

## INTRODUCTION

### BACKGROUND

During the 20th century surface transportation programs were substantially focused on the development of basic infrastructure networks. The challenge for transportation in the 21st century is managing and operating these transportation resources to deliver needed services to customers under varying conditions in the face of growing travel demand and capacity limitations. Performance measurement is emerging as a critical tool to help meet this challenge. Performance measurement is being used at several levels, ranging from day-to-day operations to long-term capital planning that enhances system operations. Performance measurement can also be used at the project level to identify design features that improve operations and at the policy level to allow stakeholders to evaluate the benefits of highway improvements.

However, evaluating and improving system operations through performance measures can be challenging. Data collection and analysis demands can be overwhelming. Different measures are appropriate for different audiences; for example, the public, elected officials, system planners, and operations managers. Some engineering measures may be useful in improving operations, but may not be effective in communicating meaningful information to the public.

### PURPOSE

This synthesis summarizes the practices used by state departments of transportation (DOTs), metropolitan planning organizations (MPOs), and local governments concerning highway operational performance measures and associated data collection. Specifically, this synthesis reports on

- Uses of performance measures,
- The intended audiences for performance measures,
- Reporting techniques for performance measures,
- Data collection techniques in support of the performance measures,
- The relative strengths and weaknesses of commonly used performance measures, and
- Examples of successful practices for performance measures.

### METHODOLOGY

This synthesis was conducted in four parts. The first was a literature review of documented research. The second was

a review of the practices of state and national transportation agencies. Third, a comprehensive survey of state transportation agencies and MPOs was undertaken. The results of parts one through three were then compiled and documented, and gaps in existing research and practices were identified.

### ORGANIZATION

This synthesis report is organized to provide an introduction to operational performance measures for highway systems and segments. A summary of performance measures programs is provided that progresses from general concepts through a number of case studies. An annotated bibliography is also provided for readers who may be interested in learning more.

Chapter two outlines the principles of performance measures, describes why these measures are needed, and reviews the key steps in performance-based management. It also describes how to identify highway systems and segments and how to define performance measures for these segments.

Chapter three summarizes the major relevant research documents and on-going efforts.

Chapter four summarizes the current state of practice in the areas of operational performance measures for highway systems and segments based on the study survey. The practice is summarized according to four classifications:

1. Federal and state guidelines and rules—Relevant federal and state guidelines and rules related to performance measures for operational efficiency are summarized.
2. Federal and state practices—Relevant federal and state projects and programs are summarized.
3. Practice by other organizations—Relevant practices by other organizations such as MPOs, and county and city governments are summarized based on the results of a literature review. The summary of federal, state, and other agency practices is based on a survey of state transportation agencies and MPOs conducted during the fall of 2001.
4. Common themes in evaluation and application—A summary of the common themes in the research and practice are provided. A matrix is developed that summarizes the relevant performance measures, their application, and usefulness.

Chapter five synthesizes the performance measures reported in the literature and the current state of the practice and discusses the strengths and weaknesses of the measures using the principles of performance measures identified in chapter two.

Chapter six summarizes the findings from the literature, agency questionnaire, state of the research, state of the

practice, and the major conclusions from the synthesis. Based on the state of the research, state of the practice, and conclusions, an agenda for research programs to improve the state of the practice is suggested.

Appendix A provides a copy of the survey of state DOTs and MPOs conducted as part of this research. A list of acronyms and abbreviations is also included.

## BASIC CONCEPTS AND DEFINITIONS

Modern use of performance measures and performance measurement systems rose out of the Deming Total Quality Management movement of the 1950s in Japan. Although performance measures had been used in some applications before this, the science of performance measurement and statistics was derived from the principles espoused in his 14 points. These principles are intended to provide a structured system for satisfying internal and external customers and suppliers by integrating the business environment, continuous improvement, and breakthroughs with development, improvement, and maintenance cycles while changing organizational culture. These principles rely on developing goals that can be related to measurable results (such as reducing the number of manufactured parts that do not meet expectation), monitoring those results, and assessing strategies to improve performance.

Prior to the late 1980s, Total Quality Management and performance measures were primarily used in industrial applications and in the private sector. As government resources became limited during the recessions of the 1970s and 1980s, the public began to take a greater interest in making government accountable to primary agency missions and goals. Some government agencies adopted more private sector business practices that included performance monitoring and measurement principles in response to these pressures. However, there was little national consistency in these practices. In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) promoted the national use of performance measures and performance-based planning through the recommendation of congestion, safety, intermodal, public transit, pavement, and bridge management systems. Many state transportation agencies and MPOs adopted these management systems and related practices although they were made optional (Shaw 1996). In 1993, President Clinton signed the Government Performance and Results Act of 1993, further institutionalizing performance measures in the federal government and requiring that specific measures be established and tracked for most major federal programs. These recommendations were based on successful programs in several state DOTs and MPOs. These measures were derived from strategic planning activities that require agencies to report on how they achieve goals through performance measures. In 1997, the National Performance Review report, *Serving the American Public: Best Practices in Customer-Driven Strategic Planning*, recommended best practices for performance measurement for federal programs and local governments.

When addressing performance measures applications for the operational effectiveness of highway systems and segments, several common questions were identified that can be used to explain the basic concepts and definitions relevant to these applications.

- What are performance measures?
- Why have performance measurement?
- How do you define highway systems and segments?
- How do you define performance measures for the operational effectiveness of highway segments and systems?
- What are the key steps in performance-based management?

### WHAT ARE PERFORMANCE MEASURES?

NCHRP Project 8-32(02), “Multimodal Transportation: Performance-Based Planning Process” (1998), defines performance measurement as

the use of statistical evidence to determine progress toward specific defined organizational objectives. This includes both evidence of actual fact, such as measurement of pavement surface smoothness, and measurement of customer perception such as would be accomplished through a customer satisfaction survey. In a service industry such as transportation, the performance measurement process starts by defining precisely the services the organization promises to provide, including the quality or level of service (LOS) (e.g., timeliness, reliability, etc.) that is to be delivered. There are often good opportunities for collecting feedback from system users in “real time,” since the transportation service is often “consumed” at the same time it is “produced.” Performance measures provide information to managers about how well that bundle of services is being provided. Performance measures should reflect the satisfaction of the transportation service user in addition to those concerns of the system owner or operator.

An alternative and more succinct definition as reported by the FHWA from the National Performance Review is as follows:

Performance measurement is a process of assessing progress toward achieving predetermined goals, including information on the efficiency with which resources are transformed into goods and services (outputs), the quality of those outputs (how well they are delivered to clients and the extent to which clients are satisfied) and outcomes (the results of a program activity compared to its intended purpose), and the effectiveness of government operations in terms of their specific contributions to program objectives.

## WHY HAVE PERFORMANCE MEASUREMENT?

Performance measures can have profound effects on the effectiveness of transportation systems and services. For example, prior to the mid-1980s, airlines in the United States commonly reported on the success of their “on-time departures.” Because the perception of success, with both the American public and the airlines, was derived from this measure, individual aircraft crews had to maintain on-time departure schedules that resulted in significant inefficiencies. Flight arrivals were often delayed due to the priority given to take-offs and many aircraft spent unnecessary time airborne circulating destination airports, which resulted in excess fuel consumption and labor costs. When measures evolved to “on-time arrivals,” airlines began scheduling arrival times at their destination airports and delaying departures to minimize the time spent airborne. Airlines saved on fuel costs and air travel became more affordable and reliable. Following this paradigm shift in the airline industry, air travel increased dramatically and economic productivity and leisure travel expanded providing many positive economic benefits to the nation’s economy.

Performance measures can be used with highway systems and segments to monitor the effectiveness of operational strategies and to assess the success of achieving targets commonly called yardsticks or benchmarks. In an operational context these measures can be used in “near real-time” to assess the performance of the highway system and implement operational strategies to improve or maximize throughput or to minimize delay. Many agencies are now using performance measures to achieve operational efficiencies and to improve the reliability of highways similar to the gains that were made in the aviation industry in the 1980s.

Performance measures of operational effectiveness are used in the planning and systems engineering context to prioritize projects, provide feedback on the effectiveness of longer-term strategies, refine goals and objectives, and improve processes for the delivery of transportation services. Performance measures in planning are principally used in reporting trends, conditions, and outcomes resulting from transportation improvements. The Florida DOT’s *Florida’s Mobility Performance Measures Program* (2000) notes the following reasons for using performance measures:

Citizens, elected officials, policy makers, and transportation professionals are seeking new ways of measuring the performance of the transportation system to answer the following questions:

- How do we improve transportation to serve people and commerce in Florida?
- What are we getting from our investment in transportation?
- Are we investing in transportation as efficiently as possible?

Performance measures are needed to answer these questions and to track performance over time. They also provide accountability and link strategic planning to resource allocation. By defining specific measures, the Florida Department of Transportation is able to measure the effectiveness of programs in meeting Department objectives. Secretary of Transportation Tom Barry has stated “We measure ourselves for two reasons—to make sure we are spending the taxpayers’ money as efficiently as possible and to try to improve how we provide transportation to the people of Florida.” Performance measures are becoming an important part of the way government works in Florida, and the Department of Transportation is helping to lead the way in this process.

Pickrell and Neumann (2000) in the presentation “Linking Performance Measures With Decision Making” at the TRB 79th Annual Meeting summarized the following reasons for adopting performance measures:

- **Accountability**—Performance measurement provides a means of determining whether resources are being allocated to the priority needs that have been identified, through reporting on performance and results to external or higher-level entities.
- **Efficiency**—Performance measurement focuses actions and resources on organizational outputs and the process of delivery; in essence, in this context, performance measurement becomes an internal management process.
- **Effectiveness**—Related primarily to planning and goals achievement, performance measurement in this case provides a linkage between ultimate outcomes of policy decisions and the more immediate actions of transportation agencies.
- **Communications**—Performance measurement provides better information to customers and stakeholders on the progress being made toward desired goals and objectives, or deterioration of performance, in some cases.
- **Clarity**—By focusing on the desired ultimate outcomes of decisions, performance measures can lend clarity to the purpose of an agency’s actions and expenditures.
- **Improvement**—Performance measurement allows periodic refinement of programs and service delivery given more intermediate results of system monitoring.

## HOW DO YOU DEFINE HIGHWAY SYSTEMS AND SEGMENTS?

As part of undertaking this synthesis there was a need for defining highway segments and systems for use in the review and analysis of performance measures. The 2000 *Highway Capacity Manual* (HCM) defines a structure consisting of points, segments, and systems (Figure 1). This definition was adopted to limit the range and scope of performance measurement practice for synthesis.

## Generalized Highway System Structure

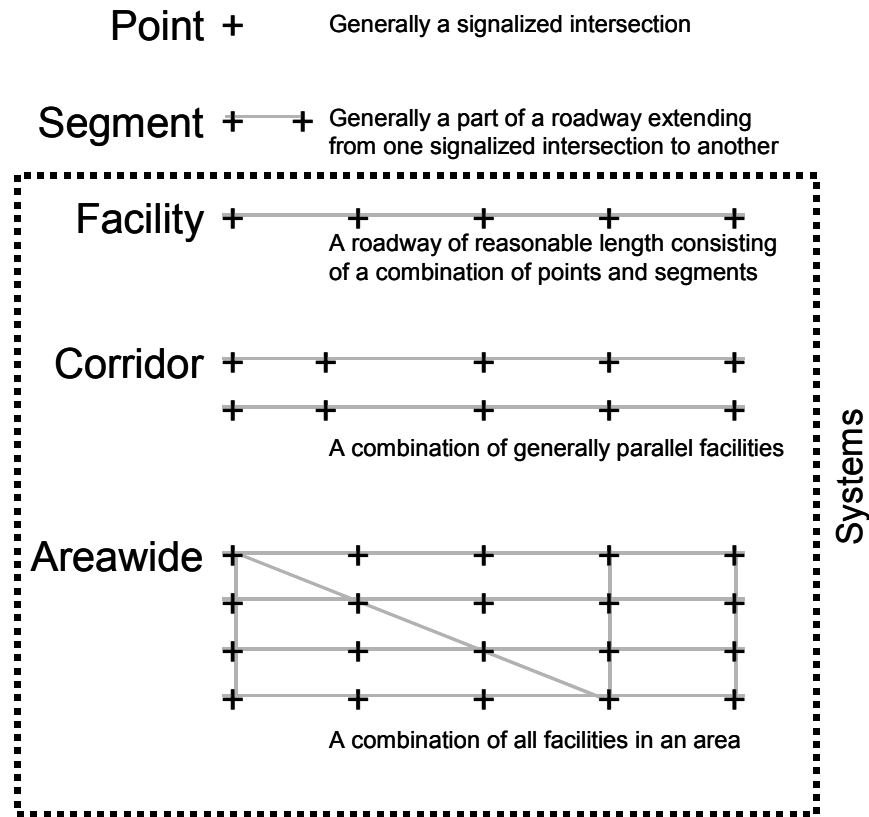


FIGURE 1 Definitions of highway segment and system (HCM 2000).

For the purposes of this synthesis, performance measures related to the operations of highway segments and systems (the facility, corridor, and areawide systems) defined by the HCM were evaluated.

### HOW DO YOU DEFINE PERFORMANCE MEASURES FOR THE OPERATIONAL EFFECTIVENESS OF HIGHWAY SEGMENTS AND SYSTEMS?

The report *Serving the American Public: Best Practices in Performance Measurement* (Office of Management and Budget 1996) recommends that a definition of a measure include

- A specific goal or objective from which it is derived;
- Data requirements, such as the population the metric, and will include the frequency of measurement, and data sources;
- The calculation methodology, including required equations and precise definition of key terms;
- Reports in which data will appear and the graphic presentation that will eventually be used to display data;
- Any other relevant rationale for the measure;

- A clear data collection plan that helps streamline the data collection process
  - Identify how much data needs to be collected, the population from which data will come, and the length of time over which to collect data.
  - Identify the charts and graphs to be used, the charting frequency, the type of comparison to be made, and the calculation methodology.
  - Identify the characteristics of data to be collected; attribute data are things that can be counted and variable data are things that can be measured.
  - Identify existing data sources or create new sources if the performance measure is new. All data sources need to be credible and cost-effective.

Common performance measures for the operational effectiveness of highway systems and segments and their definitions are identified in Table 1. In this table, the source of the measure was defined as either “Survey” (indicating it was a response to the survey of transportation agencies conducted in this research) or “TTI” [indicating the Texas Transportation Institute *Urban Mobility Report* (2001)]. This report is one of

TABLE 1  
COMMONLY USED PERFORMANCE MEASURES FOR THE OPERATIONAL EFFECTIVENESS OF HIGHWAY SYSTEMS AND SEGMENTS

Performance Measures	Typical Definition	Source	Planning Processes	Quality Initiatives	Respond to Legislative Mandates	ITS Evaluations	ITS Operations	Safety Management Systems	Congestion Management Systems	Public Information Programs	Driveway Permits	Responses (%)
Commercial vehicle safety violations	Number of violations issued by law enforcement based on vehicle weight, size, or safety	Survey	•			•	•	•		•		1.0
Congestion cost per capita	Annual “tax” per capita	TTI	•	•	•			•	•	•		
Congestion cost per eligible driver	Annual “tax” per driver	TTI	•	•	•			•	•	•		
Delay caused by incidents	Increase in travel time caused by incidents	Survey				•	•	•		•		3.0
Delay per capita	Annual time per person	TTI	•	•	•			•	•	•		
Delay per eligible driver	Annual time per driver	TTI	•	•	•			•	•	•		
Density	Passenger cars per hour per lane	Survey	•				•				•	3.0
Duration of congestion	Period of congestion	Survey	•	•	•	•	•	•	•	•		5.0
Evacuation clearance time	Reaction and travel time for evacuees to leave an area at risk	Survey	•	•	•	•	•	•	•	•		1.0
Incidents	Traffic interruption caused by a crash or other unscheduled event	Survey	•	•	•	•	•	•	•	•	•	6.0
Level of service (LOS)	Qualitative assessment of highway point, segment, or system using “A” (best) to “F” (worst) based on measures of effectiveness	Survey	•	•	•	•	•	•	•	•	•	11.0
Percent of system congested	Percent of miles congested (usually defined based on LOS E or F)	Survey	•	•	•	•	•	•	•	•	•	5.0
Percent of travel congested	Percent of vehicle-miles or person-miles traveled	Survey	•	•	•	•	•	•	•	•		4.0
Rail crossing incidents	Traffic crashes that occur at highway–rail grade crossings	Survey				•	•	•		•		3.0
Recurring delay	Travel time increases from congestion, but does not consider incidents	Survey	•	•	•	•	•		•	•		3.0
Response time to weather-related incidents	Period required for an incident to be identified and verified and for an appropriate action to alleviate the interruption to traffic to arrive at the scene	Survey				•	•	•		•		1.0



TABLE 1 (Continued)

Performance Measures	Typical Definition	Source	Planning Processes	Quality Initiatives	Respond to Legislative Mandates	ITS Evaluations	ITS Operations	Safety Management Systems	Congestion Management Systems	Public Information Programs	Driveway Permits	Responses (%)
Roadway congestion index	Cars per road space	TTI	•	•	•			•	•			
Security for highway and transit	Number of violations issued by law enforcement for acts of violence against travelers	Survey	•	•	•			•		•		1.0
Speed	Distance divided by travel time	Survey	•	•	•	•	•	•	•	•	•	7.0
Toll revenue	Dollars generated from tolls	Survey	•	•	•					•		1.0
Traffic volume	Annual average daily traffic, peak-hour traffic, or peak-period traffic	Survey	•	•	•	•	•	•	•	•	•	11.0
Travel costs	Value of drivers time during a trip and any expenses incurred during the trip (vehicle ownership and operating expenses, tolls, or tariffs)	Survey	•	•	•	•	•	•	•	•		3.0
Travel rate index	Amount of extra travel time	TTI	•	•	•			•	•	•		
Travel time	Distance divided by speed	Survey	•	•	•	•	•	•	•	•	•	8.0
Travel time reliability	Several definitions are used that include (1) variability of travel times, (2) percent of travelers who arrive at their destination within an acceptable time, and (3) range of travel times	Survey	•	•	•	•	•	•	•	•		1.0
Vehicle-miles traveled	Volume times length	Survey	•	•	•	•		•	•	•	•	10.0
Vehicle occupancy	Persons per vehicle	Survey	•	•	•				•	•		5.0
Wasted fuel per capita	Extra fuel due to congestion	TTI	•	•	•			•	•	•		
Wasted fuel per eligible driver	Extra fuel due to congestion	TTI	•	•	•			•	•	•		
Weather-related traffic incidents	Traffic interruptions caused by inclement weather	Survey				•	•	•		•		3.0

Notes: Percentages do not sum to 100% due to rounding.

the most commonly referenced sources of performance trends and conditions of congestion on the nation's highways. It provides basic system-level summary statistics of congestion in the nation's 78 largest metropolitan areas based on data provided from the Highway Performance Monitoring System (HPMS) and extrapolations of national derived assumptions.

Most performance measures used today are defined based on established programs such as the HPMS and the *Highway Capacity Manual* (various editions published since 1965). Recently, however, several performance measures have evolved for which no common definition is being used. One such area of particular importance is the travel reliability of highway segments and systems.

## WHAT ARE THE KEY STEPS IN PERFORMANCE-BASED MANAGEMENT?

The FHWA recently adopted the following key steps from the U.S. General Accounting Office, *Executive Guide: Effectively Implementing the Government Performance and Results Act* (1996, pp. 8–46.) for use in developing performance measures at the national level.

- Define mission and goals (including outcome-related goals)
  - Involve key stakeholders in defining missions and goals.
  - Identify key factors that could significantly affect the achievement of the goals.
  - Align activities, core processes, and resources to help achieve the goals.
- Measure performance
  - Develop a set of performance measures at each organizational level that demonstrate results, are limited to the vital few indicators for each goal at each organizational level, respond to multiple priorities, link to responsible programs, and are not too costly.
- Collect sufficiently complete, accurate, and consistent data to document performance and support decision making at various organizational levels.
- Report performance information in a way that is useful.
- Use performance information
  - Use performance information in systems for managing the agency or program to achieve performance goals.
  - Communicate performance information to key stakeholders and the public.
  - Demonstrate effectiveness or program performance.
  - Support resource allocation and other policy decision making.
- Reinforce performance-based management
  - Devolve decision making with accountability for results.
  - Create incentives for improved management and performance.
  - Build expertise in strategic planning, performance measurement, and use of performance information in decision making.
  - Integrate performance-based management into the culture and day-to-day activities of the organization.