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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 551

**Performance Measures and
Targets for Transportation
Asset Management**

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New York, NY

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College Station, TX

SUBJECT AREAS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

*By Crawford F. Jencks
Staff Officer
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The two volumes of this report—Volume I, Research Report, and Volume II, Guide for Performance Measure Identification and Target Setting—will help transportation agencies apply the concepts of performance management to their asset management efforts. Volume I describes the research effort and provides the current state of practice on the use of performance measures, principally in the context of transportation asset management. Volume II introduces a framework for identifying performance measures and setting target values, and its appendixes contain examples of performance measures and targets. Performance measures and target values are critical to the principles of asset management to analyze tradeoffs, make investment decisions, and monitor intended effects. The report will be of interest throughout transportation agencies as an aid to effective decision making and the optimization of resources.

Many transportation agencies have developed system-level performance measures to help track the impacts of program investments, maintenance, and operations improvements. These performance measures are usually technical in nature, capturing an engineering or operational attribute of the transportation system. A review of these measures was needed to assess their usefulness for asset management (e.g., their application in tradeoff analyses and investment decisions). Development of measures for nontraditional (e.g., security, social, environmental, and economic) issues affecting transportation decisions was also needed.

Some DOTs define targets with which current conditions can be objectively compared to determine whether the transportation system is performing acceptably. The basis on which these targets are set varies, and there is no generally accepted methodology for their establishment and use in asset management. Guidance for a methodology to establish targets for use by transportation agencies was also needed.

Therefore, the objectives of this research were to (1) investigate performance measures suitable to asset management and (2) develop a framework for establishing performance measures and setting targets for use in asset management. The emphasis was on highway infrastructure assets.

This research project specifically complements two other NCHRP projects. NCHRP Project 20-24(11), “Asset Management Guidance for Transportation Agencies,” produced a first-generation asset management guide that has been adopted by AASHTO and is available at <http://assetmanagement.transportation.org/tam/aashto.nsf/home>. NCHRP Project 20-57, “Analytic Tools to Support Transportation Asset Management,” produced two software tools, one for analyzing investments across infrastructure categories and another for demonstrating the impacts of investment choices on short-term programs of projects. Both of these software tools will be further developed and maintained as AASHTOWare products. Results were published as *NCHRP Report 545: Analytical Tools for Asset Management*, which contains a CD with the software products and user guides.

Along with the FHWA, the NCHRP (under Project 20-36) sponsored an international scan on transportation asset management to Australia, Canada, England, and New Zealand. Scan results have been published by the FHWA in report FHWA-PL-05-019. At the time of this publication, plans were being made for a domestic scan of transportation asset management practices in the United States as part of NCHRP Project 20-68.

Efforts such as these will continue to support transportation agencies by providing the concepts, methods, and tools to address the changing demands of the public, legislatures, and government leaders. Because needs are great and resources are limited, the consequences of various scenarios can be determined and compared to optimize investments for the intended outcome.

Volume I:
Research Report

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Executive Summary

■ Introduction

Asset management and performance measurement are topics of strong interest in the transportation community today. NCHRP Project 20-60 looks to the strengths of both of these concepts in considering what performance measures are best to apply within an asset management context. In doing this the study considers implications of several relevant trends now influencing U.S. transportation industry practice:

- Increased use of performance measurement in transportation policy making, planning, programming, and system monitoring;
- Formal development of asset management principles through a collaborative effort among TRB, AASHTO, and the FHWA, culminating in the production of AASHTO's *Transportation Asset Management Guide* through NCHRP Project 20-24(11);
- Development and application of maintenance quality assurance programs, which base maintenance management on explicit levels of service that, like performance measures, can serve as indicators of both current condition/performance as well as target values for improvement; and
- A renewed focus on analytic tools and other information technology resources that are needed for performance-based management and, more generally, good asset management.

The objectives of this project were to develop an understanding of what set of performance measures can best serve the principles of good asset management and to recommend procedures that help an agency apply this understanding. This study has developed a practical methodology that enables a transportation agency:

- To identify measures of transportation system performance that are best suited to good asset management, covering a range of investments for system preservation, operations, and capacity expansion; and
- To select specific performance measures and set targets for these measures that are consistent with the needs of the agency and with good asset management practice.

This report is Volume I of a two-volume set presenting the results of research conducted for Project 20-60. It includes:

- Results of a literature review and interviews with 15 transportation agencies, describing the range of performance measures now used or proposed for use by domestic and international agencies, the criteria that now govern performance measure selection, and how performance measures are applied in different agencies.

- Criteria for selecting performance measures that are useful to asset management, based on the requirements for this study set by the panel in the scope of work and the principles articulated in the *Transportation Asset Management Guide*.
- An in-depth treatment of key considerations in defining and using performance measures within an asset management context.
- A description of the framework that has been developed for agencies to use in identifying performance measures that are most useful to asset management and to select target values for these measures.

Volume II of this report is a guide to the framework for performance measure identification and target setting.

■ Transportation Asset Management

Asset management provides a strategic framework for infrastructure management that gets the most out of performance measurement. It establishes a set of principles, concepts, and techniques that can be applied to an agency's procedures for policy formulation and decisions in resource allocation and use. The core principles of asset management, from which performance measure criteria are derived, are as follows:

- **Policy-Driven**—Resource allocation decisions are based on a well-defined and explicitly stated set of policy goals and objectives. These objectives reflect desired system condition, level of service, and safety provided to customers and are typically tied to economic, community, and environmental goals.
- **Performance-Based**—Policy objectives are translated into system performance measures that are used for both day-to-day and strategic management.
- **Analysis of Options and Tradeoffs**—Decisions on how to allocate resources within and across different assets, programs, and types of investments are based on understanding how different allocations will affect the achievement of policy objectives and what the best options to consider are. The limitations posed by realistic funding constraints also must be reflected in the range of options and tradeoffs considered.
- **Decisions Based on Quality Information**—The merits of different options with respect to an agency's policy goals are evaluated using credible and current data. Decision support tools are applied to help in accessing, analyzing, and tracking these data.
- **Monitoring to Provide Clear Accountability and Feedback**—Performance results are monitored and reported for both impacts and effectiveness. Feedback on actual performance may influence agency goals and objectives, as well as future resource allocation and use decisions.

These principles already are widely understood. Many transportation practitioners would agree that investment decisions for transportation systems should be based on weighing costs against likely outcomes, that a variety of options should be considered and evaluated, and that quality information is needed for decision making. Many agencies are now pursuing performance-based approaches to planning and programming, monitoring system performance, and developing more integrated data and analysis tools to evaluate tradeoffs among capital expansion, operations, and preservation activities.

Most agencies recognize that application of asset management principles is critical in times of constrained resources, when all investment and budget decisions are subject to increased public scrutiny.

■ Performance Measurement

Performance measurement is a way of monitoring progress toward a result or goal. It is also a process of gathering information to make well-informed decisions. Transportation agencies have used performance measures for many years to help track and forecast the impacts of transportation system investments, monitor the condition of highway features, and gauge the quality of services delivered by an agency. Performance measures are valuable and provide several useful benefits:

- Greater accountability to policy-makers, the agency's customers, and other stakeholders;
- Improved communication of information about the transportation system to customers, political leaders, the public, and other stakeholders;
- Increased organizational efficiency in keeping agency staff focused on priorities and enabling managers to make decisions and adjustments in programs with greater confidence that their actions will have the desired effect;
- Greater effectiveness in achieving meaningful objectives that have been identified through long-range planning and policy formulation;
- A better understanding of the impacts of alternative courses of action that performance measures can provide; and
- Ongoing improvement of business processes and associated information through feedback.

Performance measures traditionally have been largely technical in nature, capturing an engineering or operational attribute of the transportation system. Today, however, transportation executives and managers must address an increasingly complicated and wide-ranging set of issues regarding the “best” solutions on balance to transportation problems, the cost-effectiveness of proposed projects, and the anticipated impacts of these projects. While measures of technical condition and performance are still needed, other types of measures are called for as well. The ways in which performance measures are applied are likewise changing to meet the needs and expectations of stakeholders.

■ Asset Management Implications for Performance Measures

Performance measures can best support the principles of asset management described above if they have the following principles:

- **Policy-driven**—Performance measures should capture and respond to policy objectives, providing meaningful information about how changes in the transportation system support these objectives.

- **Strategic perspective**—It should be possible to produce credible forecasts for performance measures (as is done in many current management systems) and to use these forecasts in engineering and economic analyses, including life-cycle cost calculations.
- **Consideration of tradeoffs and options**—Performance measures should support “what-if” analyses of different scenarios, reflecting a clear relationship between performance and cost. They should also inform decisions about a wide range of investments in preservation, operation, and capacity expansion and in certain cases the results of investments in different modes. Measures need to be sensitive enough to show the “amount the needle moves” as a result of different investments.
- **Decisions based on good information**—Performance measures should be supported by an agency’s management systems or other analytic tools and be an integral part of its business and decision processes. They should be compatible with analytic procedures that are appropriate to different organizational levels. Data requirements for performance measures should be realistic and feasible.
- **Feedback**—Performance measures should provide managers with sufficient information to understand problems and suggest solutions. This feedback should help an agency understand the impacts of its past and potential future actions, as distinct from exogenous influences on performance that are beyond the agency’s control. Since feedback is a continual process, periodic monitoring of performance measures needs to be economical.
- **Implementation across organizational units and levels**—Performance measures collectively should provide useful information to technical, managerial, and executive levels within the organization and apply consistent information and definitions of impacts across organizational units. The way in which measures are defined and calculated is important in achieving consistent information horizontally and vertically.

While these characteristics are the major ones associated with guidelines for good asset management, there are other characteristics of good performance measures in general that need to be met (e.g., the need for both internal and external buy-in to an agency’s measures and a clear understanding of what they mean). The project panel also has developed a complementary set of requirements on the methodology to be developed in this study (e.g., that it apply to agencies of different organizational structures and characteristics, that it support the statewide and metropolitan transportation planning provisions of current federal law, and that it accommodate the requirements of Governmental Accounting Standards Board Statement 34 as well as those of the *Transportation Asset Management Guide*).

■ Current Performance Measures and Practices

The research team reviewed a wide body of literature on transportation performance measures, including guidebooks on performance measurement and managerial accountability, studies and compilations of transportation performance measures in the United States and internationally, and specific reports by agencies (such as for long-range transportation planning, capital program development, strategic business planning, and performance accountability) that apply performance measures. In addition, interviews were conducted with 15 state transportation agencies across the country, distributed by AASHTO region as follows:

- Northeast Association of State Transportation Organizations (NASTO): Maryland, New York, and Pennsylvania;
- Southeast Association of State Highway and Transportation Organizations (SASHTO): Florida, South Carolina, Tennessee, and Virginia;
- Mississippi Valley Conference of State Transportation Organizations: Iowa, Michigan, Minnesota, and Ohio; and
- Western Association of State Highway and Transportation Organizations (WASHTO): Colorado, Idaho, Montana, and Washington.

Performance Measures

The literature concluded that performance measures are clearly of growing interest: those agencies that use them are continually refining them, and those agencies that have not yet applied them to transportation system performance are now exploring their use. Different types of performance measures are in use or have been proposed within each category of measurement, as illustrated below. The review organized the large number of identified measures within the following categories:

- Preservation of assets,
- Mobility and accessibility,
- Operations and maintenance, and
- Safety.

Table 1 provides examples of performance measures identified in the current practice review that are suitable for use within an asset management context.

This review emphasizes the “resource allocation” aspects of asset management, consistent with the project scope. However, agencies that were interviewed stressed the importance of “program delivery” measures as well in achieving the results intended during resource allocation and in strengthening the credibility of the agency for communicating both resource allocation recommendations and program delivery accomplishments. While some literature sources emphasize “outcome measures” as the most desirable for communicating accountability for results, the agencies pointed out that “output” measures also need to be considered, and a blend of output and outcome measures may be the most useful. Of course, outputs tend to precede outcomes, so there is a natural relationship between the two. Outputs have several advantages:

- They may be easier to communicate to nontechnical audiences;
- They may be easier and less expensive to measure;
- They provide an immediate indication of accomplishment when outcomes of an investment are long term;

Table 1. Example Performance Measures for Asset Management

Measure Category	Example Measures	Comments
Preservation of Assets	Pavement condition index Bridge health index Remaining life Debt index (ratio of deterioration or lost value to replacement value)	Condition and remaining life measures can be expressed as averages or distributions (e.g., percent of system length or VMT on roads in good, fair, and poor condition).
Mobility and Accessibility	Amount of congested travel (person-miles or VMT under congested conditions) Travel time index (ratio of peak travel time to free-flow travel time) Average travel time between major origins and destinations, by mode Average shipment cost between selected origins and destinations	Care must be taken to distinguish results of agency actions from changes due to growth patterns, fuel prices and other factors. This can be accomplished through use of modeling tools, supplemental socioeconomic and traffic monitoring data, and well-designed before-after studies.
Operations and Maintenance	Traffic signal malfunction rate Average incident clearance time Time interval after precipitation stops to restore road conditions to defined standard Sign and pavement marking retroreflectivity Customer satisfaction rating for different maintenance elements	Maintenance level of service approaches can be used to relate achievement of different service levels to budget levels by category of work.
Safety	Serious crashes per million VMT Fatalities per 100 million VMT Number of work zone crashes Hazard index (based on crash incidence and severity rates) Backlog (\$) of identified cost-effective safety countermeasures to address high-crash locations	Use of the fatality rate measure is recommended for consistency with the U.S. DOT's national performance target to reduce fatalities to 1.0 per million VMT.

VMT = vehicle-miles traveled

- They provide a tangible measure of accomplishment for preventive maintenance; and
- They provide a basis for relating accomplishment to the agency resources needed.

Related Agency Practices

Agency interest in performance measures and target setting is strong, as noted earlier. Agencies described in their interviews the types of measures they use, how these measures are applied to different functions and types of investments, and what aspects of asset management are supported. These descriptions provided a very useful picture of different levels of attainment in asset management, as well as of the diversity in performance measurement. While it is common to use measures to track performance over time and set targets for future performance, relating performance to cost is less familiar. Analyzing tradeoffs across programs, types of investments, or modes might now be characterized as the “frontier” of asset management. While the capabilities to relate performance to cost—a prerequisite for tradeoff analyses—are now available in many modern pavement and bridge management systems and certain maintenance management tools, only a few states reported a formal, structured consideration of tradeoffs. Practices in applying performance monitoring to feedback and updating of agency processes also varies, ranging from informal discussions and considerations to more formal comparisons and decisions.

Many agencies set performance targets, although the practices differ, ranging from definition of desired thresholds based on engineering considerations to establishment of goals based on long-term projections and scenario analyses. Several factors are accounted for by agencies in setting targets:

- Anticipated funding levels;
- Policy goals, statewide priorities, or priorities by route classification;
- Public input;
- Existing condition, historical performance trends, and implications of different proposed condition levels;
- Internal and external input, and comparison to other states;
- Discussions with the construction industry; and
- Life-cycle cost analyses, tradeoff analyses, and estimates of the marginal value of additional investment.

■ Overview of Recommended Framework

The framework developed for this study was based on the premise that there is no single, best set of performance measures suitable for every transportation agency. Each agency needs to develop

or evolve its own set of measures based on its organizational structure, decision processes, and culture and with consideration of the set of measures (and supporting data) already in place. However, there is a set of best practices for implementing performance measures that can help agencies to get the most benefit out of asset management. There is a need for clear yet flexible guidance as to how to go about identifying performance measures and setting performance targets that is compatible with an asset management approach.

The recommended framework was developed in the form of procedurally oriented guidance. This procedural (i.e., step-by-step) guidance is supplemented by the in-depth treatment of key considerations presented in this report. This volume describes the framework in summary fashion. Volume II is intended for use by agencies pursuing improvements to performance measurement in support of asset management.

The guidance is organized into three parts:

1. Identify Performance Measures,
2. Integrate Performance Measures into the Organization, and
3. Establish Performance Targets.

Guidance for identifying performance measures involves the following steps:

1. Inventory existing performance measures and identify how they are being used,
2. Identify gaps to be addressed based on coverage of critical outcome areas for agency goals and objectives and support for the asset management best practices,
3. Define criteria for selecting new measures (the guidance suggests a set of criteria but presumes that agencies will tailor criteria based on their needs and priorities),
4. Identify additional candidate measures, and
5. Select a set of measures from the list of candidates for further design and implementation.

Guidance for integrating performance measures into an organization involves the following steps:

1. Engage internal and external stakeholders to achieve buy-in;
2. Identify the different decision contexts where performance measures are to be used (project, corridor, and network levels and for short- or long-range decisions) and refine measures so that they are at the appropriate level of sensitivity;
3. Identify opportunities for using measures that are consistent across different organizational units responsible for various asset classes, modes, or work types;
4. Identify needs for additional data collection, data management, and analytic tools to support the selected measures;
5. Design communication devices with formats appropriate to the target audiences; and
6. Document measure definitions and procedures.

The guidance for establishing performance targets involves the following steps:

1. Define the context for target setting and establish time horizon(s),
2. Determine which measures should have targets,
3. Develop long-term goals based on consideration of technical and economic factors,
4. Consider current and future funding availability,
5. Analyze resource allocation scenarios and tradeoffs,
6. Consider policy and public input implications for target setting, and
7. Establish targets and track progress.

While the framework is focused on using performance measures in support of asset management principles, it is also understood that agencies use performance measures for a variety of purposes, and it is not necessary (or desirable) to create a separate and distinct “asset management” set of performance measures.

1.0 Introduction

■ 1.1 Study Context

Transportation asset management consists of a set of principles, concepts, and techniques for making more effective allocation and use of resources to address preservation, operation, and improvement of transportation infrastructure. The AASHTO *Transportation Asset Management Guide* (referred to hereafter as “the *Guide*”) produced in NCHRP Project 20-24(11) describes these principles and best practices (2). One of the fundamental underpinnings of transportation asset management, as described in the *Guide*, is the use of performance measurement to inform decision making about how to invest limited resources. From an asset management standpoint, performance measures are used to evaluate a range of solutions for addressing transportation needs, to make trade-offs across different resource allocation options, to communicate the implications of different investment levels, and to establish targets for results to be achieved based on available resources.

Many transportation agencies are using performance measurement to help track the impacts of program investments and provide accountability to the public. Some agencies define and use performance targets as an integral part of their performance management approach. However, there is no specific guidance for what types of performance measures and target-setting approaches work best in the context of transportation asset management. NCHRP Project 20-60 was undertaken to provide this guidance and to define a framework that agencies can use to identify suitable performance measures and to set performance targets. The results of NCHRP Project 20-60 are designed to complement the *Guide* that was developed under NCHRP Project 20-24(11).

■ 1.2 Study Objectives and Scope

The NCHRP 20-60 Research Project Statement included two objectives:

1. To provide an assessment of, and recommendations for, performance measures suitable for an asset management approach that effectively address resource allocation in transportation facility preservation, operation, improvement, and expansion; and
2. To develop a framework that decision-makers can use for selecting suitable performance measures and setting performance targets.

Under Objective 1, the investigation of performance measures suitable to transportation asset management should consider the following features:

- a. Utility at various organizational levels in a transportation agency and at network, corridor, and project levels for short- and long-range decisions;

- b. Applicability within the context of an expanding sphere of interest to transportation agencies with initial emphasis on highway facilities;
- c. Methods of collecting measurement data with consideration given to cost, relevance, sensitivity, precision, bias, and consistency across jurisdictional boundaries; and
- d. Extent to which performance measures are effective in:
 - Evaluating practical and appropriate investment decisions for tradeoff analyses;
 - Communicating agency goals and performance to customers (e.g., the public, the legislature, and interest groups);
 - Making decisions by top management;
 - Supporting underlying agency goals and objectives;
 - Making mode-neutral decisions; and
 - Measuring social, environmental, economic, and security impacts.

The development of a framework for selecting suitable performance measures and setting targets under Objective 2 should consider the following features, with an initial emphasis on highway facility assets:

- a. Alignment of performance measures among asset classes, vertically and horizontally, from planning through program delivery, operations, and performance tracking;
- b. Capability of predicting performance and setting performance targets based on funding;
- c. Applicability to agencies with different organizational structures;
- d. Linkages to policy development;
- e. Usefulness to executive information management systems;
- f. Internal and external buy-in;
- g. Complexity and resources needed to manage the framework;
- h. Accommodation of Governmental Accounting Standards Board Statement No. 34 (GASB 34) “modified approach” (if used) and utility in demonstrating linkage between plans and programs pursuant to Title 23, United States Code, Sections 134 and 135;
- i. Ability to demonstrate the overall health and critical deficiencies of infrastructure assets, including:
 - Compensating for overall system averaging effects and
 - Analyzing trends; and
- j. Extent to which actual performance can be attributed to the actions of the transportation agency.

The work program to meet these objectives comprised the following tasks:

Task 1. Existing Information—Review existing national and international literature and practice on the use of performance measures and approaches for developing performance measurement systems used in asset management.

Task 2. Preliminary Evaluation of Performance Measures—From Task 1, describe the methods for selecting and setting performance targets in use by transportation agencies and develop preliminary criteria for identifying promising performance measures. Discuss these with representatives of at least 15 transportation agencies. Develop preliminary approaches for agencies to select performance measures appropriate to asset management and to select targets for these measures that meet Objectives 1 and 2.

Task 3. Interim Report No. 1—Prepare a technical report on the results of Tasks 1 and 2 and meet with the NCHRP project panel to discuss.

Task 4. Detailed Evaluation—Based on NCHRP panel comments from Task 3, gather additional, more detailed information to evaluate the selected performance measures, groups of measures, and approaches. These evaluations should account for the Task 2 criteria and Objectives 1 and 2. This detailed evaluation also will include at least three site visits with transportation agencies.

Task 5. Interim Report No. 2—Submit an interim report that documents Tasks 1 through 4 and proposes the plan for finalizing the potential performance measures and framework(s) for selecting and setting performance targets.

Task 6. Final Framework—On NCHRP approval of the Task 5 Interim Report, finalize the list of promising performance measures and the suggested framework for selecting measures and performance targets.

Task 7. Final Deliverables—Document all tasks and deliver at least the following items:

- a. A research final report,
- b. An executive summary for top management of transportation agencies that includes the promising performance measures,
- c. A guide for using the framework to select performance measures and develop performance targets,
- d. Two presentations (as opportunities arise) to the AASHTO and/or TRB Transportation Asset Management Task Forces in consultation with the NCHRP, and
- e. A PowerPoint presentation that communicates the findings of this research project.

■ 1.3 Contents of Report

This report is Volume I of a two-volume final research report, summarizing the results of the research and describing the recommended framework. Volume II is a guide for using the recommended framework to select performance measures and establish performance targets.

The remainder of Volume I is organized into the following sections:

- **Section 2.0** presents background material on transportation asset management, performance management, and the relationship between the two in order to provide a clear context and set of definitions for the research.
- **Section 3.0** discusses the state of current practice with respect to performance measurement as it relates to transportation asset management. This summary is based on a **literature review and interviews with 15 agencies**, describing the range of performance measures identified for domestic and international agencies, the criteria that now govern performance measure selection, and the ways in which performance measures are used in different agencies.
- **Section 4.0** discusses **criteria for performance measures that are useful to asset management** based on the requirements for this study contained in the scope of work and the principles articulated in the *Transportation Asset Management Guide*. The asset management Self Assessment Tool from the *Guide* is revisited to derive guidelines for identifying and using performance measures in an asset management context.
- **Section 5.0** provides an **in-depth discussion of important considerations in designing and using performance measures and setting performance targets** in support of asset management. This section serves as a detailed technical resource to supplement the procedurally based framework described in Section 6.0 and Volume II.
- **Section 6.0** outlines the recommended framework for identifying, designing, and using performance measures for asset management and for setting performance targets.
- **References** cited in this report and a **bibliography** are at the end of the report.

2.0 Background

Prior to presenting an analysis of the use of performance measures for asset management, it is important to understand how the terms “transportation asset management” and “performance measurement” are defined and used for the purposes of this research. Therefore, this background section begins with a summary of the principles of transportation asset management, as defined in the *Guide*. This provides an important context for the research in that it defines the specific decision processes to be assisted via more effective use of performance measures. Once this context is established, a brief overview of performance measurement and its relationship to asset management is provided.

■ 2.1 Transportation Asset Management

Principles

Asset management is a strategic approach to managing transportation infrastructure that builds on several principles described in the *Guide*:

- **Policy-Driven**—Decisions on infrastructure management reflect policy goals and objectives that define asset condition, levels of performance, and quality of services to meet customer needs and broader economic, community, and environmental goals.
- **Performance-Based**—Goals and objectives must be tied to clear measures of performance. Targets established for these performance measures will guide decisions through the analysis of options, setting of priorities, and program budgeting and implementation.
- **Analysis of Options and Tradeoffs**—Competition for scarce resources and interrelationships among decisions in different investment areas and affecting different assets all argue for considering options and evaluating the tradeoffs among alternatives.
- **Decisions Based on Quality Information**—Choices among options during program development, project selection, and program and service delivery are based on their relative costs and consequences in meeting performance targets. Objective, high-quality information is applied at each step, using analytic methods and decision criteria that are consistent with policy goals and objectives and an agency’s business processes.
- **Monitoring to Provide Clear Accountability and Feedback**—Performance measures are monitored and reported, providing feedback on the effectiveness of transportation investments and services, work accomplished, and program and service delivery.

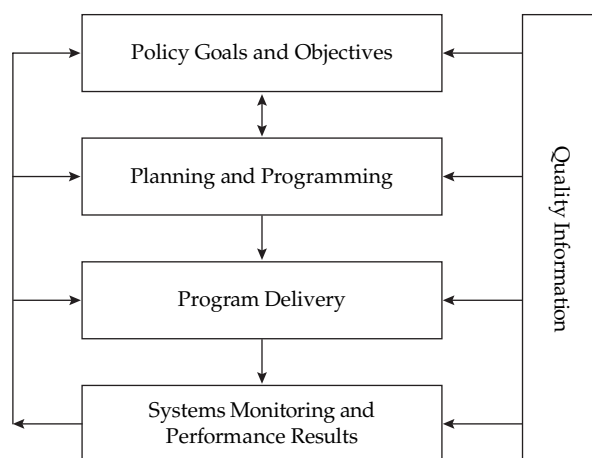
Asset management defines a “way of doing business” by applying these principles to an agency’s existing business and decision processes and its applications of information technology (IT). Asset management is not a separate function or system. It is a way of improving an agency’s existing procedures for resource allocation and use to achieve results cost-effectively, subject to available resources.

These principles already are widely understood. Many transportation practitioners would agree that investment decisions should be based on weighing costs against likely outcomes, that a variety of options should be considered and evaluated, and that quality information is needed for decision making. Many agencies are now pursuing performance-based approaches to planning and programming, monitoring system performance, and developing more integrated data and analysis tools to evaluate tradeoffs among capital expansion, operations, and preservation activities. Most agencies recognize that application of asset management principles is critical in times of constrained resources, when all investment and budget decisions are subject to increased public scrutiny.

To be most effective, asset management principles need to be applied comprehensively across all of an agency’s types of infrastructure expenditures, including preservation, operations, and system expansion as represented in capital construction as well as maintenance and operations programs. In concept, asset management should be implemented in as many resource allocation and use processes as possible—policy development, long-range planning, project development, programming and prioritization, delivery of projects, programs and services, maintenance and operations, and system monitoring and reporting—although agencies may choose to focus on selected high-priority functions initially to gain initial results quickly and affordably.

The *Guide* envisions asset management principles applied throughout key business processes and in IT support, as shown in Figure 1. Performance monitoring is a critical part of asset management, providing current information on the condition and service levels of the transportation system and serving as the catalyst for feedback on future changes that should be considered in policy formulation, planning, programming, and program delivery.

Figure 1. Asset Management Framework from the Transportation Asset Management Guide



Asset Management Practice

Example Decision Process for Resource Allocation

Figure 2 expands upon Figure 1 to illustrate specific resource allocation and delivery activities related to performance measurement that embody the asset management principles above. Key points include the following:

- **Policy Goals and Objectives** and associated **Performance Measures and Targets** are established through policy formulation and ideally are informed by the agency's planning process. Policy objectives and performance targets guide an agency's overall resource allocation and program delivery. They also may drive the agency's strategic business process, if one exists. In addition to expressing statewide policy priorities, the values established for these objectives and targets should account for a realistic projection of anticipated funding and for customer needs as determined during public outreach in the agency's planning process.
- The **Transportation Agency** makes different **Types of Investments** in its transportation system. Figure 2 shows these types in terms of **System Preservation, Transportation System Management and Operation, and Capacity Expansion** (these are explained in the next section). In practice, agencies organize and manage these investments in many different ways (e.g., by program category, type of asset, and level of analysis) whether at a program and subprogram level, corridor level, or project level. The three general types of investments that are shown help explain asset management in a general way, recognizing these differences in agency practices.
- The **Transportation Agency** manages its transportation system and related investments through several **Functions** (e.g., planning, programming, construction program delivery, maintenance and operations, and system monitoring). Again, these general descriptions acknowledge different ways in which agencies organize these functions across disciplinary lines and through centralized or decentralized relationships between central and field offices.
- A **Feedback Mechanism** applies the results of system monitoring to assess current policy goals and objectives and to inform updates in performance targets where needed. Effective feedback helps the agency respond to changing conditions, demands, and priorities regarding its transportation system.

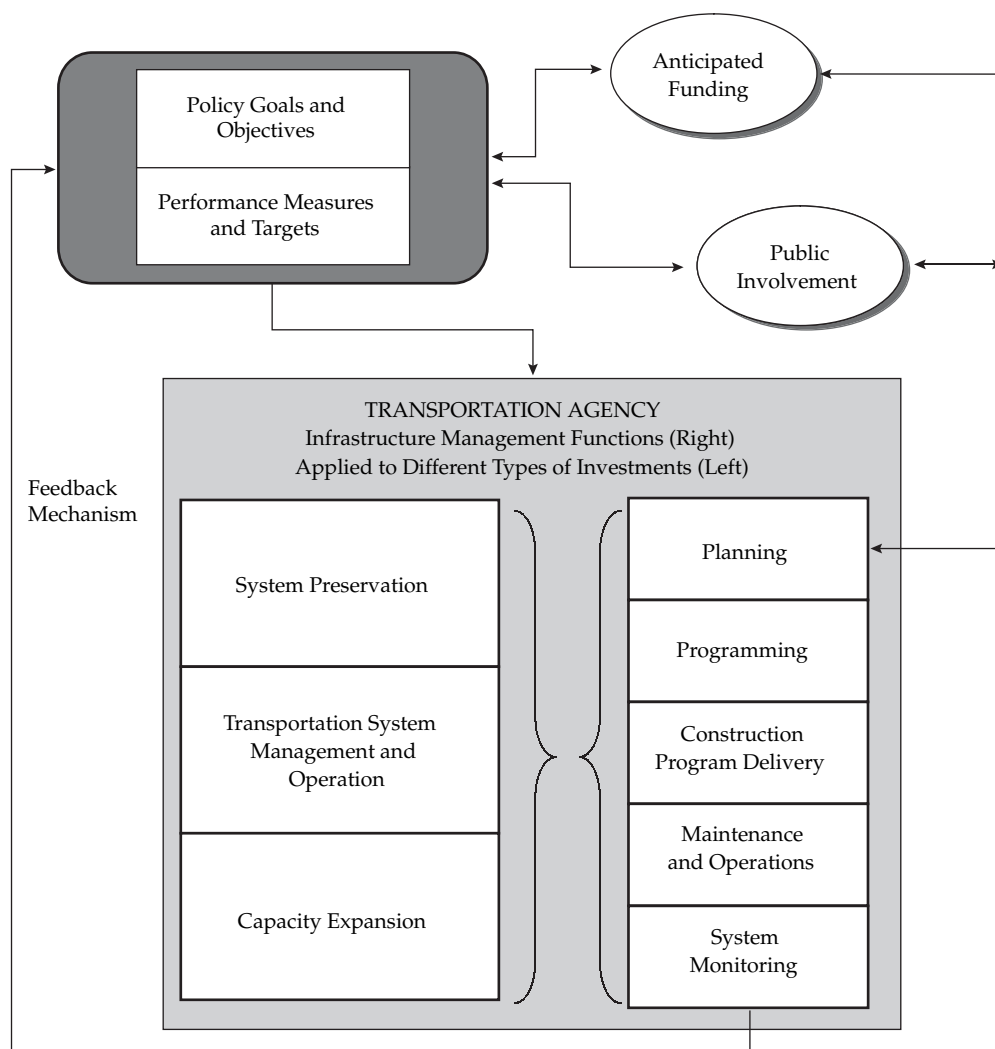
Types of Investments

Figure 2 shows three types of investment categories—preservation, operations, and capacity expansion. These are defined as follows:

1. **System Preservation** encompasses work to extend the life of existing facilities (and associated hardware and equipment) and to repair damage that impedes mobility or safety. The purpose of system preservation is to retain the existing value of an asset and its ability to perform as designed. System preservation counters the wear and tear of physical infrastructure that occurs over time due to traffic loading, climate, crashes, and aging. It is accomplished through both capital projects and maintenance actions.

2. **Transportation System Management and Operation** focuses on the real-time service and operational efficiency provided by the transportation system for both people and freight movement on a day-to-day basis. Examples of operations actions include real-time traffic surveillance, monitoring, control, and response; intelligent transportation systems (ITS); signal phasing and real-time signal controllers at intersections; high-occupancy vehicle (HOV) lane monitoring and control; ramp metering; weigh-in-motion; road weather management; and traveler information systems. For purposes of this study, safety improvements and incident response are also included here. Although operations focuses on system management, the infrastructure needed to provide this capability may be substantial (e.g., traffic control centers, ITS hardware, environmental sensors, and fire control systems in tunnels). Thus, an operations strategy requires capital, maintenance, and operations budgets as well as substantial staff resources.

Figure 2. An Asset Management Approach to Resource Allocation and Delivery of Projects and Services



3. **Capacity Expansion** focuses on adding physical capacity to an existing asset or acquiring or constructing a new facility. Capacity expansion can include mainline construction as well as facilities for intermodal connections and transfers for passengers or freight. New safety features associated with this construction are also included.

These three categories provide a general representation of an agency's broad range of transportation infrastructure expenditures, which may be organized in different ways as noted earlier. Presenting the investment areas in this way helps for the following reasons:

- The categories show that asset management is not just about preservation of highway network assets. It is about making investment decisions that address a wide range of policy goals and transportation system needs.
- The categories provide a simple, useful way for decision-makers to align program investment categories and priorities with key policy objectives. For example, many agencies establish a "preservation first" policy or favor maximizing efficiency of operations prior to investing in new capacity.
- The categories may present alternative ways of meeting a policy goal. For example, it may be appropriate to consider operational improvements to address a congestion problem as an alternative to adding a new lane.
- Decisions about the resources allocated to each category cannot be made independently. Meeting many policy goals (e.g., safety) may require a mix of investments across these categories. Similarly, an increase in capacity expansion investments may require increased operations and preservation expenditures at some point in time.

Asset management emphasizes the need to consider options and evaluate tradeoffs. Realistic funding scenarios that establish the boundaries of this analysis are critical to this process. Trade-off analysis may be done **across investment categories** as well as within them. An agency might wish to define investment areas coincident with the three categories discussed above (preservation, operation, and capacity), or they may define a different set of categories. For example, an agency may have a separate safety investment area and also incorporate consideration of safety within expenditures for system preservation (e.g., replacement of damaged guardrails), operations (e.g., maintenance of signs, markings, signalization, and traffic channelization), and capacity expansion (e.g., project design features supporting safety, such as wide shoulders). This approach would provide the framework for understanding the best mix of complementary actions within the safety area as well as tradeoffs between safety and other objectives. This is but one example; others could be developed illustrating tradeoffs in other types of investments and for other policy objectives.

Infrastructure Management Functions

The infrastructure management functions shown in Figure 2 are examples of basic procedures used by agencies to plan, build, operate, and maintain their transportation systems. While agencies may define, organize, and allocate responsibilities for these functions in different ways and across different disciplines, the descriptions below suffice as general illustrations of performance measure applications throughout the resource allocation process.

- **Planning** encompasses procedures to identify future transportation needs and recommend solutions in the long- to midterm timeframes; develop transportation strategies at a statewide, network, or corridor level across modes; undertake studies of particular needs that require major transportation investments (as for capacity or service expansion); and address strategic issues such as environmental protection and energy conservation. Forecasts of performance measures help to characterize and evaluate alternatives, and to communicate how proposed solutions will meet policy objectives.
- **Programming** and budgeting involve allocations of financial, staff, equipment, and other resources to the different investment areas. Allocation decisions also may be made within an individual investment area across strategies (e.g., preventive versus worst-first preservation), programs (e.g., rural versus urban mobility), asset classes (e.g., pavements versus structures), or projects. Programming options tend to focus on the prioritization of projects and tradeoffs within and among programs and asset classes. Decisions are oriented toward short- to midterm timeframes.
- **Construction Program Delivery** implements the programs involving construction projects, whether for new facilities or additional capacity on existing facilities, capital preservation, or installation of operations infrastructure. Delivery is accomplished in the most cost-effective manner, which involves consideration of different delivery options (e.g., work by agency forces, use of contractors, interagency agreements), as well as a delivery tracking process involving recording of actions taken, costs, effectiveness, and lessons learned to guide future activity.
- **Maintenance and Operations** include delivery of routine maintenance and system management and operations services on existing facilities. Maintenance may include both preservation (e.g., routine and preventive pavement and bridge repair, cleaning of drainage structures, and replacement of damaged signs and safety appurtenances) and operations (e.g., incident response, installation of signs and delineators, signal timing, and snow and ice operations). System management and operation include monitoring of system traffic operations (e.g., traffic loop sensors, surveillance cameras, on-site reports, and weigh-in-motion devices), ramp metering, monitoring and control of HOV lanes, real-time responses to traffic conditions (e.g., variable message signs and incident response), and traffic information services.
- **System Monitoring** tracks system conditions and service levels to determine the extent to which established performance objectives are being addressed. This activity involves data collection, processing, and analysis to compare current values of performance measures with previously established targets. Through a feedback mechanism, this information is used to refine policy goals and priorities (e.g., put more emphasis on safety in response to an increase in crash rates).

■ 2.2 Performance Measurement

Performance measurement is a way of monitoring progress toward a result or goal. It is also a process of gathering information to make well-informed decisions. Performance measures are defined in this study as indicators of work performed and results achieved. Transportation agencies have for many years used performance measures to help forecast and track the impacts of program investments, maintenance, and operations improvements; monitor the condition of system assets; and gauge the management and service delivery of the agency. The value of performance

measures, and of performance-based management processes that apply these measures, can be realized across several areas of agency activity:

- Greater effectiveness in achieving meaningful objectives that have been identified through legitimate processes of long-range planning and policy formulation.
- Greater accountability to policy-makers, the agency's customers, and other stakeholders.
- Increased organizational efficiency in keeping agency staff focused on priorities:
 - Externally, performance measures that are aligned with clear policy goals and objectives help to direct resources and actions to accomplish the agency's mission; and
 - Internally, performance measures can help align strategic business objectives of organizational units in a consistent direction, provide greater clarity in tracking results, and enable managers to make decisions and adjustments in programs with greater confidence that their actions will have the desired effect.
- Improved communication of information about the transportation system to customers, political leaders, other stakeholders, and the public. Explicit and unambiguous goals and objectives, clear and straightforward performance measures, quantitative measures of achievements and identification of future needs, and trends in performance over time all help to provide context for an agency's actions and to demonstrate tangible results of program investments.
- Ongoing improvement of business processes and associated information through feedback and the better understanding of the impacts of alternative courses of action that performance measures provide.

Performance measures traditionally have been largely technical in nature, capturing an engineering or operational attribute of the transportation system. While still important in serving this traditional function within an agency, today transportation executives and managers must address an increasingly complicated and wide-ranging set of issues. These issues include identifying the "best" solutions on balance to transportation problems and system needs, the cost-effectiveness of proposed projects, and the anticipated impacts of these projects. The scrutiny of these decisions, and of agency performance in meeting stated commitments, also has become more demanding. While measures of technical condition and performance are still needed, other types of measures are called for as well. The ways in which performance measures are applied are likewise changing to meet the needs and expectations of stakeholders.

Role of Performance Measures in Asset Management

Since asset management is performance based, performance measures and associated data collection procedures and analytic tools are critical to its successful application. The implementation of an effective, successful transportation asset management concept within an agency uses performance measures as the key to a merit-based, data-driven decision support process. Performance measures and targets embody good asset management practice at several critical points in the agency's resource allocation and delivery process:

- As the practical expression of policy objectives that reflect customer expectations and realistic funding targets.

- As guidance to procedures and criteria used at key decision points in the management functions. For example, performance targets provide a consistent framework for evaluating options in planning, defining, and valuing prioritization criteria in programming; guiding tradeoff analyses in resource allocation; and influencing priorities in delivery of projects and services.
- As the basis for system monitoring to obtain indications of system performance resulting from System Preservation, Transportation System Management and Operation, and Capacity Expansion investments.
- As signals of change through feedback to policy formulation.

This view of asset management that is illustrated in Figure 2, as well as the critical roles that performance measures play in it, will provide a framework for further development throughout this report.

Categories of Asset Management Performance Measures

For the purposes of this study, a set of performance measure categories has been established in order to (1) clearly delineate the types of performance measures being addressed in this effort and (2) facilitate the analysis and discussion of performance measurement in the context of asset management. These categories—composites of those defined in *NCHRP Report 446 (7)* and FHWA report FHWA-OP-03-080 (36)—are based on type of impact so that they can be easily related to policy goals and objectives as well as type of investment. The categories are as follows:

- **Preservation** refers to the condition of the transportation system and actions to keep the system in a state of good repair. Measures are often specific to the type of asset. Performance measures may be expressed, for example, by physical condition (e.g., extent or severity of distress, deviations from nominal track gauge), indices that combine a number of condition measurements or that relate to user perceptions of condition (e.g., pavement condition index, present serviceability index, or rideability index for pavements; bridge health index), or other measures, not necessarily technical (e.g., financial asset value). For purposes of this study, preservation also includes actions to maintain a state of good repair in emergency situations other than terrorist attacks (e.g., severe storms, earthquakes, landslides, scour around foundations, and flooding; also see Security below).
- **Accessibility** refers to the ability of people and goods to access transportation services. Examples of performance measures include a “density” of opportunities enabled by transportation services (e.g., the number of households within a 30-minute drive of key regional centers, or the number of employment opportunities within a 10-minute walk of transit stops) or the ability of a facility to serve a particular user group (e.g., a particular segment of population or type of freight). Availability of modes and modal choice also can be treated as an accessibility measure. Accessibility is often expressed from a user’s perspective.
- **Mobility** refers to the time and cost of making a trip and the relative ease or difficulty with which a trip is made, essentially congestion and the trip measures related to congestion. Some of these trip measures reflect a supplier perspective (e.g., volume-capacity ratio, capacity-related level of service), while others reflect a user perspective (e.g., speed, travel time, delay, trip reliability, and user cost).
- **Operations and Maintenance** refers to the effectiveness of the transportation system in terms of throughput and travel costs and revenues from a system perspective and maintenance level of

service, particularly the customer experience of the system. Since throughput is interpreted in terms of people or goods as well as vehicles, measures of vehicle occupancy or freight capacity may be included here. Cost efficiency includes measures such as average cost per mile or per VMT. Systemwide fuel efficiency is also included.

- **Safety** refers to the quality of transportation service in terms of crashes or incidents that are harmful to people and damaging to freight, vehicles, and transportation infrastructure. Performance measures also reflect asset conditions that contribute to or detract from safety. While safety is often gauged by the number, frequency, severity, and cost of accidents, recent trends recognize a wider sphere of interest in the vehicle- and driver-related causes of crashes, and in harm to agency personnel as well as drivers and passengers, particularly in work zones. Work is also ongoing to predict the risk of future safety problems at candidate locations.
- **Environmental Impacts** refers to the protection of the environment. Performance measures are associated with key impact areas, including air quality, groundwater, protected species, noise, and natural vistas. Output-based performance measures may also be defined for actions critical to mitigating the above impacts (e.g., protecting wetlands, constructing wildlife passages across transportation facilities, using snow and ice chemicals that protect groundwater and air quality, and monitoring and controlling hazardous materials).
- **Economic Development** refers to direct and indirect impacts of transportation on the economy. Direct impacts are typically related to the cost of transportation experienced by users and shippers and are expressed in measures such as economic output (e.g., gross state product), employment (e.g., jobs supported or created), and income. Indirect measures look at transportation's contribution to the general economy, which can be gauged by a wide variety of measures such as traffic at border crossings, manufacturers/shippers/employers who have relocated for transportation purposes, volume of freight originating or terminating in the region, number or percent of employers that cite difficulty in accessing the needed labor supply because of transportation, and measures of truck travel per unit of regional economic activity.
- **Social Impacts** refers to the effects of transportation on the broader society (e.g., neighborhoods adjacent to transportation facilities) or on population groups (e.g., disadvantaged). This is in contrast to "quality of life" impacts that are interpreted by some agencies to mean customer satisfaction specifically. (Note that customer impacts in this study are included in the appropriate category of transportation impact. For example, "customer perception of congestion severity" reflects a customer perception of mobility and is classified with other mobility measures. Similarly, "present serviceability rating" is a customer perception of road surface condition and is classified with other preservation measures. While not all agencies follow this convention, grouping customer satisfaction with other measures is very useful in relating performance measures to asset management functions, as will be illustrated later in the report.)
- **Security** refers to protection of travelers, freight, vehicles, and system infrastructure from terrorist actions. Protection of infrastructure and users of this infrastructure against other emergencies (e.g., severe storms, earthquakes, landslides, flooding, and scouring of foundations) is included in Preservation in this study.
- **Delivery** refers to the delivery of transportation projects and services to the customer. Key performance measures include output-oriented accomplishment measures that complement outcome-oriented measures in the other categories, measures of efficiency and effectiveness in use of resources, and impacts on customers that need to be considered in evaluation of alternative delivery strategies.

3.0 Current Practice Review

Current practice in performance measurement has been identified through a review of literature and in-depth interviews with 15 state transportation agencies. The literature review builds upon a considerable number of recent research studies, surveys of practice, and workshops to avoid duplicating past work. The interviews focused on current and planned agency practices in applying performance measures and how they relate to functions that are important to asset management. This section outlines specific objectives for the current practice review, provides a high-level summary of findings relevant to this research, and then presents a more focused set of observations based on a review of agency-specific references and the in-depth interviews.

■ 3.1 Objectives of the Current Practice Review

A review of current practice was conducted to provide an understanding of the current state-of-practice in performance measurement across a number of state, regional, local, and international agencies. Review of published sources of information provided a point of departure for the conduct of in-depth agency interviews. In conducting the literature review and interviews, the research team sought to gain answers to the following questions, in support of the study objectives as set forth in Section 1.2:

- What criteria are used by agencies to select performance measures?
- How are current performance measurement frameworks structured, and what kinds of measures do they include?
- How are performance measures being used to gauge the impacts of transportation investments, support resource allocation and use decisions, and assess agency performance in program delivery and cost-effectiveness?
- How are measures being tailored for different levels of transportation organizations?
- How are measures being used to communicate program status both internally and externally?

Given the extensive literature on transportation performance measurement (and the existence of other reports containing literature reviews), a specific requirement of the literature review was that it not duplicate recent research on performance measures, but rather build on it. The review therefore did not seek to develop yet another compilation of performance measures in use, but instead to apply existing compilations and reports of agency practice to develop a fuller understanding of how performance measurement could be applied practically in a comprehensive asset management environment.

■ 3.2 Summary of Current Practice

General Literature on Transportation Performance Measurement

Transportation performance measures and performance monitoring have been documented in many sources. Indeed, there is a vast literature on the topic of performance measurement in general and on transportation performance measurement in particular. None of the literature, however, has approached the subject fully from the perspective of transportation asset management as developed in NCHRP Project 20-24(11). The recent literature does reflect, though, greater industry appreciation of a broader range of applications than those dealt with historically, even if not fully engaging all aspects of asset management. This interest in more comprehensive applications of performance measures throughout an agency's functions responds to several trends now affecting transportation organizations:

- A general movement toward more policy- or mission-driven, outcome-influenced, and customer-oriented business approaches in managing programs and delivering services;
- The increasing use of performance measures as a formal component of policy formulation, long-range planning, program budgeting, and program delivery;
- The increase of strategic business planning exercises, in which goals, objectives, performance targets, and tracking of target attainment are applied to key organizational or functional areas of an agency; and
- A renewed focus on the importance of information and analytic tools in supporting performance-based management.

Several national studies and workshops on transportation performance measures provide broad-based data on current practice. They help establish a context for how performance measures are best used in an institutional environment influenced by the Intermodal Surface Transportation Efficiency Act (ISTEA), passed in 1991, and the Transportation Efficiency Act for the 21st Century (TEA-21), passed in 1998. (Key transportation-related provisions of these acts are embodied in Title 23, United States Code.) The acts identify management needs affecting U.S. transportation agencies, distill current practice in its ability to meet these needs, and cite emerging trends that will require further developments in performance measurement. Selected studies also include suggestions for additional performance measures and ways of organizing or structuring performance measures that contributed to the development of the frameworks later in this study.

- *NCHRP Report 357 (26)*. Responding to a high turnover in state DOT executives, the researchers of NCHRP Project 20-24(6)A developed a compendium of 38 program performance measures and indicators that are commonly used by state DOTs. This list is accompanied by background information on performance-based management, descriptions of information on agency services and operations that a new chief executive officer (CEO) should be aware of, and explanations of each identified measure organized in the following categories: administrative, highway program performance, public transportation program performance, and motor vehicle program performance. The report includes a supplement exploring methods for comparing state highway performance among states as requested by the American Association of State Highway and Transportation Officials (AASHTO).

- **NCHRP Synthesis 243 (20)**. NCHRP Project 20-5 (Topic 27-09) reviewed current program-development and management practices in capital programming and project selection by state DOTs. Changes in these practices during the past 10–15 years have in some cases been dramatic, driven by a number of trends (e.g., greater competition for funds; changing roles of state, regional, and local agencies; new financing approaches; greater accountability for stewardship and management of the transportation system; and new analytic tools and approaches to data management), and reinforced by the requirements of ISTEA. The study describes current practice in a number of capital programming functions, several of which are relevant more generally to good asset management. The study’s findings in performance measurement are that “use of performance measures as a means of informing program goals and objectives is not widespread.” Case studies of DOTs in Alaska, California, Florida, Illinois, Kansas, Michigan, Minnesota, Nevada, New York, Pennsylvania, and Washington State describe the types of performance measures that are applied in capital programming.
- **NCHRP Synthesis 238 (25)**. This compilation of state practices in defining and implementing performance measures was motivated by several trends that followed the passage of ISTEA (e.g., a strategic decision support, the need for increased accountability, the need to be competitive in the face of moves to privatize, and growing customer orientation). The study describes measures, techniques, and information used to characterize an agency’s multimodal transportation functions, based on a nationwide survey of state DOTs. Findings confirm that while there is still wide use of performance measures for “traditional” functions such as highway maintenance and traffic safety, many innovations are also underway. These new developments are moving performance measures in more strategic directions: more explicit ties to policy goals and objectives, looking at results or outcomes, and considering quality and customer service.
- **NCHRP Report 446 (7)**. This report is a guidebook for performance-based transportation planning. One of five related projects undertaken by NCHRP Project 8-32(2), this study (8-32[2]A) focused on the use of performance measurement and monitoring in multimodal transportation planning. It establishes a rationale for performance-based planning, discusses criteria for performance measure selection, and illustrates a number of potential applications through case studies. It includes a performance measures library that was developed through a literature review, case studies of applications, and field visits with client organizations. This library provides a comprehensive, structured inventory of performance measures in several areas: accessibility, mobility, economic development, quality of life, environmental and resource conservation, safety, operational efficiency, and system condition and performance.
- **TRB Conference Proceedings 26 (4)**. TRB cosponsored a conference on Performance Measures to Improve Transportation Systems and Agency Operations in Irvine, California, in 2000. Given the breadth of performance measurement theory and practice, the conference focused specifically on “using performance measures for transportation investment decisions, but with a clear understanding that organizational performance (including program delivery) must be considered.” The application of performance measures to outcomes relative to investment levels was particularly of interest. The conference considered all modes and multijurisdictional issues as well. Sessions included the following topics:
 - Linking performance measures with decision making;
 - Agency implementation of transportation system performance measures;
 - Selection of measures, data needs, and analytic issues;

- Connection of system performance measures to broader goals; and
- Freight performance measures.

There was general agreement among attendees on the use of performance measures, providing a point of departure for discussions on how to integrate performance measures better within several agency functions, how to incorporate multimodal and multijurisdictional considerations, results of experiments that had been tried, and a consensus on the need to share information on the processes and experiences of various agencies.

- **Key Transportation Indicators, Summary of Workshop (19).** Two National Research Council (NRC) studies (in 1992 and 1997) recommended that the Bureau of Transportation Statistics (BTS) in the U.S. DOT develop a “consistent, easily understood, and useful set of key indicators of the transportation system.” This report documents the proceedings of a workshop held in June 2000 to discuss transportation indicators and to give BTS new ideas for issues to address. Panels of experts were organized to consider indicators in three areas: safety, mobility, and economic growth and trade. Within each area, the panelists discussed measures now in use, key issues, potential new measures, and discussions of related topics such as suggested criteria for selecting measures and suggested additional practices in reporting and using measures.
- **Performance Management: A “Start Where You Are, Use What You Have” Guide (37).** This guide focuses on performance-based management in the public sector 10 years after passage of the Government Performance and Results Act (GPRA). It makes its points by posing issues or positions that have been voiced since passage of the GPRA, which claim that some aspect of performance measurement “doesn’t or can’t apply to my agency.” It discusses the issue and provides a number of “recommended responses” as guidelines to why performance measurement *can and does* apply to an agency, and by what rationale. Issues and responses are organized in several areas: Making the Case for Performance Measurement, Designing Performance Indicators, Aligning Performance Processes, Using Performance Information, and Communicating Performance Information.
- **Performance Measures for Small Communities—Final Report to the FHWA (36).** This report takes a look at performance measures from the unique perspective of small communities. Agencies at this level have smaller road networks and different scales of data collection and analysis, performance reporting, and decision support from those of larger metropolitan planning organizations (MPOs) and state DOTs. In focusing on operational performance measures for small communities, the report discusses several findings (e.g., that despite the large number of potential measures available, few are in use by small communities; that mobility measures likely to be of greatest interest are facility-level congestion measures; that operational strategies focus on major signalized arterials; and that there exist data collection strategies that can feasibly support operational performance measures for small communities).
- **NCHRP Project 20-24(20) final report (33).** Project 20-24(20) looks at performance measurement in the context of strategic management, with the objective to provide guidance to state DOT CEOs and senior managers on how to develop strategic performance measures. Strategic management comprises activities to identify important agencywide goals and objectives and then work toward achieving them. These activities may range from formal business plans to define vision, mission, goals, objectives, and the actions to achieve these, to more informal approaches. Strategic performance measurement combines strategic management and performance measurement: It links strategic goals and business processes, but without the need to track hundreds of different mea-

asures. The final report is a handbook for agencies to conduct strategic performance measurement, organized around four building blocks: basic principles, selection criteria for measures, examples of individual measures that agencies can use, and an implementation framework. The report provides examples of strategic performance measures used by state DOTs in Florida, Kentucky, Louisiana, Maryland, Minnesota, New Mexico, Pennsylvania, and Washington State.

- *Transportation Performance Measures in Australia, Canada, Japan and New Zealand* (34). This report presents the findings of an international scan tour on the use of performance measures for transportation planning and decision making. Members of the scan tour identified several good examples of the use of performance measures for setting priorities and making investment and management decisions. Approaches to safety performance measures were observed to be particularly notable, and the report devotes a separate section providing detailed treatment of this topic. It is interesting to note that the innovative practices that were found were related more to *how* performance measures were used than to which specific measures were used. One of the study's conclusions was that all of the sites visited use measures that are commonly used in the United States. However, practices identified—such as the use of before-and-after studies to document the impacts of implemented actions and provide feedback for future investment decisions—are not typically followed in the United States.

Performance Measures for Routine Maintenance

A review of performance measures associated with routine maintenance was included in this study. For those aspects of maintenance that help preserve the transportation system, routine maintenance can be included in an analysis of capital-maintenance tradeoffs for preservation. Those aspects of maintenance that involve service delivery can contribute to operational efficiency, mobility, or safety.

Performance measures for routine maintenance are not at the same stage of development as those for capital programs, but the state of the practice is advancing. Several states, including Washington, Colorado, and Arizona, have implemented maintenance quality or level-of-service approaches to improving accountability and linking maintenance resource allocation decisions to measured and projected performance. For example, Colorado DOT defines nine levels of service for each maintenance element and assigns grades based on annual surveys. The Colorado Transportation Commission reviews this information and decides on target levels of services (linked to budgets) for each element. Colorado collects data on expenditures by maintenance element on a quarterly basis, and uses this data to provide an indication as to whether they are tracking on their level of service targets.

The issues involved in advancing the state of maintenance management and their implications for performance measurement were considered in depth at a forum on “Maintenance Management for the 21st Century” held in Arlington, Texas, March 16–18, 1999. This forum identified six critical areas on which agencies needed to focus to become “high-performance maintenance organizations for the 21st century” (27):

1. **Customer service**, focusing on outcomes as perceived by transportation users in all phases of maintenance planning, budgeting, and program delivery;
2. **Integrated information systems**, providing consistent, coordinated, and performance-based information and decision support for executive, operational, and financial decisions across a number of agency functions;

3. **Data collection and processing for condition assessment**, emphasizing the need for cost-effective leveraging of technology to provide information on the condition of maintained features that is needed for effective maintenance management;
4. **Improved maintenance planning** to enable performance-based, customer-oriented development of maintenance programs and budgets and to link with other management systems and sources of information where needed;
5. **Organizational development** through training to instill the business, technical, and leadership skills that maintenance managers will need in the 21st century management environment; and
6. **Performance management** to develop a management culture within the maintenance organization that takes a strategic approach to delivering high-performance results through a process of continuous improvement.

This workshop was followed by a second workshop focusing on commonly recognized performance measures for maintenance. Expert practitioners gathered to present ideas on performance measures that could serve an outcome-based, customer-oriented approach to maintenance management (5). The AASHTO Highway Subcommittee on Maintenance advanced this idea in a resolution to work with the FHWA and TRB to adopt commonly recognized performance measures that would help deliver “improved outcome-based maintenance practices” (1). This subcommittee then conducted a survey of member and affiliate agencies to determine current practice regarding maintenance performance measurement. The findings showed that heavily used maintenance performance measures are predominantly input- and activity-based, with output-based measures to a slightly lesser degree. Outcome-based measures are used to some degree, but the trend toward using them in the future is strongly increasing (3).

Overview of Agency-Specific Practice

Agency-specific information documents performance measures in use and establishes context (i.e., the relationship of performance measures to policy goals and objectives, the use of performance measures at different organizational levels and across agency units, and their application to different functions and activities [e.g., planning, project justification, program development, and tradeoff analyses]). Agency-specific information has been obtained from several types of documents, including long-range plans, strategic business plans, program development reports, comprehensive annual financial reports prepared in compliance with GASB 34, and reports and compilations of measures prepared for agencies updating their performance-based processes.

As noted above, another source of agency-specific information is a series of interviews conducted for this study with 15 transportation agencies. The interviews have covered a geographically balanced set of states, as indicated in Table 2. These states also exhibit varying levels of development of, and approaches to, performance measurement, examples of which are presented later in the report.

The agency interviews revealed several general characteristics of current practice:

- Performance measurement is clearly a matter of continuing interest and attention. Of the agencies that already have adopted performance measures, several (e.g., New York, Florida, Colorado, Ohio, and Virginia) have ongoing initiatives to renew, redevelop, or transform their performance

Table 2. States Interviewed for This Study

State	AASHTO Regional Association
Colorado	4 – WASHTO
Florida	2 – SASHTO
Idaho	4 – WASHTO
Iowa	3 – Mississippi Valley Conference
Maryland	1 – NASTO
Michigan	3 – Mississippi Valley Conference
Minnesota	3 – Mississippi Valley Conference
Montana	4 – WASHTO
New York	1 – NASTO
Ohio	3 – Mississippi Valley Conference
Pennsylvania	1 – NASTO
South Carolina	2 – SASHTO
Tennessee	2 – SASHTO
Virginia	2 – SASHTO
Washington	4 – WASHTO

NASTO =	Northeast Association of State Transportation Organizations
SASHTO =	Southeast Association of State Highway and Transportation Organizations
WASHTO =	Western Association of State Highway and Transportation Organizations

measurement systems; to develop integrated performance measurement at strategic, business management, and operational levels; or to incorporate performance measurement more strongly into an asset management approach. Agencies that do not now use performance measures widely (e.g., Iowa and Tennessee) are taking steps to strengthen their application.

- Although the interviews dealt mostly with highway measures, agencies discussed their multi-modal operations and the performance measures applied in nonhighway modes. Modal programs are typically managed through separate organizational units and/or funding sources (e.g., Idaho and Maryland DOT).
- Although the interviews reflected this study's focus on resource allocation, several agencies (e.g., Maryland, Michigan, Montana, New York, Virginia, and Washington) stressed the importance of *program delivery* in external reporting and in contributing to an agency's credibility in

performance measurement generally. Montana noted that project delivery targets, letting schedules, and the types of work to be done to meet system performance targets were negotiated with the contractor community. Maryland observed the difficulty of establishing accurate cost estimates that could be used in delivery targets because of the ancillary costs associated with projects, a topic that has also been considered in Washington State and Montana.

- Although most agencies have well-defined performance measures for system preservation and mobility that relate to capacity expansion, agencies are now also increasingly working to develop appropriate performance measures for system management and operation, especially operational efficiency. Florida, Michigan, and Minnesota are examples of agencies that have instituted performance measures for operational efficiency, ITS deployment, freeway system performance with ITS, effectiveness of snow and ice operations, and incident response.
- Several agencies (e.g., South Carolina, Washington, Ohio, and Iowa) have tied transportation system performance to employees' annual appraisals or assessments.

The information presented in the remainder of Section 3.0 combines findings from general sources on transportation performance measurement and agency-specific information identified above. Documents contributing information to these presentations are compiled in the bibliography at the end of this report.

■ 3.3 Organizational Contexts

There are clear variations across agencies in their approach to asset management and use of performance measurement. There is no single set of universal performance measures that will work in every agency, and there is no single, standard “right way” of implementing them. While transportation asset management rests on several core principles, application of these principles to addressing transportation system problems and needs varies across agencies to accommodate their particular system inventories, organizational structure and responsibilities, and management culture. How performance measures are applied and interpreted likewise reflects individual agency characteristics. For example, although asset management and performance measurement are associated with a greater degree of integration and coordination of agency objectives across business units, several interviewees (e.g., interviewees from Idaho and Maryland) stressed the continuing importance of maintaining core business lines to provide needed technical expertise. In other words, asset management is not inconsistent with *organizational “silos”* when the term is used to denote agency units housing important skills and information. What asset management tries to address, however, is *avoiding a silo-based mentality*—that is, avoiding “working with blinders on.” Methods that agencies use to coordinate and integrate and business processes and decisions among their disciplinary units include:

- Forming cross-functional teams. For example, Colorado DOT is pursuing a core services approach to performance measurement in which teams from multiple units are responsible for action plans in key functional areas (project delivery, system operations, roadway, roadside, etc.). The core services approach is intended to promote alignment across organizational units and counteract “stovepipe thinking.”
- Assigning other agency units the specific role to coordinate across the technical units (e.g., planning and strategic policy offices).

- Relying on technological mechanisms to promote integration and coordination through shared data (e.g., geographic information systems [GIS]).

Some DOTs have in fact implemented asset management approaches that represent a comprehensive, integrated effort. Two examples for Florida and Ohio are described in accompanying Sidebars 3.1 and 3.2.

Sidebar 3.1: Summary of Florida’s Asset Management Approach

The Florida DOT is decentralized and operated through a central office and eight districts. The agency manages a system of roadways and bridges and is responsible for motor carrier compliance in the state. The department’s role with respect to public transportation is to provide funding and technical support to local agencies and private-sector entities that own and operate 14 seaports, 22 commercial airports, 3,000 miles of main route rail, 18 local and regional transit systems, and 48 specialized systems serving the transportation disadvantaged. The department is responsible for 12,000 of the 114,500 centerline miles of public roads in the state. The department maintains 6,200 of the 11,000 bridges statewide.

The Florida DOT’s mission is to provide a safe transportation system that ensures the mobility of people and goods, enhances economic prosperity, and preserves the quality of the environment and communities. The department’s asset management process is the holistic approach used for decision making, investment analysis, and management of transportation assets. It encompasses the entire process from planning and programming to system preservation. It is characterized by a solid policy framework, measurable objectives, and continuous performance monitoring. It seeks sound investment decisions with a customer focus. The asset management concepts of data-supported decision making, management systems, strong relationships between condition and performance, and an emphasis on tradeoff and investment analysis are integral components of daily business at the department. These concepts are part of the culture and are strongly supported by upper management. There is no single office responsible for asset management; rather, the department is permeated with responsibility for evaluating and reporting the results against goals and objectives.

Asset management is incorporated into a continuous process that links policies with financial planning, programming, and performance monitoring to determine if objectives are met. The performance measurement then results in appropriate decisions regarding funding levels and adjustment of plans and policies to begin a new cycle.

Asset management begins with a strong statutory policy framework documented in the Florida Transportation Plan (FTP). The FTP establishes 20-year goals and objectives and is updated and published every 5 years. The Short-Range Component of the FTP documents shorter-range (10-year) goals, objectives, and strategies and is published annually. A more detailed Program and Resource Plan sets forth specific operating policies and performance measures that guide the development of each program. The Program and Resource Plan is a 10-year plan containing program funding levels and financial and production targets that are balanced to anticipated revenues. It is produced annually for the legislature. A 5-year list of projects (called the Work Program) is developed annually based on the FTP, the Program and Resource Plan, extensive district and public involvement, and ultimately decision making by a strong executive committee at the department. Finally, a performance report is produced. The performance report is an annual report, including a summary of the financial operations of the department and the success in meeting short-term goals.

Florida has made an investment decision that preservation of the system is “taken off the top.” Preservation is divided into three categories: pavement, bridge, and routine maintenance. Each of these has an extensive inventory-driven, performance-based management system that allows for investment decisions to be made based on demonstrated needs and priorities.

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Sidebar 3.1: Summary of Florida's Asset Management Approach (continued)

Only after all preservation and public transportation dollars have been allocated are capacity dollars programmed. In 2003, the Florida legislature created the Strategic Intermodal System (SIS), a network of statewide and regionally significant intermodal facilities to help guide transportation investments that are important to Florida's future economy. The new investment policy has the objective of allocating 75 percent of discretionary funds to the SIS. The SIS will increase the emphasis on corridor-based planning and investment, encourage innovative policies and technologies (as in the use of intelligent transportation systems), and provide key input for the FTP. The remaining 25 percent of discretionary funds go to other, existing capacity programs: Other Arterials, Transit, Rail, Seaport, and Aviation, particularly for facilities that emphasize regional travel.

Decision support systems are available to help analyze investment decisions.

Sidebar 3.2: Summary of Ohio's Asset Management Approach

Ohio is divided into 12 districts, with District Deputy Directors who report to management at headquarters. Since 1995, the department has gone through a period of decentralizing, downsizing, and cost-cutting. Recognizing that existing funding was insufficient to meet program needs, in 1999 the department changed to a funding process based on need, taking explicit account of system conditions, to replace the legacy approach built on what programs had received in the past. This approach is supported by strategic plans and performance measures. Ohio DOT (ODOT) produces a District Multi-year Work Plan that identifies preservation projects for 10 years, in addition to a 30-year statewide transportation plan. An annual ODOT report card is produced.

An organizational performance index (OPI) monitors 65 key measures. These measures include metrics for pavement and bridge conditions, program delivery, and highway maintenance results. These measures are reviewed by each division and are rolled up to an index of higher-level measures. Quarterly executive reports highlight exceptions (i.e., areas that are not meeting goals). Districts are tasked with developing a plan to correct these failures, and the process is monitored. Monthly reports ensure that districts currently are meeting goals and are forecasted to meet goals in the future.

Day-to-day business operations are managed by districts. District offices oversee planning, design, and maintenance and manage construction. District Deputy Directors sit in on quarterly ODOT meetings and discuss performance. Central headquarters develops policy and training, has Quality Assurance Reviews to identify and recommend changes in current policy, and conducts statewide planning.

The department funds preservation and operations needs and then considers funds available for expansion. Recently, the expansion program has benefited from a revenue increase.

Capacity expansion projects receive separate funding of approximately \$500 million per year in a congestion relief program, an increase from \$300 million annually in the late 1990s. Half of this money is provided by the federal government, and half is derived from a 2-cent-per-year increase in the gas tax over the next 3 years. This revenue increase, passed by the legislature and signed by the governor, is one of the few recent fuel tax increases for transportation in the United States. Competition for these capacity expansion (i.e., multimodal congestion relief) projects is statewide and includes a systematic, fact-driven

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Sidebar 3.2: Summary of Ohio's Asset Management Approach (continued)

application process involving local governments, MPOs, and the review and support of ODOT districts. The applications are reviewed and decisions made by a nine-member statewide Transportation Review Advisory Council chaired by ODOT's director and members selected by the governor, president of the Senate, and speaker of the House.

- Preservation projects and operations are funded separately from expansion. Legislators did not want to lower performance in these areas by moving money toward capacity. System preservation and safety are the top priorities of the department, and this is reflected in the allocation of funds.

A Funds Management Committee (FMC) recommends funding allocations, which are reevaluated every 2 years:

- The FMC recommends to ODOT senior management the mix of performance targets and associated funding levels supported by trend analysis, deterioration projections, and tradeoff analyses among alternative scenarios.
- Sensitivity scenarios are presented by districts. For example, for \$X, Y amount of maintenance can be performed. For 10 percent more money, 15 percent more maintenance can be performed.
- Based on this information, a negotiating process determines the final funding allocation and balance among projects.
- Central headquarters sets policies on goals and performance metrics statewide and by districts.
- The highway system is considered in tiers, with a priority system composed of all interstates and the rural multilane National Highway System routes.
- The central office sets allocation targets for bridges and pavement by district, based on need and deficiencies.
- The central office gives districts goals and the task of choosing projects that will meet those goals. Goals are different for each district, and each district may be at different stages of projects. Districts must file plans for projects by a certain date.
- District goals are updated every 2 years. For pavements, districts have unique goals for FY 2004 that are based upon initial system conditions and funding. By 2008 all districts must have 90-percent acceptable pavements.

3.4 Approaches to Selecting and Organizing Measures

Existing Criteria to Select Performance Measures

Criteria that agencies now use to select performance measures are listed in Table 3. Those most commonly used include:

- Are easily understood by both technical and nontechnical audiences,
- Can be implemented with current resources (e.g., available data and existing information systems),

Table 3. Criteria Now Used to Evaluate Performance Measures

Criteria	NCHRP interim document (6)	Delcan Corp. et al. (13)	TRB Conference Proceedings (14)	Performance measures report for San Francisco Bay Area (16)	Arizona DOT Planning (24)	NCHRP Synthesis 311 (28)	Mobility Paper for FHWA (32)
Easy to understand	●	●	●		●	●	
Well-defined and quantifiable						●	
Professional credibility						●	
Describes existing condition						●	
Can be predicted	●	●			●	●	
Implemented with current resources	●	●			●	●	●
Reasonable accuracy	●					●	
Reasonable precision						●	
Applies to multiple modes	●				●	●	
Changes over time	●			●	●		
Varies by transportation alternative	●			●	●	●	
Characteristic can be controlled	●		●		●	●	
Captures user's experience							●
Interpreted consistently			●			●	
Reflects outcomes			●				
Benefits outweigh costs			●				
Supports goals	●	●			●		
Applicable across corridors		●					
Compatible with standards		●					
Reliability of source data	●	●			●		
Meaningful across geographic scales	●				●		

- Reflect impacts of different transportation alternatives, and
- Reflect characteristic(s) that can be controlled by the implementing agency.

It turns out that many of the criteria in Table 3 are consistent with good asset management practice. It should be recognized, however, that agencies may have good reasons for defining particular performance measures that go beyond the recommendations of asset management (e.g., requirements of state statute or of external reporting). The recommendations of this report, focusing on asset management, may therefore represent a subset of the full range of performance measures that an agency needs to apply.

Organizing Performance Measures

Table 4 summarizes different approaches to organizing performance measures. Many of these approaches are consistent with the set of performance measure categories established for this study (and presented in Section 2.2). Agency-specific efforts identify performance measures primarily by type of impact or aspect of performance (e.g., safety, mobility, and preservation), which are typically tied to an agency's goals and policy objectives. Tying performance measures to types of impacts promotes a direct connection between an agency's policy objectives and the results of investments intended to achieve those objectives. More general national or international studies organize performance measures in a way that reflects the particular objectives of the research.

Clearly, there are other ways to define categories of measures. Agencies tailor their own classifications of performance measures to respond to policy objectives, programs, management styles, and reporting needs. While there is general agreement on preservation as a key category, agency practices vary in how to classify measures of transportation availability and traffic movement (i.e., to what degree do accessibility, mobility, trip reliability, and operational efficiency represent separate "categories" of measures as opposed to one being a subset of another). Also, while the organization described in Section 2.2 assumes that "customer-oriented measures" are included in each of the respective categories, some agencies treat customer-oriented measures as a separate classification. These are arbitrary distinctions that should not distract from the objectives of this study.

Table 4. Examples of Ways to Organize Performance Measures

Source	Organizational Approach	Categories of Measures
NCHRP 8-32(2) (6)	Type of impact (rel. to policy goals)	Accessibility, mobility, economic development, condition, etc.
Vermont Highway System Policy Plan (9)	Type of impact (rel. to policy goals)	Preservation, safety, mobility, etc.
	Level of application	Interstate, state system, priority network, etc.

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Table 4. Examples of Ways to Organize Performance Measures (continued)

Source	Organizational Approach	Categories of Measures
Ontario Ministry of Transportation (17)	Type of impact (rel. to policy goals)	Preservation, cost efficiency and control, modal integration, etc.
	Organizational use	Corporate measures (e.g., percent highway length in good condition); and technical measures (e.g., pavement condition index, maintenance measures)
Maryland DOT (2003) (15)	Type of impact (rel. to policy goals)	Preservation, system performance, support of Smart Growth, etc.
	Class of measure	Performance indicators (e.g., dollars spent, number of projects advertised) and cost-effectiveness measures (e.g., average age of buses)
San Francisco Bay Area Metropolitan Transportation Commission (16)	Type of impact (rel. to policy goals)	Mobility, safety, economic vitality, etc.
Montana DOT (18)	Type of impact (rel. to policy goals)	Pavement, bridge, safety, and congestion
OECD (22)	Type of impact (rel. to policy goals)	Mobility, safety, environment, equity, etc.
	Stakeholder	Government, road administration, and road user
National Research Council (19)	U.S. DOT strategic goals	Safety, mobility, economic growth and trade, human and natural environments, etc.
New Zealand (21)	Asset type	Roads, structures, equipment, etc.
Arizona DOT (24)	Long-range goal	Access and mobility, safety, stewardship, etc.
Canada (30)	Measurement type	General, macrolevel indicators for road assets; indicators of service quality provided to road user; indicators of productivity and efficiency of providing roads, indicators of sectoral effectiveness, and indicators of institutional effectiveness
Mobility Monitoring Program (32)	Aspect or type of impact (rel. to policy goals)	Travel time measures, travel rate measures, delay measures, etc.
NCHRP 20-24(20) (33)	Strategic issue	Externally driven (e.g., mobility, congestion, safety, etc.) and internally driven (e.g., preservation, operations, project delivery, etc.)

■ 3.5 Current Performance Measures

Performance Measures in Use

There are thousands of performance measures now used or proposed for use in transportation that have potential applicability for asset management. Appendix A in Volume II of this report consists of a series of tables presenting sample performance measures, organized by the goal-based categories introduced in Section 2.2 (Preservation, Mobility and Accessibility, Operations and Maintenance, Safety, Economic and Economic Development, Environmental Impacts, Social Impacts, Security and Delivery). These tables are by no means exhaustive—for each measure listed, there are numerous variations with respect to the source data used—for example, pavement condition can be based on roughness, rut depth, indexes of surface distress, and/or other factors. There are also many variations with respect to how a given measure can be formulated—for example, average pavement condition, the percent of the pavement network above or below a stated threshold value of condition, and a percentile level of condition (such as the condition level defining the worst 10 percent of pavement). Some of the most common formulations were included in the tables, but each item should be viewed as representative of a larger set of performance measures that may take slightly different mathematical forms. By focusing on the essential characteristics of a measure, these abbreviated descriptions make it easy to distinguish major aspects of performance and identify options for defining measures.

Since the tabulations are composites from many sources and there is significant overlap among them, individual sources are not identified in the tables. The reference list and bibliography at the end of this volume include the sources of these example measures.

Measuring Social, Environmental, Economic, and Security Impacts and Concerns

Social, environmental, economic development, and security impacts are increasingly important aspects of decisions on transportation investments. While these measures are generally less well developed than those for preservation, mobility, and safety, a number of example measures were identified in the literature and are included in Volume II Appendix A. Since these impacts tend to be non-economic in nature, they are often characterized in qualitative rather than quantitative terms. Additional suggestions for incorporating these types of impacts within strategic evaluations of transportation performance are given in FTA report FTA-GA-26-7000 (38).

Output and Outcome Measures

“Outputs” refers to the agency costs (e.g., the number of staff hours spent or the tons of asphalt used), and “outcomes” refers to the resulting improvements in performance or condition (e.g., the increased percent of pavement in good condition, improved mobility and safety, and lower travel costs to customers). The common wisdom today is that it is preferable to measure “outcomes” rather than “outputs” (and either of these is certainly better than measuring “inputs”) to achieve results-oriented performance monitoring. This thinking is reflected in sources on performance monitoring (e.g., Wye, 2002 [37]), and in interviews with several agencies acknowledging an intention to move toward more outcome-based measures. Many interviewees admitted, however, that their state of practice is now to look at outputs.

With growing experience in performance measurement, some agencies are beginning to revisit the common wisdom and to believe that a blend of output and outcome measures may be preferable to using either type alone. The rationale for this argument builds on the prior experience of the research team in working with state DOTs and the ideas expressed by agencies in interviews conducted for this study:

- Outputs may be more easily understood by a nontechnical audience, including policy-makers in the legislative and executive branches.
- Outputs are often easier and less expensive to measure than outcomes and therefore can provide interim performance results until outcomes can be gauged. It also may be possible to relate outcomes to outputs through research, thereby enabling output measures to serve as surrogates for outcomes.
- Output measures provide an immediate indication of accomplishment for those activities whose benefits accrue over the long term (i.e., where “outcomes” are not immediately apparent). Outcomes should still be monitored over the long term, but outputs supplement this information with short-term indications of what work has been done.
- As a corollary to the above, output measures provide a tangible indication of accomplishment for preventive maintenance. Outcomes of preventive maintenance are the avoidance of damage (which is difficult to measure), cost-effective extension of service life (which is measurable, but only over the long term), and consequent benefits to customers through sustained levels of good rideability and lower road user costs (which is also measurable, but only over the long term). Again, outputs fill in the short-term need for information, while confirmation of the benefit of preventive maintenance accrues over the long term.
- A blend of outputs and outcomes serves different analytic needs in asset management, particularly in life-cycle cost analysis. Both types of measures support better quantification of life-cycle costs and benefits at different levels of investment and resulting levels of transportation service.
- Examples from agency experience include the following:
 - While Minnesota DOT began moving to outcome measures several years ago, it is now starting to emphasize output measures at lower levels of the organization to support the outcomes at higher levels.
 - The Montana DOT has observed that maintenance and operations performance measures typically deal with outputs rather than outcomes. It is therefore difficult to coordinate these activities with long-term pavement and bridge preservation strategies developed by management systems.

Performance Data Collection

Good data are critical to good performance measurement. The interviews suggest that data availability, quality, and affordability are key issues. Based on the comments received, affordability is seen more as an issue of the amount of data collected rather than the relative costs of different data collection methods or technologies. Having too much data is not only expensive, but also potentially confusing and lacking in cohesiveness to the public.

Maryland has been partly successful in obtaining approval for a revenue program in 2004. It is now employing asset management reasoning to secure a significant share of the increased funding for highway system preservation (objective: increase from \$275 million to \$450 million). The case is data driven with charts, graphs, and so forth. There is a need to overcome the perception that “the system now looks good—why are additional resources necessary?”

Additional observations on the importance of data include the following:

- Representatives from Montana and Washington said that good, well-presented data have helped agencies in making their case before their legislatures.
- Maryland makes the point that its small size gives it an advantage in the feasibility of a single inspection team for statewide data gathering, promoting greater consistency.
- A comment by Tennessee captures the sentiment—“Bad data is worse than no data at all.”

Data Supporting Preservation Measures

- Pavement condition data are typically collected annually for high-classification highways. The most common data collection methods are windshield surveys and vehicles equipped with automated sensing and recording equipment, such as an automatic road analyzer (ARAN). Other methods include customer surveys, photo logs, and video logs.
- Bridge condition data are typically collected biannually through field inspections, as required by federal regulation.
- Maintenance data are collected through periodic surveys and may employ sampling techniques.
- Some agencies (e.g., Tennessee) may apply their GASB data and targets to preservation.

Data Supporting Operations and Management Measures

DOTs vary widely in the extent to which they collect data to support operations and management performance measures. Examples of states that do support these measures include the following:

- Florida DOT tracks several measures gauging incident response and travel time and delay on limited-access freeways managed by ITS.
- Ohio DOT performs an annual maintenance survey of pavement, drainage, vegetation, signing, guardrail, and litter.
- South Carolina DOT performs an annual sign condition survey.
- Minnesota DOT and Iowa DOT track snow removal using reports filled out by plow operators.
- A common source of accident data are state and local police reports. New York DOT uses an accident surveillance system.
- Minnesota DOT tracks incident clearance time on the Twin Cities Metro Freeway system using an incident tracking system and video cameras.

Data Supporting Capacity Expansion Measures

- Traffic data are collected through permanent traffic recorders, weigh-in-motion (WIM) devices, speed detectors, temporary traffic monitors, and video cameras.
- Traffic data are often supplemented with comprehensive traffic studies (e.g., an annual mobility report or regional travel model) and individual studies that focus on a specific segment or corridor.

Tracking and Projecting Performance

Trends in performance measures provide useful information for management. Virtually all DOTs that were interviewed tracked historical levels of performance. Minnesota observed that while devices such as “dashboards” are useful in reporting the status of a program, analyzing trends in performance measures is more meaningful.

Most agencies indicated that they also project at least one category of performance measure into the future. Typically these include preservation-related measures, owing to the wide implementation of management systems for pavements, bridges, and maintenance.

Travel demand models are also used to forecast transportation needs, future congestion levels, and the types and locations of capacity expansions and improvements in operational efficiency. In addition to applying analytic models, agencies may extrapolate historical trends. Several agencies admitted an inability to predict future safety performance.

■ **3.6 Approaches to Aligning Measures within the Organization**

Organizational alignment of performance measures vertically (from top management to technical staff) and horizontally (across functional units) was an important topic of discussion in the interviews. From an asset management perspective, top-to-bottom consistency in performance measurement is essential for providing a strong linkage between policy objectives and decision making; horizontal consistency allows for tradeoffs to be made across different geographic and functional areas.

Vertical Alignment

Vertical alignment enables performance measures to be used in a consistent way by different levels of an organization. Agencies rely on several approaches to vertical alignment:

- **Shared Use**—The most basic form of vertical alignment is the shared use of performance measures at different organizational levels, as is done by ODOT and New York State DOT. This method implies the ability of performance measures to apply to networks of different scales (e.g., at a foreman or area level, districtwide, and statewide) and to “roll-up” results from one level to the next higher one.

- **Summarizing Technical Measures**—Technical performance measures may be translated to other measures more useful at a higher managerial level by mathematically summarizing performance results. For example, the New York State DOT tracks multiple technical measures related to bridge condition, such as a bridge condition index and a maintenance condition index. However, only one number, the percent of deficient bridges, is generally reported to upper management.
- **Formal Relationships Among Measures at Different Levels**—Some agencies have established formalized vertical relationships between measures. For example, the Ohio DOT visualizes a pyramid (Figure 3) to illustrate how performance measures are integrated to provide strategic guidance. Beginning at the bottom, the organizational performance index (OPI) uses a consistent set of 75 measures across the entire organization to evaluate performance across the 12 district offices and central divisions of ODOT. The OPI monitors day-to-day operations; each measure is indexed to complete a balanced scorecard that is used to track monthly changes in divisional performance. “Strategic Initiatives” are process-improvement efforts targeted where significant organizational performance gaps exist in meeting “Goals.” “Values” of system condition measures such as pavement deficiencies, bridge deficiencies, crashes, and congestion relate “Goals” to the corporate “Mission.” In addition to Ohio’s example, other agencies (e.g., Iowa, Idaho, Minnesota, South Carolina, and Tennessee) formalize hierarchies of performance measures through strategic business planning efforts; other agencies (e.g., Colorado) do so through program investment categories; and other agencies (e.g., Florida and Pennsylvania) do so through similar strategic management tools.
- **Shared Data and Data Formats**—Storing and reporting performance measures within agencywide repositories and reporting results in a single, consistent format can promote vertical alignment as well as horizontal alignment (see the next section). For example, Michigan DOT’s Transportation Management System (TMS) serves as a repository of over 100 performance measures. This system provides decision-makers throughout the agency with access to the same performance data.

Figure 3. Vertical Alignment of Performance Measures—Ohio DOT



Horizontal Alignment

Horizontal alignment implies the consistent use of performance measures across agency functions and programs in meeting the agency's different goals. This use of performance measures can facilitate tradeoffs across investments in different program areas and can provide clarity with respect to the contribution of different organizational functions to a unifying set of goals. The interviews demonstrate several ways to achieve horizontal alignment:

- **Statutory or Other Statewide Mandate**—Agencywide consistency in performance measurement can come about in responding to a state government requirement. For example, Michigan and Vermont have state statutes mandating asset management in transportation infrastructure. Michigan DOT and local transportation agencies are members of an Asset Management Council; one of the responsibilities of this council is to report on infrastructure conditions in a consistent way. Vermont's law requires the Agency of Transportation to report on condition and trends in its infrastructure according to defined guidelines. South Carolina DOT is required by legislation to submit monthly reports to the House Ways and Means Committee and the Finance Committee regarding progress toward several maintenance objectives. In complying with this mandate, all of the DOT's districts track the set of measures in a consistent manner. Iowa's Accountable Government Act requires each Iowa state agency to prepare both a Strategic Plan and a Performance Plan. The Strategic Plan outlines the agency's vision, mission, and core functions, provides a brief internal and external assessment, and outlines strategic departmental goals. The Strategic Plan is submitted by the governor's office to the legislature for approval. The Performance Plan provides desired outcome measures and targets in each of the core areas.
- **Multidisciplinary Involvement**—As a practical matter, horizontal alignment is often associated with good communication among agency units regarding goals and objectives. For example, the Michigan DOT conducts regular meetings with representatives from the planning, delivery, operations, and financial functions (including field staff) to assess the relationship between committed design and delivery schedules, available revenues, and advancing toward the DOT's performance targets. New York State DOT's goals were developed by a task force comprising representatives from all major program areas. The resulting targets apply to all functional groups. Idaho DOT facilitates discussions among its core business lines through its Planning, Administration, and Budget Policy and Intergovernmental Relations units, focusing on a long-range view of issues rather than tactical or operational matters.
- **Statewide Measures and Guidelines**—Another approach to horizontal consistency is to establish statewide measures. For example, Florida DOT has established statewide measures that can be rolled up from the district level. The districts support these statewide efforts and use the resulting measures because the central office provides consistent guidance and policies. Minnesota DOT also has a set of "core" measures that tend to be applicable at the system level (such as those used in the Statewide Plan) or to priority processes such as those used in project development.
- **Central Data Repository**—A single source of consistent data, such as Michigan DOT's TMS, promotes horizontal as well as vertical alignment, as noted above.

Challenges in Current Practice

Achieving consistency in performance measure interpretation and use throughout the organization takes work and attention, and many practical problems can impede full alignment. For

example, Washington State DOT (WSDOT) has found that a major impediment to increasing horizontal consistency is data availability. While many of WSDOT's management systems are theoretically capable of supporting agencywide performance assessment, associated databases are not fully populated.

Maryland DOT has found that vertical alignment varies among its modal administrations. Whereas the Motor Vehicle Administration has significant vertical alignment, other modes (e.g., highways, transit, aviation, ports, and toll roads) are less so, and the relationships to decision making are more indirect. In these cases, budget-makers and policy-makers are aware of operational measures and influence their direction, but there is no direct link between this guidance and day-to-day decisions. On a departmentwide basis, vertical alignment is still at an early stage. While Maryland DOT expects to make improvements in vertically integrated performance measurement over the next few years, even then this will be just one tool, not *the* tool, for managing the department.

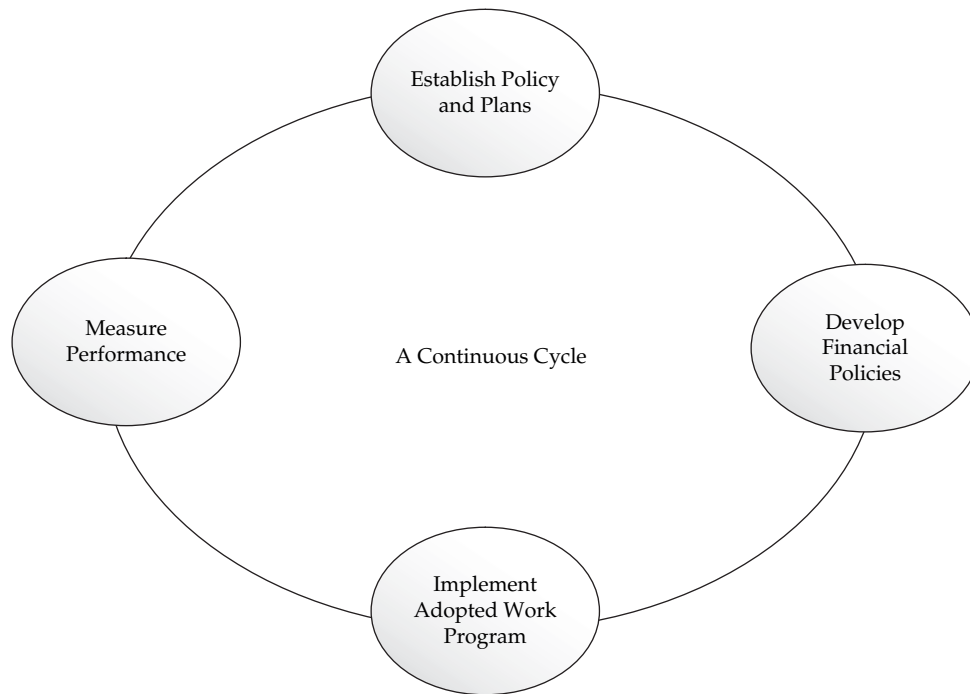
■ 3.7 Use of Performance Measures

Performance measures currently are being used to support high-level policy and resource allocation decisions, to evaluate and compare solutions at a corridor and project level, and to support daily operations. Specific ways in which agencies use performance measurement to provide feedback into decision making are discussed below.

Providing Feedback for Use in Resource Allocation

Existing feedback mechanisms among the agencies interviewed range from discussions of planned versus actual accomplishments and decisions on the next cycle's targets to formal, structured processes. Agencies also varied in the degree to which they emphasized public engagement in the feedback mechanism.

- **Structured Feedback Process**—An example of a structured approach is contained within Florida DOT's asset management process, which is referred to as a "Continuous Cycle Approach" (Figure 4). Plans and policies are established through the Florida Transportation Plan and the Short-Range Component. Financial policies are established in the Program and Resource Plan. Five-year projects are programmed in the Five-Year Work Program, and, finally, performance is measured. The results of the performance monitoring affect the development of long- and short-range plans through adjustment of policies.
- **Quarterly Management Reviews**—Colorado DOT's executive management team reviews quarterly performance reports for different business process areas. If performance is below target, responsible staff are expected to offer explanations and suggestions for improvement.
- **Public Feedback**—Montana DOT conducts public opinion surveys and meets with stakeholder groups regarding the outcomes of its Performance Programming Process (P³). This approach provides critical public feedback to its P³ and assists in future policy formulation and long-range planning (refer to the feedback and interactive processes shown in Figure 2).

Figure 4. Florida DOT's Asset Management Feedback Loop

- **Activity Adjustments Based on an Analysis of Trends**—Iowa DOT provided examples of adjustments to its maintenance program based on observed performance measure trends (e.g., the mowing activity was modified to focus on safety considerations [i.e., sight distance] rather than aesthetics, and funds were shifted to address the edge rut problem for safety reasons).

Tradeoff Analysis

Tradeoff analyses lie at the frontier of asset management. Many agencies either (1) are not yet at a stage of analytic capability or organizational readiness where they are able to perform systematic project and program tradeoffs or (2) choose not to perform these tradeoffs even if they have the prerequisites in place. One agency that described its tradeoff procedures during the interviews is Ohio DOT. A Funds Management Committee is charged with recommending how to allocate funds. Allocation is reevaluated every 2 years by the following process:

- The committee recommends to ODOT senior management the mix of performance targets and associated funding levels. These recommendations are supported by trend analysis, deterioration projections, and tradeoff analyses among alternative scenarios.
- Sensitivity scenarios are presented by districts. For example, for \$X, Y amount of maintenance can be performed. For 10 percent more money, 15 percent more maintenance can be performed.
- A negotiation process determines how funds will be allocated to achieve a balance among proposed programs of projects.

■ 3.8 Setting Performance Targets

Appendix B in Volume II presents examples of performance targets from several agencies. These targets were identified through a compilation of comprehensive annual financial reports (for FY 2002) used for GASB 34 reporting (conducted by the research team as part of NCHRP Project 19-4), and from a Cambridge Systematics report for the Vermont Agency of Transportation (9). The tables in the appendix illustrate the variety of measures, numerical scales, and target values used. The interviews with state agencies nonetheless highlighted a number of factors commonly considered when DOTs develop performance measure targets:

- Anticipated funding level through the forecast horizon (Idaho, Michigan, Minnesota, Montana, Ohio, New York, and Washington);
- Public involvement (Michigan and Montana) and customer-based market research (Minnesota);
- Existing condition (Montana), historical performance trend (Minnesota), limited information on performance compared with other states (Minnesota), and the implications of different proposed condition levels (Idaho);
- Input from the DOT director, the transportation commission or board, governor’s office, or state legislature (Michigan with Ohio);
- Policy goals/guidance and statewide priorities such as “preservation first” (Florida, New York, and Iowa);
- Discussion with the construction industry (Michigan);
- Life-cycle costs (if a model is available), marginal value of additional investment (100-percent targets are not always advisable) and tradeoff considerations (Minnesota); and
- Priorities by route classification (Iowa).

Practices and levels of attainment in setting targets vary considerably among the agencies. Some (e.g., Iowa, South Carolina, and Tennessee) regard the effort as a work-in-progress, while others (e.g., Florida, Michigan, Minnesota, and Ohio) have developed fairly refined methods. The more advanced states tend to see target-setting as a multidimensional process, involving financial considerations (current and anticipated funding), technical considerations (current and forecast conditions or performance), policy considerations (existing priorities, customer and public involvement, executive and legislative input), and economic considerations (life-cycle cost considerations where applicable). Agencies have developed several mechanisms to deal with these multiple considerations, including the following:

- **Multiple Horizons and Stages of Development**—Maryland and Minnesota DOTs recognize targets in a short-, medium-, and long-range context (Maryland: 2, 6, and 20 years; Minnesota: 6, 10, and 20 years). Financial constraints tend to be imposed on the short-term targets, with latitude allowed for long-term targets. In addition to different timeframes, Minnesota DOT

also defines three “categories” of performance measures and treats each one differently in target setting:

- Mature—baseline data exist, and targets have been set;
- Emerging—data are available, but targets are not yet established; and
- Developmental—neither data nor targets now exist.

Targets are set only after a baseline data trend has been established. Targets also may be adjusted over time, especially for emerging measures and for those measures that are only indirectly or partially influenced by the DOT (e.g., Mobility). For mature measures, current (baseline) performance is shown, as well as trend-based performance projections and policy-based performance targets. The future performance gap is also highlighted (see Figure 5). Actual levels of performance are monitored and compared with targets to ensure that the targets are achievable.

- **Value of a Systematic Process**—Montana DOT has adopted a formal process for developing targets. Over time, the state legislature has gained confidence in the process and related funding requests because it provides consistent, quantifiable performance information that is fiscally constrained. The process is well received by the districts because it sets the type of work needed to meet the targets, but provides flexibility in terms of actual project selection.

Figure 5. Minnesota DOT’s Performance Target Levels

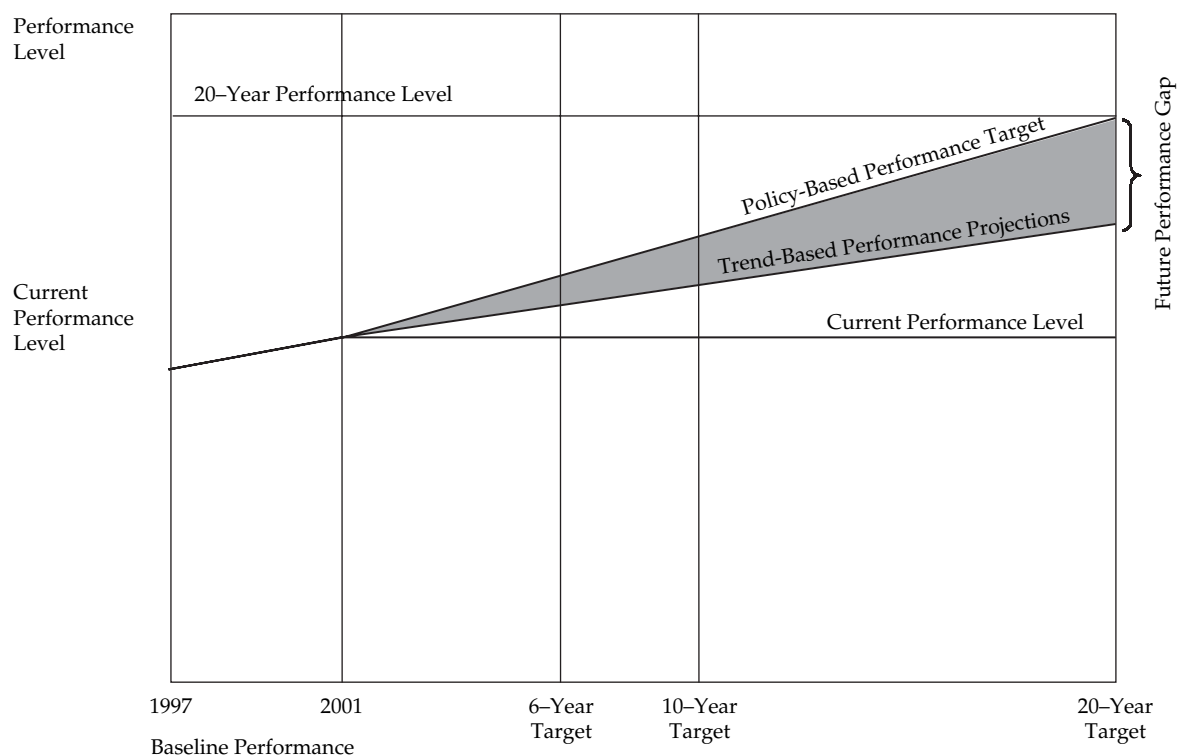
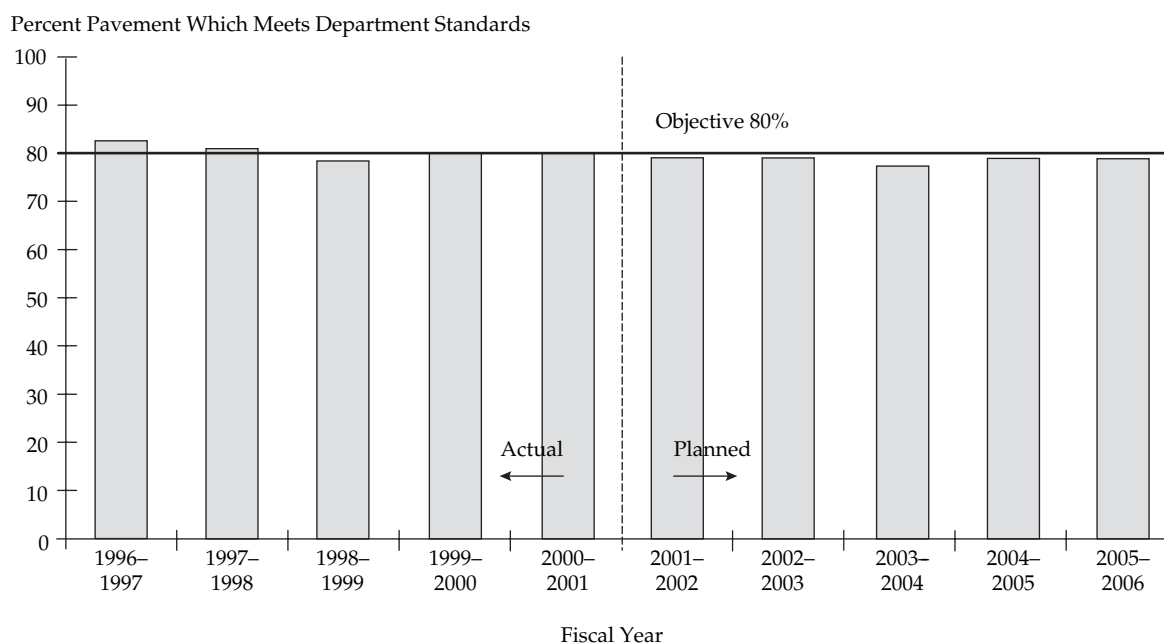


Figure 6. Florida DOT Measurable Objective
Pavement Condition



- **Communicating Targets**—Florida DOT also focuses on short-term targets (referred to as “measurable objectives”) to define realistic, fiscally constrained commitments. Figure 6 illustrates a mechanism used by Florida DOT to communicate measurable objectives, in this case for pavements.
- **Conflicts when Setting Targets**—While some agencies responded that there were “competing” but not “conflicting” targets, others readily acknowledged that conflicts do occur.
 - Ohio DOT noted that the use of multiple measures can often lead to conflicting priorities. District deputy directors review certain performance measures every day, and the agency’s standard management reports allow for comments regarding conflicting performance requirements. This information is reviewed on a monthly, quarterly, and annual basis, and performance measure and target adjustments are made accordingly.
 - Michigan DOT identified two major conflicts—preservation work versus capacity projects and increasing the speed of project delivery versus improving project quality.
 - The greatest source of conflict at WSDOT is environmental compliance, since WSDOT has a target of zero violations. Continual reevaluation of policies and procedures is needed. South Carolina DOT also noted that in the event of conflicts, environmental compliance and safety tend to win over other considerations.

4.0 Performance Measures for Asset Management: Criteria and Guidelines

This section discusses how performance measures are used in the context of transportation asset management and presents criteria and guidelines to be used for identifying performance measures that are compatible with and supportive of an asset management approach.

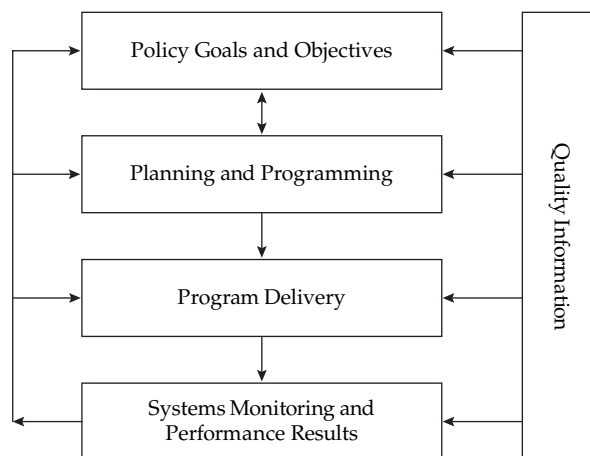
■ 4.1 How Performance Measures Support Asset Management

Using Performance Measures Within an Asset Management Framework

The basic framework of asset management decision making in resource allocation and use (see the *Guide*) was introduced in Figure 1, and for convenience is repeated in Figure 7. The major components of the framework include the following:

- **Establishment of policy goals and objectives.** Performance measures should be identified in response to goals and objectives, rather than the other way around, and should be a part of policy formulation and its interaction with long-range planning. Performance measures can help in formulating policy and setting realistic objectives. The projected outcomes of proposed policies and an agency's ability to produce those outcomes given realistic revenue projections, available staffing and other resources, and competing investment needs are ideally analyzed prior to policy adoption. A performance-based approach to policy requires thinking through the priorities of all policy goals under consideration and making decisions on the most important goals and objectives to be met. Performance measures also can be a valuable mechanism to inform and involve the public in the policy-setting process.
- **Planning and programming,** in which performance measures are used to structure the comparison of different investment options at the network and project levels. In addition, criteria used for project prioritization should be consistent with policy objectives and associated performance measures. The use of performance measures rarely makes decisions easier or automatic, but it can inform the decision-making process and communicate more effectively the consequences of investment choices. Performance measures also can improve the degree to which agency managers, staff, and the general public understand how a certain decision is reached and can contribute objectivity to deliberations about investment choices.

Figure 7. Asset Management as a Resource Allocation and Utilization Process



- **Program delivery**, in which performance measures for tracking the actual versus planned mix of projects provide important information to management. In addition, performance measures related to impacts of construction and maintenance work zones on delays and safety are of interest to many agencies, and can be used to influence decisions on work scheduling and packaging.
- **System monitoring and performance results** are critical components of performance-based planning. Monitoring is based on ongoing inspections or observations of the transportation system to track performance trends and assess the cumulative impacts of investments already undertaken. System operation and management also can be analyzed on a performance basis, using data collected in real time. These data can be gathered by various sensing devices to track performance in terms of traffic movement, transit vehicle location, and locations of transient or recurring congestion. Feedback to the planning and policy-making stages allows for assessment of performance trends and identification of need for midcourse adjustments or, potentially, updates to policy objectives or the planning process itself.

While **communicating and reporting results** is an element of system monitoring and performance results, its importance deserves special emphasis. The several audiences for performance-based information will encompass agency managers with specific responsibilities for delivering system performance, elected officials, and customers and other stakeholders. While the content and detail of reports to these groups may differ, collectively they document accomplishment, communicate the benefits of the transportation program, establish management accountability for results, and provide a point of departure for discussion of future revisions to policy goals and objectives, performance targets, or the set of performance measures themselves.

- **Quality information** is of course critical for supporting a performance measurement effort. Limitations in the scope of existing analytic tools and available data often preclude the ideal of producing performance measures that are in complete alignment with defined goals and objectives, and compromises must be made. Over time, however, data collection and processing techniques and analytic tools can evolve to yield a more robust and descriptive set of multimodal performance measures that support the policy framework established by an agency.

Importance of Information and Analytic Tools

The role of information and analytic tools is critical to the effective application of performance measures throughout the asset management cycle. Management systems and other analytic tools need to perform calculations and to report results in terms of applicable performance measures. Information and analytic capabilities that are needed to support infrastructure management and to report or predict values of performance measures include the following:

- An inventory of existing transportation infrastructure, including the type, number, and location of assets. Performance measures for inventory and historical changes can be obtained through queries of the inventory data file and retention and accessibility of inventories for multiple time periods.
- Measures of current condition and service level or performance, updated periodically through observation or inspection surveys. Performance measures for condition or performance and historical trends can be obtained through periodic inspections and updates of the current data file, queries of the current data file and retention and accessibility of condition and performance data for multiple time periods.
- Analytic procedures to forecast the change in condition, service, or performance over time. These forecasts or predictions are critical to evaluation of alternatives and to tradeoff analyses. Results need to be reported in terms of costs to achieve an alternative and the impact on the appropriate performance measures.
- Thresholds or guidelines that indicate, for a given current condition or performance level, the appropriate treatment or fix. Some systems base these guidelines on “decision rules” specified by the agency and incorporated within the management system or tool. Other systems employ mathematical optimization to determine the preferred strategy, based upon economic, engineering, and management criteria. Performance measures need to capture the systemwide effects of these thresholds or guidelines.
- Treatment and cost models to estimate the cost of each treatment or type of work and the level to which the facility is repaired or its life extended. Performance measures need to capture the life extension or change in condition or performance due to each treatment.
- Impact models to forecast the implications of the investments determined above and their effect on system performance and transportation users. Performance measures must be directly incorporated in analytic tools.

Several types of management systems have been successfully used by DOTs for many years. Systems dealing with infrastructure preservation include pavement, bridge, and maintenance management systems. Systems dealing with improvement or mobility include travel demand and system planning models. While these tools provide useful information at the technical level, their application to broader policy, program, and tradeoff analysis is more limited, and their usefulness to executive-level decision making has therefore not been as strong as it could be. Problems also exist in data availability and quality in dealing with broader issues and tradeoffs. Agencies recognize these needs, and research has been ongoing in recent years to develop, for example, models that estimate cost/benefit information for various multimodal improvement strategies, travel

demand management strategies, operational strategies, and multimodal tradeoffs. Work is also underway by these agencies to develop new approaches not only to shared or integrated data, but also to the organizational responsibilities for data stewardship needed to ensure collection, processing, storage, and retrieval of data needed by multiple users across the agency.

■ 4.2 Criteria and Guidelines for Selecting Performance Measures

Identifying performance measures suitable for asset management (Objective 1 of this study) requires criteria or guidelines that define what attributes or characteristics performance measures should have.

An initial statement of criteria for identifying performance measures was developed based on the principles of asset management from the *Guide*. These criteria were reviewed as part of the in-depth interviews with 15 agencies. This section begins by presenting the initial criteria and the agency review comments. Then, it elaborates upon these criteria through an in-depth look at the series of asset management best practices articulated within the Self Assessment Tool that was included in the *Guide*. The result is a set of final criteria and guidelines for use of performance measures within an asset management context. These guidelines reflect and reinforce the discussion presented above in Section 4.1.

Criteria for Performance Measure Identification

The following criteria derive from the basic concepts and principles articulated in the *Guide*.

Policy Driven

Asset management is policy-driven, informed by the long-range planning process and subject to realistic fiscal constraints. Performance measures should:

- Be sensitive and responsive to policy objectives and
- Convey meaningful information about the transportation system.

Strategic Perspective

Asset management encourages a long-term view of performance, cost, and impacts. Performance measures should:

- Be able to be forecast,
- Relate to an economic as well as a technical dimension, and
- Reflect a combination of outputs and outcomes.

Consideration of Options and Tradeoffs

Asset management encourages consideration of options and encourages tradeoff analyses among competing solutions and programs. Performance measures should:

- Be sufficiently sensitive to reflect impacts of a broad range of options and potentially modes;
- Help to relate system impacts to factors under the agency's control and to identify impacts of factors not under the agency's control;
- Be applicable to scenario testing or "what-if" analyses;
- Provide a clear indication of changes in impacts due to different proposed investments, funding levels, and resource allocations;
- Enable a linkage analytically between budget and performance while considering the requirements of the GASB 34 modified method; and
- Be able to relate project outcomes to the program level.

Decisions Based on Good Information

Asset management is supported by good information. Performance measures should:

- Be a part of an agency's routine business processes, supported by management system and other analytic tools;
- Meet the criteria described above in terms of how they are incorporated within an agency's management system and analytic tools;
- Be amenable to analytic procedures appropriate to different organizational levels; and
- Have realistic and feasible data requirements, relying on quantitative measurements where possible.

Feedback

Asset management entails a feedback mechanism linked to performance measurement. Performance measures should:

- Provide information enabling managers to understand problems and suggest solutions;
- Be able to be monitored economically on a periodic basis; and
- For performance measures dealing with system operations and management, be able to be monitored and provide useful feedback in real time.

Implementation Across Organizational Units and Levels

Asset management should be applied comprehensively within an agency's functions, as represented in Figure 7. Performance measures should:

- Be developed for technical as well as managerial and executive levels within the organization and
- Be of a mathematical form that permits aggregation or "rolling up" where appropriate.

Comments by Agencies in Interviews

During the interviews, agencies were presented with the performance measure criteria proposed above. The agencies were asked to indicate the level of importance of each criterion (high, average, or low) and to discuss the implications (benefits, problems, issues, etc.) of implementing measures that meet these criteria. Of 15 agencies interviewed, 11 responded to this portion of the survey. One of the 11 respondents provided ratings for all criteria except the one addressing a "long-term view" and the one for "feedback mechanisms." Highlights from this portion of the interviews are presented in Table 5.

The responses overall reflected a high priority across all of the asset management principles. Three of the six principles enjoyed a particularly strong level of support: policy-driven, need for good information, and feedback. Supporting comments included the following:

- Policies for the transportation system need to reflect statewide policies of the gubernatorial administration.
- The wealth of good information potentially available must be screened to identify those data of highest quality, usefulness, and affordability, without getting bogged down in needless detail.
- Feedback is important and certainly a cost-effective way to bring about change, but it is also impeded by several organizational and human resource issues.

While the other principles (strategic perspective, consideration of options and tradeoffs, and implementation across organizational units and levels) were also ranked highly, several respondents raised exceptions to them:

- Asset management criteria may not be applicable to all programs, business processes, and decisions.
- Developing performance measures for some policy objectives, programs, and functions may be difficult.
- Existing agency culture, organizational makeup, and legacy systems and methods of analysis may impede asset management application.

Other general comments that were offered by those interviewed include the following:

- Considering options and alternatives—Some agencies felt that this criterion did not apply across the board—it is more relevant to work by in-house employees rather than contractors, and impacts for capacity alternatives are differentiated only over the long term.

Table 5. Feedback on Performance Measure Criteria

Principles of Asset Management	Criteria for Performance Measures	Number of Responses			Additional Feedback
		High	Average	Low	
<i>Policy-driven</i>	Measures are sensitive to and reflective of policy objectives. Measures convey meaningful information for decision-makers about transportation system performance.	9	2	–	This criterion should be rated “very high.” It is important to reflect the governor’s vision for transportation. This vision will drive detailed positions. Cross-business-line performance measures reflecting policy objectives are needed. Policy-level measures are not always seen as manageable at the mid-management level.

(continued on next page)

Table 5. Feedback on Performance Measure Criteria (continued)

Principles of Asset Management	Criteria for Performance Measures	Number of Responses			Additional Feedback
		High	Average	Low	
<i>Strategic perspective</i>	<p>Performance measures can be forecast.</p> <p>Information is collected periodically to reflect changes over time.</p> <p>Measures can be incorporated in a life-cycle cost analysis of options and tradeoffs.</p>	8	1	1	<p>Conditions long-term are so uncertain that targets are not meaningful. The public and its representative-elected officials have a much shorter timeframe.</p> <p>Long-term consequences of current decisions need to be conveyed to decision-makers. This extended planning horizon supports more strategic decision-making.</p> <p>Barriers in this area include a lack of good models for forecasting, lack of technical capability among staff, and constraints of legacy systems. This is a new area not now in the industry's culture.</p> <p>This criterion is important at the system level but not at the corridor and project levels.</p> <p>Long-term measures are not always understandable to a nontechnical legislature. This issue can be addressed by using both outputs and outcomes.</p> <p>Periodic data collection should not be too frequent.</p> <p>Long-term measures for maintenance may be difficult to implement because conditions are constantly changing.</p>

Table 5. Feedback on Performance Measure Criteria (continued)

Principles of Asset Management	Criteria for Performance Measures	Number of Responses			Additional Feedback
		High	Average	Low	
<i>Consideration of options and tradeoffs</i>	<p>Measures are sufficiently sensitive to reflect impacts of a broad range of policy and investment options.</p> <p>Measures help relate system impacts to factors under the agency's control and to identify impacts of factors not under the agency's control.</p> <p>Measures are applicable to scenario testing or "what-if" analyses.</p> <p>Measures provide a clear indication of changes in impacts due to different proposed investments and funding levels.</p>	6	4	1	<p>It takes longer to see impacts on capacity than on preservation.</p> <p>It is important to demonstrate actual improvement resulting from the actions taken.</p> <p>Through an iterative process, some optimization can be achieved without sophisticated what-if scenarios. The combination of long-term views and feedback mechanisms may compensate for a less than optimal scenario-generation system.</p> <p>This principle is highly important for in-house activities, but low in importance for contracted activities.</p> <p>Outcome- and customer-oriented measures are weaker in this area.</p> <p>Performance measures are only one of many tools to address this principle.</p> <p>This is not a priority today, but will be in the future. The primary consideration today is available funding. Additional analytical capabilities are needed to evaluate alternatives on a broader basis.</p>

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Table 5. Feedback on Performance Measure Criteria (continued)

Principles of Asset Management	Criteria for Performance Measures	Number of Responses			Additional Feedback
		High	Average	Low	
<i>Decisions based on good information</i>	Measures enable a linkage between budget and performance.	10	1	–	Good information is extremely important and must be reliable and affordable. Decision-making should be data driven. Bad data are worse than no data at all.
	Measures reflect a combination of outputs and outcomes.				Too many measures can be a problem, increasing expense of data collection and presenting a confusing picture to the public.
	Measures relate project outcomes to the program level.				Not all budget categories can be linked to customer/outcome measures (like safety), and there may be uneven data quality in some areas.
	Data accuracy is validated and considered sufficient for purposes used.				This is a very big issue because a significant amount of data is potentially available for collection. It is important to avoid the trap of more data collection without considering quality and usefulness. Data quality is not consistent across all areas. Relating project outcomes to the program level is a low priority.

Table 5. Feedback on Performance Measure Criteria (continued)

Principles of Asset Management	Criteria for Performance Measures	Number of Responses			Additional Feedback
		High	Average	Low	
<i>Feedback</i>	Measures assess outcomes with sufficient sensitivity to reflect results of system changes.	9	1	–	Feedback mechanisms are important because plans are much easier to change than long-term physical assets.
	Measures provide information enabling managers to understand problems and suggest solutions.				Barriers in this area include insufficient training, lack of aptitude for analytical thinking, and reporting cycles that are tied to management cycles.
	Measures can be monitored economically on a periodic basis.				Generating good district feedback and good analysis of data can be a challenge.
	Operations measures can be monitored and provide useful feedback in real time.				A large gap in this area is an understanding of how to get the full value out of data. Information year to year needs to be consistent. Short-term changes should be more sensitive than long-term changes. Monitoring “periodically” is important; monitoring “economically” is not.
<i>Implementation across organizational units and levels</i>	Measures are applicable to technical, managerial, and executive levels within an organization.	7	3	1	An agency’s multimodal nature works against comprehensive application. Measures need to be realistic. If they are too broad, one can lose sight of actual conditions.
	Measures permit aggregation or “rolling up” where appropriate.				Aggregation and rolling up numerically is not always seen as the best approach.

- Add criteria relating explicitly to public and stakeholder involvement and references to the statewide long-range plan.
- Add criteria that will result in measures that address (1) financial issues, (2) transit systems, and (3) program delivery.
- Another possible criterion is transportation system efficiency, particularly given rising fuel prices. Example performance measures include gallons of fuel used per capita, VMT per capita, and percent of journey-to-work trips that are drive-alone (single occupancy).
- Performance-based budgeting creates anxiety that funding may be affected and may therefore lead to attempts to “game” the system.
- The process of developing measures, if conducted rigorously, is just as important as reporting results—it forces an agency to think clearly about its objectives.
- The role and growing importance of operational performance measures needs to be acknowledged.
- The role that fiscal constraints play in setting targets and implementing asset management should be reemphasized.
- Measures used by the FHWA and AASHTO and used for GASB 34 reporting should be considered.
- The link between performance monitoring, budgeting, and programming is important. Performance measures should be able to support decisions related to the actual programming of improvements.
- One agency would like to see some type of voluntary consistency among the states, especially adjacent states, in targeted conditions, to know what the current state of practice is among neighboring agencies.

Many of these observations are addressed below in the development of guidelines for using performance measures within an asset management context. They also were considered in development of the framework presented in Section 5.0 and Volume II.

Guidelines for Using Performance Measures in Transportation Asset Management

Revisiting the Asset Management Self Assessment

An extensively used feature of the *Guide* is a Self Assessment Tool that helps agencies judge their progress in implementing asset management principles and identify opportunities for improving asset management practice. The Self Assessment Tool presents a series of statements representing good asset management practice and asks for a rating of how well this matches with current agency practice. This section revisits this Self Assessment Tool with a focus on understanding the implications of asset management for performance measurement. Over 60 percent of the questions in the Self Assessment Tool directly relate to performance measures and targets.

The left column of Table 6 shows the core asset management principle(s) as described in Section 2.1 of this report. The middle column shows the asset management best practices from the Self Assessment Tool. The right column indicates the implications of the best practice(s) for evaluating an existing set of performance measures and selecting new ones.

The result of this analysis is a set of guidelines for identifying and using performance measures in a transportation asset management context. These guidelines were used to develop the framework described in Section 5.0 of this report.

Guidelines

1. Performance measures should be selected to cover established goals and objectives.
2. Performance measures should be consistent with the criteria used to make resource allocation decisions.
3. Predictive models or methods for relating investment levels to future performance should be available for each performance measure selected.
4. Performance measures should have appropriate sensitivity to show impacts of decisions about resource allocation across program areas, geographic areas, and subnetworks.
5. Performance measures used for initial resource allocation and program development should also be used to assist in determining program adjustments.
6. Performance measures used to guide project selection and resource allocation at the program level should include cost-effectiveness and benefit/cost measures, which (where feasible and appropriate) incorporate user costs or benefits.
7. Performance measures used to evaluate investment tradeoffs should reflect life-cycle benefits and costs, not just immediate impacts.
8. Performance monitoring needs to include tracking of asset condition over time at a sufficient level of detail and rigor to support development of performance curves. This is needed to provide the basis for credible prediction tools that analyze investments versus performance.
9. Performance measures should describe not only physical asset condition but also how assets are serving their intended functions with respect to comfort, convenience, safety, and service.
10. Monitoring of outcome- and output-oriented performance measures needs to be accompanied by tracking of actual activity costs in order to provide the basis for credible prediction tools that analyze investments versus performance.
11. Performance measures should be selected with consideration of the cost of data collection and available methods for maximizing efficiencies.
12. Performance measures are needed that can serve as the basis for target setting with respect to what various programs will accomplish. Because actual monitored performance may depend

on factors other than agency actions, the target setting and monitoring processes must account for the fact that many performance measures reflect not only results of actions taken by an agency, but external factors as well (e.g., traffic volumes and environmental conditions).

13. Performance measures should be useful for signaling when changes to strategies and priorities are warranted—in long-range plan updates and in development of capital, maintenance, and operations program budgets.
14. Performance measures reflecting asset condition and performance should be used consistently across different functional units and at different levels of the organization. This implies that performance measures should be amenable to “roll-up” and “drill-down” capabilities to allow them to be viewed at systemwide, district, corridor, subarea, subnetwork, or location-specific levels. This roll-up capability may include the need to calculate summary statistics (e.g., “percent poor lane-miles”) from more detailed, location-specific condition measurements.
15. To the maximum extent possible, performance measures should be understandable and meaningful to political leaders and the general public.

Table 6. Asset Management Best Practice
Implications for Performance Measurement

Asset Management Principle(s)	Asset Management Best Practice Statement(s)	Implication(s) for Identifying and Using Performance Measures
Policy-driven	The agency's goals and objectives are linked to specific performance measures and evaluation criteria for resource allocation.	1. Performance measures should be selected to cover established goals and objectives.
	Criteria used to set program priorities, select projects, and allocate resources are consistent with stated policy objectives and defined performance measures.	2. Performance measures should be consistent with the criteria used to make resource allocation decisions.
Performance-based	Our agency estimates the resources needed to accomplish particular objectives as part of policy development.	3. Predictive models or methods for relating investment levels to future performance should be available for each performance measure selected.
	Our agency's programs are based on realistic estimates of costs, benefits, and impacts on system performance.	4. Performance measures should have appropriate sensitivity to show impacts of decisions about resource allocation across program areas, geographic areas, and subnetworks.
	Our agency uses asset management decision-support tools to forecast future system performance given a proposed program of projects.	
	Our agency uses asset management decision support tools to forecast future system performance under different mixes of investment levels by program category.	
	Projects with significant changes to scope, schedule, or cost are reprioritized to ensure that they are still competitive in cost and performance.	5. Performance measures used for initial resource allocation and program development should also be used to assist in determining program adjustments.
Analysis of options and tradeoffs	Policy guidance encourages resource allocation and project selection based on cost-effectiveness or benefit-cost analysis.	6. Performance measures used to guide project selection and resource allocation at the program level should include cost-effectiveness and benefit-cost measures, which (where feasible and appropriate) incorporate user costs or benefits.

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Table 6. Asset Management Best Practice (continued)
Implications for Performance Measurement

Asset Management Principle(s)	Asset Management Best Practice Statement(s)	Implication(s) for Identifying and Using Performance Measures
Decisions based on good information	<p>Our agency regularly collects information on the condition of our assets.</p> <p>Our agency regularly collects information on the performance of our assets (e.g., serviceability, ride quality, capacity, operations, and safety improvements).</p> <p>Our agency maintains and uses information on the full unit costs of construction activities.</p> <p>Information on actual work accomplishments and costs is used to improve the cost-projection capabilities of our asset management systems.</p> <p>Our agency continually seeks to improve the efficiency of data collection (e.g., through sampling techniques, use of automated equipment, and other methods appropriate to our transportation system).</p> <p>Agency managers and staff at different levels can quickly and conveniently obtain information they need about asset characteristics, location, usage, condition, or performance.</p>	<p>7. Performance measures should describe not only physical asset condition, but also how assets are serving their intended functions with respect to comfort, convenience, safety, and service.</p> <p>8. Monitoring of outcome- and output-oriented performance measures needs to be accompanied by tracking of actual activity costs in order to provide the basis for credible prediction tools that analyze investments versus performance.</p> <p>9. Performance measures should be selected with consideration of the cost of data collection and available methods for maximizing efficiencies.</p> <p>10. Performance measures reflecting asset condition and performance should be used consistently across different functional units and at different levels of the organization. This implies that performance measures should be amenable to “roll-up” and “drill-down” capabilities to allow them to be viewed at systemwide, district, corridor, subarea, subnetwork, or location-specific levels. This roll-up capability may include the need to calculate summary statistics (e.g., “percent poor lane-miles” from more detailed, location-specific condition measurements).</p>

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Table 6. Asset Management Best Practice (continued)
Implications for Performance Measurement

Asset Management Principle(s)	Asset Management Best Practice Statement(s)	Implication(s) for Identifying and Using Performance Measures
Monitoring to provide clear accountability and feedback	Our agency regularly communicates to customers and other stakeholders our accomplishments in meeting policy objectives.	11. To the maximum extent possible, performance measures should be understandable and meaningful to political leaders and the general public.
	Our agency works with political leaders and other stakeholders to present funding options and consequences as part of our budget proposal.	
	External stakeholders and policy-makers feel that they are sufficiently updated on program delivery status.	12. Performance measures are needed that can serve as the basis for target-setting with respect to what various programs will accomplish. The target-setting and monitoring processes must account for the fact that many performance measures reflect not only results of actions taken by an agency, but external factors as well (e.g., traffic volumes and environmental conditions).
	Project selection is based primarily on an objective assessment of relative merits and the ability to meet performance targets.	
Our agency monitors actual system performance and compares these values to targets projected for its capital preservation, capital improvement, and maintenance and operations programs.	13. Performance measures should be useful for signaling when changes are warranted for strategies and priorities (e.g., in long-range plan updates and in development of capital, maintenance, and operation program budgets).	
Our agency periodically updates its planning and programming methods to keep abreast of current policy guidance, customer expectations, and critical performance criteria.		

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Table 6. Asset Management Best Practice (continued)
Implications for Performance Measurement

Asset Management Principle(s)	Asset Management Best Practice Statement(s)	Implication(s) for Identifying and Using Performance Measures
Monitoring to provide clear accountability and feedback, cont.	<p>Policy guidance considers customer perceptions and expectations.</p> <p>A maintenance quality assurance study has been implemented to define levels of service for transportation system maintenance.</p> <p>Our agency regularly collects customer perceptions of asset condition and performance.</p> <p>We periodically distribute reports of performance measures relevant to customer/stakeholder satisfaction with transportation system and services.</p> <p>Our agency has an incentive program for recognizing or rewarding outstanding performance in improving upon schedule, quality, and cost objectives.</p> <p>Our agency uses well-defined program delivery measures to track adherence to project scope, schedule, and budget.</p> <p>Agency executives and program managers are regularly kept informed of program delivery status.</p>	<p>14. Performance measures should reflect how customers perceive the transportation system condition and service.</p> <p>15. Performance measures should be used to assess quality, schedule, and budget adherence for program delivery.</p>

5.0 Performance Measures for Asset Management: Design Considerations

This section discusses key considerations in developing and using performance measures within an asset management context. The in-depth discussion and illustrative examples are intended to serve as resource material for implementation of the framework described in Section 6.0 and Volume II. The following topics are discussed:

- Addressing federal transportation planning regulations;
- Linking resource allocation to policy objectives;
- Aligning performance measures across the organization (and beyond);
- Tailoring measures to decisions—ensuring appropriate sensitivity;
- Analytic constructions of performance measures to understand overall health, critical deficiencies, and trends;
- Providing solid foundation data;
- Structuring performance tradeoffs;
- Predicting performance and setting targets based on funding;
- Setting long-term performance goals; and
- Obtaining internal and external buy-in.

■ 5.1 Addressing Federal Transportation Planning Regulations

The requirements of Sections 134 and 135 of federal highway legislation are summarized in Sidebar 5.1. These provisions govern long-range planning and capital program development by MPOs and state DOTs, respectively. The provisions of these sections have the following implications for the definition and use of performance measures:

- The need for performance measures applicable to both long-range planning and transportation improvement program/state transportation improvement program (TIP/STIP) development;

Sidebar 5.1: Summary of Provisions of 23 U.S.C. Sections 134 and 135

23 U.S.C. Sections 134 and 135 discuss requirements for metropolitan planning and statewide planning, respectively. Since many provisions of Sections 134 and 135 parallel and reinforce each other, they are discussed together below.

Long-range plans and programs. Both MPOs and state DOTs must develop long-range plans (minimum 20-year planning horizon) and programs for metropolitan area and statewide transportation, respectively, that address:

- All modes of transportation, including nonmotorized modes;
- Development and integrated management and operation of the transportation system; and
- Coordination among MPOs, state DOTs, and affected public transportation providers.

Scope of planning process. Both MPOs and state DOTs must consider projects and strategies that:

- Support economic vitality through global competitiveness, productivity and efficiency;
- Increase system safety and security;
- Increase accessibility and mobility options for passengers and freight;
- Promote environmental protection, energy conservation, and improved quality of life;
- Enhance system integration and connectivity across modes;
- Promote efficient system management and operation; and
- Emphasize preservation of the existing system.

TIP/STIP development. MPOs and state DOTs will develop metropolitan TIPs and STIPs, respectively. These programs must be developed cooperatively between the state and the MPO, with the cooperation of affected transit providers, and with opportunities for comment by public- and private-sector interests and the general public. These programs include a priority list of proposed federally supported projects and a financial plan citing public and private resources that are reasonably expected to be available to fund the projects.

Public outreach. Plans and TIPs/STIPs produced by MPOs and state DOTs should be informed by comments obtained through public outreach to citizens, public and private providers of transportation to passengers and freight, and other stakeholders.

Transportation management areas and nonattainment areas. Transportation management areas (TMAs) are metropolitan areas with populations exceeding 200,000, or any additional areas requesting designation as a TMA and approved by the U.S.DOT. TMAs are required to have a continuing and comprehensive planning process, including a congestion management system. Within a TMA that is also designated as a nonattainment area for ozone or carbon monoxide, federal funds may not be used for projects that significantly increase carrying capacity in single-occupancy vehicles unless the project is part of an approved congestion management system.

- The need to address interjurisdictional issues in performance measure definition and related data and models used in forecasts;
- The important role of outreach to public and private stakeholders and interest groups to reflect customer perspectives in formulating long-range plans and setting performance targets;
- The desirability of mode-neutral measures to evaluate modal alternatives to address transportation needs;

- The need to account for transportation system preservation, management, and operation; and
- The awareness of transportation’s broad range of impacts on society, including safety and security; economic development, productivity, and competitiveness; accessibility and mobility options for passengers and for freight; fuel efficiency; environmental protection; and improved quality of life.

■ 5.2 Linking Resource Allocation to Policy Objectives

Basing resource allocation decisions on well-defined policy goals and objectives is a central tenet of good asset management practice. This principle is illustrated in Figure 2, in which policy objectives are informed by an agency’s long-range planning process, including the benefit of customer and stakeholder perceptions as expressed through public outreach. Performance measures can be used to express policy objectives in a very practical way by setting targets for each goal area or category of impact at an early stage of system planning, as indicated at the top of Figure 2. In addition to this direct link between policy objectives and performance targets, there are several other practical ways in which performance measures assist decision making and reporting (23).

- Agencies can apply performance measures to help guide resource allocation decisions at the program level in the system planning and programming process. Applications of performance measures in program-level tradeoffs are still in their infancy, however, and only a few agencies have attempted these types of analyses.
- Agencies can use performance measures at a project or corridor level (e.g., to help screen projects or set project priorities in the development of their transportation improvement program [TIP or statewide STIP]).
- Agencies can implement performance measures in an integrated manner to set policy, allocate resources, and measure and report results, as suggested by the framework in Figure 2. These comprehensive applications of performance measures were the focus of a completed NCHRP study of performance-based planning (7) and are consistent with recommendations of the *Guide*.
- Agencies can institutionalize the linkage between policy and operational decisions through planning and programming processes that are based upon the effective use of performance measures throughout. An example is Montana DOT’s Performance Programming Process (P³) (18).
- Performance measures provide the basis for reports on system conditions and performance as a communication and reporting tool and as a mechanism for feedback to policy formulation, planning, project selection, and resource allocation in subsequent cycles.

These applications of performance measures are not mutually exclusive. Agencies that are interested in performance-based management can apply these techniques in combination—a strategy that would be entirely consistent with good asset management practice. It is also important to objectives above regarding selection of measures appropriate to different types of decisions and data collection, since care in selecting measures and periodically updating their values obviously contributes to their ability to reflect underlying goals and objectives.

Providing Feedback from Performance Measurement into Policy Development

Ideally, there is a two-way linkage between performance measures and policy goals and objectives. Performance measure definition and target-setting procedures should interact with the policy development process, as illustrated in Figure 2. This interaction includes:

- The establishment of realistic goals and objectives given current and anticipated funding;
- The application of the long-range planning process to help identify needed adjustments in policies that respond to changing trends in the demand for, and supply of, transportation services; and
- As a key part of this long-range planning engagement in policy formulation, the communication of public and stakeholder comments on existing and future transportation policy and its implications for quality of life, commerce, economic opportunity, environmental protection, and other policies of regional or statewide significance.

Sidebar 5.2 describes how one agency has successfully used an asset management approach firmly rooted in performance measurement and engagement of policy-makers as an integral part of its resource allocation process.

Sidebar 5.2: State Highway Administration's Use of Asset Management Principles to Influence Resource Allocation

The Maryland General Assembly enacted a significant transportation revenue program in 2004. During the early planning for this program, the Maryland State Highway Administration (MSHA) was advised that system preservation activities would not be effective in generating political support for increasing transportation fees; high-profile capacity projects were needed for that purpose. However, the administrator felt a professional obligation to make the asset management case that timely system preservation interventions would serve to reduce long-term costs. The two examples he most often cited were the following:

- Pavements—A thin overlay program with interventions prior to the steep segment of the deterioration curve to reduce long-term preservation costs.
- Bridge decks—A 2-inch overlay 5 years prior to the customary intervention point to extend deck life by 15 years.

This case was made first to the secretary of transportation (a member of the governor's cabinet), then to the secretary of budget and management (another cabinet member) and then to the House and Senate budget subcommittees with jurisdiction over the DOT. All were persuaded of the logic. Of the \$1.9 billion of the revenue program allocated to MSHA over the 5-year program period, \$1.0 billion was in the category of "minor projects," principally system preservation, safety, and traffic operations. The asset management approach was key to achieving this allocation.

Most legislators were content to reach a conclusion based upon the pavement and bridge examples. However, the vice-chair of a key legislative subcommittee carefully reviewed every MSHA program in order to be assured that all resource allocation decisions were based on similar objective criteria and were not politically driven. The fact that the governor was from one political party while the majority of the general assembly was from the other heightened the need for reassurance on this point.

■ 5.3 Aligning Performance Measures Across the Organization (and Beyond)

Performance measures are most effective when there is consistency and alignment in their use—both horizontally (i.e., across functional areas) and vertically (i.e., across executive, line management, and technical staff levels) within an organization. Alignment does not mean that performance measures need to be identical at all levels of the organization, but there should be clear linkages between measures used at different levels.

The concept of groups or “families” of performance measures can be used to address both vertical and horizontal alignment. A “family” can be defined as either:

- Performance measures that are expressed in different ways, but that at their core share the same property of the transportation system (e.g., average pavement condition and the percent of the network in good condition) or
- Performance measures that are similar in their expression, but reflect different related system properties (e.g., the remaining asset value for bridges and the remaining asset value for pavements).

Performance Measure Families for Vertical Alignment

Agencies use different approaches to establish a consistent set of performance measures that are useful at various organizational levels. One approach is to use measures that can be “rolled up” from field organizations to district and statewide levels. Separate but related sets of “technical” and “corporate” measures such as those defined by the Ministry of Transportation of Ontario (17) are another. A third approach is to use executive-level measures to “take the temperature” of the transportation system, with technical and midlevel measures providing backup detail. What makes these approaches work is that each set of performance measures captures some characteristic of transportation system performance, but can express that characteristic in the different ways needed by executives, midline managers, and technical staff. To illustrate, the performance measures in Table 7 express pavement condition and degree of congestion as they might be used at three organizational levels. While the measures are different in their expression, they are consistent in that they are each rooted in the same sources of data and measurements of pavement condition and of congestion.

Performance Measure Families for Horizontal Alignment

Horizontal alignment can be promoted through defining families of performance measures that share a common form but describe different program areas. For example:

- Percent of pavement mileage rated good;
- Percent of airport pavements rated good;
- Percent of transit track with track geometry rated good.

Table 7. Examples of Application to Different Organizational Levels

Organizational Level	Pavement Condition	Congestion
Technical	Specific measures of pavement cracking, roughness, rutting, faulting, etc.	Profiles of level of service by hour for specific segments
	Pavement condition index as a function of above conditions	Ratios of congested travel time to free-flow travel time by hour of day for specific segments
Midlevel	Percent of highways in Good, Fair, or Poor condition based on pavement condition index	Percent of highways with low, moderate, or high congestion (e.g., based on congested hours times miles)
	Customer perceptions of pavement condition expressed through surveys	Rankings of highway segments by congestion index, travel time, or travel time cost
Executive	Report card showing percent of highway mileage meeting or exceeding pavement performance targets	Report card showing improvements in 10 worst congestion bottlenecks
	Map illustrating highway sections with improved, stable, and declining pavement condition	Map illustrating locations of improved, constant, and worsening congestion

While each of these measures applies to different modes and assets, they share a common construction that is rooted in a preservation type of investment. Similar measures can be defined for other assets by substituting an appropriate measure of condition or performance.

Another example of a family of measures that extends across types of investments and programs is:

- Percent of highway lane-miles rated good in terms of mobility (congestion at Level of Service E or F occurs, on average, less than 1 hour per day) and
- Percent of intersections rated good in terms of safety (fewer than “x” accidents per year).

These additional members of the “family” can likewise be “rolled up,” as is done in Table 7, to provide measures suitable at different organizational levels, for different functions, and for different levels of decisions.

Members of a performance measure “family” also can be qualified to provide greater focus where needed. Consider, for example, the related set of preservation measures:

- Percent of pavement mileage rated good,
- Percent of pavement mileage rated good by functional class,
- Percent of trunk line pavement mileage rated good,

- Percent of trunk line mileage rated good when the annual average daily traffic (AADT) is more than 75,000, and
- Percent of Interstate pavement in District 1 rated good.

Different “families” can be developed by focusing on a different characteristic of the transportation system. For example, while the examples above illustrate technical measures describing pavement preservation, a different approach to pavement preservation can be obtained through an asset value concept. Different possible measures with this concept can be built using the following characteristics:

- Book value of existing pavements;
- Replacement value of existing pavements; and
- Annual depreciation in the value of existing pavements.

Sidebar 5.3 presents an example of one agency’s experience implementing and using an asset value-based performance measure.

Horizontal alignment is promoted through consistent interpretation of performance measures throughout the organization and across policy objectives and programs. For example, all agency units should adhere to the same threshold values that define “good,” “fair,” and “poor” for a performance measure. A similar tenet holds for performance targets to meet a particular policy objective.

Sidebar 5.3: Current Highway Asset Value— Ontario Ministry of Transportation

The Ontario Ministry of Transportation (MTO) tracks the current value of highway assets (pavements, bridges, furniture, etc.) relative to their replacement costs as a high-level system preservation measure. The current target is to maintain the existing baseline value of 85%. Current asset value is calculated using a set of simple deterioration curves developed as part of an effort to establish MTO’s Asset Management Business Framework. Replacement costs are calculated using MTO’s highway cost estimating system. MTO has found the use of asset valuation as a performance measure to be extremely effective in making a compelling case for preservation investments.

It is interesting to note that MTO continues to rely on asset (specifically, bridge and pavement) condition measures for more detailed performance analyses. Projected future values for these performance measures can be based on detailed technical information in MTO’s asset management systems. Thus, the simpler (and necessarily coarser) deterioration models offer the advantage of tractability for asset valuation calculations suitable for use at a high level, while the more complex and detailed models in asset management systems provide a firmer foundation for tradeoff decisions.

Another important observation with respect to the use of financially oriented measures is that while they can have the impact of encouraging continued investments to preserve asset value, they do not provide guidance for how to get the most “bang for the buck” from investments. Therefore, they should be used in conjunction with other measures (or investment policies) that emphasize cost-effectiveness or cost/benefit.

While families of performance measures may not be the answer to every situation, they should be recognized and understood as a simple but potentially powerful device to develop consistent, coordinated performance measures throughout an organization.

Interjurisdictional or Interagency Alignment of Performance Measures

A common perspective on performance measures (and associated data and analytic models) across multiple agencies and jurisdictions is sometimes needed. One common example is in the case of safety performance, where multiple jurisdictions need to coordinate in order to achieve a desired end result (i.e., reduction in fatalities). Another common example is in metropolitan areas, where the interests of state DOTs, MPOs, and transit agencies converge with respect to transportation investments. While it is often difficult to achieve complete alignment across agencies, it is useful in such cases to understand the areas of agreement and potential disagreement, so that trends and modeling forecasts of performance prepared by the several agencies can at least be understood in context. Table 8 provides an example of how such a comparison can be structured.

Table 8. Example of Interagency Comparison of Performance Measures

Performance Concept	State Agency	MPO	Transit
<i>Preservation</i>			
Condition	●		
Preservation and Modernization		●	
<i>Enhancement/Operational Improvement</i>			
Safety/Operations/Security	●		
Safety and Security		●	
Service Quality			●
<i>Expansion</i>			
Mobility	●	●	●
Use			●
<i>Other</i>			
Community Effects and Support	●		
Preservation of Community Character		●	
Accessibility		●	
Environmental Justice			●
Land Use and Economic Development	●		
Support for Lane Use Policies		●	
Economic Opportunity		●	
Economic and Lane Use Impacts			●
Environmental Effects	●		
Pollution and Energy Conservation		●	
Air Quality		●	
Provide and Improve Intermodal Connections			●
Total Cost and Cost-Effectiveness	●		
Equitable Sharing of Benefits and Burdens		●	
Cost-Effectiveness			●

■ 5.4 Tailoring Measures to Decisions— Ensuring Appropriate Sensitivity

Performance measures need to support decisions at different levels and in different timeframes. Desirable characteristics of performance measures in these situations are illustrated in Table 9.

Appropriate Sensitivity

At each stage of decision making, performance measures must be sensitive enough to show the change in performance that will result from different types and levels of investment. As noted at the recent TRB workshop on performance measurement, “One obvious rule of thumb is that the measure should be just specific enough that a change in decision causes a response in the measure (i.e., ‘moves the needle’)” (23 p. 26). Practical implications are the following:

- Use care in defining sets of performance measures, since substantial improvements in performance at a project or corridor level may have negligible impact at a network level. Useful approaches to avoid this problem include:
 - Selecting measures that are inherently more sensitive to changes in networkwide distributions of condition or performance (e.g., using “percent good” and “percent poor” rather than [or in addition to] “average” measures).
 - Focusing on specific portions of a network that are susceptible to change. For example, when gauging the impacts of intersection improvements for mobility and operational efficiency, use a measure like “time savings at intersections” rather than more general measures like “overall reduction in total network travel time.”
 - Defining performance measures that are more sensitive and meaningful at a network level. For example, “percent reduction in intersection delays” likely gives a clearer indication of potential impacts than would “minutes of travel time saved due to intersection improvements.”
- The type of measure used also can affect its sensitivity and, therefore, its suitability for different timeframes and levels of decisions. For example:
 - Some agencies use generalized measures of system health that capture several aspects of performance (e.g., pavement condition and mobility as reflected in rankings produced by the Highway Performance Monitoring System [HPMS]). While such measures are useful in long-term projections or to characterize networks, more detailed and focused measures are needed at corridor and project levels and for short-term decisions (e.g., specific pavement condition and performance measures used in the HPMS, explicit traffic demand and road supply characteristics for congestion analyses, and location-specific safety performance).
 - In system preservation, asset value can be used as a stable, aggregate measure of network system condition over the long term. For more detailed decisions at a project and corridor level, or for more technical analyses of network-level situations (e.g., evaluating the potential impacts of changes in vehicle sizes and weights), technical condition and performance measures—or measures derived from technical observations, such as percent good and percent poor—are preferred. They provide a stronger basis for understanding the relative effects of traffic use, weather, soil conditions, and maintenance; for diagnosing needs and solutions; and for translating network-level targets to specific needs at the corridor and project levels.

Table 9. Different Types and Levels of Decisions

Level of Decision	Short Term	Long Term
Network	<p>Performance measures typically represent rollups of project or corridor measures to show:</p> <ul style="list-style-type: none"> • Network-level summaries of performance; • Evaluation of program accomplishments versus targets, with identification of needed policy adjustments; and • Tradeoff analyses of program options (e.g., mobility versus preservation, or preventive maintenance versus worst-first strategies). <p>“Networks” can be interpreted as particular subnetworks (e.g., to report recent congestion trends and near-term forecasts for roads in a metropolitan area).</p> <p>Issues such as geographic equity should be addressed explicitly.</p>	<p>Measures reflect long-term objectives and strategic directions set by political leadership and senior agency management.</p> <p>Performance measures typically represent (1) long-term (e.g., 20-year) needs at the system or modal level and (2) impacts of investments as estimated in long-range planning forecasts and predictions of management systems.</p> <p>Where life-cycle cost analyses can be applied, measures reflect (1) projections of benefits and costs of alternative investments and (2) broad-based tradeoffs among modal, system, location, and program options.</p> <p>Requirements of 23 U.S.C. Section 134-135 should be satisfied in statewide and metropolitan planning that are reflected at this level.</p>
Corridor	<p>Measures reflect forecasts of needs and cost and performance impacts of investments for 3-6 years in the future.</p> <p>Data to support measures should describe existing conditions (e.g., asset condition, traffic volume, travel time-speed-congestion profiles, and reliability or variability of travel time along the length of corridor) to assess connectivity and consistency of corridor level of development by mode.</p> <p>Performance measures should assist in planning the implementation of corridor projects, including the “packaging” of projects, project and work zone length, coordination of detours and alternate routes and modes of travel, and impacts of these options. Performance measures ideally can be “rolled up” from the project level and rolled up to the system or network level.</p>	<p>Measures need to reflect proposed corridor improvements on broader systemwide performance. Measures (1) reflect long-term (20-year) needs and investment impacts by mode and (2) meet agency goals and objectives consistent with 23 U.S.C. Sections 134 and 135.</p> <p>Measures of long-term performance should be mode-neutral where possible. Measures must be specific enough to distinguish between the effect of investment in one mode or another, or between different types of investments (e.g., operational improvements versus capacity expansion).</p> <p>Management systems can help in (1) developing forecasts of needs and impacts of investments and (2) “rolling up” results from the project level. Data on performance may not be available at every location in the corridor and may require extrapolation, estimation, or special surveys.</p>

(continued on next page)

Table 9. Different Types and Levels of Decisions (continued)

Level of Decision	Short Term	Long Term
Project	<p>Technical data are generally available, supplemented by site surveys as needed, to quantify performance measures. Project prioritization criteria should be consistent with these performance measures. Management systems are useful to organize current data, forecast needs, evaluate project options, and identify preferred solutions.</p> <p>Performance measures also can be used to assist detailed project planning (e.g., length and configuration of work zone, impacts of detour and construction supply routes, and time-of-day scheduling options). Timeframe for estimates ranges typically from 1 year or less to 3 years for capital and maintenance programs.</p>	<p>Measures reflect forecasts of condition, cost, and performance suitable for program and budget development. Timeframe of forecasts is typically 3-6 years, but may be as long as 10 years.</p> <p>Major projects (typically in mobility, or those with significant environmental or social impacts) will require long lead-times (5-20 years), performance measures in key impact areas (e.g., environmental protection and neighborhood and population impacts), and transportation performance impacts.</p>

- Mobility performance offers many examples of different types of measures suitable to different decisions:
 - Measures useful at a network level or for long-term decisions: percent of VMT in congested conditions, congested lane-miles of road, person-miles-traveled (PMT) under congested conditions, and centerline-miles of urban roads that are congested. Note that many of these measures presuppose a definition of “congested” in a long-term, network context.
 - Measures useful at a corridor or project level or for short-term decisions: commercial truck travel time between major economic gateways, percent of directional urban freeway miles in a particular region or metropolitan area that are moderately congested (0–2 hours with speeds below 45 mph), variation in average speed at a selected location, highway LOS, and number of hours in which a road segment (or intersection) operates at LOS E or F.
- Similar (and often related) issues apply to the geographic coverage of performance measures. While networkwide measures are appropriate for long-range planning and broad-based evaluation of policy objectives, more focused measures are needed at a regional or district level for project programming and budgeting, and detailed measures are needed at corridor and project levels.

Dealing with Attribution Issues

“Attribution” refers to the extent to which transportation system performance can be attributed to the actions of the transportation agency as opposed to external trends that are beyond an agency’s control. When external factors affect transportation system performance, the issue is how to interpret performance targets and trends that may deviate from the original assumptions about these

factors. Examples are given below for congestion and safety performance, but attribution issues can arise in many other situations of performance measurement:

- Congestion can be mitigated by investments in operational efficiency and capacity expansion. The impact of these investments may be offset, however, by greater-than-estimated growth in population and vehicle registration, demographic shifts, and increased economic activity. These additional factors complicate the interpretation of congestion trends as well as assessments of the value of program investments to reduce congestion.
- Safety investments in transportation infrastructure and operations are often targeted to reduce accident rate and severity. Crashes are also dependent, however, on traffic volume and composition, growth in travel demand, weather conditions, and changes over time in vehicle size and weight and in driver behavior that affect safety performance. These additional factors complicate the interpretation of safety performance data and assessments of the value of safety-related investments in roadways, roadsides, interchanges, and intersections.

The attribution issue is essentially seen as a matter of an agency “not having control over outcomes.” The counterargument has been posed, however, that attribution is less a matter of measurement ability than one of *accountability*. In this view, managers have a responsibility to citizens to account for how they have spent public funds and to use the best measurement methods they can for the resources available, even if these methods are imprecise (37). At a pragmatic level, there are methods that an agency can undertake to reduce the uncertainty caused by the attribution issue, as described below.

One approach to distinguishing agency influence on outcomes—particularly for safety and operations improvements—is to use well-designed before-and-after studies as a supplement to monitoring performance trends. One of the major findings of a 2004 FHWA/AASHTO/NCHRP international scan on performance measurement (34) was the widespread use of before-and-after evaluation studies to determine the effectiveness of implemented actions. While the scan team observed that this practice is far more prevalent outside of the United States, some state DOTs have institutionalized the practice of before-and-after studies as an integral part of their performance measurement efforts. For example, Colorado DOT tracks standard crash and fatality rates, but supplements this information by conducting analyses of its safety improvement projects. These analyses provide an understanding of the reductions in fatalities and injuries that can be attributed to implementation of these projects. While these studies may be costly to conduct, they provide extremely valuable information for understanding what types of investments are most cost-effective.

Another approach to distinguishing agency impacts—particularly for operational investments—is to use traffic simulation tools that predict measures such as traveler delay, air quality and energy impacts. These tools can be used in combination with measured before-and-after implementation characteristics to derive reasonable estimates of the performance impacts of agency actions.

Finally, a well-designed performance measurement program will include monitoring of trends in relevant data that help explain and interpret system performance measures. Examples of important trend data include population, vehicle registrations, economic activity, vehicle occupancy, modal shares, zones of disadvantaged populations, and land use characteristics. Agency long-range plans as well as those produced by MPOs and transit operators are potential sources of information. These data can help the agency to recognize and understand shifts in economic and social trends, driver behavior, vehicle characteristics, and other external factors that affect travel demand and transportation system performance. They also can guide the agency in setting realistic future performance targets that account for these external shifts and, if necessary, to recommend changes in policy objectives that respond to significant changes in external forces. These additional data can sometimes serve

as performance measures themselves (e.g., tracking average vehicle occupancy can provide a measure of the operational efficiency of a highway facility in moving people as well as vehicles).

By monitoring multiple streams of data, an agency can view transportation system performance from a number of perspectives. This cross-checking ability is useful even where attribution is not the main issue (e.g., in analyzing the relative contributions of increased economic activity and operational inefficiency on congestion). At a local level, this analysis helps to identify the most effective solutions to congestion choke points; more broadly, it informs future policy to provide improved mobility in the system.

Analytic Processing and Supporting Data

Measures used for different types or levels of decisions may require different types of data, some of which are more readily available than others. For example, agencies may have ready access to support mobility measures at a project or corridor level (e.g., 24-hour traffic volumes or transit boardings), but fewer data to support systemwide measures for transportation system planning (23 p. 26). Sidebar 5.4 provides an example of how available analytic tools and data can be used to analyze options for improving corridor mobility.

Sidebar 5.4: Example Analysis of Options for Improving Corridor Mobility

Background

A four-lane arterial street with a two-way, left-turn lane lies in a high-growth area of the city. Development is occurring throughout the corridor, and traffic volumes are expected to grow at approximately 3 percent annually. Information regarding the signal timing and vehicle volumes is available for each signalized intersection along the 5-mile corridor. Signal spacing is at 1-mile intervals. The corridor has a light rail line running parallel to the street.

Options to Improve Mobility

- Signal improvements—more green time for the major street
- Signal improvements—installation of a raised median, which restricts left-turning traffic
- Additional turn lanes
- Transit priority
- Additional through lanes
- Access management

Required Data for Analyzing Performance Impacts (Using Highway Capacity Manual software)

Urban street classification II
 Capacity: 1,800 (7:00–8:00 a.m. peak hour)
 Major street volume: 7,200 (average)
 Major street green time: 60 sec

(continued on next page)

Sidebar 5.4: Example Analysis of Options for Improving Corridor Mobility (continued)

Signal cycle length: 90 sec
 Major street free-flow speed: 35 mph
 Minor street free-flow speed: 30 mph
 Average vehicle occupancy: 1.25
 Light rail trains: 10 in the peak hour
 Light rail free-flow speed: 25 mph
 Light rail average occupancy: 125 persons per train
 Light rail intersection clearance time: 15 sec
 Corridor length: 5 miles
 Minor street volume: 3,000 (average)
 Minor street green time: 30 sec
 Major street average speed: 20 mph
 Minor street average speed: 20 mph
 Light rail average speed: 15 mph

Example Performance Comparison

Performance Measure	Base Case	Signal Improvements	Turn Restrictions
V/C Ratio	1.00	1.00	1.00
Travel time (minutes)	15 (auto) 20 (rail)	15 (auto) 20 (rail)	14 (auto) 19 (rail)
Travel rate (minutes per mile)	3.0 (auto) 4.0 (rail)	3.0 (auto) 4.0 (rail)	2.9 (auto) 3.8 (rail)
Total annual delay (thousands of person-hours)	241 (auto) 42 (rail) 283 (corridor)	236 (auto) 41 (rail) 277 (corridor)	216 (auto) 37 (rail) 253 (corridor)
Travel time index*	1.75 (auto) 1.67 (rail) 1.74 (corridor)	1.74 (auto) 1.65 (rail) 1.73 (corridor)	1.67 (auto) 1.60 (rail) 1.66 (corridor)
Buffer index**	85% (corridor)	85% (corridor)	83% (corridor)

*Travel time index is the average peak travel time to off-peak (free-flow) travel time.

**Buffer index is the extra percent of time a traveler needs to allow in order to be on time 95% of the time.

Summary

This analysis provides an illustration of the use of performance measures for screening-level analysis of alternative multimodal corridor mobility improvements. Key elements include use of multiple performance measures that capture different aspects of mobility, calculations for each mode and for the corridor as a whole, and comparison of alternatives relative to a base case reflecting a consistent set of growth assumptions for a future year.

The analysis shows that of the two alternatives considered, turn restrictions will have a greater beneficial impact on performance of the corridor—both for rail and auto users. However, neither option will result in dramatic changes in the average travel time, the average travel rate, the delay experienced by travelers, the corridor’s peaking characteristics, or travel time reliability.

Analytic methods are widely available for specific modes and types of investments (e.g., preservation, traffic demand forecasting, and sketch planning for proposed installation of ITS equipment), but are more limited in other areas such as prediction of safety impacts. The precision of these models may limit their use to particular decision-making levels or timeframes.

The capabilities of modern management systems to do scenario testing enables them to support decision making at several levels (e.g., in identifying preferred solutions at the project level, in aggregating project costs and impacts and identifying “project windows” for scheduling coordination at the corridor level, and in refining project selection at the network level to account for budget constraints). Many modern pavement and bridge management systems have these capabilities.

■ 5.5 Analytic Constructions of Performance Measures to Understand Overall Health, Critical Deficiencies, and Trends

Performance measures can be valuable for demonstrating overall transportation system condition or “health,” identifying or highlighting critical deficiencies, and understanding trends. A series of examples will illustrate how, by defining and displaying measures in different ways, one can obtain insights to system performance either at an overall level or at a more detailed level to reveal critical deficiencies.

Type of Measure and Threshold Value

One way to distinguish between overall health and critical deficiencies is through the type of performance measures used and the establishment of critical threshold values.

For individual facilities, overall health can be gauged through indexes based on a set of conditions (e.g., a present serviceability index or a pavement condition index for pavement condition or a bridge health index for bridge condition). Critical deficiencies can be identified by establishing a threshold for these indexes, the value of which experience shows is serious enough to threaten the structural integrity of the facility, dramatically increase user costs, or result in many customer complaints. Another approach is to focus on particular conditions that are critical to facility performance and to define detailed measures and thresholds (e.g., for cracking, rutting, or roughness of pavements or for condition states of bridge superstructure and substructure elements). Analogous examples can be defined for mobility in terms of travel time or congestion and for other measures where data and experience are available.

Similar approaches can be used at a system level. Some agencies use, for example, rankings generated by the Highway Performance Monitoring System (HPMS) to gauge the relative health of links within their highway systems. Measures based on asset value can also be applied as a measure of overall health at a network level. Critical locations can be identified by imposing threshold values on these ratings or by considering more detailed measures of pavement condition and congestion.

Analytic Construction of Measure

The analytic construction of a measure is a second way of varying its view of a transportation system. Several types of constructions are commonly used in transportation. One set is listed below; additional examples will be given in the following section.

- A number or value—for example, total VMT, total travel time, average travel speed, total number of injury-only crashes, pavement serviceability index, and area of bridge deck cracking.
- A rate—for example, crashes per 100 million VMT, incidents per million passenger-miles traveled (PMT), and operating cost (or revenue) per million seat-miles.
- A ratio—for example, fatal to nonfatal accidents, bus ridership to rail ridership, travel time in congested conditions to travel time in free-flow conditions.

Consider the example data in Table 10, showing daily passenger trips for auto and transit modes.

Table 10. Data for Examples of Performance Measure Construction

Year (1)	Daily Passenger Trips by Mode, Thousands					Regional Data in Thousands	
	Auto (2)	Bus Transit (3)	Rail Transit (4)	Total Transit (5) = (3) + (4)	Auto Plus Transit (6) = (2) + (5)	Population (7)	Registered Autos (8)
1	1,225.0	45.0	30.0	75.0	1300.0	500.0	131.6
2	1,234.2	45.2	30.6	75.8	1310.0	502.5	132.5
3	1,243.4	44.9	31.2	76.1	1319.6	505.0	133.4
4	1,252.8	45.1	31.8	77.0	1329.7	507.5	134.4
5	1,262.2	44.8	32.5	77.3	1339.5	510.1	135.3
6	1,271.6	45.0	33.1	78.2	1349.8	512.6	136.2
7	1,281.2	44.7	33.8	78.5	1359.7	515.2	137.2
8	1,290.8	44.9	34.5	79.4	1370.2	517.8	138.2
9	1,300.5	44.6	35.1	79.8	1380.2	520.4	139.1
10	1,310.2	44.9	35.9	80.7	1390.9	523.0	140.1
11	1,320.0	44.5	36.6	81.1	1401.2	525.6	141.1
12	1,329.9	44.8	37.3	82.1	1412.0	528.2	142.1
13	1,339.9	44.5	38.0	82.5	1422.4	530.8	143.1
14	1,350.0	44.7	38.8	83.5	1433.4	533.5	144.1
15	1,360.1	44.4	39.6	83.9	1444.0	536.2	145.1
16	1,370.3	44.6	40.4	85.0	1455.2	538.8	146.1
17	1,380.6	44.3	41.2	85.5	1466.0	541.5	147.1
18	1,390.9	44.5	42.0	86.5	1477.4	544.2	148.1
19	1,401.4	44.2	42.8	87.0	1488.4	547.0	149.2
20	1,411.9	43.9	43.7	87.6	1499.4	549.7	150.2

Measures of overall condition can often be developed using number or percent constructions, applying the broadest data available. Figure 8 shows daily ridership for auto and transit, a broad view of the example in Table 10.

While Figure 8 gives an overall view of modal split, it does not indicate clearly the trends within transit. A more detailed view of transit can be obtained by first focusing on that mode, then considering alternate constructions of measures to reveal trends more clearly.

Figure 9 shows transit ridership, again in numerical terms of total daily trips. This figure indicates the following:

- Bus ridership is virtually constant through the 20-year period.
- Rail ridership grows from 30,000 to almost 44,000 daily trips.
- As a result, all the growth experienced by transit in this period is attributable to rail.

Further insights into transit performance can be obtained by constructing other types of measures (e.g., using rates and ratios).

Figure 10 shows per capita transit ridership for bus and rail. In relative terms based on population, bus ridership is declining, but rail is increasing, indicating that the rate of growth of rail ridership exceeds the rate of increase in regional population.

Figure 8. Example
Overall Auto and Transit Use

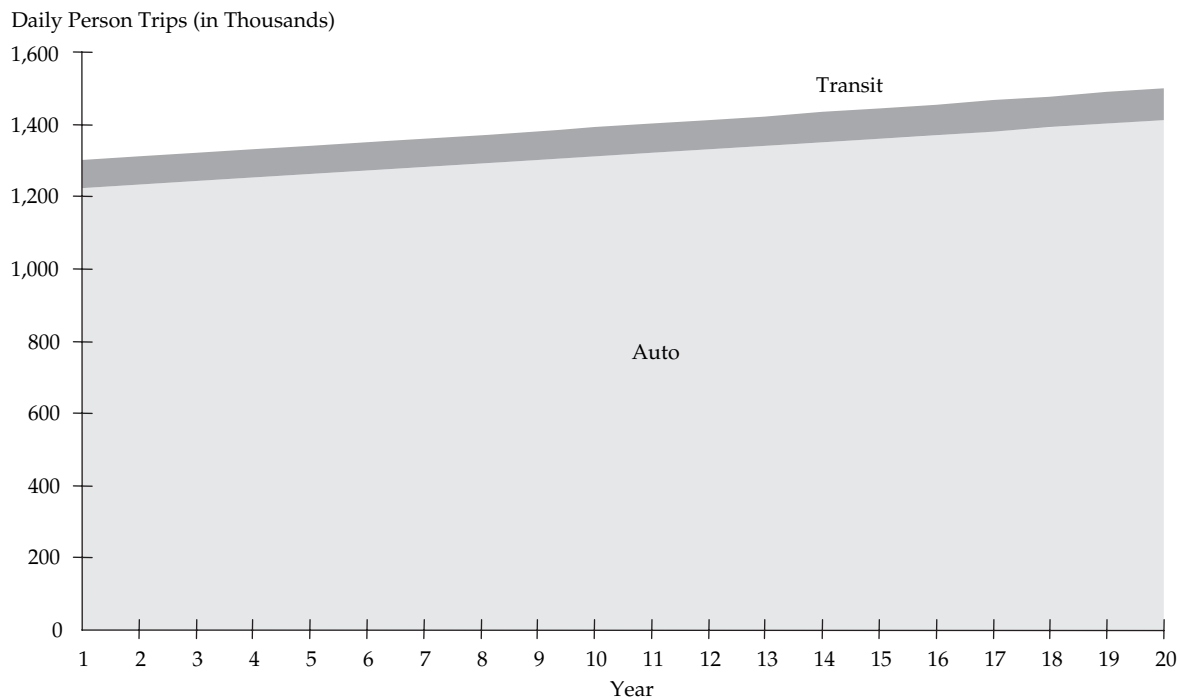


Figure 9. Example
Bus versus Rail Transit Ridership

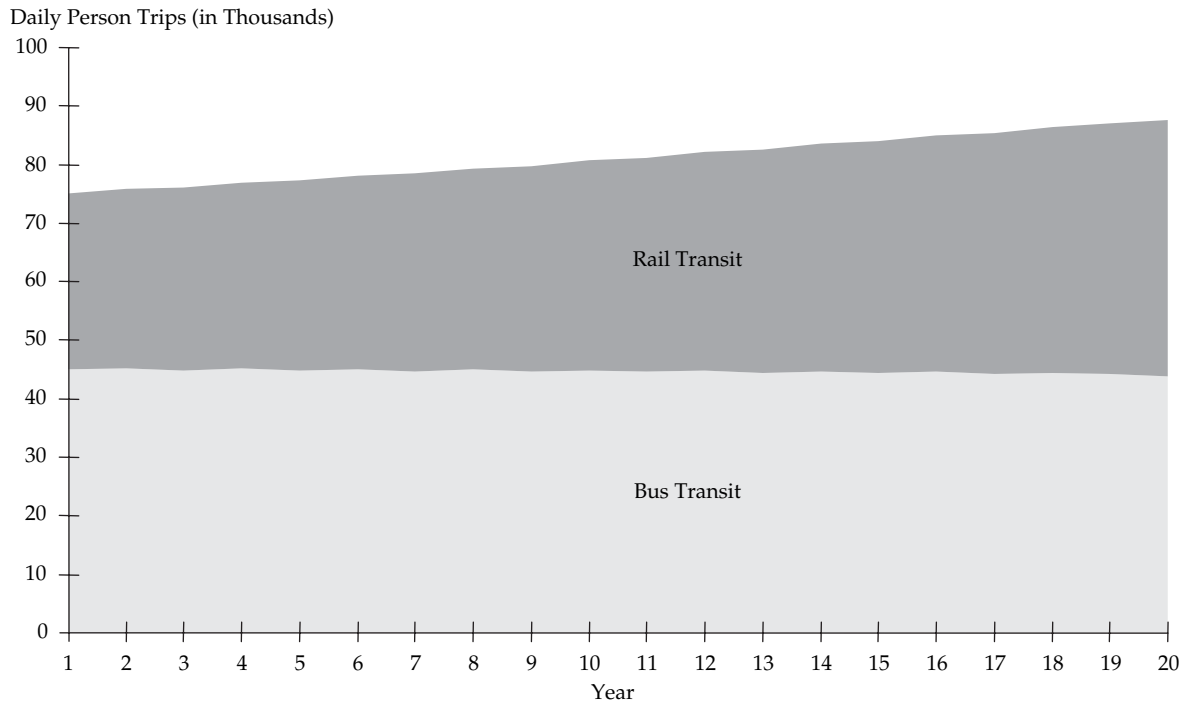


Figure 10. Example
Per Capita Ridership of Bus and Rail Transit

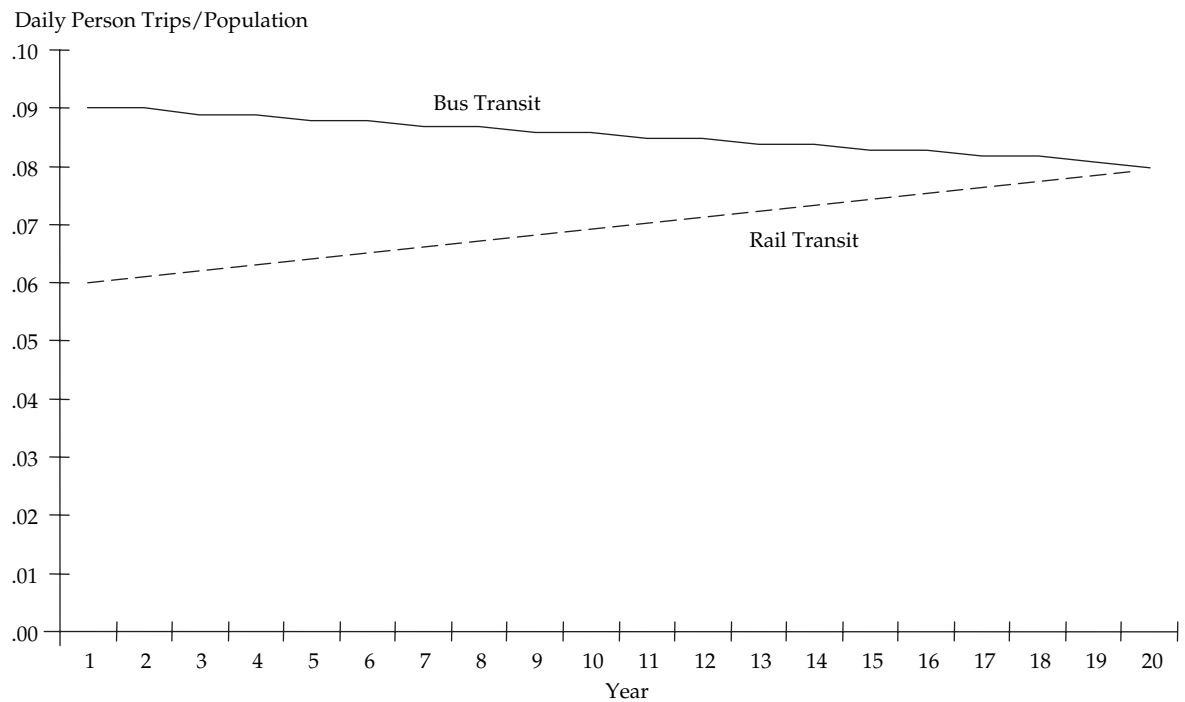


Figure 11 illustrates the ratio of rail ridership to bus ridership. Whereas rail usage at the beginning of the period was barely two-thirds that of bus, at the end of the period rail usage matches bus usage, and if the trend continues, it will exceed bus usage (i.e., the ratio percent will exceed 100 percent).

No one construction of a performance measure is superior to another; rather, each provides particular insights that, when viewed in combination, develop a better picture of what is happening than any of the measures viewed singly. Construction of measures therefore can be used to develop both overall views of performance and more detailed analyses of particular conditions. These examples also illustrate the power of displaying trends. Care must be taken, however, to select the trend that best illustrates what is intended to be communicated.

Further Examples of Analytic Constructions

Additional ways to distinguish between general condition or health and more detailed views of condition and critical deficiencies are to focus on the mathematical function used within performance measures. Consider the example of a set of assets that is subject to deterioration, as shown in Figure 12. The relative condition of each asset is measured by an index on a scale of 0 to 100; assume that the practical range of this measure extends from 95 to 25.

Assume a network of these assets having a distribution of initial conditions from 95 to 25 (i.e., some are in virtually new condition, and some are failing). Assume further that these assets are allowed to deteriorate with no further preservation or maintenance (to provide a rapidly changing trend for

Figure 11. Example
Ratio of Rail to Bus Transit Ridership

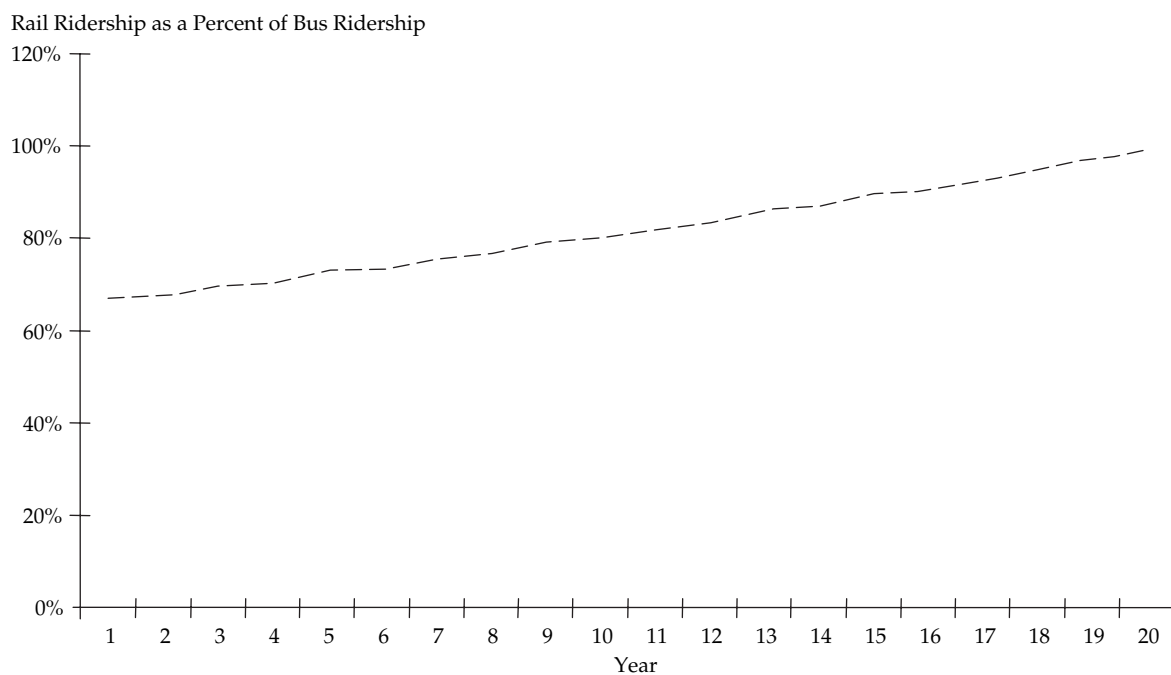
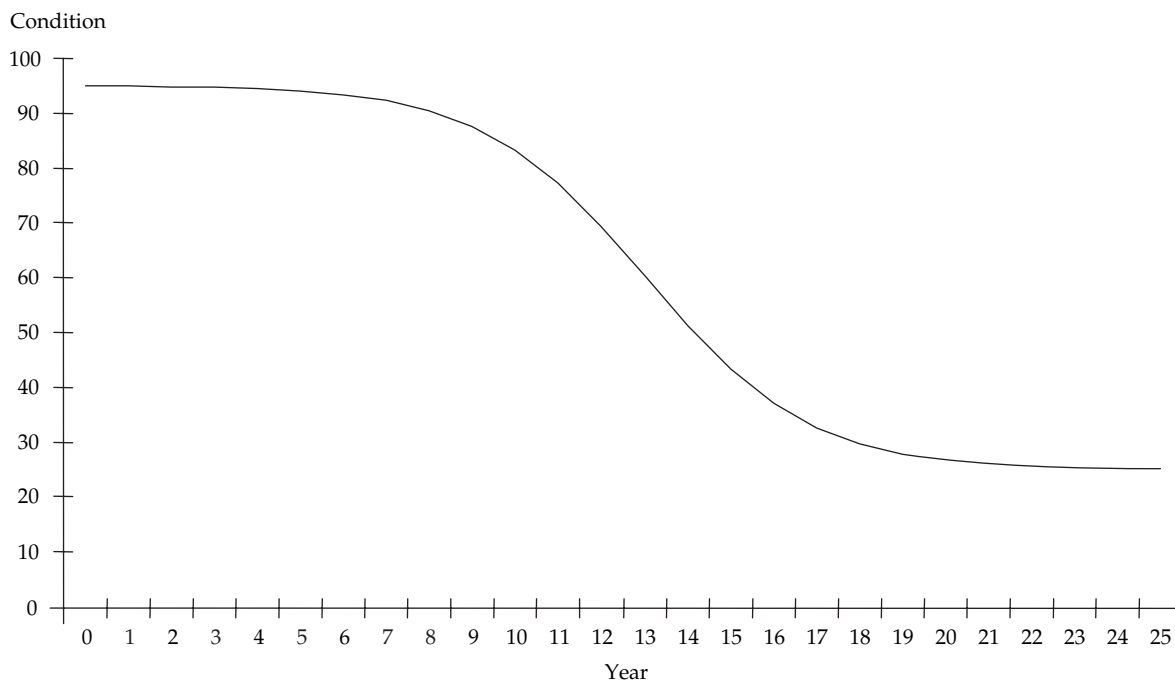


Figure 12. Example
Deterioration Curve for an Asset



this example). How might this decline in network condition be displayed using different performance measures? Figures 13 and 14 illustrate various measures based on different mathematical functions. In order of declining generality and increasing detail, the mathematical functions include the following:

- The average network condition in Figure 13 provides the most general measure of health. While it includes all assets, its trend line is gradual and does not show dramatic changes. Averages are commonly used as a general measure of condition for high-level reporting or for long-range forecasts.
- The 10-Percent-Limit-At-Upper-End curve in Figure 13 illustrates the trend of the right “tail” of the distribution, tracking the lower limit of the top 10 percent of the asset population (i.e., those in the best condition). This measure is more focused than the average. It signals critical points in system condition specifically, the rapid downturn in system condition beginning about year 10—but its scope is limited to a subset of the population. (A corresponding measure could be defined for the 10 percent of assets in poorest condition, but it would not be an interesting trend in this example—it would begin at a value of 25 and remain constant throughout the analysis period.)
- If an agency defines thresholds of good-fair-poor values of condition, the percent of assets within each of these management categories can be tracked, as shown in Figure 14. Viewed in combination, these measures give a good idea of the overall distribution of conditions, and changes in the values or slopes of these curves provide useful signals of changing trends and impending critical conditions. This type of measure is widely used, since it conveys a meaning that is useful to, and understood by, management and often nontechnical audiences as well.

Figure 13. Example
Average and Limit Measures for a System

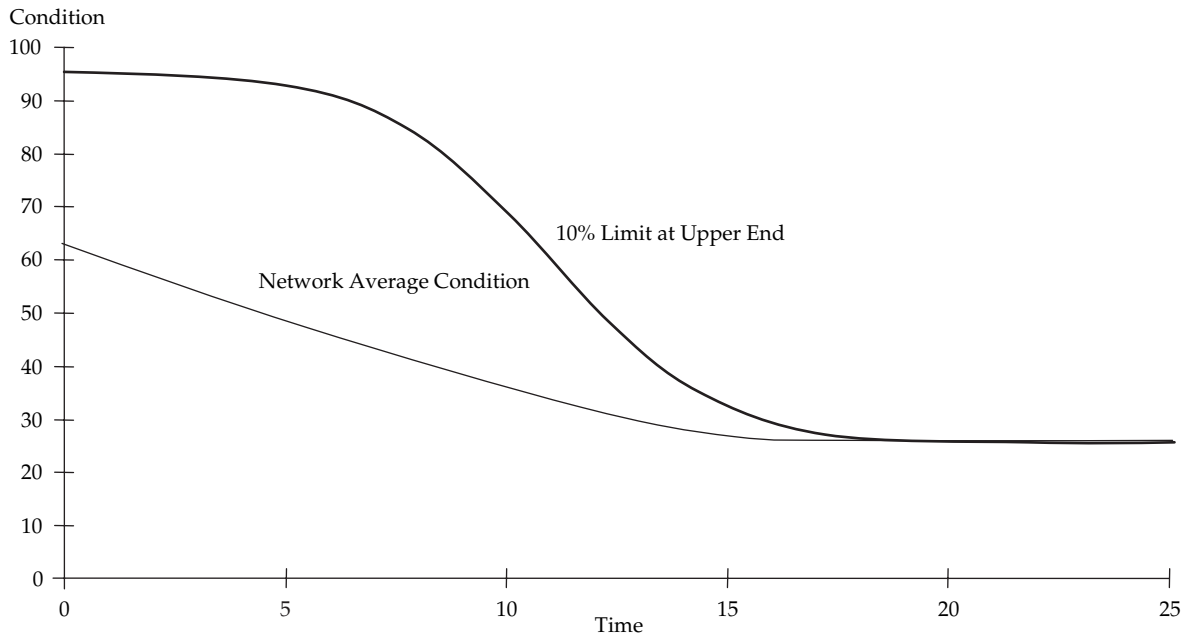
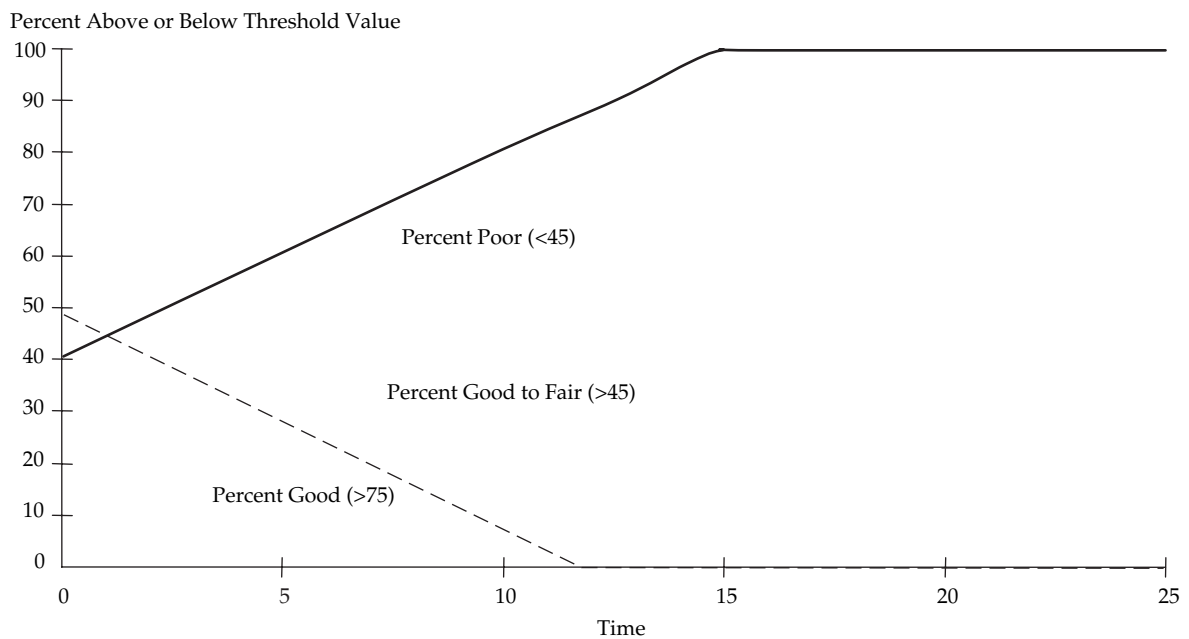


Figure 14. Example
Percent Good-Fair-Poor in a System



■ 5.6 Providing Solid Foundation Data

Data collection is expensive, and agencies continually search for data sampling techniques, non-destructive testing, and new data collection technology that can reduce this cost. Most comments in the interviews conducted for this study, however, emphasized data quality and evaluating the usefulness of data to support performance measures meaningfully, accurately, and reliably. This perception is reinforced by other authorities: “Reliable data, intelligently used and presented, are essential for the success of [performance measures]” (12 p. 76). Additional observations from this paper include the following:

- There is a direct relationship between specific performance measures and the data needed to support these measures. “The most common data problems are in ascertaining the quality of the data and in acquiring it in the exact form desired” (12 p. 78).
- Data that are highly uncertain translate into performance measure values that are likewise highly uncertain, reducing their management value. “Investments in accurate, high-quality data collection systems are essential to successful performance measurement and, by extension, to achieving the overall strategic goals of the agency” (12 p. 78).
- Some factors that are important, however, either cannot be measured at all or cannot be measured accurately at an acceptable cost. “Transportation agencies need to consider the uncertainty introduced by inaccurate data when taking action based on their system of performance measures” (12 p. 78).

To reiterate a fundamental concept of asset management, data collection should be driven ultimately by policy goals and objectives. Internal business process and decision needs will refine data requirements (e.g., to meet information needs at various organizational levels).

Specific suggestions to improve performance measurement data collection procedures include the following (4):

- Build on what already is in place, considering information and tools now in use at different levels of the organization.
- Measure what will be used and use what is measured, basing data collection on needs of the business process for performance-based information, not simply on data availability.
- Assess the need for data quality improvements in terms of accuracy, precision, timeliness, and consistency. Check for inconsistencies across systems.
- Measure or model the agency’s contribution to improved performance, collecting information on outcomes as well as outputs. Identify trend data where they are available.
- Manage data as an enterprise asset, with identified responsibilities and schedules for collection, quality checks, documentation, accessibility, and so forth. Adjust data collection procedures over time to correct for duplication, and update collection procedures to accommodate new data and new collection technologies.

- Plan for smooth transitions as legacy systems are replaced, and avoid linear referencing pitfalls. Consider outsourcing data collection if necessary.
- Develop a data business plan to address these and other issues systematically.

Interjurisdictional differences in data and modeling techniques are also an issue, particularly in metropolitan areas where coordination and cooperation are needed among the state DOT, the MPO, and transit agencies in developing plans and programs. There is no magic-bullet solution to this issue, but agencies can strive to coordinate their models, performance measures, and data to achieve at least a degree of consistency if they are not able to go further with data sharing and use of similar models. (Compatibility problems in areas such as linear referencing or geographic information systems may impede sharing.)

■ 5.7 Structuring Performance Tradeoffs

The most important performance measure characteristics for tradeoffs are the abilities to predict performance, to relate performance to estimated project or program costs, and to define measures to a suitable level of sensitivity. Under NCHRP Project 8-36(7), a methodology was developed to apply performance measures to multimodal tradeoffs (8). Under NCHRP Project 20-57, analytic tools were developed to support tradeoff analysis by applying information generated by an agency's management systems (10).

Tradeoffs Across Modal Options

A core principle of asset management is that a range of potential solutions are considered to address transportation needs. In many contexts, it is important to have performance measures that do not presume a particular mode, but rather focus on a transportation result that could be met by more than one mode. For example, a performance measure for Mobility that is based on travel time is mode neutral, since it can be used for auto, transit, rail, pedestrian, or other modes. LOS as defined in the *Highway Capacity Manual* is a useful measure of vehicle flow based on volume-capacity relationships, but it is not "mode neutral," since it presumes a highway solution. It should be noted that mode neutrality is important mainly for those measures that could be used in deciding between modes (e.g., measures of mobility, accessibility, and economic development). Preservation-related measures, as a rule, are not mode-neutral, but reflect the particular infrastructure (highway pavement, runway pavement, structures, rail track, maritime piers, etc.) or fleet that is appropriate to each mode.

■ 5.8 Predicting Performance and Setting Targets Based on Funding

The capabilities to predict performance and to relate performance to cost are central to several asset management techniques, including formulation of realistic targets based on anticipated funding availability, evaluation of alternatives, program budgeting, and tradeoff analyses, as well as GASB 34 reporting. Modern pavement and bridge management systems typically include this capability as a standard feature. While this feature is now available to many agencies, it is not now widely used

for decision making (refer to the agency interviews reported in Section 2.0). Even agencies that appreciate the value of performance-cost relationships may not yet apply this capability fully. They may use it, for example, to set realistic performance targets in light of anticipated funding, but they may not yet apply the information to conduct tradeoff analyses.

As an example of how management systems can provide performance-cost relationships, Figure 15 illustrates three scenarios that have been analyzed for an example network of 500 bridges using the AASHTOWare Pontis® 4.0 bridge management system. Each scenario tests a particular budget level to preserve the bridge network through a 10-year analysis period. Figure 16 plots the condition of the bridge network versus time in years. The network of bridges is assumed to exhibit a uniform distribution of ages and conditions. The network-average bridge condition is gauged by the percent of bridges with health index (HI) greater than 75 on a scale from 0 (poor) to 100 (excellent). Bridge health index is a measure of bridge structural condition, as described by Shepard and Johnson (29). Other measures of condition, such as sufficiency rating, also can be used. The budget levels correspond to the following projected annual expenditures:

- A relatively high annual expenditure, which results in improvement of bridge network condition through the 10-year period. This case is illustrated by the top curve in Figure 15.
- A moderate annual expenditure, which is sufficient to maintain the status quo in network bridge condition through the analysis period. This case is illustrated by the middle curve in Figure 15.
- No annual expenditure, representing a “do-nothing” policy, which results in a decline of network bridge condition through the analysis period. This case is illustrated by the bottom curve in Figure 15.

Figure 15. Example of Budget Scenarios and Effects on Infrastructure Condition

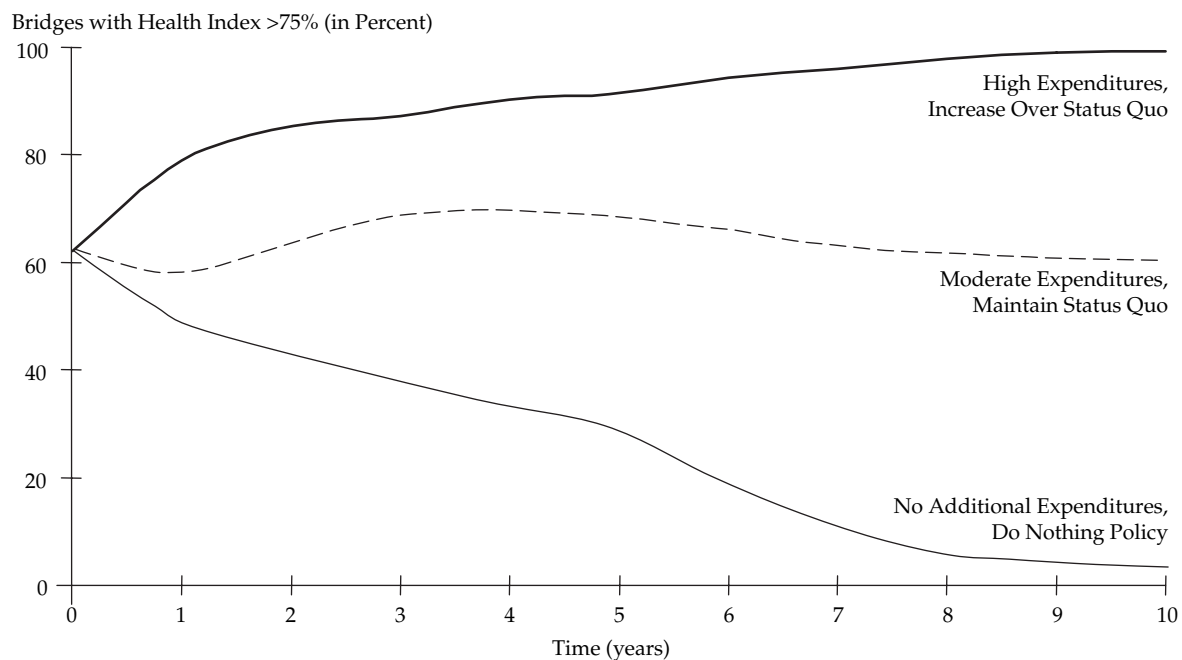
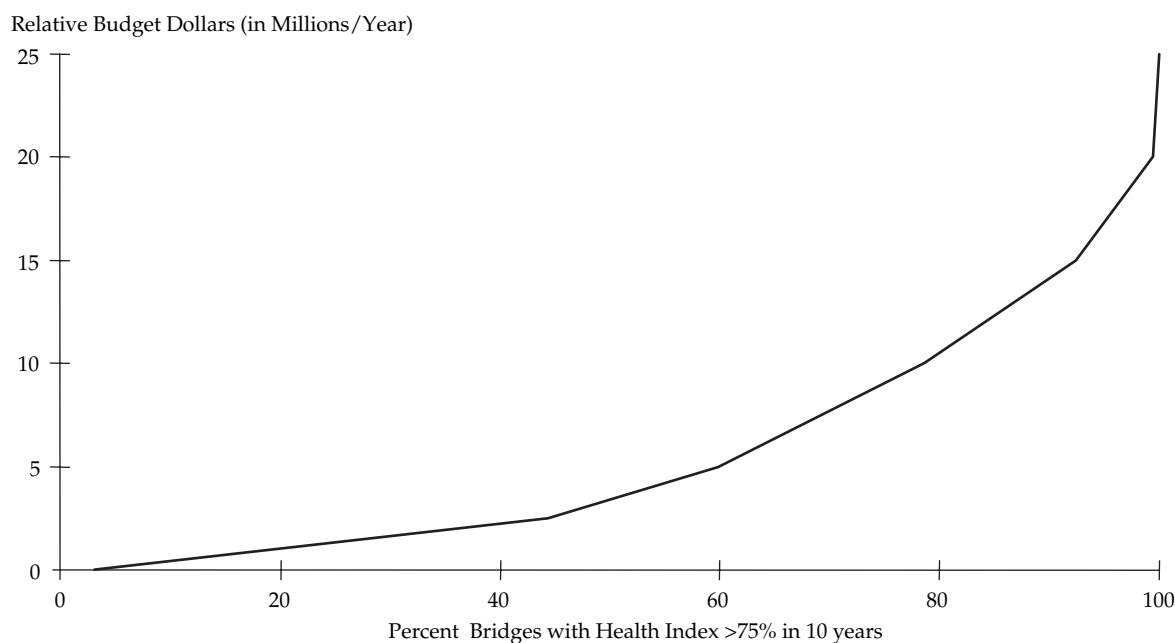


Figure 16. Resulting Relationship Between Infrastructure Condition and Needed Expenditure



The three scenarios each result in a markedly different result at the end of the 10-year analysis period and together define a range of options in funding bridge preservation. It is possible to plot the condition level at the end of 10 years versus the corresponding annual budget or expenditure level. The result is the relationship between condition level and needed expenditure, as shown in Figure 16. Figure 16 captures the tradeoff between constant expenditure level and resulting long-term condition. This relationship can be used directly as a guide identifying the expenditure level to meet a specified target condition level. It also can be used to explore long-term trends in network condition for different possible funding scenarios and to discuss these trends with policy-makers in a proactive way.

Performance Targets and GASB Statement 34

Establishment of performance targets for asset condition may be done in conjunction with the GASB 34 modified approach. The requirements of the GASB 34 modified approach are summarized in Sidebar 5.5. The practical implications of these guidelines for performance measures are the following performance measure criteria:

- A focus on preservation;
- A quantitative measure or index of condition or performance (many existing pavement, bridge, rail, and maintenance measures meet this criterion);
- Inspection surveys (at a minimum frequency of every 3 years) to update current performance measure values (typical pavement, bridge, rail, maintenance, and other periodic inspections of infrastructure can meet this criterion);

Sidebar 5.5: GASB Modified Approach Requirements

GASB 34 requires general purpose state and local governments to report the value of their infrastructure assets in Comprehensive Annual Financial Reports (CAFRs) and to depreciate the value of those assets. As an alternative to depreciation, governments are allowed to choose the modified approach for selected asset classes. Under the modified approach, the depreciation requirement is waived and, in its place, governments establish condition targets and expenditure targets at the start of the fiscal year for these asset classes. These targets are then compared against actual conditions and actual expenditures at the end of the fiscal year, and these comparisons are reported in the CAFR.

There are natural linkages between use of performance measures in asset management and performance reporting in the modified approach allowed by GASB 34. Guidelines for the modified approach are as follows:

1. “Eligible” infrastructure assets must be part of a network or subsystem of assets,
2. The agency must manage these eligible assets using a management system that has the characteristics described below, and
3. The agency must document that these eligible assets are being preserved at or above a condition level disclosed by the agency.

Transportation networks such as highways, roads and streets, railways, and rail transit meet the first guideline. Since GASB provides agencies flexibility in defining networks and subsystems, facilities such as airports, intermodal transfer points, freight transfer terminals, and port or ferry facilities qualify as well.

The second guideline calls for a management system with the following capabilities:

- It must maintain a current inventory of the eligible assets.
- Its data on the condition of eligible assets must be based upon periodic field surveys. These surveys must be performed at least every 3 years, and they may be based upon statistical samples. They must be conducted by or contracted for by the managing agency. The resulting condition assessments must be substantially replicable and should be expressed by a quantitative measure or index.
- It must be able to estimate each year the annual amount needed to maintain and preserve the eligible assets at or above the target condition level disclosed by the agency and must report actual expenditures in comparison with the targeted amount.

The third guideline calls for the agency to document, based upon the most recent series of condition surveys and assessments, that the eligible assets are indeed serving at a condition level at or above the target disclosed by the agency. This intended condition level must reflect high-level policy established by administrative or executive decision or by legislative action.

- Analytic support of performance measures using tools that relate forecast condition/performance to preservation budget needs (many modern systems for pavement management, bridge management, capital investment programming, and LOS-based maintenance management have this capability);
- Formal establishment of targets for performance measures that are disclosed publicly; and
- Verification that current performance measures meet the intended target for the current year.

These GASB requirements coincide with asset management criteria for a policy-driven and performance-based process, identification and evaluation of options through tradeoff analyses,

and feedback regarding target attainment and adjustment of either targets or budgets in subsequent periods if needed. GASB helps promote good asset management, and vice versa.

- If an agency chooses to apply the GASB modified approach and does so correctly, the procedures it uses reinforce good asset management practice in preservation.
- Conversely, if an agency follows the asset management criteria described throughout this section, it is in a position to apply the GASB modified approach if it chooses to do so.

While GASB financial reporting and asset management are two different activities, they relate closely and can benefit and reinforce each other. See Sidebar 5.6 for a review of initial experience with the GASB 34 modified approach.

Sidebar 5.6: Initial Experience with GASB 34 Performance Targets

The initial year of GASB 34's effectiveness was Fiscal Year 2002, and 23 state DOTs selected the modified approach for some or all of their infrastructure assets. The general attitude among these departments was that the comparison of targeted and actual conditions was a valid exercise that should be of interest to legislators and the public, but that the comparison of targeted and actual expenditures was of limited value and was compromised by a disconnect between the year of funding authorization and year of funding expenditure.

There was a divergence in philosophy among many of the state DOTs regarding the relative stringency of the targets. Some state DOTs selected very lenient targets (as compared with recent conditions) in order to be virtually certain that they would achieve the targets. Others were concerned that if actual conditions exceeded the targets by too great a margin, this might suggest to some observers, notably legislative budget analysts and committees, that excessive investment was being allocated to preservation and that a reduction was in order. These DOTs selected challenging targets even if this presented the risk of missing the targets.

Colorado selected a stringent target for pavements, one that permitted no degradation from recent conditions, and a lenient target for bridges, one that it was virtually sure of achieving.

Florida set a pavement condition target that required some improvement from recent conditions while the bridge condition target was somewhat less challenging.

Michigan set performance targets that were relatively easy to meet, although in the case of pavement this was so only because of significant recent improvement.

Minnesota, one of the few states to subdivide its pavement and bridge asset classes by functional classification, selected condition targets that were not especially challenging to meet initially but that allowed for little margin for deterioration from current conditions, especially for bridges on the principal arterial system.

Ohio also subdivided its pavement asset class by functional classification. It selected condition targets that were relatively easy to meet.

For these five example states, the approach to bridge condition targeting and assessment was relatively uniform and strongly influenced by the National Bridge Inventory program. In contrast, the approach to pavement targeting and assessment was more varied, reflecting local priorities and differences in local conditions. This pattern held true through most of the modified approach states.

It should be noted that some of the states using the modified approach used one set of targets for GASB-34 reporting and another (more stringent) set for internal performance management purposes.

■ 5.9 Setting Long-Term Performance Goals

Setting short- to midterm performance targets that are realistic based on funding availability is critical for helping decision-makers make performance-based resource allocation tradeoffs. This is a fundamental part of good asset management practice.

However, many agencies want performance targets to be based on goals that stand on their own, independent of resource constraints. They wish to address fundamental questions such as the following:

- What *should* the condition of our pavements and bridges be?
- What level of congestion should be tolerated on different parts of the network?
- What level of crash reduction is attainable?

General methods for establishing long-term performance goals include the following:

- Measure what the current baseline level of performance is, and then set targets for improvement using benchmark information about what peer agencies have achieved through focused efforts to improve performance.
- Align agency targets with nationally based targets (e.g., the national target of 1.0 fatality per 100 million VMT).
- Use customer surveys and/or tracking of complaint information as a guide to establish “tolerable” threshold performance levels.
- Use available models that show how user costs (e.g., travel time, vehicle operating costs, and accident costs) change with different levels of condition or performance. Examining the slope of this curve can show the performance level at which user costs begin to increase rapidly.
- Make use of the law of diminishing marginal returns to identify the point at which additional investments begin to have a declining degree of impact on improvements in performance—in other words, where the slope of the investment-performance curve begins to decline. Curves of changes in performance measure value per unit of investment (see Figures 15 and 16) can be used for this purpose.
- A corollary to the law of diminishing returns is that caution should be exercised about setting targets that call for 100-percent achievement of a particular condition or service level, since the benefit/cost ratio associated with achieving the last 1 percent will typically be quite low. For example, setting a target of no structurally deficient bridges could necessitate costly replacement of a bridge that provides a redundant link in the network and that is not heavily used.
- Use a tool such as the Highway Economic Requirements System (HERS) or the Highway Design and Maintenance Standards Model (HDM-4) to identify the performance levels that could be achieved through implementing all improvements with benefits exceeding costs.

- Define a set of minimum standards for infrastructure characteristics and performance (such standards already may be in place), and establish a long-term target of meeting these standards. Caution should be exercised in defining standards so that they are feasible and reasonable.
- Related to the standards-based approach, a methodology for defining either deficiencies or needs (i.e., the cost of addressing the deficiencies) can be applied. This then provides the basis for setting a long-term target of eliminating all deficiencies or reducing the backlog to 0. Alternatively, a target of keeping the backlog from growing might be established.

For setting infrastructure condition goals, the following additional types of approaches can be used:

- Establish a threshold for “poor” pavement based on a level of roughness that is noticeable to road users (particularly trucks) and that is associated with a marked increase in road user costs (due to vehicle wear and tear, increased fuel consumption, or reduced speed). Set a long-term goal of having minimal travel on poor roads (e.g., less than 5 percent).
- Use capabilities of pavement and bridge management systems to determine a long-term optimal network condition distribution, which minimizes life-cycle costs. Use this distribution to set targets for either average condition or percent of infrastructure (number of bridges, deck area, miles, etc.) above a given threshold condition level.
- Base goals on maintaining a steady-state condition distribution in order to avoid future peaks in preservation or replacement costs that would be difficult to address given a relatively constant level of funding. These goals would be expressed in terms of the percent of the network in different ranges of condition level (or remaining life categories).

Emerging techniques for establishing performance targets for congestion are discussed in Sidebar 5.7.

■ 5.10 Obtaining Internal and External Buy-In

Virtually all authorities agree on the importance of internal and external acceptance of performance measures to their successful application as well as public and agency support for the decisions based upon performance measurement. While there is widespread agreement on the principles to be followed and the resulting benefits, there are somewhat different takes on the relative number of performance measures that best serves this objective.

Performance measures should be designed with the customer in mind whenever possible.

- External customers include users of the transportation system, who themselves represent different interests (e.g., passenger versus freight transporters, local versus Interstate transport, and commercial versus recreational/tourist interests), as well as public and private policy-makers and interest groups. While system end-users may not always exhibit much interest in performance measures per se, their interest can be stimulated through effective public involvement and public information programs (14 p. 51). Transit agencies have used customer surveys to develop customer-oriented measures of service quality (31 p. 65). (These points reinforce the importance of the processes illustrated at the top of Figure 2).

Sidebar 5.7: Setting Performance Targets for Congestion

Congestion and the related concern, reliability, are measured in some way in several cities, but performance targets are rarely set. The targets should be connected and related to areawide targets for related measures (e.g., population and employment growth, home prices, and education quality). However, the first step is to identify some measurable targets and begin analyzing the trends and meanings. The range of possible types of targets is very broad, but might desirably contain some individual mode, program, or activity targets that can affect day-to-day agency practices and targets that relate to system-level performance.

Targets should be based on measures of congestion that are meaningful to individuals, as well as measures of the magnitude of the problem. The individual measures might express the amount of travel time or delay per person or per trip. These measures relate the problem in quantities that are relevant to travelers, shippers, and citizens. The magnitude values are used in the description of the problem and the effect of the solutions. These might be expressed in total hours or total dollars, which are values needed for benefit/cost analyses. The dollar value of congestion, reliability, or travel time is a useful method to combine passenger travel concerns and freight concerns. The higher value of an hour of delayed freight might be particularly relevant for freight corridor or facility studies.

Many state DOTs and FHWA use some version of free-flow travel conditions or travel at the speed limit as a standard for comparisons. While these work well in communications with the public, they are not as relevant to the amount of transportation service that can be provided. The California DOT (Caltrans) has used 35 mph as a standard for addressing an achievable target speed on the freeways and measured delay relative to that level in the state's urban areas for many years. Caltrans and WSDOT have recently begun to use the concept of "maximum productivity," defined as the optimum combination of speed and volume, as a target. This approach shifts the focus of the targets from a standard of what might be achievable for road additions to a focus on operating efficiency. The maximum hourly volume occurs when the freeway operates near a speed of 50 mph.

The metropolitan planning organizations and the Texas DOT have cooperated on the development of a congestion standard for a statewide needs estimate. The concept uses the elimination of serious congestion as a target for identifying the needs for transportation improvement. Capacity improvements are made to reduce the volume-to-capacity ratio on all major road segments below 1.0 in the planning year (either 2025 or 2030). The capacity additions are used to estimate the cost of the actual improvements, which are envisioned as a combination of lane additions, transit projects, operations improvement programs, demand management, and land use changes—all designed to improve congestion. The costs of road additions are easier to estimate; therefore, they are used as the cost baseline. The performance measure used in this case is the Texas congestion index, the ratio of the dollar value of travel time in the peak periods to the dollar value of travel if facilities operated at free-flow speeds. With the needs scenario adding roadway in only those sections with serious congestion, the areawide index target is composed of road sections with a range of congestion levels from just below the threshold to free-flow conditions. This results in a different target value for each metropolitan area, depending on the mix of system conditions. The larger areas with congestion on most of the system tend to have higher target values than the smaller metropolitan areas with more of the roads operating closer to free-flow speeds. "Addressing serious congestion problems" is a target that is easy to analyze and communicate and provides data useful for a variety of purposes.

- Buy-in by key internal stakeholders and decision-makers, including those who will be held accountable for meeting targets (not always the same individuals as the decision-makers), is critical to success. “Those who are expected to use [performance measures] to shape and make decisions should be allowed to influence the design of the program from the beginning” (23 p. 25). Internal support is also needed for externally reported measures, particularly among “staff whose cooperation or resources are needed to gather or summarize measures” (12 p. 41).

The most challenging buy-in efforts may occur among “peers,” particularly in metropolitan areas where considerable coordination and cooperation are required among the state DOT, the MPO, public transit agencies, and other public and private service providers. “The issue here is how to create a mutuality of interest that has a reasonable chance of leading to a cooperative effort and a win-win outcome” (14 p. 51).

The number of performance measures should be limited to the minimum needed to support decisions at the intended level. Fewer, more general measures are generally appropriate to policy formulation and planning, while more measures may be needed for programming and project selection. In all cases, however, the number of measures should not overwhelm decision-makers or bog down the data collection effort (23 p. 25).

Performance measure development is an art, not a science. Executives therefore must be creative in fashioning measures that reflect various internal and external interests in a coherent way. Furthermore, performance measure development should pay attention to the following guidelines to ensure buy-in (12 p. 79):

- Keep the measures few and simple;
- Focus the measures on agency strategic goals, and relate them to the agency’s activities;
- Use the measures as a means to improving system performance and service quality, not as report cards; and
- Invest the time and effort needed for data collection and processing.

Agencies such as Florida DOT and Minnesota DOT each use hundreds of measures. While it is important in these agencies to have a lot of measures, it is also acknowledged that this numerous pool can be boiled down to a few key measures for reporting purposes. The large number of measures is felt to be needed, however, for effective buy-in, since everyone must feel that his or her interests are represented (35 p. 88).

6.0 Recommended Framework for Transportation Agencies

■ 6.1 Introduction

This section outlines a recommended framework that transportation agencies can use to:

- Identify performance measures that are most useful for asset management,
- Integrate these performance measures effectively within the organizations, and
- Set performance targets.

Rather than a single, prescriptive set of measures that might provide a good textbook example but likely would not be suitable for all agencies, the framework is in the form of guidance on the preferred types and forms of measures and the process by which agencies should identify and implement them. The framework is based on the criteria and guidelines for identifying performance measures that were presented in Section 4.0 and on the design considerations discussed in Section 5.0.

Volume II of this report is a guide to this framework. It reviews some of the key concepts from Sections 4.0 and 5.0 in this volume and presents a step-by-step procedure that agencies can follow to implement the framework.

The framework was developed with the recognition that each agency will have a different set of circumstances and needs to consider in selecting and implementing performance measures. Furthermore, it is presumed that many agencies will already have a number of performance measures in place, along with supporting data and systems. While some agencies may wish to “start from scratch,” others may simply want to identify incremental steps to supplement their existing set of measures in certain areas or to make more effective use of measures for decision making.

Many performance measures now used by agencies are compatible with asset management concepts, associated data collection efforts, existing management systems, other analytic tools such as geographic information systems (GIS), and reporting mechanisms. In agencies that have already devoted resources to a results-based, customer-oriented performance measurement system, only modest work if any would be needed to support a broad range of asset management functions. In agencies that are looking to upgrade their performance measurement or wish to include system monitoring within a comprehensive asset management process, the framework can help identify the most suitable systems of measures to support various management functions and decisions.

Although the framework focuses on using performance measures in support of asset management principles, agencies use performance measures for a variety of purposes and it is not necessary (or desirable) to create a separate and distinct “asset management” set of performance measures. There

is also no need to apply the asset management–based criteria for selection of performance measures used for purposes other than the strategic resource allocation approach embodied in asset management.

■ 6.2 Framework Overview

The framework is organized into three separate processes, as shown in Figure 17:

- **Identify Performance Measures:** assessing existing performance measures that are in place, identifying gaps, and considering new measures to fill gaps.
- **Integrate Performance Measures into the Organization:** engaging stakeholders to ensure buy-in, designing families of measures that can be used at different organizational levels and for different types of decisions, ensuring consistency across measures, identifying needed improvements to data collection and analytic tools, designing communication devices, and documenting measurement and reporting procedures.
- **Establish Performance Targets:** establishing both long-term (desired or optimal) goals and short- to medium-term (funding constrained) targets for performance measures.

While a sequential order is shown in Figure 17, the framework is designed to be flexible. Agencies may apply each of these steps sequentially as presented in Volume II; they may follow a different order or do some of these steps concurrently, or they may choose to pursue only one of these steps, depending on their situation.

The following three sections provide a summary of the key steps in the framework. Refer to Volume II for a more detailed description of each step.

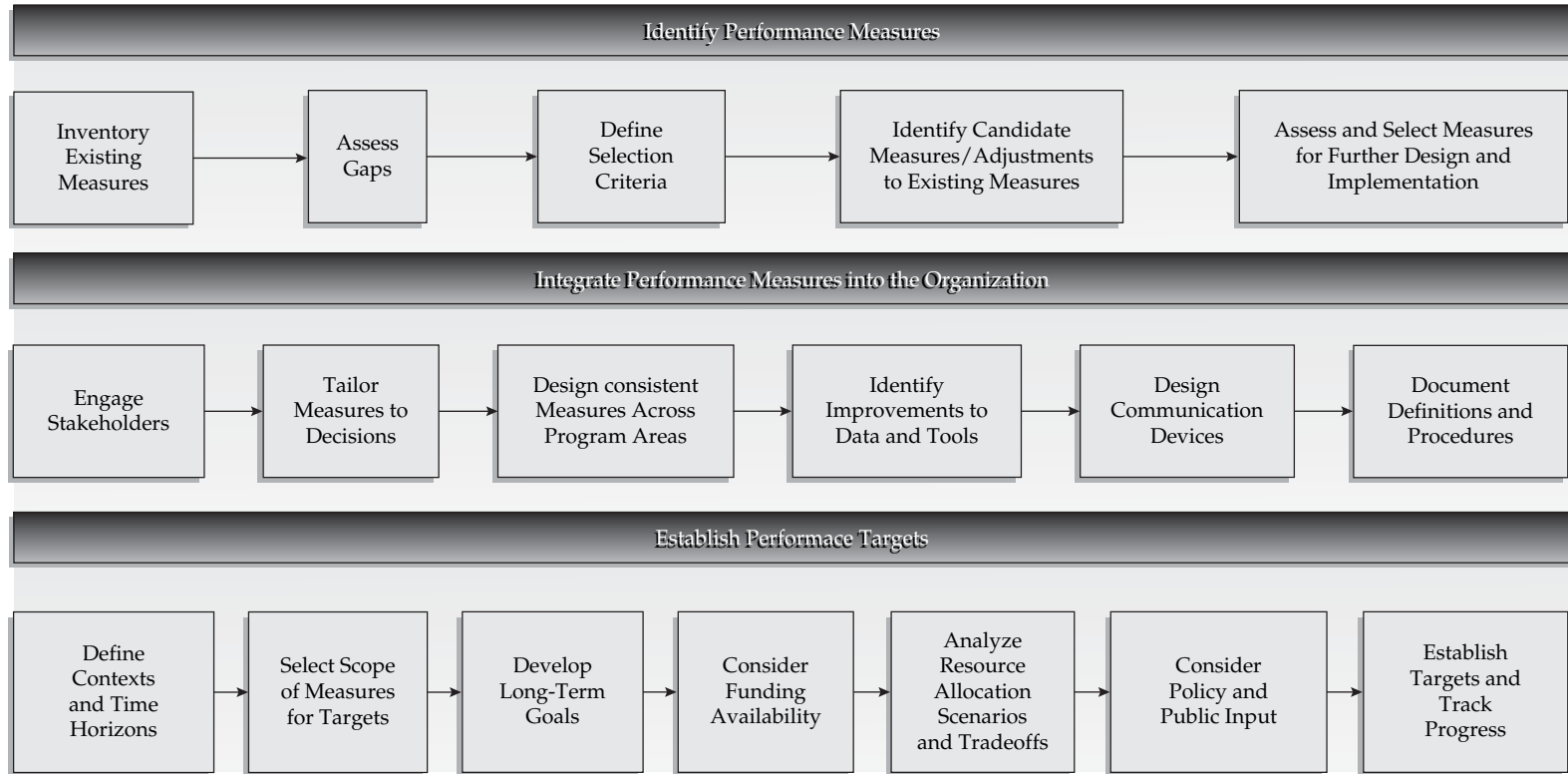
■ 6.3 Identify Performance Measures

Step 1: Inventory existing measures—Take an inventory of performance measures already in use within the agency that could be of value for resource allocation decisions. These will be measures that relate directly to the performance of the transportation system or the impacts of the system on society or the surrounding environment. Obtain an understanding of how existing measures are defined, how they are now being used, and whether data or other issues limit their current value.

Step 2: Assess gaps—Identify gaps in existing performance measures. There are two types of gaps to be identified: gaps in coverage and gaps in use of measures to guide resource allocation. Gaps in coverage are determined by examining existing measures with respect to the most critical outcome areas, based on the agency’s stated policy goals. Gaps in use are identified by assessing if and how measures are used to influence resource allocation decisions.

Step 3: Define selection criteria—Establishing explicit criteria can provide valuable focus to the performance measure development effort and impose a useful discipline on the process, providing the

Figure 17. Guidance for Performance Measures and Targets



basis for narrowing down the list of potential candidate measures. Suggested criteria include those related to feasibility of implementation (considering data availability and costs), policy sensitivity (do measures support policy objectives and provide meaningful information to decision-makers), support for a long-term strategic view, usefulness for decision support, and usefulness to different organizational levels and to external audiences.

Step 4: Identify candidate measures/adjustments to existing measures—The recommended approach is to develop a chart of candidate measures, indicating potential relevance to specific business processes, including long-range planning, performance-based budgeting, project prioritization, daily operations and maintenance management, and delivery monitoring. (Appendix A of Volume II provides examples upon which agencies can draw.)

Step 5: Assess and select measures for further design and implementation—This step involves taking the candidate measures identified in Step 4 and applying the criteria developed in Step 3 to identify measures that are worth pursuing.

■ 6.4 Integrate Performance Measures into the Organization

Step 1: Engage stakeholders—Early involvement of stakeholders is emphasized as a necessary ingredient for successful performance measurement implementation. Buy-in from both consumers or users or performance measures (i.e., decision-makers) and producers of performance measures (i.e., technical staff responsible for providing the information) is needed. This step is listed first because of its importance, but is intended to be an ongoing activity throughout the performance measure development effort.

Step 2: Tailor measures to decisions—In this step, each performance measure is examined with respect to the specific decision-making contexts in which it will be used. Appropriate form(s) of the measure are designed in order to be meaningful to the intended audience and provide sufficient sensitivity given the timeframe and geographic scope of application. Approaches to “rolling up” measures from detailed levels to higher levels are also determined in this step.

Step 3: Design consistent measures across program areas—This step looks at opportunities to implement families of measures that can facilitate tradeoffs across program areas. A variety of approaches to this are suggested for consideration—for example, using remaining life or value for each class of asset, or defining a “triage” approach to performance levels for all assets (high risk, minimally tolerable, and desirable).

Step 4: Identify improvements to data and tools—This step is concerned with making sure the necessary data (with sufficient quality) and analytic tools are available to enable effective use of each of the selected performance measures.

Step 5: Design communication devices—This step considers the critical role of communication in a performance measurement effort. Examples of effective performance-reporting approaches and formats are provided to assist agencies in designing their own. In addition, the importance of organizational mechanisms for communication of performance information (e.g., putting performance reports on the agenda at quarterly management meetings) is stressed.

Step 6: Document definitions and procedures—This step emphasizes the importance of clear documentation of the precise definitions of measures and how they are calculated. This documentation should serve as the basis for auditing performance measurement accuracy and adhering to defined procedures.

■ 6.5 Establish Performance Targets

Step 1: Define contexts and time horizons—This initial step involves developing explicit statements about how targets will be used and what time horizons they will cover (e.g., in long-range plans, in GASB-34 reporting, and in agency annual performance reports).

Step 2: Select scope of measures for targets—Determine which measures should have targets. This step involves identifying the performance measures that are suitable for target development. Some measures may not lend themselves to quantitative targets; others may not have sufficient baseline or trend information available for the agency to be comfortable with establishing a target. In addition, consistency across targets for related measures and potential conflicts across targets are considered in this step.

Step 3: Develop long-term goals—A distinction is made between long-term goals about desirable performance levels and short-term targets that represent the best that can be done given available resources. The framework stresses the importance of financially constrained performance targets as a fundamental part of good asset management practice. However, goals that are independent of resource constraints provide an important foundation. No single best approach to developing long-term goals is recommended. Rather, a range of approaches that agencies can follow is described. These approaches include use of benchmarks from peer agencies, reliance on formal or informal customer feedback to determine acceptable performance levels, and application of existing analytic tools to find performance levels that represent economically efficient conditions.

Step 4: Consider funding availability—This step involves creating realistic estimates of future resources that can be used as the basis for financially constrained performance targets. A scenario approach is recommended to address funding uncertainties.

Step 5: Analyze resource allocation scenarios and tradeoffs—The framework recommends analysis of the performance implications of different resource allocations—both within and across program categories. Use of analytic tools that project future performance as a function of investment level is fundamental to this activity.

Step 6: Consider policy and public input—There should be a two-way communication process, with the agency providing easily understandable information about the implications of different resource levels and allocations and stakeholders providing their feedback on desired performance levels and priorities across different measures.

Step 7: Establish targets and track progress—This final step involves selecting target values for performance measures and putting the procedures in place to track progress toward achievement of the targets. A process of periodic adjustment to performance targets is also recommended to reflect changes in policy or priorities or the emergence of new information that was not previously available.

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Volume II:
**Guide for Performance Measure
Identification and Target Setting**

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Executive Summary

The objective of NCHRP Project 20-60 was to identify performance measures suitable for asset management and to develop a framework that decision-makers can use for selecting performance measures and setting performance targets. This volume provides a guide for using the performance measure selection and target-setting framework that was developed.

This volume begins with an overview of transportation asset management principles and a discussion of the implications of these principles for identification and use of performance measures. From an asset management perspective, performance measures should address key agency goal areas; cover asset condition, service/function, and delivery; and provide a balanced set of perspectives. Implementation of performance measures should consider alignment and integration at different levels of the agency for different purposes, support for resource allocation decisions, and support for making choices among available options using an objective and unbiased approach.

Based on the analysis of key implications of asset management best practice for performance measurement, a framework for performance measure selection and use is presented. This framework consists of step-by-step procedures for three basic activities: (1) identifying performance measures suitable for asset management, (2) integrating performance measures into the organization, and (3) establishing performance targets. The intent is that guidance for each of these activities can be used independently. Guidance for all three activities is designed to be flexible enough for adaptation to varying agency circumstances.

Guidance for identifying performance measures involves the following steps:

1. Inventory existing measures,
2. Identify gaps to be addressed based on coverage of agency goals and objectives and support for the asset management best practices,
3. Define criteria for selecting new measures (the guidance suggests a set of criteria but presumes that agencies will tailor criteria based on their needs and priorities),
4. Identify additional candidate measures, and
5. Select a set of measures from the list of candidates for further design and implementation.

Guidance for integrating performance measures into an organization involves the following steps:

1. Engage internal and external stakeholders to achieve buy-in;
2. Identify the different decision contexts where performance measures are to be used (project, cor-

ridor, and network levels for short- and long-range decisions) and refine measures so that they are at the appropriate level of sensitivity;

3. Identify opportunities for using measures that are consistent across different organizational units responsible for various asset classes, modes, or work types;
4. Identify needs for additional data collection, data management, and analytical tools to support the selected measures;
5. Design communication devices with formats appropriate to the target audiences; and
6. Document measure definitions and procedures.

The guidance for establishing performance targets involves the following steps:

1. Define the context for target setting and establish time horizons,
2. Determine which measures should have targets,
3. Develop long-term goals based on consideration of technical and economic factors,
4. Consider current and future funding availability,
5. Analyze resource allocation scenarios and tradeoffs,
6. Consider policy and public input implications for target setting, and
7. Establish targets and track progress.

The volume ends with a list of performance measures that may be considered for transportation asset management (Appendix A) and examples of performance targets established by a wide range of departments of transportation (DOTs) (Appendix B).

1.0 Introduction

■ 1.1 Background

In November 2002, AASHTO published the *Transportation Asset Management Guide* (hereafter referred to as “the *Guide*”) (1), which describes a set of principles and practices for effective allocation and use of resources to address the preservation, operation, and improvement of transportation infrastructure. A key observation in the *Guide* is that performance measures play a central role in “making an asset management approach work in practical terms” (1 pp. 8–18). NCHRP Project 20-60, “Performance Measures and Targets for Transportation Asset Management,” was undertaken as a logical next step. This project was initiated in July 2003, with two objectives:

1. To provide an assessment of, and recommendations for, performance measures suitable for an asset management approach that effectively address resource allocation in transportation facility preservation, operation, improvement and expansion; and
2. To develop a framework that decision-makers can use for selecting suitable performance measures and setting performance targets.

This volume addresses the second objective and serves as a guide to the framework developed under NCHRP Project 20-60.

■ 1.2 Using This Document

This document is directed toward transportation agency staff responsible for implementing or enhancing performance measures in an asset management context. The agency does not need to be labeling this effort as “asset management.” The guidance will be relevant to any agency seeking to:

- Improve the technical basis for resource allocation across and within program areas,
- Ensure consistent approaches to decision making across agency functions,
- Improve capabilities to relate investment decisions to outcomes,
- Establish an improved feedback loop from observed performance to agency action, or
- Improve external accountability for resource allocation decisions.

A step-by-step process is described for identifying performance measures, implementing them within the organization, and setting performance targets. Users of this document can refer to Volume I

for more detailed discussion, examples, and substantive guidance for defining and using performance measures.

For simplicity, the framework is presented as a linear process of identifying performance measures, integrating them into the organization, and establishing performance targets. Some agencies may wish to follow the steps presented in this order. Some may use a different sequence of steps (e.g., setting the targets in conjunction with selecting measures). Others may use selected sections of this guide as a source of information or ideas that are relevant to their particular situation at a given point in time.

For example, the study team reviewed draft versions of this guide with three agencies. The first agency was starting from scratch, working to identify a new set of performance measures in support of a larger asset management initiative. This agency found that Step 1 of the framework, Identify Performance Measures (Section 3.2), provided a useful systematic approach for evaluating a large set of measures proposed by staff from throughout the organization.

A second agency had already made significant progress in establishing an approach for selecting and organizing measures around its core services. This agency was working to create buy-in throughout the agency and to make performance-based techniques an integral part of the organization. Step 2 of the framework, Integrate Measures into the Organization (Section 3.3), was highly relevant to this situation.

The third agency started with a well-defined set of performance measures that had a long history of use within the organization. The agency was working to adjust these measures for use in an asset management context and to set meaningful targets. Step 3 of the framework, Establish Performance Targets (Section 3.4), was most relevant to this agency.

■ 1.3 Document Overview

The remainder of this volume consists of two sections:

Section 2.0 discusses the role of performance measures in transportation asset management and the implications of transportation asset management best practices for the selection and implementation of performance measures.

Section 3.0 presents the framework for selecting performance measures and setting performance targets.

The appendixes provide performance measures that may be considered for transportation asset management and examples of performance targets established by a wide range of DOTs.

2.0 Using Performance Measures for Asset Management

■ 2.1 Definitions

The *Guide* defines **asset management** as “a strategic approach to managing transportation infrastructure” (1 p. G-1). Although transportation officials manage a wide range of **assets**, the *Guide* focuses on the physical infrastructure of the transportation system, such as roads, bridges, and appurtenances.

At the heart of asset management is a performance-based approach to making decisions on how best to allocate and use resources for managing this infrastructure. The *Guide* defines **resources** as inputs into the infrastructure management process (e.g., human resources, financial capacity, corporate information, equipment, and materials).

Performance measurement is a way of monitoring progress toward a result or goal. It is also a process of gathering information to make well-informed decisions. Transportation agencies have used performance measures for many years to help track and forecast the impacts of transportation investments, monitor the condition of highway features, and gauge the quality of its services. General guidance on transportation performance measures and performance-monitoring concepts is available in a wide variety of sources. (Highlights from several of these documents are presented in Section 3.0 of Volume I.) NCHRP Project 20-60 focused on two specific types of measures—(1) **transportation system performance measures** that support resource allocation and (2) **program delivery measures** that help make the connection between outputs and outcomes.

■ 2.2 The Benefits of Asset Management

As defined in the *Guide*, the goals of asset management are to:

- “Build, preserve, and operate facilities more cost-effectively with improved performance;
- “Deliver to an agency’s customers the best value for the public tax dollar spent; and
- “Enhance the credibility and accountability of the transportation agency” (1 pp. 1–3).

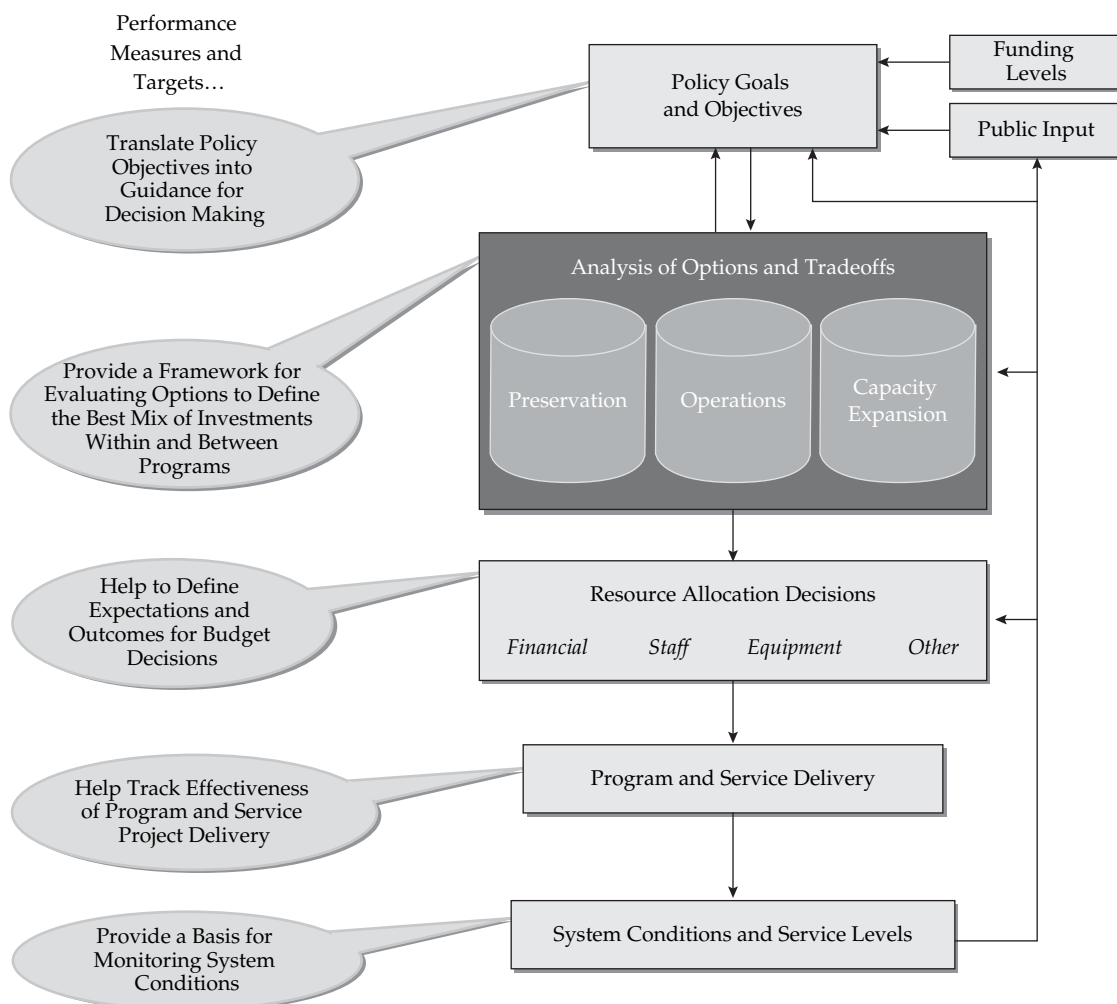
The principles of asset management can impact nearly every aspect of an agency’s business—policy development, planning, finance, programming, project development, construction, and maintenance. Asset management should be viewed as a way of doing business as opposed to a separate

program. It brings a new perspective to how an agency conducts its existing procedures, reaches decisions, and applies its information technology (IT) capabilities. Asset management suggests principles and techniques for making better decisions based on better information.

2.3 The Role of Performance Measures in Asset Management

Performance measures represent a critical underpinning of any successful application of transportation asset management (hereafter referred to as simply “asset management”). Building on the general asset management framework used throughout the *Guide*, Figure 1 illustrates that performance measures and targets are required at several points in an agency’s resource allocation and delivery process:

Figure 1. Role of Performance Measures and Targets in Asset Management



- As the practical expression of policy objectives that reflect customer expectations and realistic funding levels;
- As a framework for evaluating options in planning, prioritizing projects in programming, guiding tradeoff analyses in resource allocation, and influencing priorities in delivery of projects and services;
- As a method to provide feedback on the effectiveness of expenditures to decision-makers involved in policy formulation and target setting; and
- As the basis for monitoring to obtain indications of system performance over time.

■ 2.4 Characteristics of Performance Measures to Support Asset Management

The following guidelines can be used as a checklist by agencies wishing to assess and improve their use of performance measurement in support of asset management best practices. These guidelines are organized according to key principles of asset management from the *Guide*.

Principle: There are clear links between policy goals and objectives and decisions at all levels.

1. Performance measures should be selected to cover established goals and objectives.
2. Performance measures should be consistent with the criteria used to make resource allocation decisions.

Principle: Connections are made between proposed investments and expected results.

3. Predictive models or methods for relating investment levels to future performance should be available for each performance measure selected.
4. Performance measures should have appropriate sensitivity to show impacts of decisions about resource allocation across program areas, geographic areas, and subnetworks.

Principle: Project selections are linked to an understanding of program-level impacts.

5. Performance measures used for initial resource allocation and program development should also be used to assist in determining program adjustments.

Principle: Project selection and program resource allocation options and tradeoffs are analyzed based on their technical merits.

6. Performance measures used to guide project selection and resource allocation at the program level should include cost-effectiveness and benefit/cost measures, which (where feasible and appropriate) incorporate user costs or benefits.

Principle: A long-term view of asset performance is held.

7. Performance measures used to evaluate investment tradeoffs should reflect life-cycle benefits and costs, not just immediate impacts.
8. Performance monitoring needs to include tracking of asset condition over time at a sufficient level of detail and rigor to support development of performance curves. This is needed to provide the basis for credible prediction tools that analyze investments versus performance.

Principle: Decisions are supported by good information.

9. Performance measures should describe not only physical asset condition but also how assets are serving their intended functions with respect to comfort, convenience, safety, and service.
10. Monitoring of outcome- and output-oriented performance measures needs to be accompanied by tracking of actual activity costs in order to provide the basis for credible prediction tools that analyze investments versus performance.
11. Performance measures should be selected with consideration of the cost of data collection and available methods for maximizing efficiencies.
12. Performance measures are needed that can serve as the basis for target setting with respect to what various programs will accomplish. Because actual monitored performance may depend on factors other than agency actions, the target setting and monitoring processes must account for the fact that many performance measures reflect not only results of actions taken by an agency, but external factors as well (e.g., traffic volumes and environmental conditions).

Principle: There is a feedback loop from observed performance into planning and programming decisions.

13. Performance measures should be useful for signaling when changes to strategies and priorities are warranted—in long-range plan updates and in development of capital, maintenance, and operations program budgets.

Principle: Decisions at different levels of the organization are made based on consistent criteria and data.

14. Performance measures reflecting asset condition and performance should be used consistently across different functional units and at different levels of the organization. This implies that performance measures should be amenable to “roll-up” and “drill-down” capabilities to allow them to be viewed at systemwide, district, corridor, subarea, subnetwork, or location-specific levels. This roll-up capability may include the need to calculate summary statistics (e.g., “percent poor lane-miles”) from more detailed, location-specific condition measurements.

Principle: Clear accountability is provided.

15. To the maximum extent possible, performance measures should be understandable and meaningful to political leaders and the general public.

■ 2.5 Designing a Performance Measurement Approach in Support of Asset Management: Key Considerations

The guidelines listed above can be used to address the following questions:

- **Content and Scope**—Is our current set of performance measures sufficiently broad and inclusive to cover important goal areas and perspectives?
- **Integration and Alignment**—Do we have measures that are suitable for use at different levels of our organization, and are these measures sufficiently integrated and aligned to ensure consistency across units and efficiency in use of performance data?
- **Support for Making Choices**—Do we have measures that help us make choices among options for addressing transportation needs using an objective and unbiased approach?
- **Support for Resource Allocation**—Do we have measures that we can use for performance-based resource allocation and target-setting?

Each of these questions is discussed below.

Content and Scope

Performance measures are needed that:

- Cover key policy goals and objectives, including asset preservation, service to transportation system users, and (to the extent possible) broader economic, social, and environmental concerns;
- Reflect physical asset condition, the extent to which transportation facilities are serving their intended functions, and the ways in which customers perceive and value the services that are being provided;
- Provide a long-term, facility life-cycle view in order to assist with evaluation of preservation strategies and capital versus maintenance tradeoffs (e.g., a recently resurfaced and very smooth pavement may actually be at the end of its useful life from a structural point of view; therefore, measures of structural condition, remaining life, or value provide a more long-term perspective than roughness); and
- Track program delivery quality, schedule, and budget adherence.

Figure 2 illustrates a structure for assessing the *coverage* of performance measures in an agency. Columns indicate that performance measures should be in place to cover asset condition; asset service and function; and the delivery of projects and services to operate, preserve, and improve assets. Rows indicate the different views to be reflected by performance measures. The agency view includes measures required for good stewardship of the transportation system—indicators of condition, status, critical deficiencies, and needs. These agency measures are defined with consideration of both the customer view and the societal view. The customer view reflects what transportation

Figure 2. Scope and Coverage of Performance Measures for Asset Management

	Asset Condition	Asset Service and Function	Delivery
Agency View	<ul style="list-style-type: none"> • System Health • Physical Condition • Remaining Life • Remaining Value • Preservation Need/Cost 	<ul style="list-style-type: none"> • Deficiencies • Efficiency • Effectiveness • Benefit-Cost • Improvement Need/Backlog 	<ul style="list-style-type: none"> • Quality • Efficiency • Activity Costs • Accomplishments • Schedule and Budget Adherence • Use of Resources
Customer View	<ul style="list-style-type: none"> • Accessibility, Travel Time and Cost, Delay, Reliability, Safety, Comfort, Convenience • Perception/Understanding/Satisfaction/Value 		
Societal View	<ul style="list-style-type: none"> • Economic Health • Security • Environmental Quality • Equity 		

system users experience as a result of asset condition and service levels and delivery of projects and services. The societal view reflects broader economic, social, and environmental impacts that are also impacted by asset condition, service, and delivery. These measures can vary widely, but should be well-aligned with established agency policy goals and objectives.

Integration and Alignment

Effective use of performance measures requires that the measures be tailored to the specific decision contexts within which they will be used. Performance measures must be suitable for use by different audiences (i.e., external customers and stakeholders, political leaders, agency executives and line managers, and agency technical staff) and for different types of decisions (i.e., long-, medium-, and short-term; systemwide, corridor/subarea, and location-specific). Integration of performance measures within the organization involves tailoring measures for different decision contexts while at the same time ensuring consistency across different levels.

For any given policy area (e.g., pavement preservation), there is typically a large set of measures required for use at low levels of the organization (e.g., rut depth, roughness, and cracking). This can be translated into a small set of measures required by managers for making resource allocation decisions (e.g., percent poor pavements or percent remaining value). There is also typically a need to “roll up” location-specific measures for use at corridor, district/regional, subnetwork, and systemwide levels. Ideally, related measures that are required for different purposes can be derived from a relatively focused set of monitored or predicted data items and nested together to ensure vertical consistency. In this way, even though each part of the organization may be looking at a different technical form of the measure, they all get a consistent picture based on the same underlying data, and the overall performance-monitoring costs are kept to a minimum. The overall performance

measurement and monitoring program should be designed to maximize efficiencies and provide needed support information.

Support for Evaluation of Options and Priority Setting

Asset management best practice implies use of performance measures for evaluation of different options for meeting objectives and for prioritization of alternative investments. This kind of analysis can take place in the context of a long-range planning effort, a corridor or regional study, a project development process, or a development process for a capital or maintenance program. Performance measures should be used to make the following types of tradeoff decisions:

- **Alternative preservation strategies**—for example, spending more on preventive maintenance at the right time in a facility’s life cycle to increase asset life and minimize life-cycle costs. This decision implies the need for predicting values of performance measures over the asset life cycle and selecting performance measures that capture the structural capacity, remaining life, or value of the asset, in addition to performance measures that reflect the current level of service to the customer.
- **Operational versus capacity options**—for example, intelligent transportation systems (ITS) investment versus capacity expansion. This decision implies the need for performance measures that focus on travel time, delay, and reliability.
- **Modal options**—for example, rail versus highway options for improving freight mobility. This decision implies the need for mode-neutral measures focusing on end-to-end shipment cost, time, and reliability.
- **Delivery options**—for example, packaging multiple projects together within a corridor versus timing work based on other factors. This decision implies performance measures that consider work zone costs associated with alternative delivery schemes.

In several of these contexts, economic measures (benefit/cost or cost-effectiveness) are appropriate and useful.

Support for Resource Allocation Tradeoff Analysis and Targets

Performance measures must be suitable for use within a resource allocation tradeoff process involving (1) understanding the current or baseline value of the performance measures, (2) projecting how the values of the measures would change under different investment scenarios (i.e., different allocations of a given budget across program categories), and (3) setting performance targets that reflect a realistic and balanced allocation of resources that best meets established objectives. Although true tradeoff analysis requires all three of these items, accurate trend information based on multiple cycles of condition assessments (item 1 above) can greatly improve resource allocation while the system capabilities required for items 2 and 3 are being developed.

Support for tradeoffs implies that a clear causal link can be established between an allocation of resources and the observed value of a performance measure and that, for any given allocation of

resources, the resulting value of the performance measure can be credibly forecast. Many performance measures are impacted by a variety of factors outside of a particular agency's control. For example, congestion levels depend not only on an agency's investment to widen roads and improve operations, but also on factors such as overall growth patterns, individual driving patterns, and gasoline prices. Therefore, there is often a need to base performance tradeoff analysis on simulated results from analytical tools. Such tools can be used to explore the likely performance impacts of a set of transportation investments under different assumptions about exogenous factors.

Tools and techniques for producing forecasts of performance for a given investment level depend on having good predictive methods that are based on credible data. Therefore, ongoing tracking of asset condition over time (to support deterioration modeling), actual work activity costs (to support cost modeling), impacts of implemented strategies, and other factors affecting performance (e.g., traffic trends) are important elements of an overall performance measurement program for asset management. When it is not possible to track outcomes (due to expense or difficulty of obtaining this information in a timely enough fashion to support decision making), output-oriented performance measures can be used as proxies for the outcomes of interest. A mix of output- and outcome-oriented measures can provide useful feedback for both short- and long-range decision making.

The next section of this guide presents a step-by-step process for selecting performance measures based on the considerations discussed above and using them to make well-informed resource allocation decisions.

3.0 Framework for Performance Measure Selection and Use

■ 3.1 Overview

This framework for selecting and applying performance measures recognizes that each agency will have a different set of circumstances and needs. Some agencies may already have a solid set of performance measures in place and are looking to refine measures in a few specific areas. Other agencies may have a large set of measures in place across different units that are not well coordinated or integrated and are looking to rationalize or streamline the measures in use. Still others may want to start from scratch and identify a complete new set of performance measures for use in their agency. The framework also acknowledges that an agency's performance measurement efforts will likely evolve over time in response to lessons learned. In some cases, targets will be adjusted to account for new circumstances; in others, the measures themselves may be modified or completely replaced as new data, system capabilities, and business processes evolve.

The framework is organized into three sections, as shown in Figure 3, which can be used independently. Section 3.2 provides guidance for identifying performance measures that are in place, identifying gaps, and considering new measures. Section 3.3 provides guidance for integrating performance measures into the organization, including how to design related measures that can be used at different levels and for different purposes. Section 3.4 provides guidance for establishing performance targets within a resource allocation process.

■ 3.2 Identifying Performance Measures

Hundreds of possible performance measures can be useful for asset management, and no single set of measures will work well in every situation. The challenge is to identify a manageable set that can be effectively implemented and used within a given organization.

Step 1: Inventory Existing Measures

Most agencies have a set of existing performance measures that provide a base from which to begin. A recommended first step is to take an inventory of these measures and create a table, such as the one shown in Table 1. This approach can identify existing measures that are currently not used or that have issues that impede full implementation. Eliminating these measures can free up resources that can be used for implementation of more useful measures.

Figure 3. Guidance for Performance Measures and Targets

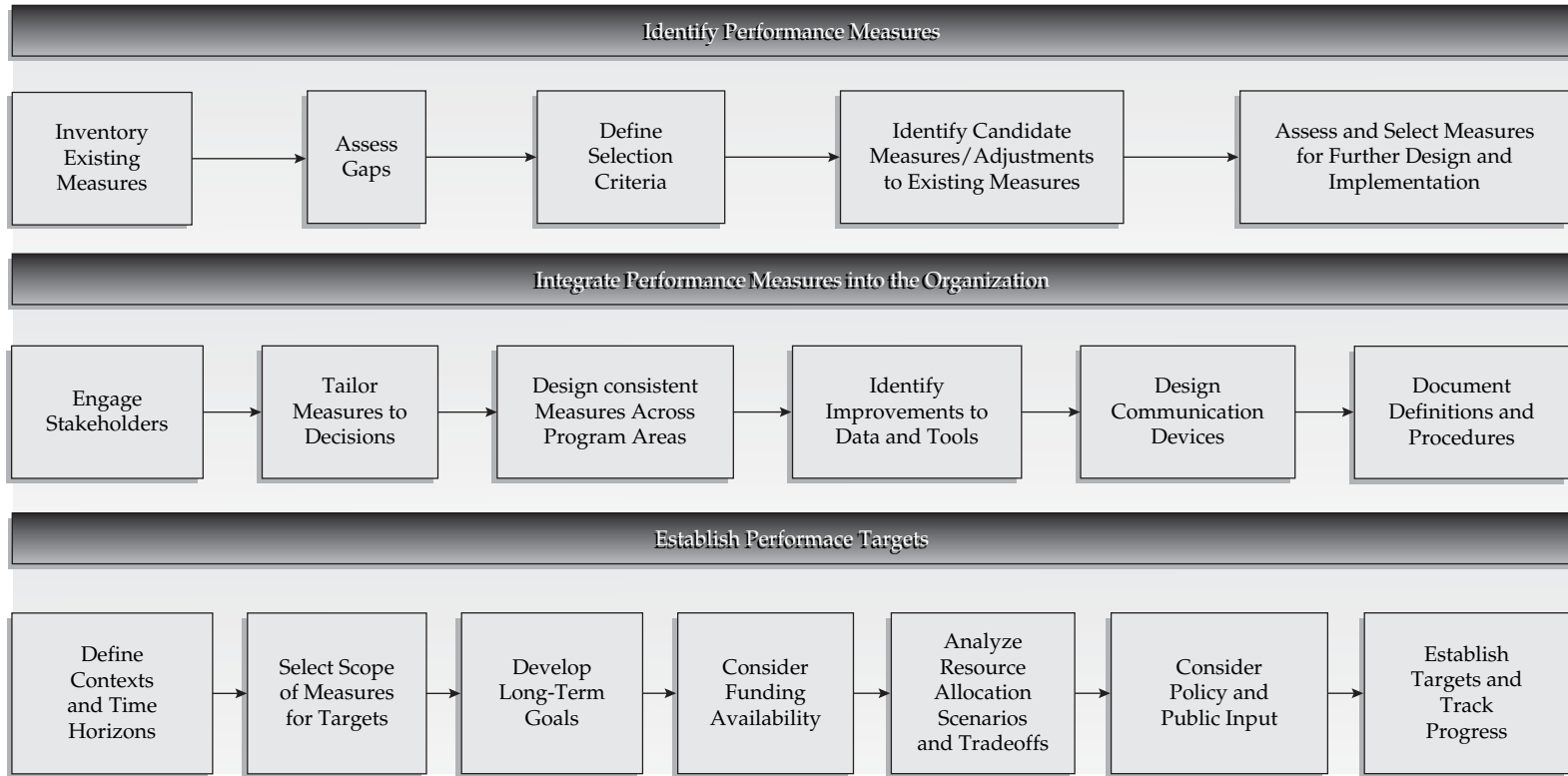


Table 1. Performance Measure Inventory
Example Format

Measure	Owner	How Used	Comments/Issues
Percent good pavement	Materials section	External reporting District performance targets	Stable and well-accepted
Crash rate	Safety office	External reporting Project prioritization	Only includes serious crashes
Travel rate index	Traffic management center	Internal reporting	Urban freeways only
Congested VMT	Traffic management center	Internal reporting	Urban freeways only
Asset value	Finance office	GASB 34 reporting External performance reporting	Need to improve basis for calculations

Step 2: Assess Gaps

The next step is to decide on the scope of your efforts by conducting a gap analysis of your agency's existing measures. Gaps in performance measurement to be addressed include (1) gaps in *coverage* of key policy goals or result areas, (2) gaps in *use* of performance measures to guide resource allocation, and (3) gaps in *alignment* of performance measures both vertically and horizontally within the agency. Even though measures in some areas may be defined and used to some extent for reporting, it is important to see where there may be disconnects between (1) information gathered and reported for a particular policy objective and (2) the resource allocation decisions that are made that impact achievement of that objective. For example, in Table 1, one might ask if congested vehicle-miles traveled (VMT) is used to help determine priorities for corridor improvements or to support decisions on allocation of funds across different operational program areas. It is also important to assess the need for greater horizontal and vertical alignment across measures. Improved horizontal alignment may be needed when existing measures do not adequately support tradeoffs across asset classes, geographic areas, and/or investment types. Improved vertical alignment may be needed when there are inconsistencies in measures used to make decisions related to a given policy objective. For example, if an agency uses pavement smoothness targets as the basis for setting the pavement preservation budget level, but then uses structural condition as the basis for identification and prioritization of projects, this reflects a lack of vertical alignment.

A logical way to assess gaps in coverage of performance measures is to review your performance measure inventory against your agency's stated goals and objectives to see where there may be gaps or areas where existing measures need to be improved. Figure 2 may also be helpful in determining areas where additional measures are needed. The following list of questions can be used as a guide in assessing gaps in performance measures:

- Given your agency's goals and objectives, what are the most important outcomes to be achieved? Do your existing performance measures adequately cover these outcome areas?

- Do you currently track the condition of all of your major assets?
- Do you have measures related to the level of service or function provided by these assets?
- Do you have measures that reflect customer perspectives?
- Do your performance measures align with national guidance, statewide priorities, governor's initiatives, and so forth?
- Are your performance measures aligned internally?
- Are you tracking program delivery in order to monitor accomplishments and identify where agency and user costs can be reduced?
- Do your performance measures adhere to federal highway legislation governing long-range planning and capital programming (Title 23 U.S.C. Sections 134 and 135)?:
 - Do your performance measures capture the impacts of preservation, management, and operations activities carried out by your agency?
 - Do you have performance measures that are applicable to both long-range planning and transportation improvement program/state transportation improvement program (TIP/STIP) development?
 - Do you have mode-neutral measures that can be used to evaluate modal alternatives to address transportation needs?
 - Do you have measures that capture transportation's broad range of impacts on society, including safety and security, economic development, productivity and competitiveness, accessibility and mobility options for passengers and freight, fuel efficiency, environmental protection, and improved quality of life?

There may be too many gaps to address at once. Some gaps may be fundamentally difficult to fill, given the lack of reasonable measures for some types of policy objectives, programs, and functions or constraints on data collection resources. In deciding where to focus, you will want to consider where additional performance measures will have the greatest impact on your agency's ability to make better resource allocation decisions, gain public confidence, and secure needed resources.

Step 3: Define Selection Criteria

There are many factors to consider in selecting performance measures for asset management. It is therefore helpful to explicitly define selection criteria that are important to your agency and follow a systematic evaluation process in which candidate performance measures are assessed based on these criteria. Most agencies find that they need to periodically change performance measures in order to respond to changes in leadership and policy. Having documentation that shows both the alternative measures that were considered and the basis for choosing current measures can provide a valuable resource for addressing future questions about why the measures were selected and for investigating future changes to measures.

Not all selection criteria are applicable to all measures. Selection criteria should reflect the intended purpose, use, and audience for the performance measure. A performance measure to be used for

tracking agencywide progress toward targets needs to meet different criteria than one used to help prioritize locations for pavement work. A measure to be used to evaluate the progress of a highway division's ITS program in alleviating congestion does not need to meet criteria for mode neutrality, whereas a measure used to evaluate agencywide efforts to improve mobility likely would.

The following criteria can be used to assess whether a given performance measure is a good candidate for implementation. You may wish to add other criteria based on your agency's particular needs and history. You may also want to ignore criteria that are not relevant given the intended purpose of the performance measures.

Criterion 1: Feasible

- **Data Requirements.** Does the measure have realistic and feasible data requirements? Does the agency currently have the data required for a particular measure?
- **Data Quality and Accuracy.** Can sufficient data quality, reliability, and accuracy be ensured to provide credible and usable information?
- **Cost Versus Value Added.** Would the benefits of having this measure available for decision making outweigh the cost of collecting the data required for it?

Criterion 2: Policy Sensitive

- **Reflects Policies.** Can the measure be easily related to the agency's stated policy objectives? Does it provide a good measure of whether the outcomes intended by the policies are occurring?
- **Meaningful.** Does the measure convey meaningful information to decision-makers about the transportation system?

Criterion 3: Supports Long-Term, Strategic View

- **Trend Information.** Are a baseline value and quality trend information available for this measure? If not, is long-term tracking of trends feasible?
- **Forecasts.** Are reasonable and defensible methods available to forecast the future value of this measure (i.e., how the value of the measure would change in the absence of actions taken by the agency)?
- **Life-Cycle Analysis.** Is this measure suitable for incorporation into an analysis comparing long-term investment alternatives based on life-cycle costs and benefits?

Criterion 4: Useful for Decision Support

- **Feedback.** Does the measure provide information that enables managers to understand problems and suggest solutions?
- **Responsiveness.** Can the measure be tracked and reported in a timely enough fashion to support the needs of decision-makers? (For measures to be used by operational managers, real-time monitoring may be required.)

- **Sensitivity.** Is the measure sufficiently sensitive to reflect impacts of agency actions given the levels at which it will be applied (e.g., network, corridor, and project level and for short-, medium-, and long-range decision making)?
- **Linkage to Actions.** Are there methods available to predict how the value of this measure would change as a result of:
 - A specific project or budget line item (e.g., an intersection improvement project or purchase of 10 new maintenance trucks)?
 - Implementation of a program of defined projects (e.g., capital projects in the STIP)?
 - Allocation of a given budget level to a specific program area (e.g., \$10 million per year over the next 5 years to pavement preservation)?
- **Scenario Testing.** Is this measure amenable to “what-if” analysis, in which the performance implications of multiple budget scenarios are estimated? Can predictions be automated so that what-if testing is not overly time consuming?
- **Neutrality.** Is the measure sufficiently neutral to allow for evaluation of the impacts of a wide range of possible agency investments or actions (e.g., highway versus transit improvements to improve mobility)? (This question will not be relevant for measures that are used to track performance for a particular mode or asset class.)
- **Agency Influence.** Can this measure be used to help distinguish changes in transportation system performance that have occurred due to your agency’s actions from changes that have occurred due to factors not under your agency’s control?

Criterion 5: Useful Across the Organization and Beyond

- **Ease of Understanding.** Can this measure be easily understood and interpreted by its intended audiences at technical, management, and executive levels of the organization and by outside stakeholders?
- **Vertical Alignment.** Can this measure function as part of a family of measures that can be used to describe performance at different levels of aggregation (e.g., corridor, district, and system), for different time horizons, and for different audiences? Is it consistent with other measures in use?
- **Horizontal Alignment.** Can this measure be used by multiple horizontal units of the organization (e.g., across units that manage different classes of assets and/or modes) in order to promote consistency in performance measurement and to facilitate investment tradeoffs across areas?
- **Cross-Jurisdictional.** Can this measure be used at a broad level outside of the organization across other jurisdictions in order to enable a consistent regional or statewide view of performance?

Step 4: Identify Candidate Measures/Adjustments to Existing Measures

Appendix A provides a list of performance measures that can be of value for asset management. Performance measures for consideration are organized by goal area: preservation, mobility and

accessibility, operations and maintenance, safety, economic development, environmental impacts, social impacts, and security. A list of delivery-oriented measures is also included at the end. Even though there are many performance measures listed, this is not intended to be a comprehensive set. There are a number of other references to consult for additional ideas—see the bibliography at the end of Volume I.

Table 2 provides a sample format for organizing the measures that you select according to their intended uses and audiences.

Table 2. Performance Measures: Uses and Audiences
Example Format

Policy Objective/Performance Measure	Strategic Planning	Long-Range Planning	Corridor Planning	Performance-Based Budgeting	Project Prioritization	Daily Operations/Management	Delivery	Annual reporting
SYSTEM PRESERVATION								
a Percent Poor Pavements	✓	✓	✓	✓				✓
b Average Bridge Health Index	✓	✓	✓	✓				✓
c Remaining Value	✓	✓	✓	✓	✓			✓
d Backlog		✓		✓	✓		✓	
e Customer Ratings	✓	✓	✓	✓	✓	✓	✓	✓
MOBILITY/ACCESSIBILITY								
a Travel Time Index (Urban Freeways)		✓	✓	✓				✓
b Annual Change in Travel Time Between Major Cities		✓	✓					✓
c Percent Population Within 10 Minutes of a State Highway		✓	✓					✓
d Time from End of Snow Event to Bare Pavement	✓			✓		✓	✓	
e Backlog—System Completion	✓	✓		✓	✓		✓	✓
SAFETY								
a Serious Crashes/Million VMT	✓	✓	✓	✓	✓	✓		✓
b Number of Fatalities	✓	✓	✓	✓	✓			
c Backlog—Economically Justified Safety Improvements	✓	✓	✓	✓	✓		✓	

This classification will be of value for evaluating the measures in Step 5. Categories in the chart are as follows:

- **Strategic Planning**—Describing organizational objectives and establishing annual performance targets for the agency’s strategic business plan.
- **Long-Range Planning**—Characterizing current systemwide or subnetwork performance, defining long-term system condition and service objectives, analyzing the impacts of different investment levels or strategies, and estimating investment needs associated with alternative performance levels.
- **Corridor Planning**—Defining condition and service objectives for specific corridors and evaluating alternatives for corridor improvements.
- **Performance-Based Budgeting**—Allocating dollars to program areas in a performance-based budgeting process.
- **Project Prioritization**—Prioritizing and selecting projects for programming.
- **Daily Operations/Management**—Short-term and real-time decisions by operations and maintenance program managers with respect to work prioritization and resource allocation across competing needs to maximize effectiveness.
- **Delivery**—Assessment of program and project delivery progress and effectiveness and evaluation of alternative delivery methods.
- **Annual Reporting**—Annual system performance reporting for establishing accountability and demonstrating good stewardship to external stakeholders and to the public at large and/or for informing transportation policy decisions considered by the agency management team and elected officials.

Note that some measures will fit in several of these categories. For example, the remaining value of assets can be useful for high-level, strategic, and long-range planning decisions to make the case for additional investment. It can also be used at a corridor level as part of a study of future corridor development and management options in order to characterize future preservation needs. In a program development context, budget amounts for different categories of assets or for different geographic areas might be influenced by looking at the relative remaining value. Similarly, prioritization of rehabilitation projects within a given program area might also be based on looking at the remaining value for candidate projects.

At this point in the process, do not be too concerned about the specific functional form of the performance measure—this can be refined later using the process described in Section 3.3.

Step 5: Assess and Select Measures for Further Design and Implementation

Once your criteria are established, you can develop a format such as the one shown in Table 3 to assess each candidate measure. The table rates a variety of measures using the criteria described in Step 3. (Note that the table is meant as an illustrative example and that the ratings may vary based

Table 3. Performance Measure Assessment
Example Format

Policy Objective/Performance Measure	Feasible–Data/Tools	Meaningful for Policy	Trend Info Feasible	Can Forecast	Useful Feedback	Sensitivity	Can Link to Agency Actions	Scenario Testing	Neutrality	Vertical alignment	Horizontal Alignment	Cross-Jurisdictional
SYSTEM PRESERVATION												
a Percent Poor Pavements	●	●	●	●	●	●	●	●	—	●	—	○
b Average Bridge Health Index	●	●	○	●	●	○	●	●	—	●	—	—
c Remaining Value	●	●	○	○	●	●	●	○	●	○	●	○
d Backlog	●	●	○	●	●	●	●	●	—	○	○	—
e Customer Ratings	○	●	○	—	●	○	○	—	—	○	●	○
MOBILITY/ACCESSIBILITY												
a Travel Time Index (Urban Freeways)	●	●	●	○	●	●	●	○	●	●	●	●
b Annual Change in Travel Time Between Major Cities	●	●	●	●	○	●	○	○	●	—	●	●
c Percent Population Within 10 Minutes of a State Highway	●	●	●	●	●	●	○	●	●	—	●	●
d Time from End of Snow Event to Bare Pavement	●	●	—	○	○	●	●	○	—	●	—	●
e Backlog—System Completion	●	●	●	●	●	●	●	●	—	●	●	●
SAFETY												
a Serious Crashes/Million VMT	●	●	○	○	●	●	○	○	—	●	●	●
b Number of Fatalities	●	●	●	○	●	○	○	○	●	●	●	○
c Backlog—Economically Justified Safety Improvements	○	●	●	●	●	○	○	○	—	●	●	○
KEY: ● Meets criterion. ○ May meet criterion (depends on measure formulation or application context). — Does not meet criterion, or criterion is not applicable.												

on your agency’s organizational, institutional, and technical characteristics.) Completing this evaluation will provide a structured way to consider each of the criteria. There are likely to be questions raised along the way and action items for further investigation. For example, you may want to research how other agencies have approached prediction or impact assessment using some of the candidate measures and assess whether similar methods would work in your agency.

Table 3 can also be used as an initial screen to filter out potential measures that may not be feasible or meaningful from an asset management perspective. This formal evaluation approach can save you time by enabling you to focus on measures that are most promising.

It may also be helpful to complete the evaluation as a group process or to give the evaluation to a few different individuals and then get together to compare and discuss the results. This will allow for a broader set of concerns to be raised and will provide a larger base of knowledge to draw upon that is relevant to understanding whether a given measure would function well.

Based on the results of your evaluation, you can narrow down the set of candidate measures to those that you want to move forward with. It is important at this point to clearly document the definitions of each measure so that everyone understands what is being measured and how it is to be calculated and reported.

In the next section, you will take these measures and look more closely at where and how they will be used in your organization. This activity will likely result in further refinement to the set of measures.

■ 3.3 Integrating Performance Measures into the Organization

In the previous section, individual performance measures were evaluated and selected to fill gaps in coverage and decision support needs. This section takes a more detailed look at how to integrate a set of performance measures into the organization.

Step 1: Engage Stakeholders

Necessary ingredients for a successful performance measurement implementation are:

- Top management support and leadership,
- Stakeholder buy-in and commitment to use the measures,
- Integration of performance measures into existing business processes and decision-making forums, and
- Clear ownership and responsibility for each measure and associated data and tools.

These ingredients need to be considered during the process of performance measure selection. It is important to have active support from people who will be receiving performance measure reports and who will be asked to make decisions in response to these measures and be accountable for results. It is also important to have buy-in from people whose cooperation or resources are needed to gather or summarize measures. Stakeholders should be involved early on in the performance measure development process. Although stakeholders should be given the opportunity to participate in all stages of performance measure identification, evaluation, and implementation, it is important to make sure that the overall implementation moves forward at a reasonable pace. A strong leader for

the performance management effort is essential for ensuring that the effort does not become stalled or overwhelmed with the need to address too many issues at one time. The right balance of stakeholder involvement will maximize the chances that the resulting measures will be used to improve decision making and help ensure that they are implemented in a timely fashion.

Depending on the types of performance measures being implemented, stakeholders may all be within a single agency, or they may be in several different agencies—for example, a state DOT and the state’s metropolitan planning organizations (MPOs) (in the case of congestion measures) and a state DOT, Governors Highway Safety Office, state police, and local jurisdictions (in the case of safety measures). When stakeholders are dispersed across multiple agencies, extra effort should be anticipated to allow for sufficient communication to achieve buy-in.

Some additional guidelines for working with stakeholders and designing performance measures to achieve buy-in are the following:

- Emphasize the use of performance measures as a means to improve system performance and quality, not as a report card or judgment on productivity or effectiveness.
- Keep the measures focused on the strategic goals and related to the activities of the agencies.
- Keep the measures focused on the customer.
- When multiple agencies are involved and consistency in performance measures can be achieved, work toward identifying mutual interests.
- Depending on the situation, use judgment to determine whether it is best to keep the number of measures limited (to keep things simple and facilitate consensus) or pursue an expanded set of measures that represents the interests and needs of a diverse set of stakeholders.

Step 2: Tailor Measures to Decisions

The purpose of this step is to examine your candidate performance measures in the context of decision-making processes in your agency and to design appropriate forms of the measures that are responsive to the different types and levels of decisions. The more specific you are in thinking through the activities where performance measures would be used, and the units of your organization that would use them, the better.

The activities defined in Section 3.2, Step 4 (and shown in the columns of Table 2) can provide a good starting point for identifying the various decision contexts within which performance measures are to be used. These decision contexts vary by geographic scope (network, corridor, site, or project) and timeframe (from immediate or real time to a 20-year horizon).

Some categories of performance measures will be applicable to multiple geographic scopes and timeframes—for example, there is a need to track pavement preservation at the project, corridor, subnetwork, and statewide levels; and this information is valuable for short-, medium-, and long-range decisions. Where this is the case, it is important to ensure that performance measures are consistent across different levels and timeframes—for example, the performance measures and targets established in the agency’s long-range plan should be consistent with the performance criteria used to prioritize projects or activities for the program. This does not mean, however, that the specific

form of the measures needs to be identical. In fact, for each type of decision, the specific form of the performance measure should be tailored to the type of decision being made (i.e., geared to the needs of the target audience or user) and defined at the appropriate level of sensitivity so that the impact of decisions can be detected.

Table 4 provides an overview of applications of performance measures at different levels and time-frames. This table can be used as a framework for defining appropriate forms of performance measures to be used for different types and levels of decisions.

An example of a set of related measures for pavement preservation is illustrated in Table 5. Defining groups such as these will help to ensure that performance measures can be applied effectively in your agency’s decision-making processes. They will also help you to ensure consistency in the use of performance measures across different decision-making levels. Finally, it will help you to identify needed activities for improvements to data access, management, and analytical tools for automating calculations to translate performance data from one form to another (e.g., “roll-ups”) or to estimate future values.

Table 4. Performance Measures for Different Types and Levels of Decisions

	Short- or Medium-Term	Long-Term
Network	<ul style="list-style-type: none"> • Summary roll-ups of corridor or subnetwork performance • Evaluation of accomplishments versus targets • Comparisons of performance under different 3- to 6-year investment scenarios 	<ul style="list-style-type: none"> • Progress toward long-term, strategic policy objectives • Predicted long-term conditions or needs at system or modal level (life-cycle analyses where appropriate) • Broad-based tradeoffs among modal, system, location and program options
Corridor	<ul style="list-style-type: none"> • Description of existing conditions to assess connectivity and consistency of corridor level of development by mode • Forecasts of performance for different corridor investment options • Assessment of options for project packaging and staging (considering coordination of detours and alternative routes and modes of travel) 	<ul style="list-style-type: none"> • Forecasted 10- to 20-year corridor-level conditions (requires use of management systems, travel demand models, and extrapolation/estimation methods) • Impacts of proposed corridor investment on broader systemwide performance (consistent with Title 23 U.S.C. Sections 134 and 135) • Measures for evaluating alternative types of investments—different modal options; operational versus capacity
Project	<ul style="list-style-type: none"> • Technical information required to design appropriate corrective solution • Prioritization criteria for selecting among candidate projects • Assistance with detailed project delivery planning (e.g., work zone configuration, detour routes) 	<ul style="list-style-type: none"> • Forecasts of performance and cost suitable for program and budget development • Evaluation of wide range of transportation, environmental, and social performance impacts of major projects with long lead times for project development

Table 5. Measures for Different Decisions
Pavement Preservation Example

	Short- or Medium-Term	Long-Term
Network	<ul style="list-style-type: none"> Percent of mileage in poor condition (based on pavement condition index, or PCI) by system category, current and projected, given currently programmed projects or expenditures Percent of network resurfaced per year (versus level needed to achieve condition targets) 	<ul style="list-style-type: none"> Projected percent of mileage in poor condition in 10 years for alternative funding scenarios
Corridor	<ul style="list-style-type: none"> Average PCI 	<ul style="list-style-type: none"> Projected average PCI in 10 years
Project	<ul style="list-style-type: none"> PCI Distress/cracking by type International Roughness Index (IRI) 	

General guidance on tailoring performance measures to ensure appropriate sensitivity and usefulness at different levels is as follows:

- Use more detailed measures for project-level decisions, which can be translated (ideally in an automated fashion) into less technical and more general measures for use at corridor and network levels.
- For support of network-level, short- and medium-term decisions, select measures of performance distribution (e.g., percent in good condition) rather than average performance, since substantial improvements in performance at a project or corridor level will likely have a negligible impact on networkwide averages.
- Use performance measures to identify critical infrastructure deficiencies by establishing a threshold value of a condition index based on experience or engineering judgment about what level is serious enough to threaten structural integrity, dramatically increase user costs, or result in many customer complaints. An alternative to using a condition index is to focus on one or more conditions that are judged as critical to facility performance (e.g., pavement roughness or rut depth for pavement preservation, condition of bridge superstructure and substructure elements for bridge preservation, or congestion level for mobility). Economically based thresholds can also be established to signal concern about the planned level and pattern of investment (e.g., for percent of remaining asset value).
- Design measures to reflect the target scope of implemented strategies. For example, to measure impacts of intersection improvements for mobility and operational efficiency, use a measure like “time savings at intersections” rather than a more global measure such as “overall reduction in total network travel time.”
- Use normalized indexes of performance measure values (0–1 or 0–100 scale) to facilitate understanding of how performance varies within the range of allowable or achievable values.

- Use rates (e.g., crashes per 100 million VMT or incidents per million passenger-miles traveled, or PMT) to facilitate comparison of performance measures across different portions of the network and to allow for meaningful tracking of trends.
- Use ratios (e.g., ratio of travel time in congested conditions to travel time in free-flow conditions and number of fatal accidents divided by total accidents) to put the measures into perspective and to provide useful insights. Both rates and ratios can be helpful in understanding and communicating the extent to which transportation performance can be attributed to the actions of the agency as opposed to external trends that are beyond an agency's control.
- Use measures of agency activity or "output" in order to provide short-term feedback on planned versus actual accomplishment. However, also monitor outcomes (where feasible) for longer-term decisions and work toward improving your agency's ability to predict the relationship between outputs and outcomes using simple models or more sophisticated analytical tools.
- Institutionalize the process of conducting before-and-after studies in order to distinguish performance impacts of agency projects.

Step 3: Design Consistent Measures Across Program Areas

Consistency and alignment of criteria for decision making within an organization is a central concept of asset management. Developing a consistent set of performance measures will enable an agency to describe asset condition or service level for engineers, administrators, legislative bodies, and the traveling public.

Performance measures that are consistently defined across program areas responsible for different asset classes and/or functions can be extremely valuable for providing a high-level understanding of performance for upper-level managers and for facilitating tradeoff analysis and target setting. These types of measures can be defined based on the more detailed performance information shown in Appendix A and discussed in Section 3.2.

Implementing consistent measures is often challenging because it requires coordination and agreement across different units of the organization on criteria and methods for performance measurement calculations. Strong upper management leadership and good communication among agency units is a necessary ingredient for their successful implementation. It may be helpful to designate a single office with specific responsibility for coordination across different parts of the organization. Alternatively, cross-functional teams can be formed, charged with defining and implementing a consistent package of measures for a given set of agency business functions. Agencywide central performance data repositories, reporting tools, and geographic information system (GIS) tools can be helpful to support implementation of these measures as well. Uniformity and consistency in data are critical to support tradeoffs across asset classes and across geographic areas.

One straightforward approach to consistency in performance measurement across asset classes would be to define the following three measures for each major class of asset:

1. Percent of assets (based on quantity or value) operating at "desirable" levels,
2. Percent of assets (based on quantity or value) operating at "minimum tolerable levels," and
3. Percent of assets (based on quantity or value) designated as "high-risk" (for structural failure, operational failure, or hazard to the traveling public) where immediate action or evaluation is needed.

Each of these performance measures could be defined based on threshold values for physical condition, congestion levels, crash rates, design features versus standards, and so forth.

Other examples of performance measures that could be defined consistently across asset classes include:

- Percent of assets in “good” or “poor” physical condition,
- Percent of assets (based on quantity or value) in a “state of good repair” (defined based on either condition or maintenance records),
- Percent of assets with more than (or less than) X years of remaining life,
- Percent of assets that are more than X percent of their design life,
- Percent of assets that are at the end of their economic life (i.e., maintenance and rehabilitation cost would equal or exceed the replacement cost),
- Remaining asset value (or related measures such as the ratio of remaining value to replacement value or the ratio of deteriorated value to replacement value),
- Backlog of need (where need is defined based on specified service or condition thresholds),
- Percent of target work completed or programmed (based on asset quantity, dollars, and numbers of projects),
- Customer satisfaction or utility measures derived from customer satisfaction and importance ratings, and
- User costs associated with deficiencies or benefits associated with correcting the deficiencies (these measures would be based on available user cost models for pavement condition, bridge condition, safety, and congestion).

Step 4: Identify Improvements to Data and Tools

Successful integration of performance measures into your organization’s decision-making processes will depend on the quality of data that you use and the availability of credible analytical methods and tools for prediction of performance measure values. These were identified as key screening criteria for performance measure selection in Section 3.2. The task now is to assess current capabilities and develop a detailed plan of data and tool-related work that will be required to implement the measures that you have selected. As a result of this exercise, you may find that some of your selected measures are infeasible at present or that they can only be used in a limited set of contexts (e.g., they can be tracked but not yet predicted). For measures that you intend to pursue, the objective is to identify specific actions that will need to be taken and ensure availability of budget and staff time for completing them.

The format shown in Table 6 can be used to structure the investigation of data and tool requirements in support of performance measurement.

Table 6. Data and Tool Assessment for Performance Measurement

	Current Method and Owner	Known Issues	Actions Required
Data Sources/ Collection Methods			
Data Transformation/ Measure Calculation			
Impact Assessment and Forecasting Tools			

This investigation should consider:

- Data collection methods or data sources for all of the inputs required for calculating a given performance measure,
- Methods to transform and process the data for different purposes (e.g., assumptions and techniques used to calculate asset value from inventory, condition, and financial information), and
- Forecasting and impact assessment tools (automated or manual) for (1) predicting the value of the performance measure that would result from implementation of a particular project or program strategy or from investing a given level of resources and (2) predicting how the value of the measure (or its components) would change over time assuming no action on the part of the agency.

For each of these elements, identify:

- The current methods in use (if any) and the responsible units;
- Known issues, questions, or concerns with respect to data quality, prediction accuracy, reasonableness of tool inputs, and so forth; and
- A list of specific actions needed to ensure data quality and accuracy (both initially and on an ongoing basis), address concerns, and fill gaps in methodologies or tool sets.

In developing the list of required actions, consider the following kinds of activities:

- New data collection efforts.
- Changes in equipment or methods used in existing efforts to obtain better accuracy, reliability, and/or timeliness. This might include investigation of emerging data collection technologies that may provide better information at a lower cost.
- Consolidation of existing data collection efforts. For example, instead of separate inspections for different data elements on the highway network, coordinate inspection activity so that all items are collected at one time.

- Changes to data processing procedures to improve data quality and timeliness.
- Collection/reporting of additional supporting data elements in order to better understand factors influencing trends in performance that are outside of the agency's control (e.g., vehicle registrations, fuel prices, employment, population/demographics, activities of other agencies, and weather monitoring).
- New formal data quality checking procedures, including improved validation based on specific test criteria (and automation of validation checking where feasible), consistency checks across different data sources, and spot verification of inspection data.
- New initiatives to correct known data quality or consistency problems.
- Establishment of standards across different parts of the agency (or across agencies, where applicable) to ensure consistency in performance measurement calculations and predictions. Such standards could:
 - Identify “official” data sources to be used for performance measures that are calculated using system quantities (e.g., mileage by functional class), VMT, annual average daily traffic [AADT], population, employment, and other items;
 - Establish common geographic and temporal referencing methods to allow for integration of performance data from different sources (geographic referencing would include linear referencing, spatial referencing, and zone systems);
 - Establish requirements for documentation of performance data so that data can be properly interpreted and consolidated, particularly for performance measurement efforts involving multiple agencies;
 - Establish parameter values to be used in economically based calculations (e.g., value of time, accident costs, and discount rate);
 - Define methodologies for calculating asset value; and
 - Establish common time horizons and base years for projections.
- Identification of major agency initiatives that are likely to impact data and tools used for performance measurement (e.g., replacement of legacy systems).
- Planning for smooth transitions in order to maintain or improve capabilities and ensure that tracking of trends will not be impacted.
- Improvements to (or a new initiative to implement) performance-monitoring systems to consolidate performance information from different sources, automate calculations, and provide reporting and query capabilities suitable for different users. These improvements may include updates or enhancements to existing executive support systems that are in place.
- Identification of needs for new analytical tools (or improvements to tools already in place) to calculate or predict performance, including tools that can be used for assessing performance impacts of planned strategies or different investment scenarios.

Step 5: Design Communication Devices

It goes without saying that effective and timely communication of performance results to stakeholders is of critical importance. Communication devices need to be tailored to different audiences: external/public, agency executives, line managers, and technical staff. Once measures are selected, it is important to carefully consider how each measure will be reported and ensure that reports match the needs of the intended users. Report formats should be designed to make the measures easily understandable (ideally using graphics). In addition, steps should be taken to ensure the timeliness and dependability of reporting.

Internal communication of performance measures will ideally be well integrated into business planning, budgeting, and management reporting procedures. For example, regularly communicating progress toward targets at quarterly or monthly management meetings can help create a cultural shift toward more performance-based operations. In many transportation agencies, there will be a need for an education process for engineering staff on the fundamentals of performance-based management.

Devices that have been used successfully by agencies for performance reporting include the following:

- Continual reports of performance such as Washington DOT's accountability website, including the quarterly Gray Notebook: Measures, Markers, and Mileposts (www.wsdot.wa.gov/accountability/default.htm).
- Public report cards. See, for example, Virginia DOT's quarterly report card (<http://www.virginiadot.org/infoservice/ctb-qtrlyrpt.asp>).
- Dashboards that summarize performance in a concise, easy-to-read diagram. See, for example, the Virginia DOT Project Dashboard (<http://dashboard.virginiadot.org>).
- Regular performance reports linked to annual or biannual business planning and budgeting activities. See, for example, Minnesota DOT's Departmental-Level Business Plan Measures and Targets (<http://www.dot.state.mn.us/dashboards/pdfs/2year.pdf>).

Step 6: Document Definitions and Procedures

Credibility is essential to the success of a performance measurement initiative. The willingness of people to base decisions on performance results depends on their understanding of how the measures are to be interpreted and their level of confidence that the measures were derived from accurate data, calculated using a sound technical methodology, and quality-checked to ensure that they are free from errors.

Good documentation of the performance measures is necessary to provide a common detailed understanding of how the measures are defined, how they are calculated, and what steps are to be taken to ensure accuracy. This detailed documentation should be made available to all of the people responsible for producing the performance data, and to the consumers of the data. It can and should also provide the basis for periodic audits of performance measurement accuracy and adherence to defined procedure.

The basic documentation can be established as the performance measurement program is launched. Updating should occur whenever new measures are added or procedures are modified. Separate documentation (i.e., metadata) should be maintained on specific performance results—for example, to note special factors that influenced the results (e.g., sharp rise in gas prices or severe weather), or deviations from standard procedures (e.g., statistical procedures used to compensate for missing data).

If and when the agency decides to change the performance measures that it uses or to modify the details of how a given performance measure is calculated, the documentation for the old measure should be archived along with the performance results that exist. This documentation will be invaluable for future construction and interpretation of performance trends.

■ 3.4 Establishing Performance Targets

Setting performance targets involves a mix of considerations:

- **Financial**—Targets need to reflect a realistic projection of available funding levels.
- **Policy**—Targets need to reflect current policies and priorities, as well as input from executives, legislators, and customers.
- **Technical**—Targets need to be achievable based on current and forecast conditions or performance.
- **Economic**—Targets should be set (where feasible) based on economic efficiency considerations, including minimizing life-cycle costs and maximizing the benefit obtained for a given level of investment.

This section describes steps for establishing performance targets by considering all of these factors and using them as an integral part of the agency's resource allocation process.

Step 1: Define Contexts and Time Horizons

The first step is to make sure you have a clear picture of how the performance targets will be used and what time horizons they will cover. Performance targets may be used in a variety of contexts:

- In long-range transportation plans.
- In regional or corridor plans.
- In short- or medium-range (e.g., 1- to 5-year) internal business planning processes.
- As part of the agency's capital or operating budget process (including TIP/STIP development) involving communication to legislative bodies and/or transportation commissions.
- As part of fulfilling requirements for the GASB 34 modified approach to asset financial reporting. If you are setting targets for GASB 34 reporting, you will need to establish targets for the condition of eligible assets, disclose these targets publicly, and verify each year that the current performance values meet the stated targets for the year.

The contexts you identify will help to clarify over what timeframes targets are needed. Many agencies set both long- and short-range targets, using different processes. Short-range targets are more firmly based on financial constraints, whereas long-range targets can be based more on technical, economic, and policy considerations. However, for targets to be credible, care should be taken to make targets set for different timeframes and in different contexts consistent with one another.

Step 2: Select Scope of Measures for Targets

For each of the target-setting contexts identified in Step 1, you will need to identify which measures are to be included. Not all performance measures are amenable to quantitative target setting because some are qualitative in nature and some agencies do not have sufficient control over their value.

Some performance measures may be candidates for quantitative target setting, but do not have sufficient baseline or trend data established to allow for reasonable targets at present. Others may have baseline data available, but tools or methods are not available to reasonably predict their value. It may be helpful to label performance measures as “mature” (baseline data and targets exist), “emerging” (baseline data are available, but no target has been set), and “developmental” (neither data nor targets exist yet).

Where targets for multiple measures are being considered for a given policy objective (e.g., pavement preservation), technical analysis should be conducted to see if one of the measures acts as a “controlling target.” For example, if targets for both “average condition” and “percent in poor condition” are set, it may be the case that achieving one target (average condition) will always automatically result in achieving the other (percent in poor condition). In this case, you may want to consider setting a target for only one of the two measures.

The potential for conflicts or competition across the targets should be anticipated. Some of these conflicts relate to resource allocation and can be addressed in Step 5—for example, it may not be possible to achieve targets for both hazard elimination and preservation. Other types of conflicts (e.g., between project delivery speed improvement and project quality improvement) will require careful consideration to arrive at a reasonable balance.

Step 3: Develop Long-Term Goals

Setting short- to mid-term performance targets that are realistic based on funding availability is critical for helping decision-makers to make performance-based resource allocation tradeoffs. This is a fundamental part of good asset management practice.

However, many agencies want to establish long-term performance goals that stand on their own, independent of resource constraints. In some cases, such performance goals can be established based on considering the current baseline and the level of improvement that is feasible and desirable based on public input or benchmark values from peer agencies. However, there are also a host of technical and economic considerations that should be explored that can serve as solid justifications for long-term goals. Targets based on these goals that are backed up by technical and economic analysis can be used as compelling arguments for budget requests.

Approaches to establishing long-term performance goals include the following:

- Measure what the current baseline level of performance is, and then set goals for improvement using benchmark information about what peer agencies have achieved through focused efforts to improve performance.
- Align agency goals with nationally based targets (e.g., the national highway safety target of 1.0 fatality per 100 million VMT).
- Use customer surveys and/or tracking of complaint information as a guide to establish “tolerable” threshold performance levels.
- Use available models that show how user costs (e.g., travel time, vehicle operating costs, and accident costs) change with different levels of condition or performance. Examining the slope of this curve can show the performance level at which user costs begin to increase rapidly.
- Use the law of diminishing marginal returns to identify the point at which additional investments begin to have a declining degree of impact on improvements in performance—in other words, where the slope of the investment performance curve begins to decline. Curves of changes in performance measure value per unit of investment (see Figures 4 and 5) can be used for this purpose.
- A corollary to the law of diminishing returns is that caution should be exercised about setting goals or targets that call for 100-percent achievement of a particular condition or service level, since the benefit/cost ratio associated with achieving the last 1 percent will typically be quite low. For example, setting a goal of no structurally deficient bridges could necessitate costly replacement of a bridge that provides a redundant link in the network and is not heavily used.
- Use a tool such as the Highway Economic Requirements System (HERS) or the Highway Design and Maintenance Standards Model (HDM-4) to identify the performance levels that could be achieved through implementing all improvements with benefits exceeding costs.
- Define a set of minimum standards for infrastructure characteristics and performance (such standards may already be in place), and establish a long-term goal of meeting these standards. Caution should be exercised in defining standards so that they are feasible and reasonable.
- Related to the standards-based approach, a methodology for defining either deficiencies or needs (i.e., the cost of addressing the deficiencies) can be applied. This then provides the basis for setting a long-term goal of eliminating all deficiencies or reducing the backlog to 0. Alternatively, a goal of keeping the backlog from growing might be established.

For setting infrastructure condition goals, the following additional types of approaches can be used:

- Establish a threshold for “poor” pavement based on a level of roughness that is noticeable to road users (particularly trucks) and is associated with a marked increase in road user costs (due to vehicle wear and tear, increased fuel consumption, or reduced speed). Set a long-term goal of having minimal travel on poor roads (e.g., less than 5 percent).
- Use capabilities of pavement and bridge management systems to determine a long-term optimal network condition distribution, which minimizes life-cycle costs. Use this distribution to set goals for either average condition or percent of infrastructure (e.g., number of bridges, deck area, and miles) above a given threshold condition level.

- Base goals on maintaining a steady-state condition distribution in order to avoid future peaks in preservation or replacement costs that would be difficult to address given a relatively constant level of funding. These goals would be expressed in terms of the percent of the network in different ranges of condition level (or remaining life categories).

In conjunction with many of these approaches, separate goals can be established for different portions of the transportation network to reflect differing degrees of strategic importance (e.g., based on functional class, truck routes, and trunk line networks).

Step 4: Consider Funding Availability

It can be a challenge to gain consensus on performance targets when levels of performance that are desirable from an economic, engineering, or customer perspective are not feasible from a financial perspective. However, performance targets need to be achievable in order to be meaningful and to serve a useful purpose in an agency's decision-making process.

Ideally all performance targets, particularly those that apply to a relatively short time horizon (e.g., fewer than 5–7 years), should be placed within the context of future funding availability. Projections of future funding can be made based on past trends and available information about future appropriation levels. Historical breakdowns of funding allocation and use to program areas and cost components can provide useful input to future projections.

In many instances, a scenario approach can be used, in which targets are set based on continuation of current funding levels, 10–20 percent lower, and 10–20 percent higher. Additional scenarios for allocation of available funds across program areas can be analyzed, as discussed below in Step 5.

Step 5: Analyze Resource Allocation Scenarios and Tradeoffs

The ability to meet performance targets depends not only on overall funding availability, but also on how funds are allocated across and within program areas. Performance targets can provide the basis for determining how resources are to be allocated when there is available flexibility to do so.

The capability to predict performance and relate performance to cost is required for formulation of realistic targets based on anticipated funding availability. Many pavement and bridge management systems include this capability as a standard feature. Other tools, such as the FHWA Highway Economic Requirements System—State Version (HERS-ST), can predict a broader set of preservation, safety, and congestion-related performance measures for different resource allocation scenarios. Some agencies have developed in-house tools or informal spreadsheet-based or “back-of-the-envelope” calculation methods to provide this capability as well. Available analytical tools for relating asset performance to cost were identified in *NCHRP Report 545 (2)*.

Figures 4 and 5 illustrate examples of performance-cost relationships that can be produced by management system tools and used as guides for target setting based on funding and resource allocation scenarios.

Figure 4. Example of Budget Scenarios and Effects on Infrastructure Condition

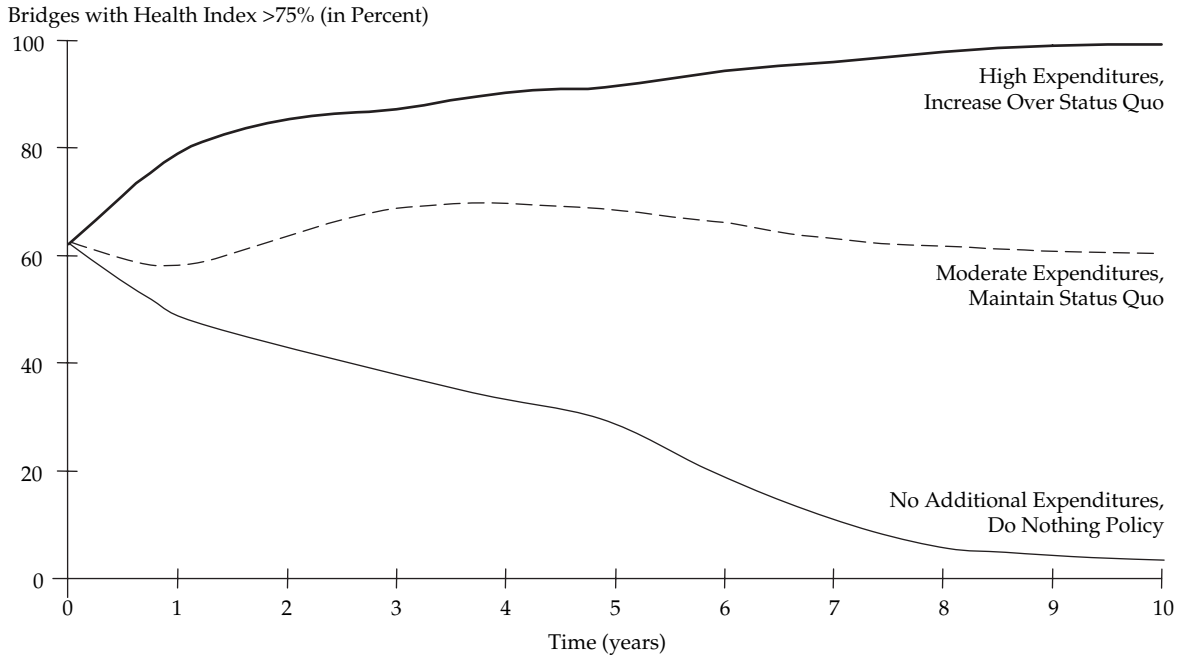
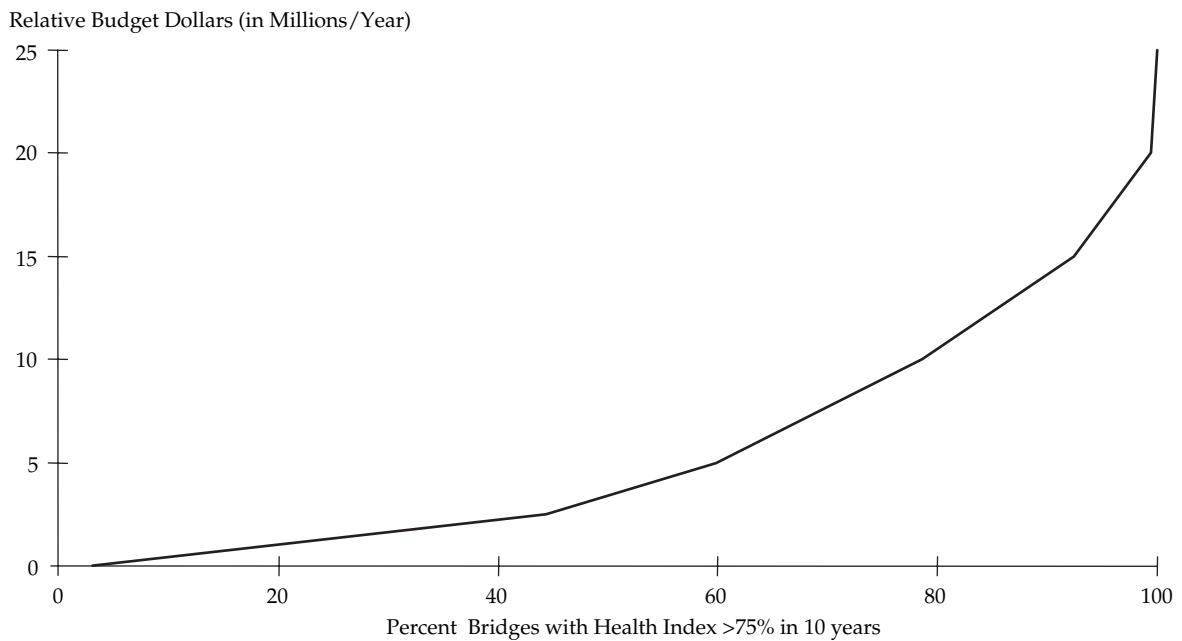


Figure 5. Relationship Between Infrastructure Condition and Needed Expenditure



Step 6: Consider Policy and Public Input

For many agencies, target setting is a process that involves engagement with agency executives, transportation commissions or boards, elected officials, and customers. Approaches to obtaining input can vary, but ideally should involve a two-way communication process in which:

- The agency educates external stakeholders about current baseline performance and trends, feasible levels of performance given alternative levels of resources, and technical and economic factors to be considered and
- External stakeholders provide feedback on desired performance levels and priorities across different measures.

Public opinion surveys can also be helpful in the target-setting process to understand the relationship between different transportation system performance levels and the level of inconvenience or discomfort perceived by users.

Step 7: Establish Targets and Track Progress

This final step involves selecting actual target values based on the work accomplished in prior steps, reporting these targets, and tracking progress toward meeting the targets (as discussed in the section on designing communication devices). Periodic adjustments to targets should be considered based on the degree of progress made, changes in policy or priorities, or emergence of information or factors not previously considered when the initial targets were established (e.g., dramatic rise in gasoline prices or passage of a new transportation finance package).

Examples of targets established by state DOTs are provided in Appendix B. Figures 6 through 8 illustrate useful graphical formats for communicating performance measure values with respect to targets.

Figure 6. Minnesota DOT's Performance Target Levels

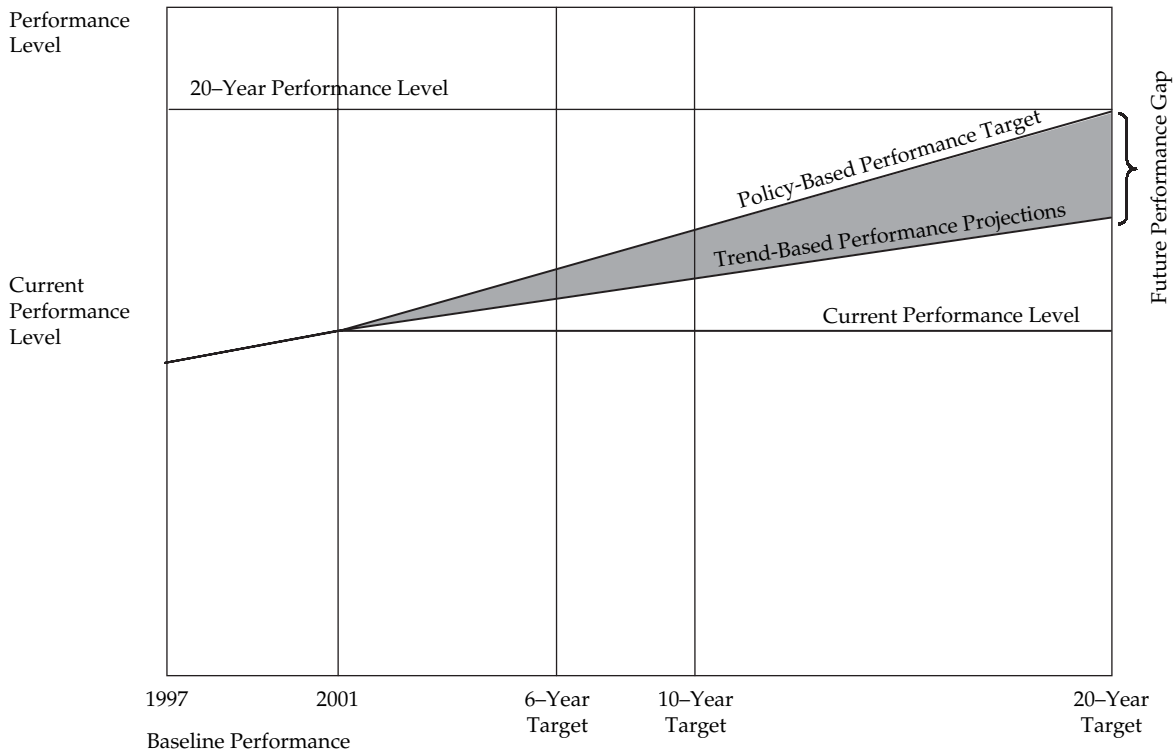


Figure 7. Florida DOT Communication of Performance Targets

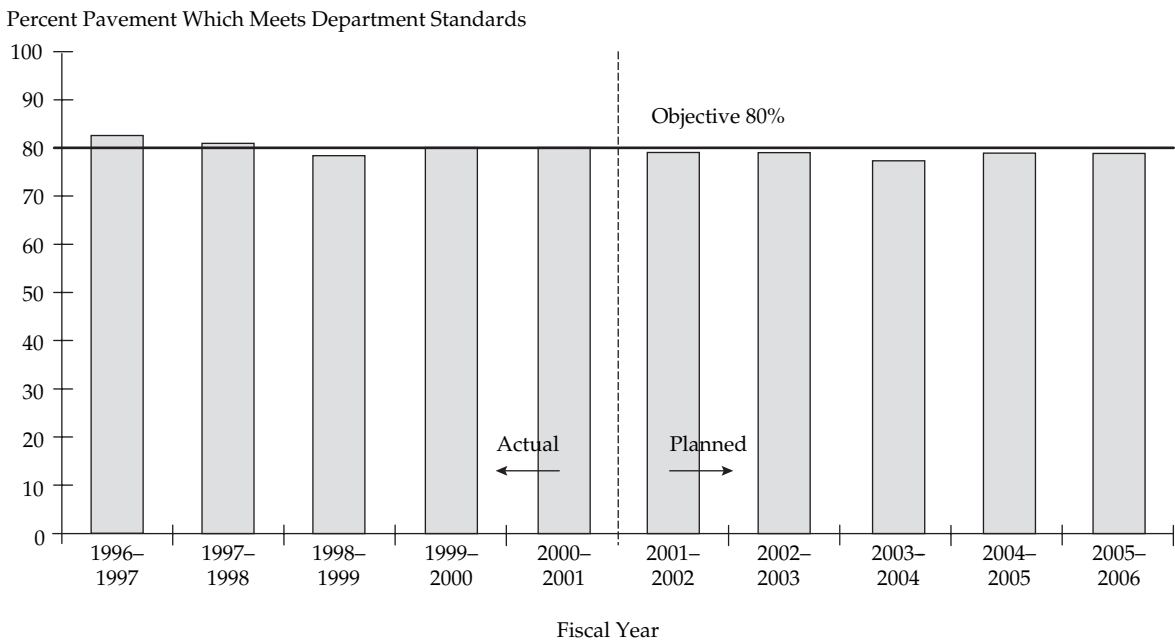
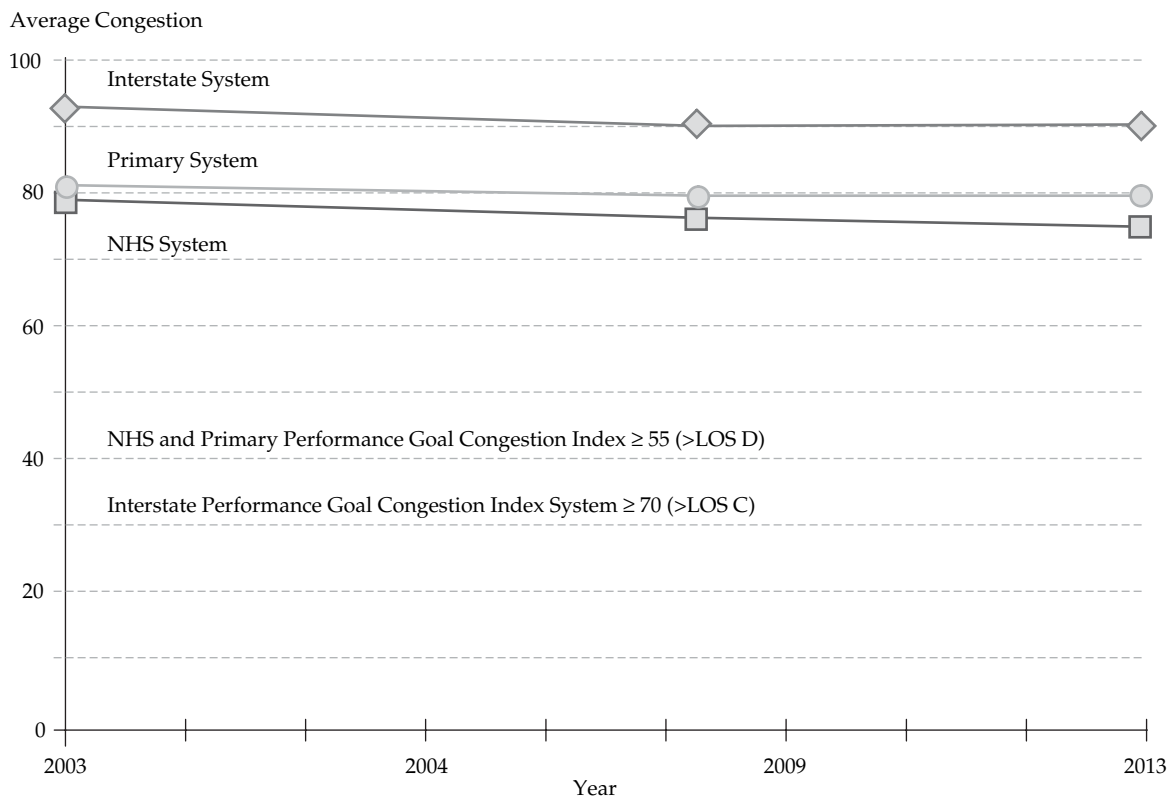


Figure 8. Montana DOT Communication of Performance Targets



Sources

1. AASHTO, *Transportation Asset Management Guide*, Washington, D.C. (November 2002).
2. Cambridge Systematics, Inc., PB Consult, Inc., and System Metrics Group, *NCHRP Report 545: Analytical Tools for Asset Management*, Transportation Research Board (2005).

Appendix A. Performance Measures for Asset Management

The tables on the following pages provide lists of performance measures that may be considered for transportation asset management. These measures have not been fully vetted as the best ones for asset management because this distinction depends largely on the characteristics of the implementing agency. However, if implemented properly, these candidates have potential for being “good measures.”

Categories used for measures are defined as follows:

- **Preservation**—Measures the condition of the transportation system and actions to keep the system in a state of good repair. Measures are often specific to the type of asset. Performance measures may be expressed, for example, by physical condition (e.g., extent or severity of distress and deviations from nominal track gauge), by indexes that combine a number of condition measurements or that relate to user perceptions of condition (e.g., pavement condition index, present serviceability index, or rideability index for pavements or bridge health index for bridges), or by other, not necessarily technical, measures (e.g., financial asset value). For purposes of this study, preservation also includes actions to maintain a state of good repair in emergency situations other than terrorist attacks (e.g., severe storms, earthquakes, landslides, scour around foundations, and flooding).
- **Mobility and Accessibility**—Measures the ease of movement of people and goods. Accessibility is the ability of people and goods to reach desired activities or destinations. Mobility and accessibility are grouped together here because they are related and share common measures. Mobility measures include the time and cost of making a trip and the relative ease or difficulty with which a trip is made, especially congestion and the trip measures related to congestion. Some of these trip measures reflect a supplier perspective (e.g., volume-capacity ratio and capacity-related level of service), while others reflect a user perspective (e.g., speed, travel time, delay, trip reliability, and user cost). Accessibility measures include a “density” of opportunities enabled by transportation services (e.g., number of households within a 30-minute drive of key regional centers or number of employment opportunities within a 10-minute walk of transit stops) or the ability of a facility to serve a particular user group (e.g., a particular segment of population or type of freight). Availability of modes and modal choice can also be treated as an accessibility measure. Accessibility is often expressed from a user’s perspective.
- **Operations and Maintenance**—Measures the effectiveness of the transportation system in terms of throughput and travel costs and revenues from a system perspective and maintenance level of service measures focused on the customer experience of the system. Since throughput is interpreted in terms of people or goods as well as vehicles, measures of vehicle occupancy or freight capacity may be included here. Cost efficiency includes measures such as average cost per mile or per VMT. Systemwide fuel efficiency is also included.

- **Safety**—Measures the quality of transportation service in terms of crashes or incidents that are harmful to people and damaging to freight, vehicles, and transportation infrastructure. Performance measures also reflect asset conditions that contribute to or detract from safety. While safety is often gauged by the number, frequency, severity, and cost of accidents, recent trends recognize a wider sphere of interest in the vehicle- and driver-related causes of crashes and in harm to agency work crews, particularly in work zones. Work is also ongoing to predict the risk of future safety problems at candidate locations.
- **Economic Development**—Measures direct and indirect impacts of transportation on the economy. Direct impacts are typically related to the cost of transportation experienced by users and shippers. Indirect measures look at transportation’s contribution to the general economy and are expressed in measures such as economic output (e.g., gross state product), employment (e.g., jobs supported or created), and income. Various proxy measures are often used to gauge economic development impacts, including traffic at border crossings, manufacturers/shippers/employers who have relocated for transportation purposes, volume of freight originating or terminating in region, number or percent of employers that cite difficulty in accessing the needed labor supply because of transportation, and measures of truck travel per unit of regional economic activity.
- **Environmental Impacts**—Measures effects on the environment, including air quality, groundwater, protected species, noise, and natural vistas. Output-based performance measures may also be defined for actions critical to mitigating the above impacts (e.g., protecting wetlands, constructing wildlife passages across transportation facilities, using snow and ice chemicals that protect groundwater and air quality, and monitoring and controlling hazardous materials).
- **Social Impacts**—Measures effects on broader society (e.g., neighborhoods adjacent to transportation facilities) or on population groups (e.g., disadvantaged). This is in contrast to “quality of life” impacts, which are interpreted by some agencies to mean customer satisfaction specifically.
- **Security**—Measures protection of travelers, freight, vehicles, and system infrastructure from criminal and terrorist actions. Protection of infrastructure and users of this infrastructure against other emergencies (e.g., severe storms, earthquakes, landslides, flooding, and scouring of foundations) is included in preservation.
- **Delivery**—Measures the delivery of transportation projects and services to the customer. Key performance measures include output-oriented accomplishment measures that complement outcome-oriented measures in the other categories, measures of efficiency and effectiveness in use of resources, and impacts on customers that need to be considered in evaluation of alternative delivery strategies.

Table A.1 Preservation Performance Measures

Measure Type	Examples
Pavement Condition/ Ride Quality	<ul style="list-style-type: none"> • Average condition • Number of miles below a threshold acceptable condition level (e.g., number of miles with rut depth greater than ¼ inch) • Percent miles in good/fair/poor condition
Bridge Condition	<ul style="list-style-type: none"> • Average health index (0–100 scale) • Percent structurally deficient (SD) • Percent with sufficiency rating less than 50 • Percent of bridges that meet department standards • Number of posted or restricted bridges • Number of steel bridges with section loss in a member • Percent of bridges with deck, superstructure, substructure National Bridge Inventory (NBI) rating 4 or below
Asset Condition (General)	<ul style="list-style-type: none"> • Percent length/count/area in good/fair/poor condition • Percent length/count/area in “state of good repair”
Remaining Life/ Structural Capacity	<ul style="list-style-type: none"> • Percent asset quantity with fewer than 5 years remaining service life (RSL) • Average RSL • Percent of design life achieved • Percent asset quantity forecast to achieve full design life • Average age or percent asset quantity greater than <i>n</i> years old (age can be a useful proxy for remaining life when data are limited) • Percent pavement miles with weight restrictions due to structural limitations • Percent assets eligible for replacement • Percent asset quantity out of service due to deteriorated condition
Asset Value	<ul style="list-style-type: none"> • Replacement value • Book value (historical or appreciated to current dollars) • Ratio of current value to replacement cost

(continued on next page)

Table A.1 Preservation Performance Measures (continued)

Measure Type	Examples
Backlog or Need	<ul style="list-style-type: none"> • Current value of cost to preserve assets in state of good repair over defined time horizon • Backlog of deferred maintenance • Estimated cost to achieve target condition level or eliminate deficiencies • Ratio of deferred maintenance dollars to replacement value (facility condition index) • Ratio of deterioration or lost value to replacement value (debt index)
Agency Financial Impacts	<ul style="list-style-type: none"> • Cost of emergency maintenance due to asset age or poor condition • Agency cost due to deferred maintenance (present value of deferred maintenance minus cost to do it now)
Customer Benefit or Disbenefit (or Surrogates)	<ul style="list-style-type: none"> • VMT-weighted average pavement condition • Percent of VMT on roads in poor condition • Percent of truck VMT or tonnage affected by weight or clearance restrictions • Number of overload permits rejected due to bridge structural capacity deficiency • Number of functionally obsolete bridges • User costs associated with rough roads or detours due to bridge posting or road restrictions • Hours or days during which asset not in service due to preservation work
Customer Perception	<ul style="list-style-type: none"> • Customer rating of asset condition or agency preservation activities • Customer satisfaction rating

Table A.2 Mobility and Accessibility Performance Measures

Measure Type	Examples
Congestion	<ul style="list-style-type: none"> • Level of service (LOS)—measure of congestion from A–F based on volume-to-capacity ratio (facility-specific measure) • Volume-to-capacity (V/C) ratio (facility-specific measure) • Travel time index (ratio of peak travel time to free-flow travel time) • Travel rate index (amount of additional time required due to congestion) • Misery index—measurement of the severity of congestion on the worst 20 percent of trips (ratio of average travel rate for the longest 20 percent of trips to average travel rate for all trips) • Speed reduction index (ratio across different facilities of decline in speeds due to congestion)—used to compare relative congestion levels on different facilities • Amount or percent (VMT or PMT) of congested travel • Number or percent of highway-miles (by class of road) operating under capacity, approaching capacity, or over capacity (or at particular V/C thresholds for <i>n</i> hours per day) • Number of intersections congested (e.g., with LOS E or F) during peak hours • Travel time under congested conditions • Lane-mile duration index (number of congested lane-miles times the duration of congestion) • Maximum queue lengths (facility-specific measure)
Speed	<ul style="list-style-type: none"> • Travel rate (e.g., minutes per mile)—for a roadway segment or corridor • Average speed for given roadway segment or origin-destination pair • Average annual rate of change in average speed • Ratio between bus speed and automobile speed • Percent of time average speed is below (or above) a threshold level • Percent of high-priority highways with average speed of 60 mph • Mobility index (VMT, PMT or ton-miles times average speed)
Travel Time	<ul style="list-style-type: none"> • Average travel time (by mode or cross modes) for a given origin-destination pair or trip type • 95-percent reliable travel time • Travel time from freight intermodal facilities to highway facilities • Average shipment time (by commodity, mode, local versus long-distance) • Changes in average, median, and 90th-percentile travel time over time • Percent difference in travel time between second fastest emergency route and the fastest route

(continued on next page)

Table A.2 Mobility and Accessibility Performance Measures (continued)

Measure Type	Examples
Travel Time Reliability	<ul style="list-style-type: none"> • Buffer time index—percent of extra time a traveler needs to allow in order to be on time 95 percent of the time • Variation in average speed (location-specific measure) • Standard deviation of travel time • Deviation from average trip time for selected origin-destination pair • Number of days when peak-period travel time exceeds twice the free-flow travel time on key commuting routes • Percent on-time shipments (by commodity or mode)
Delay	<ul style="list-style-type: none"> • Total hours of delay (difference between actual travel time and defined standard for acceptable travel time) • Hours of incident-related delay • Relative delay rate (difference from target or standard)—used to compare delay on different roadway facilities or modes • Congestion severity index (hours of delay per million VMT) • Average delay per peak-period traveler • Hours of stopped time per traveler • Percent of peak-period travelers delayed
Travel Cost	<ul style="list-style-type: none"> • Average shipment cost between specified origins and destinations or facilities • Trip cost by mode for origin-destination pairs • Vehicle operating cost increases due to congestion • Travel time cost of congestion • Annual percent increase in unit costs of transport industries • Dollar losses due to freight delays • Economic efficiency/net discounted benefits
Accessibility to destinations	<ul style="list-style-type: none"> • Percent of target population that can conveniently reach a specific destination (e.g., within X hours, no more than Y-percent circuitry, with less than Z minutes of delay) • Percent of working population within X miles of employment • PMT per capita

Table A.2 Mobility and Accessibility Performance Measures (continued)

Measure Type	Examples
Accessibility to facilities and services	<ul style="list-style-type: none"> • Average time from snow event to bare pavement operations • Percent of population within <i>X</i> miles or minutes of the state highway system • Percent of facilities (e.g., rail stations) that are ADA compliant • Number of driveway cuts per mile (for defined corridors)—both a measure of accessibility and “side friction” impacting corridor mobility • Percent of urban population with convenient access to public transit (e.g., living within a quarter mile of a transit stop with a non-rush-hour service frequency of 15 minutes or less) • Access time to passenger or intermodal facilities
Accessibility to different modes	<ul style="list-style-type: none"> • Modal split by trip purpose • Average automobile ownership • Transit service availability by county • Ability of shippers to access desired suppliers or markets within specified service parameters (based on shipment time, cost, and circuitry) • Percent of roadway-miles with bicycle accommodations • Percent of roadway-miles with pedestrian accommodations • Percent of planned bike route system implemented • Number of autos (or taxis) per capita • Percent of ADA-compliant vehicles
Backlog or Need	<ul style="list-style-type: none"> • Estimated cost to achieve a given performance level or to eliminate deficiencies (e.g., eliminate peak-hour congestion on priority routes or complete bike route system) • Estimated cost of recommended work with benefit/cost ratio greater than 1
Customer Perceptions	<ul style="list-style-type: none"> • Customer ratings of trip time, reliability, congestion severity, travel cost, travel time, and so forth • Customer satisfaction with snow and ice removal

Table A.3 Operations and Maintenance Performance Measures

Measure Type	Examples
System operations efficiency	<ul style="list-style-type: none"> • See mobility measures (e.g., congestion and speed) • VMT per lane-mile (per capita) • Passengers per vehicle-mile or hour (transit) • Percent of road-miles with low speed limits or restrictions • Average circuitry for truck trips between a selected origin-destination pair • Number of extended breakdowns in travel flow on freeways for a given time period
Incident Response/ Winter Operations	<ul style="list-style-type: none"> • Average annual incident response time on limited access miles managed by ITS • Average time to clear incident or percent of incidents cleared in less than X minutes • Time interval after precipitation stops to restore road conditions to defined standard • See also Delay measures
Capacity and Availability	<ul style="list-style-type: none"> • Number of hours (or days) of road closure • Intermodal terminal capacity • Bulk material loading rate (number of trucks per hour) • Number of truck units, railroad cars, or containers that can be stored at intermodal facility • Railroad grade crossing-related delay time • Percent of arterials and/or downtown intersections under closed loop control • Traffic signal malfunction rate
Maintenance Level of Service	<ul style="list-style-type: none"> • Lineal feet of damaged guardrail • Number of pieces of roadside litter per mile • Lineal feet of ditches more than 50-percent full of sediment or other material • Number of deficient (e.g., clogged) catch basins • Sign and pavement marking retroreflectivity
Cost Efficiency	<ul style="list-style-type: none"> • Average cost per lane-mile constructed • Average operations and/or maintenance cost per lane-mile • Construction and maintenance expenditures per VMT • Cost per passenger trip (urban versus rural) • Cost per percent point increase in lane-miles in good condition • Ratio of oversize/overweight permit fees collected to dollar value of damage caused

Table A.3 Operations and Maintenance Performance Measures (continued)

Measure Type	Examples
Occupancy	<ul style="list-style-type: none"> • Percent or number of multiple-occupant vehicles • Percent of work trips by single-occupant vehicles (SOVs) or non-SOVs • Average vehicle occupancy (by peak/off-peak, and location)
Fuel Efficiency	<ul style="list-style-type: none"> • Average fuel consumption per trip by type (or shipment) • Annual fuel consumption per VMT • Gallons of wasted fuel
Backlog or Need	<ul style="list-style-type: none"> • Estimated cost to achieve a given performance level or eliminate deficiencies (e.g., bring 80 percent of arterial network under closed-loop control or cut incident response time by 20 percent) • Estimated cost of recommended operational improvements with benefit/cost ratio greater than 1
Customer perceptions	<ul style="list-style-type: none"> • Customer ratings of facility operations and availability

Table A.4 Safety Performance Measures

Measure Type	Examples
Crashes	<ul style="list-style-type: none"> • Number of crashes by type, mode, system, location type, and so forth • Crash rates—number of crashes (by type) per 100 million VMT • Percent reduction in crashes (by type) • Number of crashes involving hazardous materials • Number of alcohol-related crashes • Number of crashes in which speed or traffic violation is a factor • Number of crashes in highway construction zones
Crash Impacts	<ul style="list-style-type: none"> • Number of fatalities (or rate per amount of travel) • Number of road workers killed • Number of injuries (or rate per amount of travel) • Crash costs (total or average)—by type of cost (e.g., property damage or medical) • Hours of delay related to crashes • Average incident duration or percent of incidents disrupting traffic for more than X minutes
Transportation Infrastructure	<ul style="list-style-type: none"> • Hazard index (location-specific measure) • Number of locations with high crash rates or hazard indexes (exceeding defined threshold) • Number of roadway sections (or percent of system miles) not meeting safety standards • Number of roadway sections with excessive curves or grades (e.g., as defined by the Highway Performance Monitoring System) • Number of roadway locations with identified hazards (barriers, obstacles, and distractions) • Number of roadway sections (or miles) with identified cost-effective safety countermeasures
Need/Backlog	<ul style="list-style-type: none"> • Cost to implement identified safety countermeasures
Customer Perception	<ul style="list-style-type: none"> • Number of safety-related complaints • Customer ratings of transportation facility safety or operational response to incidents • Shipper satisfaction with damage/loss rates

Table A.5 Economic Development Performance Measures

Measure Type	Examples
Economic Costs and Benefits	<ul style="list-style-type: none"> • Number of jobs within X minutes of population centers • Transportation-related impacts: jobs created, percent of state or regional gross product • Economic costs of pollution
Direct User Costs	<ul style="list-style-type: none"> • Average cost per trip • Average cost per ton-mile
Transportation Infrastructure Support for Freight Movement	<ul style="list-style-type: none"> • Road mileage converted to all-weather surfacing • Road mileage upgraded to support truck traffic
Support Improved Service to Existing Urbanized Area	<ul style="list-style-type: none"> • Extent to which projects fall within census urbanized area
Support of Brownfield or Infill Sites	<ul style="list-style-type: none"> • Serves one or more Brownfield or infill sites (expressed as Yes/No on project basis; percent or qualitative measure on system basis)
Customer Perceptions	<ul style="list-style-type: none"> • Percent of businesses that cite problems with transportation as a major factor in relocation, productivity, or expansion

Table A.6 Transportation Environmental Impacts Performance Measures

Measure Type	Examples
Vehicle Emissions	<ul style="list-style-type: none"> • Vehicular emissions by type—NO_x, VOC, CO₂, CO, ozone, fine particulate matter (PM_{2.5})—can be limited to nonattainment areas and identified by source (e.g., passenger versus freight) • Tons of greenhouse gases generated
Air Quality Standard Attainment	<ul style="list-style-type: none"> • Number of counties that experience isolated transport-related excesses over air quality standards • Urban areas in nonattainment status • Population of nonattainment areas
Length or Extent of Air Quality Problem	<ul style="list-style-type: none"> • Number of days that pollution standard index is in the unhealthful range • Percent of time air quality is rated good at monitoring stations • Percent or number of counties meeting transport-related national ambient air quality standards • Number of days of air quality noncompliance • Number of infractions where agency is charged • Number of highway funding sanctions imposed for noncompliance with Clean Air Act • Percent of permit inspections that result in violations
Water Quality, Wetlands, Aquatic Life	<ul style="list-style-type: none"> • Acres of wetlands replaced or protected for every acre affected by highway projects • Level of fish habitat reduction as a result of new construction
Hazmat Impacts	<ul style="list-style-type: none"> • Number of incidents involving hazardous materials (or rate per vehicle-mile of hazmat traffic) • Number of pipeline spills and accidents • Quantity of fuel or hazardous materials released, by mode, per transportation incident • Number of oiled seabirds
Energy Impacts	<ul style="list-style-type: none"> • Percent of vehicles using alternative fuels • Average fleet-miles per gallon • Fuel consumption per VMT, PMT, or ton-mile
Noise Impacts	<ul style="list-style-type: none"> • Number of residences or percent of population exposed to highway noise exceeding established standards (or greater than X decibels) • Number of noise receptor sites above threshold • Constraints on use due to noise (or water) • Percent of road network (including concrete sections) with quieter road surface by 2010
Recycling	<ul style="list-style-type: none"> • Amount (or percent) of recycled material used in road construction

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Table A.6 Transportation Environmental Impacts Performance Measures (continued)

Measure Type	Examples
Completion of Mitigation Steps	<ul style="list-style-type: none"> Number of environmental impact analyses, conformity analyses, or environmentally friendly partnership projects completed
Customer Perceptions	<ul style="list-style-type: none"> Customer satisfaction with transportation decisions affecting the environment Customer perception of air quality

Table A.7 Transportation Social Impacts Performance Measures

Measure Type	Examples
Social, Societal, Neighborhood, Community Quality of Life	<ul style="list-style-type: none"> Percent of projects in which community is actively engaged Number of archaeological and historical sites that are not satisfactorily addressed in project development before construction begins Participation (number of projects and number of communities) in neighborhood conservation program. Relative service levels and impacts by community (to address environmental justice considerations)
Customer Perceptions	<ul style="list-style-type: none"> Customer perceptions of highway project impacts

Table A.8 Transportation Security Performance Measures

Measure Type	Examples
Incident Rates	<ul style="list-style-type: none"> Number (or rate per capita or number of travelers) of crimes at rest areas, bus stops, highways, and so forth by type or severity Value of losses from theft per capita, person-trip, shipment value, ton
Prevention Activity	<ul style="list-style-type: none"> Percent of facilities with specific security features (e.g., cameras, lighting, and guards) Percent of facilities passing security tests
Customer Perceptions	<ul style="list-style-type: none"> Percent of customers identifying security as a concern Change in customer concern about security over time

Table A.9 Transportation Delivery Performance Measures

Measure Type	Examples
Accomplishment	<ul style="list-style-type: none"> Quantity of work completed (e.g., lane-miles of pavement resurfacing and number of bridges reconstructed) Dollar value of work completed by type
Quality	<ul style="list-style-type: none"> Quality index (based on materials testing, pavement smoothness and inspection results) Percent of material samples meeting specification
Efficiency	<ul style="list-style-type: none"> Cost per lane-mile constructed Administrative costs as percent of total program Preliminary engineering (PE) and construction engineering (CE) costs as percent of construction costs Design costs as percent of construction dollars let Percent of highway capital costs spent on construction (contractor payments and direct on-site construction oversight) Percent of cost of preliminary engineering rework Duration of construction (by project type)
Schedule and Budget Adherence	<ul style="list-style-type: none"> Unprogrammed costs as percent of total Number of projects let versus planned for letting Number of projects certified versus scheduled for certification Number of consultant contracts executed versus planned Percent of contracts (or contract value) completed on-time Percent of contracts (or contract value) completed on-budget
Responsiveness	<ul style="list-style-type: none"> Average response time to emergency work request Percent of work requests closed within X hours or days
Backlog	<ul style="list-style-type: none"> Ratio of work under contract to programmed work Backlog of programmed construction work to be let
Customer Impact and Safety	<ul style="list-style-type: none"> VMT impacted by work zones Lane-hours restricted due to construction Hours of delay due to work zones Vehicle-miles of detour due to work zones Number of work zone-related crashes Number of road worker injuries

Appendix B. Example State DOT Performance Targets

This appendix contains sample performance targets documented for illustrative purposes that were established at some point in time by each of the referenced states; they are not necessarily current and are likely to change over time.

Table B.1 Examples of State DOT Performance Targets
Pavement Preservation

Measure	Description	State	Target
Distress Rating	0–100 scale based on roughness, cracking, rutting, patching, raveling	Alabama	≥75
Highway Adequacy	0–100 scale based on pavement condition rating, safety, backlog, average daily traffic, posted speed, and shoulder	Maine	Overall—60
International Roughness Index (IRI)	Index based on vehicle response to roughness (lower = smoother)	Federal	93% ≤170
		Louisiana	<15% >170
		Nevada	I—70% <80
			II—65% <80
III—60% <80			
		Pennsylvania	94
Maintenance Assessment Program	1–5 scale based on pavement, traffic operations and roadside	Texas	Interstate ≥80% Other ≥75%
Maintenance Rating Index	1–100 scale based on pavement, shoulders, roadside elements, drainage, and traffic services	Tennessee	Overall ≥75
Nebraska Serviceability Index	0–100 scale based on surface distresses—cracking, patching, roughness, rutting, faulting	Nebraska	Overall ≥72%
Overall Pavement Condition	0–5 scale based on pavement distress	Delaware	≤15% Poor
Pavement Condition Index	Good, fair, and poor based on pavement smoothness	Kentucky	≤30% Poor
Pavement Condition Rating	1–100 scale based on cracking, pot-holes, deterioration, and other	Ohio	Priority ≥75% ≥65 Other ≥75% ≥55

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Table B.1 **Examples of State DOT Performance Targets (continued)**
Pavement Preservation

Measure	Description	State	Target
Pavement Condition Survey	0–10 scale for pavement segments based on ride smoothness, pavement cracking, and rutting	Florida	80% >6 for all 3 criteria
Pavement Quality Index	0–100 scale based on 3 surface distress factors	Indiana	Interstate—75 NHS—75 Other—65
Pavement Quality Index	0.0–4.5 scale based on smoothness and distress (cracking)	Minnesota	Principal ≥3.0 Other ≥2.8
Pavement Serviceability Rating	0–5 scale based on ride, rutting, and cracking	Wyoming	NHS—3.5 Other—3.0
Performance Levels	PL-1: good condition; PL-2: requires maintenance; PL-3: poor condition	Kansas	Interstate ≥80% PL1 Other ≥75% PL1
Present Serviceability Rating	0–5 scale based on subjective rating by road users	Arizona	≥3.23
Remaining Service Life	Poor (0–5 years), fair (6–10 years), or good (11+ years) based on surface distress	Colorado	Interstate ≥80% NHS ≥70% Other ≥55%
Ride Index	1–5 scale based on vehicle response to roughness with adjustment for pavement type	Utah	50% ≥2.75 ≤15% ≤1.84
Roughness Index and Cracking Index	Roughness index—0.0 to 5.0 based on public perception Cracking index—0.0 to 5.0 for each pavement section	Idaho	≤18% <2.5
Sufficiency Rating	Excellent, good, fair, poor, very poor, based on surface distresses	Michigan	≤30% Poor or Very Poor

Table B.2 **Examples of State DOT Performance Targets**
Structure Preservation

Measure	Description	State	Target
Bridge Value Index	Ratio of current value to replacement value	Oregon	87–90%
GASB 34 Bridge Rating	0–10 scale assigned to each component-rating category	Alabama	≥5
Health Index	0–100 scale based on condition of several elements	Kansas	Overall ≥80
NBI Appraisal Ratings	0–9 scale based on deck, substructure, and superstructure condition	Ohio	≥85% of deck area ≥5
		Delaware	75% ≥6 <10% ≤4
		Washington	95% Good or Fair
Number of Closed Bridges	Bridges closed	Pennsylvania	Reduce by 50% by 2010
Number of Posted Bridges	Bridges with weight restrictions	Oregon	0
		Pennsylvania	Reduce by 30% by 2010
Structural Condition Rating	Good, fair, or poor based on National Bridge Inventory (NBI) condition and appraisal ratings	Minnesota	Principal—92% Fair to Good Other—80% Fair to Good
Structurally Deficient (SD) or Functionally Obsolete (FO)	SD—FHWA rating that indicates a bridge is restricted to light vehicles, requires immediate rehabilitation to remain open, or is closed FO—FHWA-defined rating based on deck geometry, load-carrying capacity, clearance, and approach roadway alignment	Colorado	≤25% SD
		Federal	<20% of NHS either SD or FO
		Florida	90% ≥5 SD
		Georgia	<5% (based on deck area)
		Kentucky	≤7% SD
		Michigan	≤35% SD
		Tennessee	>75% neither SD nor FO
	Wisconsin	≤15% SD	
Structures Inventory System	1–100 scale based on condition of major elements	Utah	50% ≥80 ≤15% ≤49
Sufficiency Rating	0–100 scale based on 4 factors reflecting ability to remain in service	Indiana	Interstate—87% NHS—85% Other—83%
		Maine	Overall—60%
		Wyoming	NHS—83% Other—80%

Table B.3 **Examples of State DOT Performance Targets**
Operational Efficiency

Measure	Description	State	Target
Toll Operations Costs	Operational costs per toll transaction	Florida	<\$0.16
Incident Clearance Time	Average clearance time for incidents on the Twin Cities urban freeway system that occur between 6:00 a.m. and 7:00 p.m. on weekdays	Minnesota	35 minutes
	and Monthly incidents with clearance times over 90 minutes	Washington	0
Snow and Ice Removal Time	Average time required to provide bare pavement on super commuter routes following a weather incident	Minnesota	2–5 hours

Table B.4 **Examples of State DOT Performance Targets**
Capacity Expansion

Measure	Description	State	Target
Congestion	Percent of urban freeway miles in regional trade centers that are moderately congested (0–2 hours of speeds below 45 mph)	Minnesota	21%
Level of Service	Describes operating condition in terms of speed, travel time, and safety	Washington	D for urban areas and C for rural areas
Traffic Density	Annual percent growth in vehicles per mile on Interstate	Florida	<4%
	and Freeways with annual ADT (AADT) greater than 20,000 vehicles per lane	Maryland	<32%
Travel speeds	Percent of interregional corridor miles where travel speeds met or exceed minimum levels	Minnesota	90% by 2020

Table B.5 **Examples of State DOT Performance Targets**
Safety

Measure	Description	State	Target
Correctable Crash Sites Improved	Number of correctable crash sites funded for improvement	Montana	Improve over time
Crash Rate	3-year average rate per million VMT	Minnesota	0.73
Fatal and Disabling Crashes	Percent decrease in number of fatal and disabling crashes since 1990	Washington	Decrease over previous year
Fatalities	3-year average	Minnesota	550 (3-year average)
		Pennsylvania	Reduce by 10% by 2010
Fatality Rate	5-year fatality rate (fatalities per 100 million VMT)	Idaho	1.8
Injury Rate	5-year serious injury rate (serious injuries per 100 million VMT)	Idaho	10.22
Road Condition–Related Crashes	Percent of crashes on strategic highway system where road-related conditions are a contributing factor	Florida	<1%

Table B.6 **Examples of State DOT Performance Targets**
Transportation Environmental Impacts

Measure	Description	State	Target
NO _x Emissions	Transportation-related VOC emissions as a percent of total VOC emissions	Maryland	<33.9%
VOC Emissions	Transportation-related VOC emissions as a percent of total VOC emissions	Maryland	<40.2%
Impacted Wetlands Replaced	Ratio of acres of wetlands replaced to acres impacted	Minnesota	1

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation