency measures.

TABLE 7.1 Operational Efficiency
Passenger or Freight
Financial Measures
General

Performance Measure	Reference
Public cost for transportation system	9
Private cost for transportation system	9
Total public expenditures on modal systems (freight vs. passenger)	4
Dollar value of flexible federal funding programmed for non-highway projects	3
Percent of variances between actual versus predicted DOT revenues	13

TABLE 7.2 Operational Efficiency
Passenger or Freight
Financial Measures
Infrastructure Construction, Eng, Admin

Performance Measure	Reference
Cost/benefit of existing facility vs. new construction	3
Number and dollar value of projects that improve travel time on key routes	5
Dollar allotment and percent of trunk highway funds going to construction	5
Administrative, engineering and construction cost/person – (or ton) mile (owner cost)	3
Average cost per lane-mile constructed	3
Cost per percentage point increase in lane miles rates fair or better on pavement condition	13
Percentage of increase in final amount paid for completed construction over original contract amount	12
Unprogrammed construction costs as a percentage of total construction costs	13
Percent cost of re-work	13
All engineering costs/construction funds	5
Dollar allotment and percent of funds going to non-engineering activities	5
Dollar allotment and percent of department funds consumed by overhead	5
Administrative costs as a percent of total program	12
Data center costs as a percentage of total program	12
Construction Productivity Index (Cost of contract lettings, utilities, real estate acquisition, construction, change orders, and cost overruns DIVIDED BY staff costs, consultant contracts, and design construction change orders)	13
Proportion of infrastructure investment from private sources	3
Partnership benefits (to taxpayers and partners)	5
Savings to taxpayers/public from partnerships	5
Number and dollar value of projects jointly funded	5

TABLE 7.3 Operational Efficiency
Passenger or Freight
Financial Measures
Infrastructure O&M

Performance Measure	Reference
Infrastructure maintenance expense	4
Maintenance cost of connector link	3
Operational cost per toll transaction	12

TABLE 7.4 Operational Efficiency
Passenger or Freight
Financial Measures
Vehicle, Traveler Operations

Performance Measure	Reference
Average cost per mile	3
Average cost per trip	3
Vehicle operating cost reductions	3
Additional costs per trip (user fees)	3
Reduced costs per trip (subsidies)	3
Use cost/person-mile (user cost)	3
Insurance costs	3
Value of fuel savings	3

TABLE 7.5 Operational Efficiency
Passenger or Freight
Time, Speed Measures
Infrastructure Construction, O&M

Performance Measure	Reference
Percentage of increase in number of days required for completed construction contracts over original contract days	12
Units of work completed per hour worked	13
Average days to complete driver licensing or vehicle registration transactions	13
Percent of invoices processed within five days of receipt	13

TABLE 7.6 Operational Efficiency
Passenger or Freight
Time, Speed Measures
Vehicle, Traveler Operations

Performance Measure	Reference
Origin-destination travel times (by mode)	*3, 4, 5, 7, 8, 11*
Total travel time (by mode)	*3, 4, 5, 7*
Average travel time from facility to destination (by mode)	3
Average travel time from facility to major highway network	3
Average speed	4
Speed limits and difference between modes	3
Flow time in minutes as it compares to the number of connecting transfers	3
Delay due to incidents	5, 11
Delay time at primary commercial airports	3

TABLE 7.7 Operational Efficiency
Passenger or Freight
Operational Measures
Infrastructure Construction, O&M

Performance Measure	Reference
Percent of projects rated good to excellent in quality audits	13
Percent of projects with no premature maintenance problems	13
Percent of projects requiring few or no significant change orders due to plan errors	13
Vehicle-miles traveled per highway department employees	13
Number of projects applying technology developed or available in last 'X' years	5
Transactions completed per motor vehicle division employee	13
Percent of error-free data in IMS database	3
Percentage of information and data exchanged between intrastate agencies	3

TABLE 7.8 Operational Efficiency
Passenger or Freight
Operational Measures
Vehicle, Traveler Operations

Performance Measure	Reference
Number of projects (area and population) accessible to designated development centers	5
VMT per mile of roadway	4
Average daily traffic per freeway lane	2
V/C ratio	*1, 4, 5, 8*
V/C by route	8
Performance of state roads based on HPMS ratings	3
Ton-miles per gallon of fuel	
Average fuel consumption per trip for selected trips (or shipments)	11
Percent of lane miles with toll pricing	11
Percent of highway tolls pre-paid	5
Number of toll transactions	12
Number of people provided service at travel information centers	3

TABLE 7.9 Operational Efficiency
Passenger or Freight
Perception Measures
Infrastructure Construction, O&M

Performance Measure	Reference
Management/employee satisfaction with progress toward targeted focus area	5
Management/employee satisfaction with diversity efforts	5
Management/employee satisfaction with communication of agency goals	5

TABLE 7.10 Operational Efficiency
Passenger or Freight
Perception Measures
Vehicle, Traveler Operations

Performance Measure	Reference
Customer perception of satisfaction with completed projects	5
Customer perception of promises kept on project completion	5
Percent of customers satisfied with licensing and registration process	13

TABLE 7.11 Operational Efficiency
Passenger or Freight
Mode Share Measures

Performance Measure	Reference
Overall mode split	3
Mode split by facility or route	3
Percent of change in mode splits	3

TABLE 7.12 Operational Efficiency
Passenger or Freight
Intermodal, Transfer Measures

Performance Measure	Reference
Percent of transfers between modes to be under 'X' minutes and 'N' feet	3
Transfer time between modes	3
Number of users of intermodal facilities	3
Percent of intermodal connecting points and facilities accurately placed on a map	3

TABLE 7.13 Operational Efficiency
Freight Specific
Financial Measures

Performance Measure	Reference
Revenue per ton-mile by mode	3
Cost per ton-mile by mode	3, 4
Cost per ton of freight shipped	5, 7
Cost per fuel-mile as it compares to cost per air (or water or rail) mile	3
Shipping cost per shipment	4
Cost by commodity	3
Average transfer costs	3, 5
Rail freight revenue versus operating expenses	13
Additional revenue earned by producers when shipping via rail	5
Ratio of oversize/overweight permit fees collected to dollar value of damage caused	3, 4

TABLE 7.14 Operational Efficiency
Freight Specific
Time, Speed Measures

Performance Measure	Reference
Line-haul speed	3
Average travel time between intermodal facility and rail	3
Tons transferred per hour	3
Average transfer time/delays	*3, 4, 5*
Average processing time for shipments at intermodal terminals	11
Delay of trucks at facility per VMT	3
Delay of trucks at facility per ton-mile	3
Hours of access lost	3
Flow time in minutes as it compares to the number of connecting transfers	3
Customs and administrative processing time	3

TABLE 7.15 Operational Efficiency
Freight Specific
Perception Measures

Performance Measure	Reference
Freight carrier (or local shippers) appraisal of quality of highway service in terms of travel time/speed, delay, circuity, scheduling convenience	11

TABLE 7.16 Operational Efficiency
Freight Specific
Operational Measures

Performance Measure	Reference
Regional truck VMT per unit of regional economic activity/output	11
Number of restricted routes, additional mileage, increased costs	3
Productivity and utility by mode	3
Mode split (by ton-mile)	4
Facility usage by mode (V/C)	3
Proportion of freight traffic at facility on portion of network	3
Percentage of street traffic delivered off-peak	3
Number of carloads shipped/received on rail project lines	5

TABLE 7.17 Operational Efficiency
Passenger Specific
Multimodal, Modal Comparisons

Performance Measure	Reference
Cost of an intermodal trip as a percent of cost of auto use	3
Origin-destination travel times (by mode)	*3, 4, 5, 7, 8, 11*
Demand service elasticities for auto vs. transit	11
Demand service elasticities for work vs. non-work	11
Percent of workers who work at home because of transportation cost or level of service	11
Percent of work trips that are SOV	4
Percentage of all trips made by bicycling and walking	3
Average commuting time for urban population	3, 4
Change in commute travel person-miles and vehicle-miles per telecommuting occasion	3, 5
Worktrips completed per vehicle hour or commute travel	1

TABLE 7.18 Operational Efficiency
Passenger Specific
Roadway

Performance Measure	Reference
Cost per vehicle for parking fees	3
Percent of workers who have paid parking at employment sites	11
Percent of workers who have free parking at employment sites	11
VMT/PMT	1
Average vehicle occupancy	*3, 4, 5, 6, 11*
Percent of vehicles using high-occupancy lanes	13

TABLE 7.19 Operational Efficiency
Passenger Specific
Transit
Financial Measures

Performance Measure	Reference
Fare recovery rate of urban transit systems	*3, 4, 5*
Cost per PMT for urban transit systems	*1, 3, 5*
Cost per VMT for urban transit systems	*1, 3, 5*
Cost per revenue-mile for urban transit systems	*1, 3, 5*
Cost per passenger for urban transit systems	*1, 3, 5*
Cost per PMT in rural areas	3
Cost per VMT in rural areas	3
Cost per revenue-mile in rural areas	3
Cost per passenger in rural areas	3
Total transit operating expenditures per transit-mile	2
Grant dollars per transit trip	13

TABLE 7.20 Operational Efficiency
Passenger Specific
Transit
Ridership Measures

Performance Measure	Reference
Transit ridership per capita	*4, 5, 8*
Transit ridership-to-capacity ratio	5, 8
Transit riders per VMT	4, 13
Transit riders per route-mile	4, 13
Transit riders per revenue-mile	4, 13
Transit riders per gallon of fuel	4, 13
Ridership per VMT in rural areas	3
Number of public transportation trips	3, 11
Transit peak-load factor	4, 5
Riders at maximum load point	4
PMT on intercity rail and bus service	3
Intercity rail and bus service ridership	3
Rural service passengers	4

TABLE 7.21 Operational Efficiency
Passenger or Freight
Transit
Operational Measures

Performance Measure	Reference
Number of peak-period vehicles	4
Revenue vehicle hours per transit employee	13
Average wait time to board transit (or between modes)	3
Ratio of number of transit incidents to investment in transit security	5

TABLE 7.22 Operational Efficiency
Passenger or Freight
Other Modes

Performance Measure	Reference
V/C for bicycle and pedestrian facilities	3
Average cost for vehicle on ferry system	10
Enplanements per aviation system employee	4

8.0 SYSTEM PRESERVATION

System preservation refers to the physical condition of transportation infrastructure and equipment. Like operational efficiency, system condition is a characteristic of the transportation system rather than a purpose. Nonetheless, the preservation of transportation infrastructure is properly seen as an important mandate by most practitioners. Those measures that specifically refer to physical conditions or dimensions have been classified under the System Preservation category, recognizing that system condition can have an impact on the more fundamental goals for transportation systems.

System preservation measures are first divided by whether they measure the condition of the system itself (e.g., roadways with deficient ride quality) or whether they measure how efficiently transportation programs are delivered (e.g., cost to maintain roadways). The system condition measures are further subdivided by mode, and the program delivery measures are further divided into time-efficiency and cost-efficiency measures.

The most commonly cited type of system preservation measure has to do with roadway/bridge condition and age. For State-controlled and -operated roads, this information is maintained by the Department of Transportation. For local roads, this information is collected by each individual city and municipality. Other frequently cited system preservation measures are transit vehicles' servicing requirements and age. This information can be obtained directly from transit operators. For more information, see Figure 8 and Tables 8.1 through 8.11.

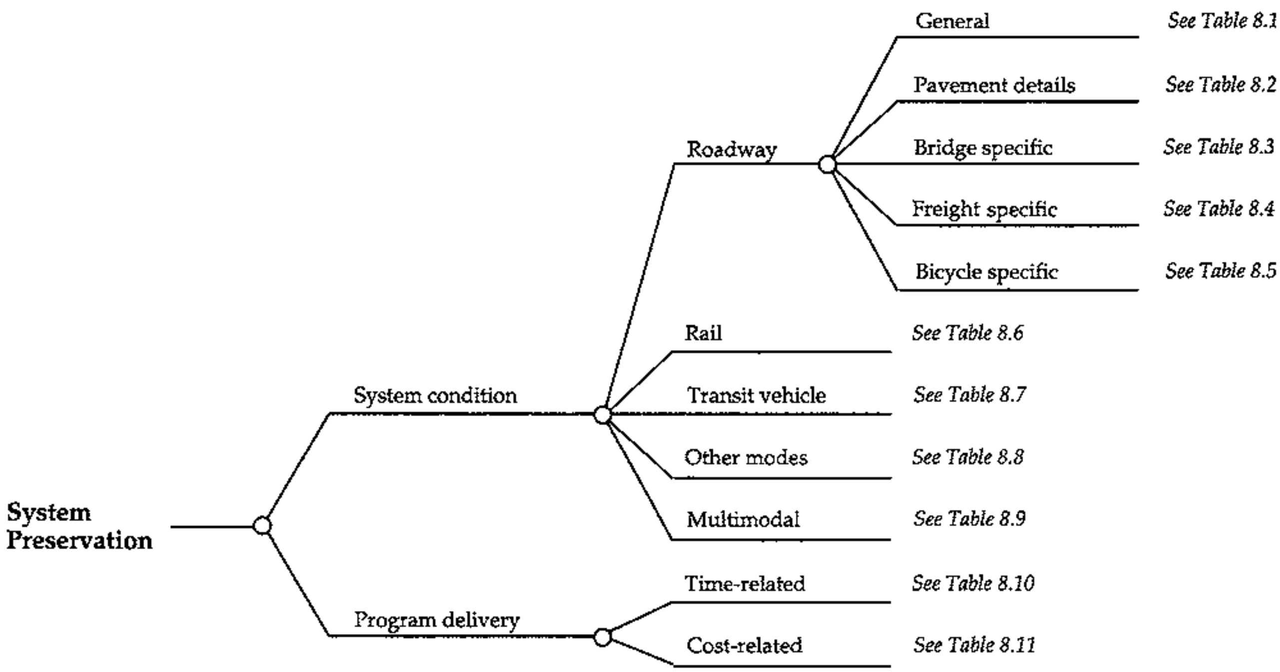

Figure 8. System preservation measures.

TABLE 8.1 System Preservation
System Condition
Roadway
General

Performance Measure	Reference
Percent of VMT on roads with deficient ride quality	4
Percent of roadway/bridge system below standard condition	*1, 5, 11, 12*
Age distribution	*4, 7, 11*
Remaining service life	4
Capacity/Remaining useful life index	8
Highway performance based on HPMS	10
Distribution of miles in PSC intervals	8
Present serviceability rating	4
Alignment (number of curves/grades defined as excessive by HPMS)	4, 9
Maintenance condition as measured against departmental standards	12

TABLE 8.2 System Preservation
System Condition
Roadway
Pavement Details

Performance Measure	Reference
Percent of lane-miles by pavement condition	7
Percentage of highway mainline pavement (or bridges) rated good or better	*3, 4, 5, 7, 8, 11, 12*
Pavement quality index	5
Remaining life of pavement	3
New composite index incorporating roughness and distress (pavement)	7
Roughness/ride index (IRI)	4, 7
Rut depth	4, 7
Skid/friction	4, 7
Distress index	4, 7
Joint condition	4, 7
Distress extent/severity by type (pavement)	7
Tons of asphalt placed by maintenance crews	12

TABLE 8.3 System Preservation
System Condition
Roadway
Bridge Specific

Performance Measure	Reference
Percentage of highway mainline bridges rated good or better	*3, 4, 5, 7, 8, 11, 12*
Scour criticality (bridges)	7
Deck chloride content (bridges)	7
Paint distress (bridges)	7
Backlog of repairs by different priority categories	7, 8
Steel bridges with section loss in a member (bridges)	7
Railings below standard (bridges)	7
Frequency distribution of bridge element condition (Pontis)	7

TABLE 8.4 System Preservation
System Condition
Roadway
Freight Specific

Performance Measure	Reference
Percentage of state truck highway system rated good or better	5
Miles of roadway not useable by certain traffic because of design or condition deficiencies	4
Percent of truck VMT or tonnage affected by weight restrictions (or clearance) on bridges	7
Percent of road system carrying unrestricted loads year round	6
Pavement condition on links to intermodal facilities	3

TABLE 8.5 System Preservation
System Condition
Roadway
Bicycle Specific

Performance Measure	Reference
Miles of highway rated 'good' or 'fair' for bicycle travel	5

TABLE 8.6 System Preservation
System Condition
Rail

Performance Measure	Reference
Track condition	3
Miles of track not useable by certain traffic because of design or condition deficiencies	4
Miles of track in operation (by FRA rating)	3, 4, 8, 11
Track-miles abandoned	3
Track-miles under threat of abandonment	3
Miles of rail line acquired and rehabilitated for rail service	5

TABLE 8.7 System Preservation
System Condition
Transit Vehicle

Performance Measure	Reference
Miles between road calls for transit vehicles	5, 7, 11
Age distribution	4, 7, 11
Remaining service life	4
Capacity/remaining useful life index	8
Present serviceability rating	4

TABLE 8.8 System Preservation
System Condition
Other Modes

Performance Measure	Reference
Miles of highway rated 'good' or 'fair' for bicycle travel	5
Miles to be dredged	9
Runway resurfacing frequency (airports)	8
Number of state-owned navigational aids	5

TABLE 8.9 System Preservation
System Condition
Multimodal

Performance Measure	Reference
System condition	3
Customer perception of condition of system	5
Hours (or days) out of service (for roads or bridges or transit equipment or airports)	*4, 7, 8*
Customer perception of amount of work being done to improve system	5
Missed trips due to operation failures	7, 8
Number of deficiencies corrected vs. number remaining	7
Backlog of repairs by different priority categories	7, 8
Number of right-of-way parcels acquired	12

TABLE 8.10 System Preservation
Program Delivery
Time-Related

Performance Measure	Reference
Percent of contracts planned for letting that were actually let	12
Number of lane miles let to contract for capacity improvements	12
Number of lane miles let to contract for resurfacing	12
Number of bridges let to contract for repair (or replacement)	12
State (or federal) construction (or maintenance) grants issued	5
Number of projects certified ready for construction	12
Number of transit (or rail or aviation or intermodal) projects funded (capital and operating)	12
Maintenance hours	4

TABLE 8.11 System Preservation
Program Delivery
Cost-Related

Performance Measure	Reference
Net present value of future transit vehicle (or facility or bridge or pavement), equipment and facility capital, operating and maintenance costs	4, 7
Percent of budget allocated to system preservation activities	1
Current average maintenance costs	4, 5
Expenditures to retire deficiencies	3
Agency and user cost of doing nothing or cost-benefit of MR&R (Pontis) (bridges)	7
Maintenance cost of connector link	3
Expenditures for freight rail	3
Non-motorized expenditures	3

9.0 MEASURES RELEVANT TO MULTIPLE GOAL CATEGORIES

A number of the performance measures in this library are relevant to more than one of the eight goal categories and, thus, appear in more than one of the previous eight sections. Table 9.1 is an alphabetical index of all the measures that occur in this library. In particular, the entries in Table 9.1 show which specific tables in Sections 1.0 through 8.0 the various measures appear in. This index provides a convenient way of determining which measures occur in multiple goal categories.

TABLE 9.1 Index of Performance Measures

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
Access time to passenger facility	1	1.15, 1.21							
Accessibility index	1	1.1							
Accident rate, deaths, injury, property loss by type of corridor	1						6.1		
Accident risk index ('Safety Index')	1						6.2		
Accidents (or injuries or fatalities) caused by air transportation	1						6.15		
Accidents (or injuries or fatalities) caused by waterborne transportation	1						6.15		
Accidents (or injuries or fatalities) per 1,000 vehicles at park-and-ride lot	1						6.10		
Accidents (or injuries or fatalities) per 'X' users of intermodal transfer points	1						6.1		
Accidents (or injuries or fatalities)/PMT	2				4.3		6.5		
Accidents (or injuries or fatalities)/VMT	2				4.3		6.5		
Accidents at major intermodal crossings	1						6.11		
Accidents related to bridge characteristics	1						6.6		
Additional costs per trip (user fees)	1							7.4	
Additional revenue earned by producers when shipping via rail	1							7.13	
Administrative costs as a percent of total program	1							7.2	
Administrative, engineering and construction cost/person- (or ton)mile (owner cost)	1							7.2	
Age distribution	1								8.1, 8.7
Agency and user cost of doing nothing or cost-benefit of MR&R (Pontis) (bridges)	1								8.11
Air quality rating	1					5.2			
Air transportation capacity	1	1.6							
Airport improvement and cost scheduled at airports	1	1.6							
Airports within a 30-minute drive of agricultural centers capable of supporting twin-engine piston-powered aircraft	1	1.6							
Alcohol-related fatal accidents/all fatal accidents	1						6.1		
Alignment (number of curves/grades defined as excessive by HPMS)	1								8.1
All engineering costs/construction funds	1							7.2	
Amount of recycled material used in road construction	1					5.8			
Amount of salt used per VMT or per lane-mile	1					5.6			
Amount of scheduled service between major cities	1	1.6							
Amount of turning radius from major highway to intermodal facility	1	1.10							
Availability of intermodal ticketing and luggage transfer	1	1.17, 1.21							
Availability of real-time cargo information	1	1.8							
Average accident cost per trip	1						6.1		
Average circuity for truck trips of selected O-D pattern	1	1.9							
Average commuting time for urban population	2		2.13					7.17	
Average cost (or speed) for a sample of shipments	1		2.12						
Average cost for vehicle on ferry system	1							7.22	
Average cost per lane-mile constructed	1							7.2	
Average cost per mile	1							7.4	
Average cost per trip	1							7.4	
Average daily traffic	1		2.3						
Average daily traffic per freeway lane	2		2.3					7.8	
Average days to complete driver licensing or vehicle registration transactions	1							7.5	
Average distance to intermodal terminals from different community shipping points	1	1.10							
Average duration of incidents	1						6.3		
Average fuel consumption per trip for selected trips (or shipments)	2					5.3		7.8	
Average miles per gallon (MPG)	1					5.3			
Average number of hours spent traveling	1				4.1				
Average processing time for shipments at intermodal terminals	2		2.11					7.14	
Average response time for emergency services	1						6.9		
Average speed	2		2.1					7.6	
Average transfer costs	1							7.13	

TABLE 9.1 (Continued)

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
Average transfer time/delays	2		2.11					7.14	
Average travel time between intermodal facility and rail	3	1.10	2.11					7.14	
Average travel time from facility to destination (by mode)	3	1.1	2.1					7.6	
Average travel time from facility to major highway network	3	1.1	2.7					7.6	
Average trip length	1	1.1							
Average vehicle occupancy	1							7.18	
Average wait time to board transit (or between modes)	2		2.18					7.21	
Backlog of repairs by different priority categories	1								8.3, 8.9
Bicycle accidents (or injuries or fatalities) per bicycle-mile of travel	1						6.14		
Bicycles per boarding	1		2.19						
Bridge weight limits	1	1.9							
Business volume by commodity group	1			3.3					
Capacity of intermodal terminals	1	1.10							
Capacity of package express carriers	1	1.8							
Capacity restrictions	1		2.10						
Capacity/remaining useful life index	1								8.1, 8.7
Change in commute travel person-miles and vehicle-miles per telecommuting occasion	1							7.17	
Compliance with affirmative action goals	1				4.8				
Connectivity deficiency	1	1.14							
Constraints to utilization due to noise (hours of operation)	1					5.8			
Constraints to utilization due to water (dredge fill permits)	1					5.8			
Construction fatalities/dollars of construction cost (or per 100 highway related crew)	1						6.8		
Construction Productivity Index (Cost of contract lettings, utilities, real estate acquisition, construction, change orders, and cost overruns DIVIDED BY staff costs, consultant contracts, and design construction change orders)	1							7.2	
Cost by commodity	1							7.13	
Cost of an intermodal trip as a percent of cost of auto use	2		2.15					7.17	
Cost per passenger in rural areas	1							7.19	
Cost per fuel-mile as it compares to cost per air (or water or rail) mile	1							7.13	
Cost per passenger for urban transit systems	1							7.19	
Cost per percentage point increase in lane mile rates fair or better on pavement condition	1							7.2	
Cost per PMT for urban transit systems	1							7.19	
Cost per PMT in rural areas	1							7.19	
Cost per revenue-mile for urban transit systems	1							7.19	
Cost per revenue-mile in rural areas	1							7.19	
Cost per ton of freight shipped	1							7.13	
Cost per ton-mile by mode	1							7.13	
Cost per vehicle for parking fees	1							7.18	
Cost per VMT for urban transit systems	1							7.19	
Cost per VMT in rural areas	1							7.19	
Cost/benefit of existing facility v. new construction	2		2.9					7.2	
Crime at rest areas and other facilities	1						6.10		
Crimes per 1,000 passengers	1						6.12		
Current average maintenance costs	1								8.11
Customer perception of amount of salt used on trunk highways	2				4.6	5.6			
Customer perception of amount of work being done to improve system	1								8.9
Customer perception of condition of system	1								8.9
Customer perception of ease of travel through highway construction areas	1		2.8						
Customer perception of promises kept on project completion	2				4.7			7.10	
Customer perception of quality of transit service	1				4.1				
Customer perception of safety while in travel system	2				4.3		6.4		
Customer perception of satisfaction with air quality	2				4.4	5.2			
Customer perception of satisfaction with commute time	1				4.1				

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TABLE 9.1 (Continued)

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
Customer perception of satisfaction with completed projects	2				4.7			7.10	
Customer perception of satisfaction with involvement in pre-project planning	1				4.7				
Customer perception of satisfaction with transportation decisions which impact the environment	2				4.6	5.7			
Customer perception of time it takes to drive through highway construction areas	1		2.8						
Customer perception of time it takes to travel to places people/goods need to go	1		2.8						
Customer satisfaction with snow/ice removal	1						6.6		
Customs and administrative processing time	1							7.14	
Customs delays	1		2.11						
Data center costs as a percentage of total program	1							7.2	
Deck chloride content (bridges)	1								8.3
Delay due to incidents	2		2.2					7.6	
Delay of trucks at facility per ton-mile	2		2.11					7.14	
Delay of trucks at facility per VMT	2		2.11					7.14	
Delay per ton-mile traveled (by mode)	1		2.10						
Delay per VMT (by mode)	1		2.2						
Delay time at primary commercial airports	2		2.2					7.6	
Demand service elasticities for auto v. transit	1							7.17	
Demand service elasticities for work v. non-work	1							7.17	
Direct jobs supported (or created)	1			3.1					
Distress extent/severity by type (pavement)	1								8.2
Distress index	1								8.2
Distribution of miles in PSC intervals	1								8.1
Dollar allotment and percent of department funds consumed by overhead	1							7.2	
Dollar allotment and percent of funds going to non-engineering activities	1							7.2	
Dollar allotment and percent of trunk highway funds going to construction	1							7.2	
Dollar value of flexible federal funding programmed for non-highway projects	1							7.1	
Dollar value of property loss per 'X' users of intermodal transfer points	1						6.1		
Double-stack capacity (or rating)	1	1.10							
Dwell time at intermodal facilities	1		2.11						
Economic costs of accidents	1			3.1					
Economic costs of congestion	1			3.1					
Economic costs of fatalities	1			3.1					
Economic costs of lost time	1			3.1					
Economic costs of pollution	1			3.1					
Economic indicator for goods movement	1			3.3					
Economic indicator for people movement	1			3.4					
Employee-related percent of employers who have relocated for transportation reasons	2	1.12		3.4					
Enplanements per aviation system employee	1							7.22	
Environmentally friendly partnership projects per year	1					5.7			
Existence of access for persons with disabilities to all areas	1	1.13							
Existence of information services and ticketing	1	1.17, 1.21							
Existence of railroad electrification	1	1.5							
Expenditures for freight rail	1								8.11
Expenditures to retire deficiencies	1								8.11
Exposure (AADT and daily trains) factor for rail crossings	1						6.11		
Facility usage by mode (V/C)	2		2.10					7.16	
Fare recovery rate of urban transit systems	1							7.19	
Fatality (or injury) rate of accidents	1						6.1		
Flow time in minutes as it compares to the number of connecting transfers	2	1.14						7.6, 7.14	
Fluctuations in traffic volumes	1		2.4						
Freight carrier (or local shippers) appraisal of quality of highway service in terms of travel time/speed, delay, circuity, scheduling convenience	2		2.10					7.15	

TABLE 9.1 (Continued)

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
Freight dock availability	1	1.10							
Frequency distribution of bridge element condition (Pontis)	1								8.3
Frequency of delays at intermodal facilities	1		2.11						
Frequency of transit service	2	1.16	2.18						
Fuel consumption per PMT	1					5.3			
Fuel consumption per ton-mile traveled	1					5.3			
Fuel consumption per VMT	1					5.3			
Fuel usage	1					5.3			
Geometrics of connector link	1	1.9							
Grade crossing safety improvements (MI)	1						6.11		
Grant dollars per transit trip	1							7.19	
Hazard index (calculated based on accidents per VMT by severity)	1						6.1		
Highway emissions levels within non-attainment areas	1					5.2			
Highway performance based on HPMS	1								8.1
Hours (or days) out of service (for roads or bridges or transit equipment or airports)	1								8.9
Hours of access lost	1							7.14	
In-vehicle travel time	1		2.13						
Indirect jobs supported (or created)	1			3.2					
Infrastructure maintenance expense	1							7.3	
Insurance costs	1							7.4	
Intercity rail and bus service ridership	1							7.20	
Interference of movement at grade crossings—delay time and speed	1		2.2						
Intersection LOS	1		2.2						
Joint condition	1								8.2
Joint-use bicycle crossings	1						6.14		
Lift capacity (annual volume)	1	1.11							
Lighting and security staff at parking areas	1						6.10		
Line haul speed	2		2.10					7.14	
LOS	1		2.2						
LOS at intersections serving facility	1		2.7						
LOS on facility access roads	1		2.7						
Lost time due to congestion	2		2.2		4.1				
Maintenance condition as measured against departmental standards	1								8.1
Maintenance cost of connector link	2							7.3	8.11
Maintenance hours	1								8.10
Management/employee satisfaction communication of agency goals	1							7.9	
Management/employee satisfaction with diversity efforts	1							7.9	
Management/employee satisfaction with progress toward targeted focus area	1							7.9	
Market share of international or regional trade by mode	1			3.3					
Miles between road calls for transit vehicles	1								8.7
Miles of freight routes with adequate capacity	1		2.10						
Miles of highway rated 'good' or 'fair' for bicycle travel	1								8.5, 8.8
Miles of rail line acquired and rehabilitated for rail service	1								8.6
Miles of roadway not useable by certain traffic because of design or condition deficiencies	1								8.4
Miles of track in operation (by FRA rating)	2	1.5							8.6
Miles of track not useable by certain traffic because of design or condition deficiencies	1								8.6
Miles to be dredged	1								8.8
Minimum layover times at airports or passenger terminals	1	1.21							
Minute variation in trip time	1		2.4						
Missed trips due to operation failures	1								8.9
Mobility index (person-miles (or ton-miles) of travel/vehicle-miles of travel (PMT/VMT) times average speed)	1		2.16						
Mode split (by ton-mile)	1							7.16	

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TABLE 9.1 (Continued)

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
Mode split by facility or route	4	1.3	2.5			5.1		7.11	
National rank for accident, injury, fatality rates	1						6.1		
Net present value of future transit vehicle (or facility or bridge or pavement), equipment and facility capital, operating and maintenance costs	1								8.11
New composite index incorporating roughness and distress (pavement)	1								8.2
Non-motorized expenditures	1								8.11
Number (or percent) of highway miles driven above speed limit	1						6.7		
Number (or percent) of motorists driving under the influence of alcohol or drugs	1						6.7		
Number and dollar value of projects jointly funded	1							7.2	
Number and dollar value of projects that improve travel time on key routes	2		2.9					7.2	
Number and miles of designated scenic routes	1					5.8			
Number and percent of lane-miles congested	1		2.2						
Number of accidents in which speed or traffic violation is a factor	1						6.7		
Number of accidents involving hazardous waste	2					5.8	6.13		
Number of accidents occurring in highway construction zones	1						6.8		
Number of accidents per capita	1						6.1		
Number of accidents per intermodal movement	1						6.1		
Number of accidents per ton-mile traveled	1						6.1		
Number of accidents per trip	1						6.1		
Number of accidents per VMT	1						6.1		
Number of accidents per year	1						6.1		
Number of airports where weather information is collected for dissemination to pilots	1						6.15		
Number of archeological and historical sites that are not satisfactorily addressed in project development before construction begins	1				4.6				
Number of bridges let to contract for repair (or replacement)	1								8.10
Number of carloads shipped/received on rail project lines	1							7.16	
Number of cities over 1 million population served directly by nonstop commercial airline flights from airports in state	1	1.6							
Number of commercial vehicle safety inspections performed	1						6.13		
Number of commercial vehicles weighed (by fixed and portable scales)	1						6.13		
Number of commuters using transit park-and-ride facilities	1		2.18						
Number of counties in State with countywide transit systems	1	1.15							
Number of cruise embarkations	1			3.4					
Number of days that Pollution Standard Index is in unhealthful range	2				4.4	5.2			
Number of deficiencies corrected vs. number remaining	1								8.9
Number of demand-response trip requests	1		2.18						
Number of dockage days at seaports	1		2.12						
Number of environmental problems to be taken care of with existing commitments	1								
Number of fatalities and injuries occurring on the rail system	1					5.7			
Number of high accident (or hazardous) locations	1						6.11		
Number of highway miles driven at high accident locations	1						6.2		
Number of intercity bus and rail accidents	1						6.6		
Number of intermodal facilities	1						6.12		
Number of intermodal facilities that agency assists in development	1	1.10							
Number of landing areas inspected	1	1.10, 1.14							
Number of lane miles let to contract for capacity improvements	1						6.15		
Number of lane miles let to contract for resurfacing	1								8.10
Number of miles of non-motorized facilities	2	1.20				5.1			8.10
Number of miles with intelligent transportation service	1	1.2							
Number of new rest areas constructed v. planned	1	1.2							
Number of noise receptor sites above threshold	1				4.5				
Number of non-work trips	1		2.14						
Number of overload permits rejected due to structural capacity deficiency	1	1.9							

TABLE 9.1 (Continued)

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
Number of package express carriers	1	1.8							
Number of peak-period vehicles	1							7.21	
Number of pedestrian accidents (or injuries or fatalities)	1						6.14		
Number of people provided service at travel information centers	2		2.16					7.8	
Number of pick-up and discharge areas for passengers	1	1.18, 1.21							
Number of pipeline spills	1					5.5			
Number of ports with railroad connections	1	1.11							
Number of projects (area and population) accessible to designated development centers	2	1.1						7.8	
Number of projects applying technology developed or available in last 'X' years	1							7.7	
Number of projects certified ready for construction	1								8.10
Number of public transportation trips	2		2.18					7.20	
Number of residences exposed to noise in excess of established thresholds	1				4.5				
Number of restricted routes, additional mileage, increased costs	1							7.16	
Number of right-of-way parcels acquired	1								8.9
Number of safety-related complaints	1						6.4		
Number of safety-related improvements	1						6.2		
Number of shipping establishments per 1,000 businesses	2	1.8		3.3					
Number of state-owned navigational aids	1								8.8
Number of statewide traffic accidents (or injuries or fatalities)	1						6.5		
Number of structures with vertical (or horizontal) clearance less than X ft.	1	1.9							
Number of T.E.U.'s (10'x 21') (or railroad cars or containers) that can be stored on the premises of the intermodal facility	1	1.10							
Number of toll transactions	1							7.8	
Number of transit (or rail or aviation or intermodal) projects funded (capital and operating)	1								8.10
Number of transit systems in state	1	1.15							
Number of transportation control measures (TCMs) accomplished v. planned	1					5.7			
Number of truck-days of highway closure on major freight routes	1	1.9							
Number of trucks that can be loaded with bulk material per hour of loading time	1	1.10							
Number of Trunk System lane miles planned v. completed	1	1.2							
Number of urban areas (or population in areas) classified as nonattainment status	2				4.4	5.2			
Number of users of intermodal facilities	2		2.6					7.12	
Number of weather products provided to pilots on computer weather terminals	1						6.15		
On-time performance of transit	1		2.18						
Operational cost per toll transaction	1							7.3	
Origin-destination travel times (by mode)	2		2.1, 2.13, 2.15					7.6, 7.17	
Overall mode split	4	1.3	2.5			5.1		7.11	
Paint distress (bridges)	1								8.3
Parking spaces available loading/unloading by autos	1	1.18, 1.21							
Parking spaces per passenger	1	1.18, 1.21							
Partnership benefits (to taxpayers and partners)	1							7.2	
Passenger-trips per household	1		2.14						
Passengers per capita within urban service area	1		2.18						
Pavement condition on links to intermodal facilities	1								8.4
Pavement quality index	1								8.2
Perceived deficiencies	2	1.4	2.8						

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TABLE 9.1 (Continued)

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
Percent of aviation community reached through aviation service programs	1	1.6							
Percent of budget allocated to system preservation activities	1								8.11
Percent of change in mode splits	4	1.3	2.5			5.1		7.11	
Percent of commercial vehicles that pass safety inspections	1						6.13		
Percent of commercial vehicles weighed that are overweight (by fixed and portable scales)	1						6.13		
Percent of contracts planned for letting that were actually let	1								8.10
Percent of cost of re-work	1							7.2	
Percent of customers satisfied with licensing and registration process	1							7.10	
Percent of drivers complying with seat belt law	1						6.7		
Percent of employers that cite difficulty in accessing desired labor supply due to transportation.	2	1.12		3.4					
Percent of error-free data in IMS database	1							7.7	
Percent of general aviation needs funded	1	1.6							
Percent of goods moved with option of more than one modal choice	1	1.8							
Percent of highway miles built to target design and operational standards to handle traffic at a steady 55 mph rate	1						6.6		
Percent of highway tolls pre-paid	1							7.8	
Percent of highways not congested during peak hours	1		2.2						
Percent of increase in intermodal facilities use	1			3.3					
Percent of intermodal connecting points and facilities accurately placed on a map	1							7.12	
Percent of invoices processed within five days of receipt	1							7.5	
Percent of jobs within 45 minutes of airports	1	1.21							
Percent of lane-miles of recreational routes operating below LOS D	1		2.17						
Percent of lane-miles which are truck priority (or excluded)	1		2.10						
Percent of lane-miles with toll pricing	1							7.8	
Percent of lane-miles by pavement condition	1								8.2
Percent of manufacturers/shippers that have relocated for transportation purposes	1			3.3					
Percent of manufacturing industries within 30 miles of interstate or four-lane highway	1	1.7							
Percent of passengers traveling under five miles made by means other than SOV	1		2.15						
Percent of persons who are elderly or have disabilities and who have special transit service available	1	1.13							
Percent of population exposed to levels of highway noise above 60 decibels	1				4.5				
Percent of population that can reach specified services by transit, bicycle, or walk	1	1.12							
Percent of population that perceives that its environment has become more 'livable' over the past year with regard to ability to access desired activities	1				4.1				
Percent of population which perceives that response time by police, fire, rescue or emergency services has become better or worse and whether that is due to transportation factors	2				4.3		6.4		
Percent of population with access to (or within 'X' miles of) transit (or fixed route transit) service	1	1.15							
Percent of population within 5 miles or 10 minutes of state-aided public roads	1	1.19							
Percent of population within 'X' miles of employment	1	1.12							
Percent of projects rated good to excellent in quality audits	1							7.7	
Percent of projects requiring few or no significant change orders due to plan errors	1							7.7	
Percent of projects with no premature maintenance problems	1							7.7	
Percent of rail station parking lots with midday spaces available	1	1.18							
Percent of region which is developed	1					5.4			
Percent of region's residents who can reach specific activities by public transportation or by walking/wheelchair	2	1.13			4.1				
Percent of region's unemployed or poor who cite transportation access as a principal barrier to seeking employment	2			3.4	4.1				
Percent of road system carrying unrestricted loads year round	1								8.4
Percent of roadway/bridge system below standard condition	1								8.1

TABLE 9.1 (Continued)

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
Percent of rural population with access to transit service	1	1.15							
Percent of state gross product	1			3.1					
Percent of state residents aware of intermodal opportunities	2	1.4		3.3					
Percent of total transit trip time spent out of vehicle	1	1.16							
Percent of traffic on regional highway which is heavy truck	1						6.13		
Percent of transfers between modes to be under 'X' minutes and 'N' feet	3	1.14	2.6					7.12	
Percent of transit demand-response trip requests met	2	1.13	2.18						
Percent of transit-dependent population served	1	1.13							
Percent of transit facilities accessible to persons with disabilities	1	1.13							
Percent of truck highway bridges sufficient in load capacity, vertical and horizontal clearance	1	1.9							
Percent of truck VMT or tonnage affected by weight restrictions (or clearance) on bridges	2	1.9							8.4
Percent of urban and rural areas with direct access to passenger rail and bus service	1	1.15							
Percent of users with option of more than one modal choice	1	1.3							
Percent of vehicle crashes on highway system where roadway-related conditions were listed as a contributing factor	1						6.6		
Percent of vehicles using alternative fuels	1					5.1			
Percent of vehicles using high-occupancy lanes	1							7.18	
Percent of VMT at LOS 'X'	1		2.2						
Percent of VMT on roads with deficient ride quality	1								8.1
Percent of VMT which occurs on facilities with V/C greater than 'X'	1		2.2						
Percent of wholesale and retail sales in the significant economic centers served by unrestricted (10-ton) market artery routes	2	1.7		3.3					
Percent of work trips that are SOV	1							7.17	
Percent of workers who have free parking at employment sites	1							7.18	
Percent of workers who have paid parking at employment sites	1							7.18	
Percent of workers who work at home	1		2.15						
Percent of workers who work at home because of transportation cost or level of service	2		2.15					7.17	
Percent of workforce that can reach worksite in transit within one hour and with no more than two transfers	1	1.15							
Percent trips with transit advantage	1		2.15						
Percent use of walking and bicycling for commute trips (or all trips)	3	1.20	2.19			5.1			
Percent variances between actual versus predicted DOT revenues	1							7.1	
Percentage increase in final amount paid for completed construction over original contract amount	1							7.2	
Percentage increase in number of days required for completed construction contracts over original contract days	1							7.5	
Percentage of airports that meet federal and state planning and design standards	1						6.15		
Percentage of all trips made by bicycling and walking	1							7.17	
Percentage of emergency road calls that get through to state highway agency	1						6.9		
Percentage of highway mainline bridges rated good or better	1								8.3
Percentage of highway mainline pavement (or bridges) rated good or better	2						6.6		8.2
Percentage of highway system with bridges that structurally deficient or functionally obsolete	1	1.9							
Percentage of information and data exchanged between intrastate agencies	1							7.7	
Percentage of parking areas that are secured	1						6.10		
Percentage of scheduled departures that do not leave within a specified time limit	1		2.4						
Percentage of state truck highway system rated good or better	2						6.13		8.4
Percentage of street traffic delivered off-peak	1							7.16	
Percentage of time average speed is below threshold value	1		2.2						
Percentage on-time performance	1		2.4						
Performance of state roads based on HPMS ratings	1							7.8	
PHT	1		2.14						

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TABLE 9.1 (Continued)

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
PMT by congestion level	1		2.13						
PMT on intercity rail and bus service	1							7.20	
PMT per capita	1		2.14						
PMT per worker	1		2.14						
Present serviceability rating	1								8.1, 8.7
Price index for selected local delivery service	1			3.3					
Private cost for transportation system	1							7.1	
Productivity and utility by mode	1							7.16	
Property damage accidents/vehicle miles traveled	2			3.1			6.5		
Proportion of freight traffic at facility on portion of network	1							7.16	
Proportion of infrastructure investment from private sources	1							7.2	
Proportion of persons delayed	1		2.13						
Public cost for transportation system	1							7.1	
Public transportation passenger-miles/ total vehicle-miles	1					5.1			
Queuing of vehicles (including rail) and its relationship to overall delays	1		2.2						
Rail freight revenue versus operating expenses	1							7.13	
Railings below standard (bridges)	1								8.3
Railroad/highway at-grade crossings	1						6.11		
Ratio of number of transit incidents to investment in transit security	2						6.12	7.21	
Ratio of oversize/overweight permit fees collected to dollar value of damage caused	1							7.13	
Reduced costs per trip (subsidies)	1							7.4	
Regional truck VMT per unit of regional economic activity/output	2			3.3				7.16	
Remaining life of pavement	1								8.2
Remaining service life	1								8.1, 8.7
Reserve capacity	1		2.2						
Response time to incidents	1						6.3		
Revenue per ton-mile by mode	1							7.13	
Revenue vehicle hours per transit employee	1							7.21	
Riders at maximum load point	1							7.20	
Ridership per VMT in rural areas	1							7.20	
Roadway sections not meeting safety standards	1						6.6		
Roughness/ride index (IRI)	1								8.2
Route spacing	1	1.16							
Route-miles (or seat-miles or passenger miles) of transit service (or per capita or per employee or per licensed driver)	1	1.16							
Runway resurfacing frequency (airports)	1								8.8
Rural service passengers	1							7.20	
Rut depth	1								8.2
Savings to taxpayers/public from partnerships	1							7.2	
Scour criticality (bridges)	1								8.3
Shipping accidents occurring on waterways	1						6.15		
Shipping cost per shipment	1							7.13	
Skid/friction	1								8.2
Speed limits and difference between modes	1							7.6	
Sprawl: difference between change in urban household density and suburban household density	2				4.2	5.4			
State (or federal) construction (or maintenance) grants issued	1								8.10
Steel bridges with section loss in a member (bridges)	1								8.3
Sufficiency rating (percent bridges meeting federal sufficiency rating)	1	1.9							
System condition	1								8.9
The degree to which pipeline spills and accidents are minimized	1					5.5			
Time to access intermodal facilities	1		2.7						
Ton-miles of rail freight into/through metropolitan areas	1		2.10						
Ton-miles traveled by congestion level	1		2.10						
Ton-miles per gallon of fuel	1							7.8	

TABLE 9.1 (Continued)

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
Tonnage moved on various transportation components (by mode)	2		2.10	3.3					
Tonnage originating and terminating	1			3.3					
Tons of asphalt placed by maintenance crews	1								8.2
Tons of commodity undergoing intermodal transfer	1		2.11						
Tons of greenhouse gases generated	1					5.2			
Tons of pollution (or vehicle emissions) generated	2				4.4	5.2			
Tons transferred per hour	1							7.14	
Total annual attendance at pilot safety seminars	1						6.15		
Total freeway lane-miles (or per capita or per measure of regional business volume or per square mile or truck VMT)	1	1.2							
Total freeway lane-miles in acceptable condition (or per capita or per measure of regional business volume or per square mile or truck VMT)	1	1.2							
Total public expenditures on modal systems (freight v. passenger)	1							7.1	
Total transit operating expenditures per transit-mile	1							7.19	
Total travel time (by mode)	2		2.1					7.6	
Total VMT	1		2.3						
Track capacity (size, acreage)	1	1.10							
Track condition	1								8.6
Track-miles abandoned	1								8.6
Track-miles under threat of abandonment	1								8.6
Traffic at border crossings	2		2.12	3.3					
Transactions completed per motor vehicle division employee	1							7.7	
Transfer distance at passenger facility	1	1.14, 1.17, 1.21							
Transfer time between modes	2		2.6					7.12	
Transit accidents (or injuries or fatalities)/PMT	1						6.12		
Transit accidents (or injuries or fatalities)/VMT	1						6.12		
Transit peak-load factor	1							7.20	
Transit riders per gallon of fuel	1							7.20	
Transit riders per revenue-mile	1							7.20	
Transit riders per route-mile	1							7.20	
Transit riders per VMT	1							7.20	
Transit ridership per capita	1							7.20	
Transit ridership-to-capacity ratio	1							7.20	
Travel-time contours	1		2.4						
Travel time under congested conditions	1		2.2						
Truck delivery and loading interference with street traffic	1		2.10						
Truck turnaround time at intermodal terminals	1		2.11						
Truck VMT by light duty, heavy duty, and through trips	1		2.10						
Types of modes handled	1	1.10							
Units of work completed per hour worked	1							7.5	
Unprogrammed construction costs as a percentage of total construction costs	1							7.2	
Use cost/person-mile (user cost)	1							7.4	
Use of safety equipment by bicyclists	1						6.14		
User identification of access issues	1	1.4							
V/C by route	2		2.2					7.8	
V/C for bicycle and pedestrian facilities	2		2.19					7.22	
V/C of parking spaces during daily peak hours for bus, rail, park-and-ride, or other passenger terminal lots	1	1.18, 1.21							
V/C on facility access roads	1		2.7						
V/C ratio	2		2.2					7.8	
Value of fuel savings	1							7.4	
Vehicle operating cost reductions	1							7.4	

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TABLE 9.1 (Continued)

Measure	No. of Occurrences in Tables	Accessibility	Mobility	Economic Development	Quality of Life	Environmental & Resource Conservation	Safety	Operational Efficiency	System Preservation
Vehicle ownership, demand per licensed driver (or worker)	1		2.17						
Vehicle-miles traveled per highway department employees	1							7.7	
Vehicle-trips per household	1		2.14						
VHT per capita	1		2.3						
VHT per employee	1		2.3						
VMT by congestion level	1		2.2						
VMT growth rate relative to population, employment	1		2.3						
VMT per capita	1		2.3						
VMT per employee	1		2.3						
VMT per mile of roadway	1							7.8	
VMT within urban areas	1		2.3						
VMT/PMT	1							7.18	
VMT/speed relationships	1					5.8			
Worktrips completed per vehicle hour or commute travel	2				4.1			7.17	

APPENDIX C

ITS DATA FOR PERFORMANCE-BASED PLANNING

The following tables provide additional information about ITS data sources, features of the data, and potential applications to performance-based planning.

Ref. No.	ITS data source	Primary data elements	Features of the Data Source: Typical collection equipment	Spatial coverage	Temporal coverage	Real-time uses	Possible multiple uses of ITS-generated data
FREEWAY AND TOLL COLLECTION							
1	Freeway traffic flow surveillance data	• volume • speed • occupancy	• loop detectors • video imaging • acoustic • radar/ microwave	Usually spaced at 1 mile or less; by lane	Sensors report at 20- to 60-second intervals	• ramp meter timing • incident detection • congestion/queue identification	• Congestion monitoring • Link speeds for TDF and air quality models • AADT, K- and D-factors • Saturation flow rates • Pre-planned TMC operations
		• vehicle classification • vehicle weight	• loop detectors • WIM equipment • video imaging • acoustic	Usually 50-100 per state; by lane	Usually hourly	Pre-screening for weight enforcement	• Truck percents by time of day for TDF and air quality models • Truck flow patterns • Pavement loadings
2	Ramp meter and traffic signal preemptions	• time of preemption • location	Field controllers	At traffic control devices only	Usually full-time	Priority to transit, HOV, and EMS vehicles	Network details for microscopic traffic simulation models (e.g., TRAF, TRANSIMS)
3	Ramp meter and traffic signal cycle lengths	• begin time • end time • location • cycle length	Field controllers	At traffic control devices only	Usually full-time	Adapt traffic control response to actual traffic conditions	• Network details for microscopic traffic simulation models (e.g., TRAF, TRANSIMS) • Pre-planned TMC operations
4	Visual and video surveillance data	• time • location • queue length • vehicle trajectories • vehicle classification • vehicle occupancy	• CCTV • aerial videos • image processing technology	Selected locations	Usually full-time	• coordinate traffic control response • congestion/queue identification • incident verification	• Congestion monitoring • Car-following and traffic flow theory
5	Vehicle counts from electronic toll collection	• time • location • vehicle counts	Electronic toll collections equipment	At instrumented toll lanes	Usually full-time	Automatic toll collection	Traffic counts by time of day
6	TMC-generated traffic flow metrics (forecasted or transformed data)	• link congestion indices • stops/delay estimates	TMC software	Selected roadway segments	Hours of TMC operation	• incident detection • traveler information • preemptive control strategies	• Congestion monitoring • Effectiveness of prediction methods
7	Arterial traffic flow surveillance data	• volume • speed • occupancy	• loop detectors • video imaging • acoustic • radar/ microwave	Usually midblock at selected locations only ("system detectors")	Sensors report at 20- to 60-second intervals	• progression setting • congestion/ queue identification	• Congestion monitoring • Link speeds for travel forecasting models (free flow only) • AADT, K- and D-factors

Ref. No.	ITS data source	Primary data elements	Features of the Data Source: Typical collection equipment	Spatial coverage	Temporal coverage	Real-time uses	Possible multiple uses of ITS-generated data
8	Traffic signal phasing and offsets	• begin time • end time • location • up/down-stream offsets	Field controllers	At traffic control devices only	Usually full-time	Adapt traffic control response to actual traffic conditions	Network details for microscopic traffic simulation models (e.g., TRAF, TRANSIMS)
9	Parking management	• time • lot location • available spaces	Field controllers	Selected parking facilities	Usually daytime or special events	Real-time information to travelers on parking availability	Parking utilization and needs studies
10	Transit usage	• vehicle boardings (by time and location) • station origin and destination (O/D) • paratransit O/D	Electronic fare payment systems	Transit routes	Usually full-time	Used for electronic payment of transit fares	• Route planning/ run-cutting • Ridership reporting (e.g., Section 15)
11	Transit route deviations and advisories	• route number • time of advisory • route segments taken	TMC software	Transit routes	Usually full-time	Transit route revisions	Transit route and schedule planning
12	Rideshare requests	• time of day • O/D	CAD	Usually areawide	Daytime, usually peak periods	Dynamic rideshare matching	• Travel demand estimation • Transit route and service planning
13	Incident logs	• location • begin, notification, dispatch, arrive, clear, depart times • type • extent (blockage) • HazMat • Police accident rpt. reference • cause	• CAD • computer-driven logs	Extent of Incident Manage-ment Program	Extent of Incident Management Program	Incident response and clearance	• Incident response evaluations (program effectiveness) • Congestion monitoring (e.g., % recurring vs. nonrecurring) • Safety reviews (change in incident rates)
14	Train arrivals at Highway Rail Intersections	• location • begin time • end time	Field controllers	At instru-mented HRIs	Usually full-time	• coordination with nearby traffic signals • notification to travelers	Grade crossing safety and operational studies
15	Emergency vehicle dispatch records	• time • O/D • route • notification, arrive, scene, leave times	CAD	Usually areawide	Usually full-time	Coordination of Emergency Management response	• Emergency management labor and patrol studies • Emergency management route planning
16	Emergency vehicle locations	• vehicle type • time • location • response type	Automatic Vehicle Identification (AVI) or GPS equipment	Usually areawide	Usually full-time	• tracking vehicle progress • green wave and signal preemption initiation	• Emergency management route planning • Emergency management response time studies

Ref. No.	ITS data source	Primary data elements	Features of the Data Source: Typical collection equipment	Spatial coverage	Temporal coverage	Real-time uses	Possible multiple uses of ITS-generated data
17	Construction and work zone identification	• location • date • time • lanes/ shoulders blocked	TMC software	Varies by work zone	Varies by work zone	Traveler information	Congestion monitoring
18	HazMat cargo identifiers	• type • container/ package • route • time	CVO systems	At reader and sensor locations	Usually full-time	• identifying HazMat in specific incidents • routes for specific shipments	• HazMat flows • HazMat incident studies
19	Fleet Activity Reports	• carrier • citations • accidents • inspection results	CVO inspections	N/A	Usually summarized annually	May overlap with SAFETYNET functions	
20	Cargo identification	• cargo type • O/D	CVO systems	At reader and sensor locations	Usually full-time	Clearance activities	Freight movement patterns
21	Border crossings	• counts by vehicle type • cargo type • O/D	CVO systems	At reader and sensor locations	Usually full-time	Enforcement	Freight movement patterns
22	On-board safety data	• vehicle type • cumulative mileage • driver log (hrs. of service) • subsystem status (e.g., brakes)	CVO systems	At reader and sensor locations	Usually full-time	Enforcement and inspection	Special safety studies (e.g., driver fatigue, vehicle components)
23	Emissions Management System	• time • location • pollutant concentrations • wind conditions	Specialized sensors	At sensor locations	Usually full-time	Identification of hotspots and subsequent control strategies	• Trends in emissions • Special Air Quality studies
24	Weather data	• location • time • precipitation • temperature • wind conditions	Environmental sensors	At sensor locations	Usually full-time	Traveler information	• Congestion monitoring (capacity reductions) • Freeze/thaw cycles for pavement models
25	Location referencing data	Special case; pertains to all location references in ITS and planning					Need conversion from lat/long to highway distance and location (e.g., milepost references for queue lengths)
26	Probe data	• vehicle ID • segment location • travel time	• probe readers and vehicle tags • GPS on vehicles	GPS is areawide; readers restricted to highway locations	Usually full-time	• coordinate traffic control response • congestion/ queue identification • incident detection • real-time transit vehicle schedule adherence • electronic toll collection	• Congestion monitoring • Link speeds for travel forecasting models • Historic transit schedule adherence • Traveler response to incidents or traveler information • O/D patterns

Ref. No.	ITS data source	Primary data elements	Typical collection equipment	Spatial coverage	Temporal coverage	Real-time uses	Possible multiple uses of ITS-generated data
			Features of the Data Source				
27	VMS messages	• VMS location • time of msg • msg content	TMC software	VMS locations	Hours of TMC operation	Traveler information	Effects of VMS message content on traveler response
28	Vehicle trajectories	• location (route) • time • speed • acceleration • headway	• AVI or GPS equipment • advanced video image processing	AVI restricted to reader locations; GPS is areawide	1- to 10-second intervals	Collected as part of surveillance function	• Traffic simulation model calibration for local conditions (driver type distributions) • Modal emission model calibration • Traffic flow research
29	TMC and Information Service Provider generated route guidance	• time/date • O/D • route segments • estimated travel time	TMC/Information Service Provider software	Usually areawide	Hours of TMC operation	Traveler information	• O/Ds for travel demand forecasting model inputs • Interzonal travel times for travel demand forecasting model calibration
30	Parking and roadway (congestion) pricing changes	• time/date • rte. segment/ lot ID • new price	TMC software	Facilities subject to variable pricing	Hours of TMC operation	Demand management	• Special studies of traveler response to pricing • Establishment of pricing policies