



## Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes

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**The Second**

**S T R A T E G I C   H I G H W A Y   R E S E A R C H   P R O G R A M**



**SHRP 2 REPORT S2-L05-RW-1**

# Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes

CAMBRIDGE SYSTEMATICS, INC.

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**TRANSPORTATION RESEARCH BOARD**

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The need for SHRP 2 was identified in *TRB Special Report 260: Strategic Highway Research: Saving Lives, Reducing Congestion, Improving Quality of Life*, published in 2001 and based on a study sponsored by Congress through the Transportation Equity Act for the 21st Century (TEA-21). SHRP 2, modeled after the first Strategic Highway Research Program, is a focused, time-constrained, management-driven program designed to complement existing highway research programs. SHRP 2 focuses on applied research in four areas: safety, to prevent or reduce the severity of highway crashes by understanding driver behavior; renewal, to address the aging infrastructure through rapid design and construction methods that cause minimal disruptions and produce lasting facilities; Reliability, to reduce congestion through incident reduction, management, response, and mitigation; and Capacity, to integrate mobility, economic, environmental, and community needs in the planning and designing of new transportation capacity.

SHRP 2 was authorized in August 2005 as part of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The program is managed by the Transportation Research Board (TRB) on behalf of the National Research Council (NRC). SHRP 2 is conducted under a memorandum of understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and the National Academy of Sciences, parent organization of TRB and NRC. The program provides for competitive, merit-based selection of research contractors; independent research project oversight; and dissemination of research results.

SHRP 2 Report S2-L05-RW-1

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## FOREWORD

William Hyman, *SHRP 2 Senior Program Officer, Reliability*

The objective of Project L05, Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes, was to provide guidance to transportation planning agencies about how to incorporate reliability into the transportation planning, programming, and budgeting processes. This report reviews domestic and international literature describing current research and state of the practice in using travel time reliability in transportation planning; summarizes case studies from agencies working to incorporate reliability into their transportation planning processes; summarizes travel time reliability performance measures, strategies for improving travel time reliability, and tools available for measuring the impacts strategies have on travel time reliability; and describes the framework for incorporating reliability performance into transportation planning processes.

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Virtually all transportation agencies have a strong customer orientation. An important concern of road users is congestion that is both recurring and nonrecurring. Recurring congestion is periodic in nature, such as rush hour or holiday travel. Nonrecurring congestion is unexpected and is due to crashes, weather, unfamiliar work zones, special events, failure of traffic control devices, surges in demand, and the interaction of inadequate base capacity with these factors. All these sources of congestion affect travel time reliability.

In the past decade or two, agencies have begun to collect data and measure reliability; in other words, they are measuring how travel time varies over time. A critical question is how agencies should use their limited funds to achieve more cost-effective outcomes, such as improved congestion, and consequently reduce delay and less reliable travel times. A related, critical question is, can greater collaboration both within and outside their agencies result in better programs and projects that achieve agency objectives, including improving travel time reliability?

With the enactment of Moving Ahead for Progress in the 21st Century (MAP-21), state and metropolitan transportation agencies must adopt performance-based planning and programming that embraces measures and targets for travel time reliability along with safety, infrastructure condition, congestion reduction, sustainability, freight movement and economic vitality, and reduced project delivery delays. Performance-based planning and programming is expected to address future highway and other transportation needs and how to obtain better results, provide a feedback mechanism for assessing progress, and provide a framework for undertaking expenditure decisions—in particular, steering resources toward improving an agency's performance.

Over many decades transportation decision making has become increasingly challenging and complex for reasons ranging from technological change to growing environmental concerns. Erosion in gas tax revenues has exacerbated the problem. Many transportation agencies continue to emphasize major highway construction, either new construction or large reconstruction projects. Other transportation agencies give the highest priority to maintaining the transportation system they now have, both its physical condition and operational functionality.

Whatever their posture and priorities, transportation agencies will need to carry out their work within the context of MAP-21. To do this will often require revised policy, more foresight,

organizational change, and a willingness to determine the best use of money, to the extent that laws and regulations allow, across stovepipes as opposed to sticking with customary divisions of resources. Also, agencies will need a process for allocating their limited funds across the huge number of competing demands on the transportation network.

It will be imperative to identify and illuminate for all key stakeholders trade-offs among the key goal areas, including those of MAP-21, as well as to account for benefits that should be monetized. The categories of benefits that have been monetized and compared to costs have historically consisted of avoidable accidents, avoidable vehicle operating costs, avoidable travel time, and sometimes avoidable emissions. As a result of research from many parts of the world, including SHRP 2 in the United States, it appears that drivers on many types of trips value improvements equal to a substantial fraction of improvements in average travel time. It is likely that improvements in travel time reliability will increasingly be included among the benefits expressed in terms of money. While the benefits of all types of improvements, including major projects, will increase, overall operational improvements will be more cost-effective.

SHRP 2 Project L05 has resulted not only in a report but also in a guide; a technical reference; a case study report; and three spreadsheets. The guide is an easy-to-read explanation aimed at managers and others about how to incorporate travel time reliability into planning and programming through a collaborative process. The guide introduces the concept of travel time reliability, identifies various reliability measures, explains how to incorporate reliability in policy statements, describes how to evaluate reliability needs and deficiencies, and, finally, offers suggestions on how to incorporate reliability measures into program and project investment decisions.

The technical reference amplifies the information in the guide and is aimed at analysts. Highlights include tools and methods for estimating reliability suitable for planning, conducting a reliability analysis, incorporating reliability into benefit-cost analysis, and improving an agency's planning and programming capability. If an agency can climb the ladder to higher levels of organizational capability and maturity, operations is then likely to be treated in an even-handed manner alongside construction, maintenance, safety, and other modes.

The L05 case study report is actually a series of case studies from the L05 research. The case studies depict much of the process for incorporating reliability into planning and programming and also serve to validate portions of the material in the guide and in the technical reference.

The L05 researchers also prepared three simple spreadsheets for several of the case studies. These spreadsheets are instructive regarding how to incorporate reliability into sketch planning methods.



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## CHAPTER 1

# Introduction

The objective of SHRP 2 Reliability Project L05, Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes, is to provide guidance to transportation planning agencies on incorporating reliability into the transportation planning, programming, and budgeting processes. This final report summarizes this effort, providing a foundation of knowledge and research on which the products of this project were developed.

Chapter 2 of the final report reviews domestic and international literature describing current research and practical use of travel time reliability in transportation planning. Chapter 3 summarizes results from a survey of state departments of transportation (DOT) and metropolitan planning organizations (MPO) that uncovers the current state of the practice of using travel time reliability in transportation planning. Chapter 4 summarizes case studies of agencies that currently are working to incorporate reliability into their transportation planning processes. Chapter 5 summarizes the technical reference (travel time reliability performance measures, strategies for improving travel time reliability, and tools available for measuring the impacts strategies have on travel time reliability); and Chapter 6 describes the framework for incorporating reliability performance into the transportation planning process. Figure 1.1 shows the overall structure of the L05 research project and describes the linkages among its deliverables. The key deliverables of this project are (1) the guide, a brief, descriptive how-to that explains how to incorporate reliability into the key steps in transportation planning and programming; and (2) the technical reference, a detailed how-to for estimating reliability.

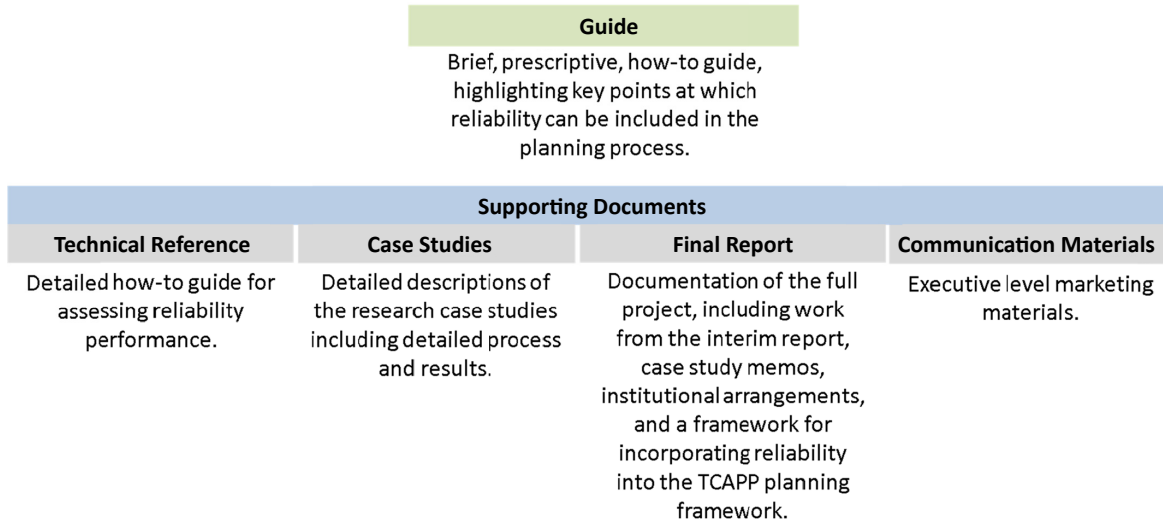
The terms *travel time reliability* and *reliability* are used interchangeably in this report. The remainder of the introduction summarizes the findings from each of these efforts.

### Literature Review

Chapter 2 of this report summarizes the literature on reliability performance measurement and the use of travel time reliability within the planning process. The literature contains

information about how to implement reliability in the planning process; however, success in accomplishing this is rare other than with the selection of measures. The following are among key findings from the literature review:

- *Travelers care about reliability.* The public and decision makers express reliability issues and concerns frequently during comment periods, and the literature finds that drivers place significant value on reliability when making travel decisions. Some regions are responding to this by providing a variety of regional, project, and program reports on reliability, but there remains a gap between the concern over reliability and the use of the concept in planning. The L05 project targets this gap.
- *Agencies monitor travel time reliability, but many do not yet use it in planning.* Travel time reliability monitoring and reporting efforts are detailed and used by many transportation agencies, but are not commonly used in formal transportation planning. This chapter describes the several best-practice examples of agencies that have been incorporating reliability into their planning processes. The L05 guide explains how to incorporate travel time reliability into the transportation planning and programming process.
- *Several sources of travel time data estimate reliability performance measures.* The emergence of continuous speed monitoring, including by the private sector, has made traffic speed data available to more agencies. Agencies can combine these speeds with traffic volume and roadway inventory databases to measure multiple facets of traveler mobility, including reliability. As agencies become more familiar working with travel time data sources, they can turn to available procedures to calculate reliability measures. The L05 technical reference will explain how to find, collect, and analyze travel time data to estimate performance measures.
- *Operations can be incorporated into the planning process.* The Federal Highway Administration (FHWA) and others have developed several guidebooks for incorporating transportation system management and operations into a



**Figure 1.1. SHRP 2 L05 deliverable relationships.**

performance-based transportation planning process. The approach is built to help MPOs and DOTs develop transportation improvement programs that include management and operations projects and fulfill federal requirements.

- *Long-range transportation planning models cannot forecast reliability.* There is little experience using long-range transportation planning models to estimate reliability directly. Recent research [e.g., SHRP 2 L03 (1)] developed sketch planning and travel demand model post-processing techniques that can be used to estimate travel time, congestion, and reliability performance measures. These methods can be implemented without significant modifications to existing travel demand models and would allow planners to project future reliability, similar to the way other performance measures can be projected. The L05 technical reference will explain how to use transportation planning models and analysis techniques to forecast reliability performance measures.
- *Reliability can be monetized.* This may be a promising method for incorporating travel time reliability into the transportation planning process and, in particular, into benefit-cost analysis. Results of several research studies suggest the value of unreliable travel time is between 0.8 and 1.5 times the value of average travel time. The L05 guide and technical reference explain how to incorporate the monetized value into the transportation planning process.

### State of the Practice

Chapter 3 of this report presents a summary of a state-of-the-practice survey conducted with state DOTs and MPOs. Larger DOTs and MPOs (representing the more populous regions and states) are far more likely to collect travel time data, track performance measures, and define and measure travel time

reliability. Only a few agencies monetize reliability in a meaningful way or use it in their planning and programming products and processes.

The state-of-the-practice survey revealed significant interest in travel time reliability among transportation agencies. Ninety-two responses were received, with responses from 29 state DOTs and 39 MPOs. More than half of responding agencies reported tracking or planning to track reliability performance measures. However, travel time data and measures are used infrequently in the planning process. When reliability is included in the planning process, it is most likely to be a goal or objective in an agency’s Long-Range Transportation Plan (LRTP) or congestion management process (CMP). Nearly 20 agencies do identify reliability deficiencies or needs in CMPs and other planning products and processes. Only a few agencies use reliability to help prioritize projects.

Over 60% of survey respondents noted lack of data availability as a challenge to incorporating reliability into the planning process. As noted in the literature review, travel time data are becoming more readily available. This response indicates that DOTs and MPOs are not uniformly aware of the increasing availability of data. Over 50% of respondents indicated that the newness of the subject area was a challenge, and nearly 45% of respondents indicated a lack of staff. About one-third of agencies said that there is “no clear way to link reliability with planning and programming process,” indicating a strong interest and need for the guide and technical reference developed as part of this project.

### Validation Case Studies

Chapter 4 of the report presents the SHRP 2 L05 approach to conducting validation case studies. Each case study focused on an agency working to incorporate reliability performance into

one or two of the key transportation planning process steps. The case studies were selected from a pool of agencies working to incorporate reliability based on the following criteria:

- *Understanding of reliability.* Different agencies have different levels of sophistication and understanding of performance measures in general and travel time reliability performance measures in particular; levels of sophistication should be addressed to the degree possible.
- *Area size.* Metropolitan regions face different degrees of congestion and reliability problems. Validation case studies need to include agencies that represent a range of sizes, although it is likely that all of the agencies will be in transportation management areas (TMA), which include regions with more than 200,000 people.
- *Agency type.* DOTs and MPOs have different requirements and responsibilities. It is anticipated that most of the validation case studies will generally include both state DOTs and MPOs.
- *Work product.* Planning products require a range of transportation planning tools, processes, and institutional arrangements; each planning product needs to be addressed.
- *Geographic coverage.* Each region of the United States has different conditions based on weather, prevailing development style, emergency evacuation considerations, and geography; each region needs to be addressed.

## Reliability Measures and Strategies

Chapter 5 of the report describes the contents of the technical reference, which covers reliability performance measures, strategies to address reliability, and how they relate to each other. Research suggests a clear link between the implementation of transportation improvement strategies and an actual improvement in travel time reliability. This linkage will encourage planners and programmers to incorporate travel time reliability performance measures into transportation planning, programming, and budgeting processes. For example, the SHRP 2 L03 research concluded that reliability is a feature or attribute of congestion, not a distinct phenomenon, and found that reliability cannot be considered in isolation. This finding has several implications.

- Most strategies are likely to improve average congestion and reliability. In addition, a small, specialized set of strategies (e.g., hurricane evacuation) is aimed at mitigating the effect of high impact, extremely rare events. These strategies will have little effect on average congestion and reliability, as defined by the performance measures in this report, but are an important facet of transportation operations. Additional capacity (in relation to demand) makes a roadway able to

absorb the effects of some events that would otherwise cause disruption. One implication of this tendency is that not accounting for the reliability benefits of all strategies leaves some benefits to users unaccounted for.

- Most management and operations strategies designed to minimize disruptions (e.g., incident management) can only improve congestion when those disruptions appear, but the disruptions only appear periodically. Although most maintenance and operations strategies do not affect the underlying root causes of congestion, they are critical for addressing travel time reliability.
- Transportation system operators can use volume-to-capacity ratios to allocate management and operations strategies more efficiently. That is, the ratios can help them implement strategies at times and locations that are most vulnerable to flow breakdowns.

Table 1.1 summarizes the reliability performance measures commonly used in practice. SHRP 2 L03 researchers suggest using the planning-time index as the best single reliability measure for urban conditions because it produces consistent and intuitive results. However, researchers recognize that different reliability measures may be appropriate for different audiences or analyses. Strategies that have the potential to improve reliability include a range capacity, operations, travel demand management, and addressing all modes of travel. Analytical tools for estimating reliability and evaluating strategies are referenced in Chapter 5, including sketch-planning methods, travel models, and simulation. The technical reference includes more detail.

## Framework for Incorporating Reliability into Planning and Programming

This report provides a review of the literature and state of the practice in the use of reliability performance measures in the transportation planning and programming process. Many transportation agencies understand the concept of reliability and recognize the reliability challenges their systems face, but few are actively using reliability performance measures to make decisions about how to make program or project-level investment. From the literature review, there is a clear base of knowledge on which to build an approach to addressing reliability in the planning and programming process, but many agencies do not feel they have access to the information they need.

Based on the review conducted as part of this effort, the research team developed a framework for incorporating reliability into the planning and programming process. The framework was built on the understanding from the state of the practice survey of what transportation agencies need and want out of this effort. Chapter 6 of the report presents the

**Table 1.1. Reliability Performance Measures (1)**

Reliability Performance Metric	Definition	Units
Planning-Time Index	95th percentile travel time index (95th percentile travel time divided by the free flow travel time)	None
Buffer Index (BI)	The difference between the 95th percentile travel time and the average travel time, normalized by the average travel time The difference between the 95th percentile travel time and the median travel time, normalized by the median travel time	Percent
Failure/On-Time Measures	Percent of trips with travel times less than 1.1 * median travel time or 1.25 * median travel time Percent of trips with space mean speed less than 50 mph; 45 mph; or 30 mph	Percent
80th Percentile Travel Time Index	80th percentile travel time divided by the free flow travel time	None
Skew Statistic	(90th percentile travel time minus the median) divided by (the median minus the 10th percentile travel time)	None
Misery Index (Modified)	The average of the highest 5% of travel times divided by the free flow travel time	None

framework, and Appendix B provides further explication for how the framework relates to the cornerstone product of the SHRP 2 Capacity program, PlanWorks, formerly known as Transportation for Communities—Advancing Projects through Partnership (TCAPP).

The final report is accompanied by an in-depth technical reference that provides detailed background and instruction describing how to collect travel time data and how to select and evaluate reliability performance measures using the full range of available analytical tools and methods. The primary audience for the technical reference is technical staff members within DOTs and MPOs who need detailed information to estimate and forecast reliability performance.

The guide is written for planning, programming, and operations managers and focuses on the choices and options that need to be made to integrate reliability into the planning and programming process. The guide describes how agencies can address reliability in the development of key planning products (e.g., long-range plans, transportation improvement programs) and processes (measuring and tracking reliability, examining

reliability in policy statements, evaluating reliability needs and deficiencies, and incorporating reliability into program and project investment decisions). The primary audience for the guide is management staff members who want to understand what they could be doing to incorporate reliability into the planning process.

Detailed case studies were also created as part of the L05 project to develop and validate the guidance and techniques presented in the guide and the technical reference. *Case Studies in Using Reliability Performance Measures in Transportation Planning* describes the detailed findings from each of the case studies (<http://www.trb.org/main/blurbs/168854.aspx>).

## Reference

1. SHRP 2 Project L03 Report S2-L03-RR1: *Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies*. Transportation Research Board of the National Academies, Washington, D.C., 2013. <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2179>.

## CHAPTER 2

# Literature Review

Chapter 2 of this report describes the literature on measurement, value, and use of travel time reliability in planning. While interest in travel time reliability is growing, few transportation agencies are actively using reliability performance measures within their planning and programming processes. For example, at a 2007 conference on MPO capacity-building needs, reliability and analytical improvements for estimating and forecasting reliability were not raised as major topics (1). While there has been significant research domestically and internationally on the topic in recent years, relatively few studies have been done on the role of reliability in transportation planning. Planners are beginning to conceptualize the relationships and procedures to incorporate reliability issues into the planning process. Operators are working to understand reliability analysis methods and performance measures. However, significant work remains to raise the overall exposure of reliability within the planning process.

This literature review covers several topics, including the value of travel time reliability, the use of reliability within the planning process (including how transportation agencies plan for operations), the measurement of reliability, and the important relationship between freight planning and reliability. Freight is addressed separately because of the importance of transportation system reliability for just-in-time delivery and the increased national focus that freight planning has received in recent years.

### Travelers Value Travel Time Reliability

Research clearly indicates that travelers place a value on the reliability and predictability of their travel. Transportation agencies that include travel time reliability benefits are able to develop a more comprehensive benefits assessment of a transportation project. Additionally, agencies that appreciate the value of travel time reliability can begin to consider it as an important mobility factor in their transportation planning

processes and products. The L05 project will provide guidance on how to integrate reliability measures into project assessment and more globally into transportation planning.

Gaver investigated traveler reactions to variability in travel time and found that travelers will plan to depart early when they anticipate a variance in travel time (2). Knight used travelers' response data to estimate a "safety margin" (3). Small empirically established that the timing of commuter departures is greatly affected by scheduling costs (4). Noland and Small built on this theory accounting for how departure times are related to different levels of congestion (5). These findings paved the way for researchers to determine how travel time reliability affected the utility of travel and mode and route choices. Black and Towriss conducted a stated-preference survey in London and found that the standard deviation of travel time is a significant and negative attribute in the travelers' utility function (6). Guttman observed that risk-averse travelers chose the transportation mode or route with lesser travel time variability, whichever that may be (7). Results of a stated-preference survey in southern California by Abdel-Aty et al. showed that the number of respondents selecting a route with more travel time variability decreased substantially when the standard deviation of travel time was greater than half the mean travel time (8).

On the basis of stated-preference surveys, Sullivan observed that some express-lane users prefer toll lanes even when the value of average travel time is less than the toll paid; driving safety and comfort were the primary reasons for this behavior, with travel time reliability a "distant" third reason (9). In direct contrast to this finding, the results of a panel survey of users of San Diego's I-15 express lanes conducted by Supernak et al. indicated that travel time reliability was the primary reason for choosing the express lanes in the morning peak hours (10). Ghosh observed a similar reason for the use of the express lanes (11). Tseng et al. and Small et al. observed that people with rigid arrival and departure times place a greater emphasis on the value of reliability (12, 13).

Small et al. observed that travelers experienced better service quality in express lanes because of travel time savings and travel time reliability (13). Travel time savings account for two-thirds of the service quality differential between free and express lanes, and travel time reliability accounts for the remaining one-third.

Pozdena et al. used options theory to define the value of reliability as “The reduction in average speed that I would be willing to accept in return for elimination of the risk of slower speeds” (14). They called the acceptable reduction in speed the “certainty-equivalent” value of reliability. They estimated the value to be 0.09 min per mile for single occupant vehicles, high-occupant vehicles, and trucks.

## Planning for Reliability

The literature suggests that while many agencies measure performance in some areas, few actively integrate measures into transportation planning, and many do not calculate or use travel time reliability measures. While agencies often do not integrate reliability performance *measures* into planning, they often do include the *concept* of reliability in their policy statements (i.e., goals and objectives). Innovative international transportation agencies have integrated reliability measures into planning through a project evaluation process and by creating reliability performance targets. For example, the United Kingdom incorporated the value of reliability into a process for detailed transportation project appraisal, including establishing a rationale for the investment, setting objectives for the investment, and quantifying the costs and benefits. The Dutch set specific travel time reliability goals in their 15-year transportation plan; and, while the Australians do not tie near-term or long-range investment plans to specific reliability performance measures, they do consider travel time variability in benefit-cost analysis.

While researchers in the past decade have produced a substantial body of work aimed at incorporating operations into the transportation planning process, operations planning often is still not included. Transportation operators and planners often work in distinct institutional silos with communication between these silos somewhat limited. At the statewide and metropolitan levels, operations staff often focuses more on coordinating operations activities (signal timing, incident responses) than on major investment planning. Only a few states have formal statewide transportation plans that identify transportation system management and operations (TSM&O) projects and costs.

## Transportation Planning

Federal Highway Administration’s (FHWA) Monitoring Metropolitan Mobility Program was the first multiregion effort to

collect and report reliability performance measures (15). Subsequent metropolitan region studies, including the Georgia Regional Transportation Authority’s Metropolitan Atlanta Performance (MAP) Report, are becoming important components of the public discussion about improvement programs and their effect (16).

Lyman and Bertini analyzed the contents of 20 regional transportation plans from across the country to determine the use of travel time reliability and its value as a congestion measure (17). The study found the most common measures of congestion to be volume-to-capacity ratio, vehicle hours of delay, and mean speed; all measures are based on average travel conditions. The study found that travel time reliability was not used as a measure of congestion in any of the regional transportation plans reviewed. Researchers concluded that MPOs should use travel time reliability by

- Incorporating it as a system-wide goal;
- Evaluating roadway segments according to travel time reliability measures; and,
- Prioritizing roadway segments using those measures.

Many states include performance measures in state long-range transportation planning efforts. The most common performance measures at a system level include travel time delay, travel-rate index, and reliability, although these are far from used universally by DOTs.

Researchers noted that the integration of operations programs like Nevada’s Integrated Transportation Reliability Program (ITRP) and Las Vegas’ Freeway and Arterial System of Transportation (FAST) into the MPO functions provides a useful model for future partnerships. The blend of expertise and mission enable flexible responses to problems and cost-effective programming (1).

The Minnesota Statewide Transportation Plan recommends several strategies to improve travel time reliability, including incident management programs, ice and snow removal, and strategies to improve operations at border crossings, inland waterway lock operations, and weigh stations (18). The Minnesota Department of Transportation (DOT) measures average clearance time for incidents on the instrumented portion of the Twin Cities metropolitan area urban freeway system that occur between 6:00 a.m. and 7:00 p.m. on weekdays to track the performance of its incident management strategy. The DOT has set a goal to hold the clearance time near existing levels to reduce as much nonrecurring delay caused by incidents as possible. Minnesota has a long history of measuring the performance of this program; it has been tracking this measure since 1993. While the Minnesota DOT does not run the program, the metropolitan area traffic management center (TMC) dispatches incident management teams and notifies other agencies involved in incidence clearance.

Srivavidurage et al. of the University of Leeds forecasted day-to-day variability in travel time on the UK motorway network (19). Several studies had analyzed urban street travel time variability; this study extended the analysis to motorways to provide the UK Department for Transport information about the potential benefits of transport schemes or policies. Managed motorway systems, such as mandatory variable speed limits and hard shoulder running, were noted as possibly providing significant day-to-day travel time variability benefits. The research team was commissioned by DfT to carry out the project to calibrate functions for predicting the day-to-day variability on several road types and to incorporate these into the Incident Cost-Benefit Assessment (INCA) software (20). As well as day-to-day variability, INCA calculated delays and travel time variability costs relating to incidents, as well as the benefits from improvement strategies.

INCA is one of many tools used in the UK for project appraisal, or project development and evaluation. The DfT prepared the Green Book (GB), Appraisal and Evaluation in Central Government, to guide the appraisal process for transportation investments (projects, programs, or policies), including establishing a rationale for the investment, setting objectives for the investment, and quantifying the costs and benefits. The process also includes monitoring and evaluation, the results of which are fed back in to the process. This detailed methodology is followed for all projects and studies that require government approval, and serves as a best practice guide for projects and studies that do not require government approval. The GB and the analytical tools employed provide a process to ensure that transportation investments are evaluated in a standardized, consistent, and transparent way and that they ask two fundamental questions:

1. Are there better ways to achieve the objectives?
2. Does it provide value for money?

The foundation of what is done in the United Kingdom is termed the New Approach To Appraisal or NATA, representing an updated framework to evaluate and inform the prioritization of transportation investment proposals. NATA aligns with the GB, but has evolved since it was first introduced in 1998, and there has been continued research and enhancements to practice. From a user's perspective, NATA can be considered a body of advice, software, and data products for use in developing proposals for transportation investment. The UK state of the practice was summarized in a 2006 *Eddington Transport Study*, and since that time, the DfT has been enhancing the appraisal framework to account for the Eddington Study's recommendations, with a new more general expansion of the economic analysis framework described by the term *value for money* (21).

The DfT provides extensive guidance, known as Transport Analysis Guidance (TAG), for local agencies on how to conduct

transportation studies for appraisal. A key feature of the DfT's GB is consistency in the accounting conventions applied to all transportation investment studies. NATA analytical tools ensure that transportation proposals are developed and evaluated in a comparable and consistent way. Information about a transportation investment proposal is presented in two ways: with an appraisal summary table (AST) and with extensive supporting documentation.

The TAG approach addresses five transportation goals through a comprehensive set of guidance organized under objectives and sub-objectives. For all sub-objectives, the DfT provides TAG units that include background information on each subject and identify the processes, tools, and data required for quantitative or qualitative analysis. The tools include worksheets, tables, or software recommendations to assist in benefit-cost calculations and scoring. Totals from calculations, scoring, and other results from worksheets are then transferred to the AST. The modular approach of TAG units allows individual units to evolve and be updated over time as new data, tools, and information become available.

The process for updating TAG units includes several stages.

- *For Consultation*: This version of a TAG unit reflects the findings of current research and experience from practitioners in the United Kingdom and elsewhere. Throughout the consultation period, a TAG unit is under public review, and comments concerning ways to improve the guidance are solicited. The guidance may change substantially before being released as "in draft" guidance.
- *In Draft*: Feedback from the "for consultation" version is incorporated and the TAG unit is rereleased. At this point, a TAG unit has passed through the public review process and either no changes or minor changes are made before the TAG unit is formally finalized.

The reliability TAG unit is organized by the DfT under the Economy Objective. This TAG unit provides guidance on calculating the economic impacts of private vehicles, public transportation, and freight. The term *reliability* refers to travel time variability, and in this TAG unit, the impact of a proposed transportation investment on improving travel time reliability for transportation users is assessed:

- Public transportation lateness (delayed arrival time compared with schedule):
  - Average lateness; and
  - The variability of lateness, measured by the standard deviation of lateness.
- Freight and other private transportation, assuming travelers have an average time they expect their trip to take:
  - Reliability should be measured in terms of the unpredictable variability in travel times about these averages, measured by the standard deviation of travel time.



Methodologies for calculating lateness and variability for different modes are established in the TAG. A qualitative score is reported for reliability for instances when quantitative measures cannot be calculated. The DfT provides guidance on scoring and a worksheet so that values for reliability are calculated and presented consistently.

The Dutch national transport policy document, the *Nota Mobility*, lists a number of probabilistic travel time reliability measures that are used to express explicit policy goals for the years 2005 to 2020 (22). The document states that for routes that are shorter than 50 kilometers, at least 95% of all travel times in a certain period should not deviate more than 10 min from the median travel time, while for longer routes, 95% of the travel times should stay within a 20% margin around the median.

Australia's transportation plans in most regions include investments in both road and public transportation capacity and operating improvements. The plans and reporting for both modes include reliability as an element of concern, and, while near-term or long-range investment plans are not tied to specific reliability performance measures, travel time variability is considered in benefit-cost analysis (23). Unreliability is recommended to be included as the standard deviation of trip time for road traffic (though no specific dollar values are suggested), and unexpected waiting time is recommended for public transit (24).

However, specific application of reliability in benefit-cost analysis varies by state and region, as in the United States. Specific examples of the use of reliability measures include the following programs.

- *New South Wales Region:* New South Wales Roads and Traffic Authority measures reliability by monitoring morning and evening average travel times on its seven most important urban routes. It has invested considerably in both operational and capital improvements to sustain travel times as the population grows, including the 1970s Sydney Coordinated Adaptive Traffic System. The computerized traffic control system is used to adapt signal timing to changes in traffic flow. Linking the traffic signals allows the optimization of traffic flow in the regional system.
- *Queensland Region:* The Queensland Department of Transport and Main Roads has a strategic plan to maximize the efficiency of the transportation network. They combined the city and suburban traffic operations units into regional traffic management centers that coordinate the region's urban traffic signals and several local transit bus providers. The agency uses this multimodal approach in their draft long-range plan (25). Travel reliability and traffic management are an agency priority.
- *Victoria Region:* Victoria has produced an annual report on the performance and management of its freeway and

arterial network since 1994. It reports travel speeds, travel volumes, tram speeds and reliability, journey trends by bicycling, and traffic volumes. The report influences program trade-offs and investment in projects to improve reliability. The long-range plan and congestion improvement program recommend improving road and transit service reliability (26).

## Congestion Management

A number of U.S. MPOs have begun to consider reliability measures in their congestion management processes. The Madison Area Transportation Planning Board (TPB) adopted a new, enhanced CMP in November 2011 that establishes performance measures and targets for reliability. At the most basic level, TPB staff wanted reliability measures and targets to relate back to the goals and objectives in their 2035 Regional Transportation Plan, and, specifically, to their goal to achieve a transportation system that is "Reliable—minimizes and alerts persons to unexpected travel delays."

Madison TPB adopted a freeway travel time index goal of 1.75 (i.e., the travel time index for the morning peak period should not exceed 175% of free flow travel time in a specified corridor). They also adopted an urban arterial street travel time index goal of 1.75 (i.e., traffic speeds on 30–40 mph roadways should not experience incident-related speed reductions of more than 30%). All indices will be used on selected corridors beginning in 2013, and performance targets will be modified over time.

The 2011 CMP states, "It is important to understand that [performance] targets do not in themselves establish priorities to guide investment in the transportation system. The MPO Plan and TIP [Transportation Improvement Program] development process will accomplish priority setting in terms of how congestion relief fits with safety, system preservation, and other modal improvement needs in the Madison area. The CMP targets guide choices within the congestion goal area."

The Madison Area TPB adopted reliability measures for the first time in its November 2011 CMP. The Board's challenge was identifying the best performance measures to use, considering the limited data available. The MPO strove to develop a set of measures that included the following items:

- At least one average congestion measure and one travel time reliability measure for each mode of travel.
- Both peak and off-peak measures. While congestion often focuses on peak period commutes, off-peak measures can identify different system problems, including those that can be important to freight movement efficiency.
- The right level of geography, including not only the region, but also key subareas and corridors that reflect primary modal travel patterns.

Madison TPB adopted the travel time index (the ratio of travel time in the peak period to the travel time at free-flow conditions) to measure reliability on freeways and arterials. Staff members noted that the travel time index was easily understandable by their board and the public. “They understand congestion on familiar roadways.”

One major concern noted by Madison TPB staff is that resources are required to implement the CMP and the performance measures. Raw data are available on Interstate roadways and the Beltline in the region, but the MPO is still figuring out the best way for the Wisconsin Department of Transportation (WisDOT) State Transportation Operations Center (STOC) to share the data. The MPO understands that the performance-based framework will evolve over time as data become available. Additional data may result from decisions made to invest in new data collection hardware and software. There is also the potential to purchase additional travel data from private sector vendors. Increased resources will be needed to process, analyze, and archive these new data sources.

The Capital District Transportation Committee (CDTC) adopted an incident-related delay performance measure in its 2007 CMP update. This is monitored through planning-time indices (the ratio of 95th percentile travel time to free flow travel time), which are calculated on Capital District expressway segments for a.m. and p.m. peak periods using Management Information System for Transportation (MIST) data. MIST provides traffic count, speed and incident data for every 15-min interval throughout the year. The system was implemented in the Capital Region in 2000 and collects data from loops embedded in the pavement. Planning-time indices were calculated based on an entire year of data for 2003, and separate indices were calculated for summer and winter travel.

Their 2007 CMP update states, “Although measures of nonrecurring delay and the effectiveness of operational and management strategies cannot be easily modeled for 2030 conditions given state-of-the-art travel models, it is most valuable to consider these measures for current conditions and for CMP planning, since nonrecurring delay represents the most severe and intolerable delay.”

At the beginning of the CMP update, CDTC formed a working group to evaluate potential performance measures. CDTC staff believes this helped expose their policy board to the concept of performance measures in the planning process. Incident-related delay was thought to be effective since it is something the public (drivers) can understand and perceive. It allows the planning-time index to be confirmed anecdotally by drivers on the expressways.

The CDTC plans to work with their regional operations committee to further refine the delay measures and develop measures that can be used to assess the effectiveness of operational and management strategies. Examples of such measures could include frequency of incidents, duration of incidents,

response times for emergency service vehicles and the HELP (Highway Emergency Local Help) program. Efforts are under way to update and refine their data more frequently.

Metropolitan Washington Council of Government’s (MWCOG) 2010 CMP uses planning-time index (the ratio of 95th percentile travel time to free flow travel time) and buffer index (the difference between 95th percentile travel time and average travel time, normalized by normal travel time) to quantify travel time reliability, for each road segment as well as a measure of the average of all the covered highways in the region as a whole. MWCOG staff noted that these indices are a challenge to explain to their board and the public, especially the calculations required to compute the index. To ensure coordination of the CMP with the long-range plan, the CMP results are incorporated into the long-range plan when it is updated and when CMP staff members interact with the necessary long-term planning subcommittees. Further, CMP documentation is included in the agency’s process for soliciting projects. Agencies must submit a congestion management document when proposing to increase single-occupancy vehicle (SOV) capacity and must submit documentation that they have considered CMP strategies in significant federally funded projects.

MWCOG leveraged the I-95 Corridor Coalition/INRIX Vehicle Probe Project data to examine travel time reliability for their 2010 CMP for the first time. This is a complementary data source to Skycomp aerial survey data, which covers approximately 200 centerline miles of freeways and 190 centerline miles of arterials across the COG member jurisdictions. It is also possible for COG to obtain continuous, probe-based data from other valid providers. This includes coverage made available through the efforts of the Virginia Department of Transportation (DOT) on Dulles Toll Road, I-66 inside the Beltway, Virginia Route 7, and Virginia Route 123 around Tysons Corner. Furthermore, Maryland State Highway Administration has been seeking additional coverage beyond the core coverage of the Vehicle Probe Project. It is expected that more facilities in Maryland will be covered in the future. As a result, MWCOG is conducting more robust congestion and reliability analyses in their 2012 CMP update. The agency also believes that up-to-date congestion information would be available as needed to inform decision making.

In estimating planning-time and buffer indices for their 2010 CMP, MWCOG noted that caution is required in interpreting the segment-based planning-time index. According to the 2010 report, “Route or corridor level of planning-time index was not calculated[;] thus one should not interpret the segment-based index as a route or corridor-based index. For example, if all the segments of a corridor have planning-time index of 3.0 (e.g., I-66 EB from Fairfax Parkway to the Beltway), the corridor has a large chance of having a planning-time index less than 3.0. A simple explanation is the worst

condition of each segment on the corridor does not necessarily occur at the same time. Statistically, the 95th percentile travel time of the whole corridor should be less than or, at most, equal to the sum of each segment's 95th percentile travel time."

The 2012 CMP report will expand the segment-based reliability analysis to a corridor-based analysis. Travel time reliability will also be used as one of the performance measures to assess congestion management strategies. While the segment planning-time index gives detailed information about each road segment's reliability performance, travelers may be more interested in route- or corridor-specific reliability.

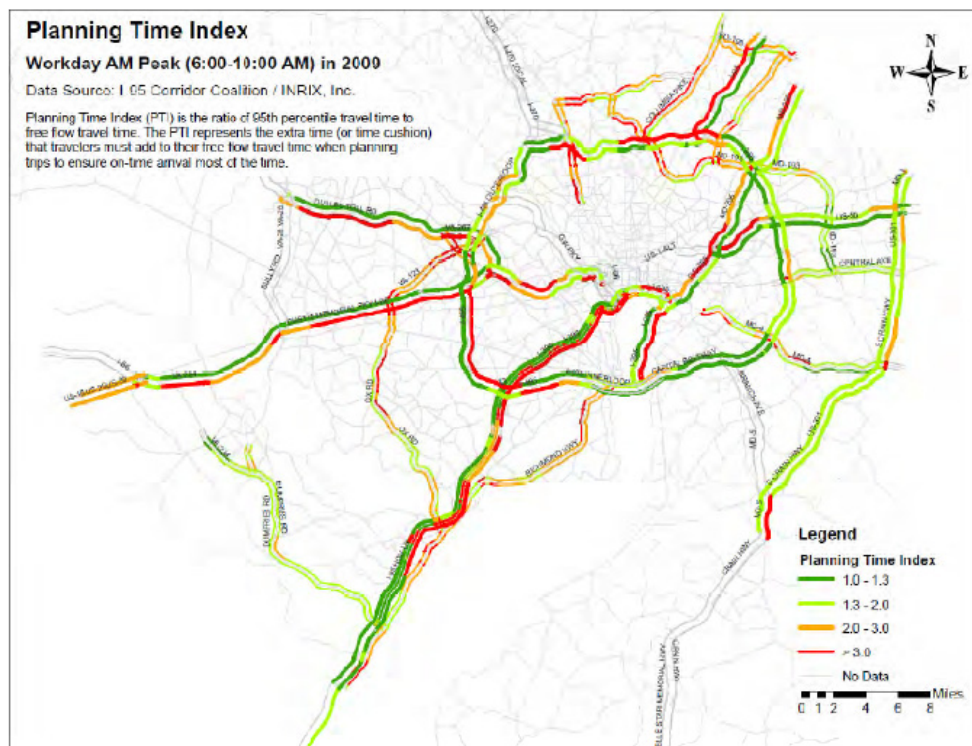
MWCOG staff also observed that the buffer index was not consistent with the average congestion measures and was not stable from year to year (this was also noted in SHRP 2 L03), which makes communication with nontechnical audiences a challenge. The spatiotemporal distribution of the buffer index differs significantly from the travel time index and planning-time index. Increases in the buffer index do not always accompany an increase in congestion. Staff members observed that some usually congested segments had a lower buffer index compared with other segments that were usually less congested. The highest buffer indices do not necessarily equate to the locations with the highest levels of congestion; rather, they equate to the locations with the highest variability and unreliability. Segments that are "reliably bad" (i.e., congested) can

have low buffer indices because the buffer index is a measure of day-to-day differences. MWCOG staff concluded that use of a median-based buffer index and failure rate is preferable to avoid underestimating unreliability. For CMP priorities, the COG uses the planning-time index.

MWCOG's 2010 CMP update contains several best practice examples of visualizing and reporting reliability performance. Figure 2.1 and Figure 2.2 present example maps used by MWCOG. Figure 2.3 presents an example graph showing the month-to-month variations in planning-time index from one year to the next, while Figure 2.4 shows the time of day and day of week variations for a single year.

The San Diego Association of Governments (SANDAG) has had a robust transportation planning process for the past decade. The agency has developed reliability time indices as part of its CMP and its long-range plans. SANDAG uses a planning-time index. The agency has begun work on its next metropolitan transportation plan (MTP) and is working toward aligning its monitoring processes across plans and policies. SANDAG publishes an annual *State of the Commute* report for its planning area that provides updates in the indices and other measures related to reliability. In the annual update, the planning-time index is presented to the public as budget time within the corridor and is quantified in minutes.

Because of its history of using these tools, staff did not identify problems with policy board or public understanding



**Figure 2.1. Example map of planning-time index: Workday a.m. peak (2009) for the I-95 Corridor Coalition–covered highways.**

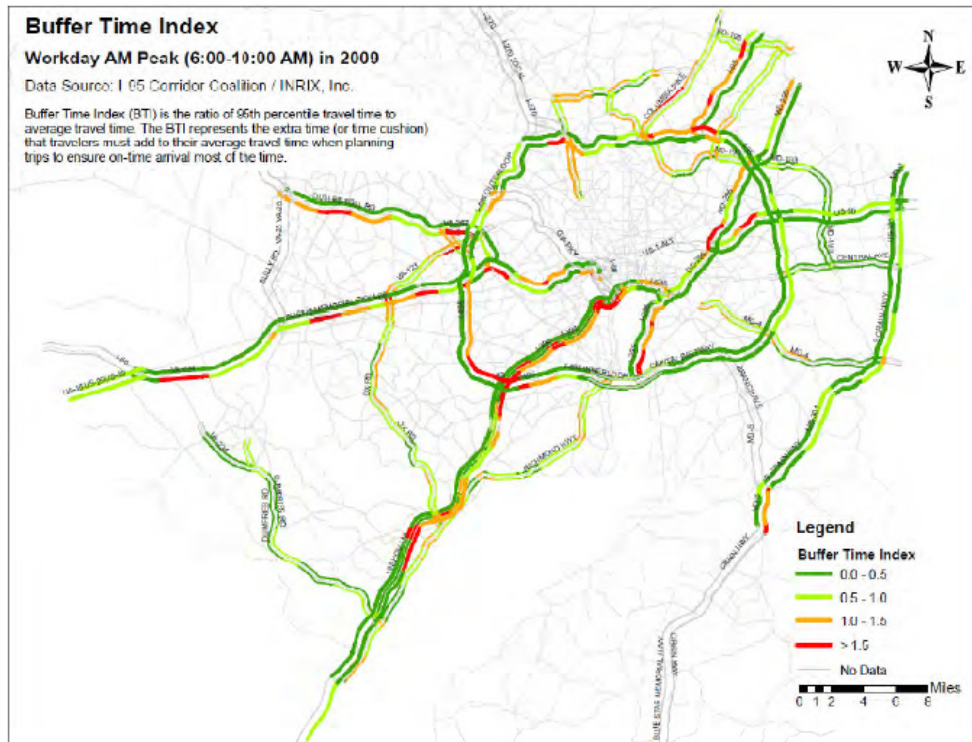


Figure 2.2. Example map of buffer-time index: Workday a.m. peak (2009) for the I-95 Corridor Coalition-covered highways.

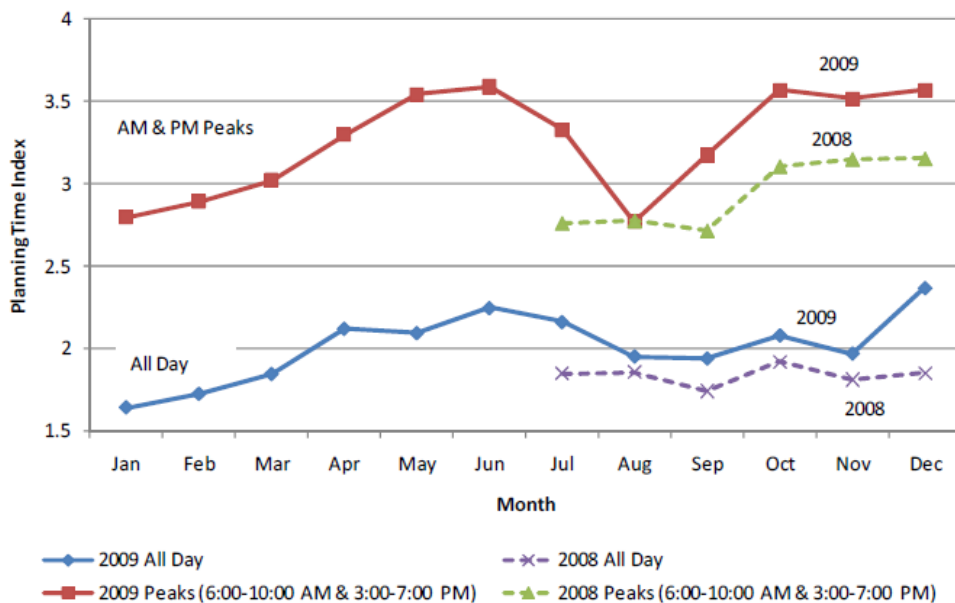
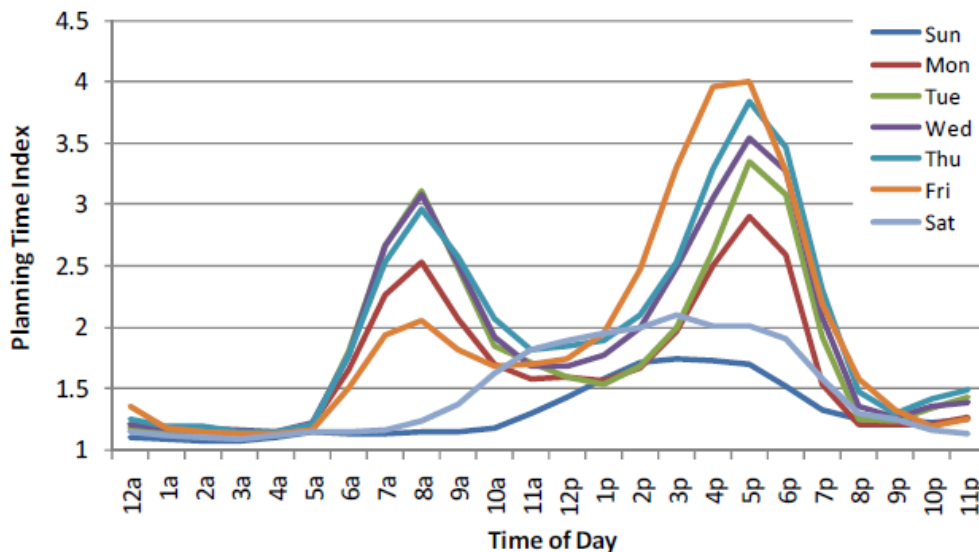


Figure 2.3. Example graph: month-to-month planning-time index variations of a.m. and p.m. peak periods and all day for 12 months in 2009 and the last 6 months in 2008.



**Figure 2.4. Example graph: planning-time index by time of day and day of week (2009) for the I-95 Corridor Coalition-covered highways.**

of the measures or concepts. They did note that measures that are more technical can sometimes be difficult to convey but are nevertheless functional, useful, and comparatively easy to implement, even when such measures are not quickly understood by the public.

SANDAG is implementing an integrated corridor management (ICM) project in its region. It relies on advancements in data processing, sophisticated algorithms, and the development of software applications that provide real-time multimodal modeling and simulation capabilities. It extrapolates historical data and combines it with real-time data to develop dynamic decision support systems (DSS). These DSSs are used to forecast traffic patterns and then analyze and recommend operational changes to minimize or reduce traffic congestion. This technology allows transportation system managers to modify traffic signal timing and ramp meters, provide travelers with route information and options during recurring congestion or incidents, and analyze and develop new transportation system management (TSM) strategies and action plans. This is significant for the North Central Texas Council of Governments (NCTCOG), as they have a similar project for the US-75 corridor.

One of the primary data tools for the ICM is the connected vehicle platform. Connected intelligent vehicles will enable transportation system managers to receive and send enhanced decision-quality data to vehicles about the status of the network. It will enhance the ability of system managers to put into effect proactive congestion management strategies that have the potential to deliver major impacts on travel time reliability.

The program will provide ample amounts of data to system managers and users. In the context of the CMP, the connected

vehicle platform can be used for analysis of performance measures. It will generate data that provides metrics to measure the effectiveness of system operation, including travel time, stops, delays, and travel reliability; condition metrics, including indicators of pavement traction, pavement roughness, precipitation, visibility, and air quality; and demand metrics, such as vehicle counts.

In its 2010 CMP Update, the Maricopa Association of Governments (MAG) developed a project screening process that allows for qualitative assessment of the congestion reduction impacts of candidate projects based on CMP objectives. The intent of the screening tool is to assess the potential impact of a candidate project in terms of CMP objectives, such as minimizing delay, enhancing travel time reliability, and other congestion management objectives.

For example, one of the objectives of the CMP is to promote projects that reduce travel time variability. The ITS Deployment Analysis System (IDAS) measure for travel time reliability and hours of unexpected delay is used. A candidate project would be scored based on its ability to reduce variability, as follows: A score of 1 is assigned if the project has no impact on travel time variability, a score of 2 is assigned if the project may reduce travel time variability, a score of 3 is assigned if the project addresses and will result in a reduction in travel time variability, and a score of 4 is assigned if the project has the highest potential to reduce travel time variability.

Table 2.1 shows the evaluation criteria based on CMP objectives and how they are used to score candidate projects in MAG's CMP Analysis and Screening Process. MAG staff and modal committees consult the project descriptions from the regional transportation plan (RTP), life-cycle program project applications, corridor studies, and the MAG 2009 Performance

**Table 2.1. MAG Qualitative Assessment Criteria Based on CMP Objectives**

CMP Objectives	Evaluation Criteria	Addresses	Score			
			1	2	3	4
1. Minimize delay and improve travel time	<ul style="list-style-type: none"> <li>Increased vehicle throughput</li> <li>VHT reduction</li> <li>Travel time savings</li> </ul>	<ul style="list-style-type: none"> <li>Does the project decrease travel time or delay?</li> </ul>	No impact on travel time or delay	May reduce travel time or delay	Likely to reduce travel time or delay	Highest impact on travel time and delay
2. Reduce travel time variability	<ul style="list-style-type: none"> <li>Travel time reliability (hours of unexpected delay)</li> </ul>	<ul style="list-style-type: none"> <li>Does the project reduce crash risk?</li> <li>Does the project reduce weave/merge conflicts?</li> </ul>	No impact on travel time variability	May reduce travel time variability	Likely to reduce travel time variability	Highest impact on travel time variability
3. Improve system connectivity	<ul style="list-style-type: none"> <li>Network connectivity and completeness</li> </ul>	<ul style="list-style-type: none"> <li>Does this project improve connections to regional intermodal or emergency facilities?</li> </ul>	No impact on system connectivity	May improve system connectivity	Likely to improve system connectivity	Highest impact on system connectivity
4. Increase alternative mode share	<ul style="list-style-type: none"> <li>Vehicle trip reduction/reduce SOV mode share</li> <li>Increased HOV mode share</li> <li>Increased transit mode share</li> </ul>	<ul style="list-style-type: none"> <li>Does the project reduce mode share for drive alone trips?</li> <li>Does the project increase alternative mode share?</li> </ul>	No impact on alternative mode share	May increase alternative mode share	Likely to increase alternative mode share	Highest impact on alternative mode share
5. Improve level of service/ reduce congestion	<ul style="list-style-type: none"> <li>LOS improvement</li> <li>V/C ratio</li> <li>Increased person-throughput</li> </ul>	<ul style="list-style-type: none"> <li>Does the project improve the level of service of the facility?</li> <li>Does this project increase the roadway capacity?</li> </ul>	No impact on congestion	May reduce congestion	Likely to reduce congestion	Highest impact on congestion
6. Reduce emissions and fuel consumption	<ul style="list-style-type: none"> <li>Emissions Reduction</li> <li>Fuel consumption rates</li> </ul>	<ul style="list-style-type: none"> <li>Does the project reduce vehicle emissions?</li> </ul>	No impact on emissions	May reduce emissions	Likely to reduce emissions	Highest impact on emissions
7. Measures of cost effectiveness	<ul style="list-style-type: none"> <li>B/C ratio</li> </ul>	<ul style="list-style-type: none"> <li>Does the project provide system-wide benefits?</li> <li>Do the project benefits outweigh the costs?</li> </ul>	No impact on systemwide benefits	May provide some benefit	Likely to provide systemwide benefit	Highest impact on systemwide benefit

Measures Framework Report to conduct the qualitative assessment.

### Operations Planning

Operations planning is a joint effort between operations and traditional planning that encompasses the important institutional underpinnings needed for effective regional transportation systems management and operations. Operations planning includes three important aspects:

1. Regional transportation operations collaboration and coordination activity that facilitates regional transportation systems management and operations;

2. Management and operations considerations within the context of the ongoing regional transportation planning and investment process; and
3. The opportunities for linkage between regional operations collaboration and regional transportation planning.

FHWA defines “Planning for Operations” as “a set of activities that takes place within the context of an agency, jurisdiction, and/or regional entity with the intent of establishing and carrying out plans, policies, and procedures that enable and improve the management and operation of transportation systems” (<http://plan4operations.dot.gov/glossary.htm>).

Four levels are incorporated in planning for operations, each having different methods of using reliability data and incorporating reliability into their processes.

- *Local level:* an operating agency such as a state DOT district traffic management center (TMC) or a city TMC will conduct what is often referred to as operations planning, which is planning for spot improvements using management techniques or low cost geometric changes. This planning is usually done within that agency without outside collaboration and within the agency operations budget.
- *Regional level:* this level of planning is usually within a metropolitan area regional planning agency, often the MPO or occasionally a regional operating agency (e.g., Freeway and Arterial System of Transportation [FAST] in Las Vegas). Regional planning is commonly done through a management and operations committee of the MPO and requires collaboration among a large number of stakeholders, including many that are not traditionally part of the MPO process (public safety, emergency management, and special events managers).
- *Statewide level:* planning that is conducted at a DOT central office that will enable the allocation of funds to maintenance and operations budgets or that will prioritize operations improvements identified at the district level.
- *Multiregion and multistate regional operating agencies:* planning that enables coordination, resource sharing and information sharing among a group of operating agencies, authorities, and state DOTs (e.g., the I-95 Corridor Coalition).

Statewide transportation plans tend to focus on policy, goals, objectives, strategies and performance measures, not on specific investments and projects. MPO regional transportation plans are required to be fiscally constrained, and therefore usually consider specific projects, though they do not typically include operations projects or programs. As a result, a handful of transportation agencies have developed transportation system management and operations (TSM&O) plans, but these are not widespread.

Transportation operators and planners often work in distinct institutional silos with communication between these silos somewhat limited. Transportation operators often use an informal process for deciding which projects to implement, typically investing in incremental, modest cost, technology-oriented, procedure-intensive improvements. At the statewide and metropolitan level, operations staff typically focuses more on coordinating operations activities (signal timing, incident responses) than on major investment planning.

A few states have more formal statewide transportation plans that identify TSM&O projects and costs. Maryland's Coordinated Highways Action Response Team (CHART) program, for example, focuses on transportation management, as well as operations and incident management; it has

separate capital, operating, and maintenance and staff budgets. The corridor plans of the Washington State Department of Transportation (DOT) are a relatively unique example of combined capacity and operation improvement budgeting. The Florida Department of Transportation (DOT) has an official TSM&O program, and two urban southeast districts have adopted TSM&O programs specifically aimed at measuring and improving travel time reliability through operations improvements.

In the absence of formalized statewide planning, state DOT operations staff implements operations projects on key corridors or subareas (e.g., Fort Lauderdale and Seattle). Operations staff utilizes industry best practice and conventions to implement projects likely to create user benefits, often with only a minimum of formal analysis. To fund projects, operators negotiate funds from the maintenance and operations budgets; maintenance and operations budgets are sometimes funded along with other DOT programs (e.g., preservation, safety, capacity expansion), but just as often have separate funding sources. Typically, only large intelligent transportation systems (ITS) or operations projects (e.g., a new traffic management center or the deployment of a network-wide technology) are shown as a line item in the maintenance and operations budget.

At the metropolitan scale, the operations planning practice has even greater variation. MPOs are more likely to include operations projects in their Transportation Improvement Programs (TIP) when capital expenditures are involved (e.g., physical traffic signal improvements) than when operations expenditures only are involved (e.g., signal timing coordination). Some MPOs have a committee that serves as a forum for cooperation among jurisdictions involved in multijurisdictional projects like traffic signal coordination. These committees typically are separate from the formal MPO planning process, in part because most MPO's typically do not own or manage transportation assets.

The level of formal transportation planning and informal operations planning at the metropolitan level depends on a range of factors.

- *The specific strategy and the number and type of agencies* that must be involved in implementation and operations. Some strategies, like signal improvements, require inter-jurisdictional consensus.
- *The role that agencies play.* When transportation systems are owned or managed by a single agency, the owner may proceed independently (e.g., a turnpike authority). Where they cut across multiple jurisdictions or system owners, an MPO or other agency may need to play the role of a facilitator or originator.
- *The involvement of public safety agencies and private entities.* Some state DOTs and MPOs are bringing these groups more directly into the planning process. For example, the Atlanta Regional Commission (ARC) works with the Atlanta towing industry to implement operations strategies.

- *Source of funding.* Operations improvements that already are part of state funding through the maintenance and operations program budget may have less MPO and local involvement; and
- *Potential negative impacts.* For example, ramp metering can cause local arterial backup. Avoiding backups on these facilities requires local transportation agency input to ensure a coordinated system.

Over the past decade, FHWA and others have conducted extensive research on designing a conceptual framework for integrating operations practices into transportation planning. FHWA has been working to incorporate planning and operations by producing and cataloguing literature on their *Planning for Operations* website (<http://plan4operations.dot.gov/>), including several desk references, reference manuals, and guidebooks explaining how to

- *Incorporate operations into transportation planning objectives, performance measures, and strategies.* FHWA offers practitioners a menu of options for incorporating operations into their plans using sample operations objectives and performance measures. They include excerpts from a model metropolitan transportation plan to illustrate the results of an objectives-driven, performance-based approach to planning for operations (27).
  - *Integrate operations by state, regional, corridor, subarea, or project level.* FHWA provides a how-to for transportation professionals to integrate operations into safety and multimodal planning. They highlight the important role of multidisciplinary teams; data collection, sharing, and analysis; and the broad use of performance measures (28).
  - *Integrate operations into the metropolitan transportation planning process* to maximize the performance of the existing and planned system. FHWA describes an approach to developing a metropolitan transportation plan that contains specific, measurable operations objectives, performance measures, and management and operations strategies that directly influence the projects selected for the Transportation Improvement Program (TIP). A plan structured using this approach will fulfill federal planning requirements and will be better able to meet customer needs by creating a more optimal mix of transportation investments (29).
  - *Improve the use of analysis tools* to improve transportation planning decisions about operations projects. FHWA helps planners and operations professionals use existing transportation planning and operations analysis tools and methods in a systematic way to improve decision-making through better analysis, evaluation, and reporting the benefits of needed investments in operations projects (30).
  - *Use a performance-based approach to transportation planning* that enhances the quality of operations in the planning process. FHWA highlights opportunities to use an objectives-driven, performance-based approach to facilitate
- an objective allocation of resources, to prioritize regional investments in management and operations, to increase accountability, to engage the community, and to expand the focus of the metropolitan transportation plan to include both short- and long-range operations needs (31).
- *Improve collaboration between regional transportation planners and operations managers* to realize benefits of operations strategies at the regional scale. FHWA uses nine examples of collaborative efforts to illustrate the benefits of sharing resources and expertise, performing joint operations, using common operations procedures, and exchanging real-time information (32).
  - *Conduct benefit-cost analysis of operations strategies.* FHWA is developing guidance to help practitioners select appropriate measures of effectiveness, identify relevant analysis tools and methods, and present the results of benefit-cost analysis conducted on operations strategies to make a better investment case for these projects (33).
  - *Identify and implement appropriate analysis strategies for integrated operations strategies with complex analysis needs.* FHWA is developing guidance to assist agencies looking to deploy integrated corridor management (ICM) strategies in identifying the multiple and intertwined short- and long-term effects of ICM, including impacts on reliability, and developing appropriate analysis capabilities to assess these impacts (34).
- Other pertinent literature sources for integrating operations and transportation planning include:
- *Incorporating intelligent transportation systems into the transportation planning process.* The report defines and develops an integrated decision process that embraces ITS and addresses gaps in perspective, institutions, and funding between those that operate and maintain our transportation system of today (e.g., traffic and transit operations, maintenance) and those that plan, design, and construct our transportation facilities and infrastructure (the focus of conventional planning) for the future. The integrated process is one where ITS, system management, and operations strategies are considered on an equal basis with traditional elements of the transportation system (35).
  - *A description of the relationship between congestion management and the transportation planning process.* Researchers report on the best practices of three MPOs that related congestion management processes (CMP) to their transportation planning process, including how they presented data, prioritized projects, and involved stakeholders (36).

## Measuring Reliability

Measuring travel time reliability includes collecting time-series travel time data in a systematic way from freight truck and vehicle fleets or other traffic data collection devices and



estimating travel time reliability performance measures. The L05 project relates available reliability performance measures to the public and compiles the techniques from current literature to develop concise guidance for transportation professionals to collect data and estimate reliability performance measures.

## Travel Time Data

### *Intelligent Transportation Systems*

Intelligent transportation system (ITS) instruments measure transportation activity as an integral step in congestion management. The instruments collect data on traffic conditions (i.e., speed and travel time data) and these data can be stored and used to calculate performance measures such as incident-response times, system efficiency, travel delay, and travel time reliability. If the data are not archived, then these measures cannot be tracked over time and used for long-term planning and performance analysis. Many agencies do not archive their data. For example, Maryland Department of Transportation's (DOT) incident-response-time data were held for two weeks before being deleted. Washington State Department of Transportation (DOT), on the other hand, archives ITS data to track recurring and nonrecurring delays (37). Comprehensive reporting on congestion and mobility problems is typically limited to freeway systems, because of the lack of available arterial monitoring data.

### *Truck Fleets*

The Federal Highway Administration (FHWA) Office of Freight Management and Operations, through a research partnership with the American Transportation Research Institute (ATRI), has developed numerous performance measures for the nation's highway system through the Freight Performance Measures (FPM) initiative, including average operating speed on highway segments. ATRI calculates the measures using confidential onboard data from several hundred thousand trucks. By accessing this system, transportation data analysts, researchers, and other practitioners can determine where, when, and how efficiently trucks are moving on selected interstate highways (38).

A Texas Department of Transportation (DOT) study noted that real-time freight data are available but that processing limitations constrain them to be used for less precise planning measures rather than detailed real-time performance measurement (39). Several private sector companies use freight hauler data for real-time information (e.g., INRIX, NAVTEQ, and TomTom). The use of real-time data may increase in the future as technology costs and processing times decrease. The study identified three factors that could

alter the course of freight performance measure development for the agency:

1. Turnaround time for information;
2. Linking intercity and urban corridors; and
3. Data quality and data collection technologies.

Washington State's Truck Performance Measure research project tracked truck travel times and analyzed reliability of the highway and local road network in Central Puget Sound in 2009 (40). The onboard truck global positioning system (GPS) documented where truck trips originated, where they terminated, and how long it took to travel between origin and destination.

Researchers identified several advantages of GPS-powered truck data:

- GPS-powered truck data are the only ways to accurately track truck speeds on the state and local road network;
- The state can monitor the performance that matters to trucking companies and shippers: delay, stops, and speeds on specific routes; and
- Data are available from commercial vendors, and quality will improve as technology advances and more trucking companies install GPS units.

Disadvantages of GPS truck data noted were

- The newness of the service;
- Tracking truck performance requires ongoing resources to obtain and analyze GPS data and manage the project; and
- At the time of the project, vendors were not capturing enough GPS data on many local roads across the state; therefore, analysis of the performance of this portion of the network was less accurate and more difficult than would have been desirable.

## Reliability Measures

SHRP 2 Project L03 reviewed reliability measures in use throughout the United States and internationally and developed a combined list of performance measures recommended for general practice (Table 2.2). SHRP 2 L03 researchers suggest using the planning-time index as the best single reliability measure for urban conditions because it produces consistent and intuitive results. However, researchers recognize that different measures may be appropriate for different audiences and analyses.

The National Transportation Operations Coalition (NTOC) defined 12 operations performance measures for local, regional, and national mobility applications. A National Cooperative Highway Research Program (NCHRP) project coordinated

**Table 2.2. Reliability Performance Measures**

Reliability Performance Metric	Definition	Units
Planning-time index	95th percentile travel time index (95th percentile travel time divided by the free flow travel time)	None
Buffer index (BI)	The difference between the 95th percentile travel time and the average travel time, normalized by the average travel time The difference between the 95th percentile travel time and the median travel time, normalized by the median travel time	Percent
Failure/on-time measures	Percent of trips with travel times less than 1.1 * median travel time or 1.25 * median travel time Percent of trips with space mean speed less than 50 mph; 45 mph; or 30 mph	Percent
80th Percentile travel time index	80th percentile travel time divided by the free flow travel time	None
Skew statistic	The ratio of (90th percentile travel time minus the median) divided by (the median minus the 10th percentile)	None
Misery index (modified)	The average of the highest 5% of travel times divided by the free flow travel time	None

pilot tests and input from senior transportation professionals to refine NTOC data collection, compilation, implementation, and selection of measures. During the pilot test initiative, state DOTs, MPOs, and cities contributed sample data and shared their experience implementing various measures (41).

Among measures investigated in the pilot test (95th percentile travel time, planning-time index and buffer-time index), the study identified the buffer-time measure as the most useful reliability performance measure. Buffer time describes the additional planning time required in excess of the expected travel time to ensure travelers arrive at their destination at or before the intended time 95% of the time. The measure is meant to account for travel times on all roadway and mode types under recurring and nonrecurring events. The measure applies to a specific time of day and typical traffic and roadway conditions. It is measured in minutes or as a percentage of total trip time (i.e., as the buffer-time index). Four agencies tested the buffer-time performance measure, including the Georgia Regional Transportation Authority, the Maricopa Association of Governments, the Southern Nevada Regional Transportation Commission, and the Washington State Department of Transportation. This study's finding that the buffer time is the most useful measure is in contrast to the more recent findings of SHRP 2 L03 that the planning-time index is the best single measure. SHRP 2 L03 found that in some situations, when overall congestion improves, the buffer time degrades. This counterintuitive finding led the authors to suggest the use of the planning-time index instead of buffer-time related measures. See the L05 technical reference for further details.

SHRP 2 L03 identified and analyzed five performance measures, including buffer index, failure/on-time measure, planning-time index, skew statistic, and the misery index

(42). These measures are calculated from the shape of the distribution of travel times on a road segment or network.

Lomax et al. investigated changes in congestion and reliability performance measures under different congestion thresholds (i.e., when a roadway is considered congested) (43). The research collected ITS data from 147 freeway sections in seven metropolitan areas and evaluated delay per mile, travel time index, and planning-time index. The research examined (1) the changes in congestion levels (i.e., which segments have the most congested values) that result from changing the congestion threshold, and (2) whether the changes in congestion measures caused by threshold changes have a linear relationship. The study found that the congestion rankings hold steady, regardless of the threshold identified for congestion. This finding held for all the performance measures evaluated, including the reliability measure, the planning-time index. In addition, the congestion measure displays a predictable non-linear relationship to the threshold. The research results indicate that the congestion threshold speed chosen by the analyst or policy-maker is not a factor in determining which freeway segments would be ranked as most congested or least reliable (43).

Franklin modeled reliability as "expected lateness," using a schedule-based approach (44). The study examined travel time data for mean lateness, an important component of scheduling. To produce a complete estimate of user benefit, the study estimated a model of mean lateness for use in conjunction with a model of mean travel times. The model produced significant results, but it only partially explains variations in mean lateness, and it generated large biases in certain cases.

Several domestic and international transportation agencies have been calculating reliability performance measures for their use. Examples of such performance measures are provided by agency.

## California

The California Department of Transportation (Caltrans) has produced performance measures for the entire multimodal system. The measures are intended to

- Monitor and evaluate system performance.
- Share existing data and forecast future performance information.
- Develop mode-neutral customer and decision information.
- Build consensus using performance measures information.
- Improve accountability of system development and operations (45).

Caltrans will begin to measure travel time reliability in January 2011. They define travel time reliability as the predicted mean travel time compared to the actual travel time. The geographic coverage of the measure is evolving, and recent changes have focused it on selected corridors. For each corridor, division and district transportation professionals calculate one or more reliability measures.

California tested the measures on corridors in four metropolitan counties in 2000. Analysts found that peak period travel time varied 10% to 50% on all corridors. They also found that reliability might not be directly correlated with delay; some areas that had high delay exhibited low variability in travel time, in part because it is difficult to deviate from slow speeds. Travel time reliability depended on several factors, including distance between interchanges and geometrics.

## Florida

The planning office of the Florida Department of Transportation (DOT) uses the Florida Reliability Method, a benchmarking technique, to estimate travel time reliability for Florida's Mobility Performance Measures Program. The DOT defines travel time reliability as the percentage of travel on a corridor that takes no longer than the expected travel time, plus a certain acceptable additional time (46).

The Florida method calculates travel time reliability measures based on speed data collected through loop detectors, speed estimates using volume and lane-occupancy data, or travel time data from floating car studies. The DOT makes the following recommendations:

- Reliability should be measured for one peak hour rather than an entire peak period. This allows comparisons between facilities, and enables annual monitoring of reliability on the same facility, because the peak period may change from year to year. This definition also is consistent with approaches in the *Highway Capacity Manual*.

- The time interval for aggregating speed and volume from sections of roadway should be shorter than the travel time under free-flow conditions.
- The optimum data collection period for the reliability measurement was reported as a six-week period using data collected at intervals of 5 min or less.
- Data collected over a four-week period at 15-min intervals is the minimum recommended to provide an adequate sample size. The method outlined above was tested in several Interstate highway corridors in Florida. These corridors varied in the levels of congestion and reliability observed.

The Florida DOT Operations Office measures and reports on travel time reliability for all its ITS-managed freeways on an annual basis. For this purpose, Florida DOT uses the buffer index calculated as the ratio between the difference of the 95th percentile travel time and the average travel time divided by the average travel time. A secondary metric is the travel time index (TTI), which is used as a measure of traffic congestion. TTI is calculated as the ratio of average peak travel time to an off-peak (free-flow) standard, in this case 60 mph for freeways. Travel time, travel speed, and volume data are the basis of these measures. Travel time and speed data are obtained from either speed data from roadside detectors that communicate in real time to TMCs or probe data from various sources that report travel time directly.

## Nevada

The Integrated Transportation Reliability Program (ITRP) of the Nevada Department of Transportation (DOT) aims to implement new and innovative programs to prevent congestion and improve reliability. As part of the program, the DOT coordinates with statewide stakeholders to develop strategies to improve travel time reliability in Nevada.

Las Vegas' Traffic Incident Management Coalition brought southern Nevada emergency response and transportation agencies together to enhance emergency response to the over 15,000 traffic crashes that occur each year in the Las Vegas valley. The group established collision clearance-time goals to restore road travel following traffic crashes (47).

## International Research

This section draws from a range of experiences by international transportation agencies. Some of this information is drawn from a recent FHWA International Scan of transportation performance measurement practices that included visits to transportation agencies with mature performance management systems in Australia, Great Britain, New Zealand, and Sweden. The scan focused on how these organizations demonstrate accountability to elected officials and the public.

One of the interests of the scan team was how transportation agencies used reliability performance measures and practices to meet their goals (48).

All of the agencies reported that their reliability measures were evolving and they were not entirely satisfied with their measurement tools. However, it was clear that the more urbanized agencies in the United Kingdom, Australia, and Sweden had invested considerable effort in measuring real-time highway, transit, and rail operations to improve travel time reliability, enhance transportation choices, and reduce greenhouse gas emissions. This section describes several findings from the international scan and research in Japan and the Netherlands.

**GREAT BRITAIN.** The British have invested considerable effort in measuring reliability on high-volume national routes. The Highways Agency (HA) of Great Britain has identified a Strategic Road Network of 2,700 km (1,678 mi) of motorways and 4,350 km (2,703 mi) of other trunk routes. These routes are analyzed in 103 sections with 2,500 total links. The HA actively tracks reliability performance on a daily basis across this network and defines travel time reliability as the average vehicle delay on the slowest 10% of the journeys.

The network reliability program has improved British officials' understanding of system performance and the HA has increased its use of reliability analysis in the evaluation of improvement strategies. The HA identified several difficulties in measuring reliability, including shortcomings in data and varying definitions. They also noted difficulties explaining the results to the public because the performance measures are not very sensitive to the improvements. For example, improvements reduced the average of the worst 10% of trips making a 16-km journey, from 3.9 min to 3.4 min of delay; for a slow trip, an improvement of 30 s is marginal. It is unclear if the improvement created this travel time reliability benefit or if the benefit is a function of changes in economic conditions.

**SWEDEN.** The Swedish Road Administration (SRA) includes travel reliability among a large set of transportation performance measures. Travel times and speeds are tracked on major routes in the three major cities (Stockholm, Malmo, and Goteborg) and on routes to towns for rural residents. The SRA reports are designed to connect the performance of the system with "the steps taken in each area to improve traffic flow and reliability and report on planned improvement strategies for the next year." Rural reporting includes the effect of seasonal weather problems and summarizes the number of residents who saw increases or improvements in travel times between towns.

**JAPAN.** Use of predicted reliability within project benefit-cost analysis is in its nascent stages in Japan. Higatani et al. examined the characteristics of travel time reliability measures using the traffic flow data from the Hanshin expressway network. The

Hanshin Expressway is an urban toll expressway network that stretches from Osaka to Kobe. For this study, travel time reliability indices were calculated for five radial routes that are connected to the downtown loop route in Osaka City. Several measures were calculated for one radial route (Route 11 Ikeda Line), including average travel time, 95th percentile travel time, standard deviation, coefficient of variation, buffer time, and buffer-time index. The buffer time and buffer index showed similar tendencies as the standard deviation and coefficient of variation, respectively. The time-of-day variation of traffic flow was also investigated for all five radial routes, and the effect of traffic incidents on travel time reliability measures was analyzed for one radial route (Route 14: Matsubara Line) (49).

**LONDON.** Bates et al. found that travel time varies in three ways: interday variability (caused by seasonal and day-to-day variations in travel times), interperiod variability (caused by different departure times and consequent changes in congestion), and inter-vehicle variability (caused by personal driving styles and behavior of traffic signals along a certain route) (50). The authors measured travel time reliability using the mean-variance approach (based on variance or standard deviation of travel times), the scheduling approach (based on disutility caused by late arrivals), or the probabilistic/mean lateness approach (based on mean lateness at departure/arrival).

**NETHERLANDS.** Delft University of Technology (51) and Van Lint et al. (52) find that travel time variance only accounts for a portion of the delay effects from unreliability. The studies recommend including the skew of travel time distribution (e.g., the amount of extra travel time for the worst 5% of trips) to measure the remaining effects of unreliable travel times.

## Freight Reliability

An important component of reliability is the relationship of reliability to the movement of goods. Transportation planners are well aware of the importance of just-in-time delivery to the functioning of business. Shippers and business often care about measures such as delivery time, unloading capacity, and inventory requirements. Reliable travel times allow shippers and businesses to plan better and to meet service commitments and customer expectations. Shippers also can help improve reliability by implementing strategies to reduce the number of commercial collisions and breakdowns (53). As with traveler reliability benefits, the L05 project addresses the incorporation of freight reliability benefits into project assessment and into broader transportation planning processes and products.

Several states and regions have embarked on measuring the performance of significant freight corridors. In 2007, the Washington State Legislature initiated one of the first state truck performance measure projects in the United States

(54). By accurately tracking truck trip travel times and network reliability, the Truck Freight Performance Measure project can help the State of Washington incorporate key truck freight bottlenecks in the identification and prioritization of transportation investments.

North Dakota State University Department of Civil Engineering conducted a comprehensive study of freight performance measures addressing all modes and facility types for the Minnesota Department of Transportation (DOT) (55). The study found that freight operators and shippers need a reliable travel time window within which delivery can be expected. Shippers deal with travel time contingencies as a matter of business, but travel time reliability is important. The Minnesota Statewide Transportation Plan included freight reliability performance measures in general but noted that additional work was required to analyze and deploy them.

Lam et al. investigated the impact of travel time reliability on freight truck route choice and total travel time (56). The study found that truckers took more circuitous but more reliable routes when deliveries required more reliable deliveries (e.g., just-in-time ready-mix concrete delivery).

## Estimating and Forecasting Reliability

The classic four-step travel demand models, at their simplest, are designed to account for travel demand between origins and destinations (e.g., home and work) and are not sensitive to travel time reliability. As a result, there is no research involving modifications to the traditional long-range travel demand model to account for travel time reliability in the literature. However, a few post-processors can use travel demand model output for sketch-level planning. Simulation models are sensitive to travel time reliability, and several studies have modeled the impact of reliability on travel decisions. While the simulation models analyze a section of road or corridor, some of the concepts may be adaptable to travel demand models. The L05 project compiles analysis techniques from current literature to

develop concise guidance for transportation professionals to forecast and predict reliability performance measures. Several SHRP 2 projects are developing analytic methods for estimating reliability directly, from a variety of resolution scales, from sketch planning to microscopic simulation:

- SHRP 2 L03 developed statistically derived reliability equations based on empirical data. Two types of models were developed: data-poor, that required only an estimate of recurring delay, and data-rich, that requires information on demand, capacity, incident characteristics, and weather conditions. The data-poor equations have also been adapted for use in Projects C10B and C11.
- SHRP 2 L04 is developing a simulation-based approach to reliability estimation, using a combination of mesoscopic and microscopic models. It fits into the “emerging traffic flow modeling methods” category, described earlier in this report.
- SHRP 2 L07 is developing a hybrid approach for predicting reliability based on combining microsimulation experiments with the data-rich equations from L03.
- SHRP 2 L08 is developing a scenario-based approach combined with macroscopic modeling methods for inclusion of reliability into the *Highway Capacity Manual*. Project L08 also fits into the “emerging traffic flow modeling methods” category described previously, but its analytic engine is macroscopic in nature.
- SHRP 2 L11 did not develop reliability prediction methods but did develop an original approach to valuing reliability based on options theory.

Table 2.3 presents some ideas on which of the methods are most appropriate for different scales of analysis. Note that benefit/cost analysis could be part of any of these analysis types.

### **Highway Capacity Manual 2010**

FHWA is creating a new Chapter 35 in Volume 4 of the *Highway Capacity Manual* (HCM) to develop a method for estimating

**Table 2.3. Analysis Types Matched to Reliability Prediction Tools**

Analysis Type/Scale	Supporting Tools
Sketch-planning	L03 reliability prediction equations
Project planning	L07 hybrid method where data inputs are limited L08 multi-scenario methods where additional data are available and more resolution in results are desired
Facility performance	L08 multi-scenario methods most directly applicable L04 pre-processor (Simulation Manager) and post-processor (Trajectory Processor) could be used; then the performance of an individual facility can be isolated
Travel demand forecasting	L03 reliability prediction equations and L07 method can be adapted as post-processors L08 multi-scenario methods could be used to develop custom functions for post-processing
Traffic simulation	L04 pre-processor (Simulation Manager) and post-processor (Trajectory Processor) most appropriate L08 scenario generator can be adapted

the impact of active traffic management (ATM) techniques such as lane and shoulder treatments, demand metering, electronic toll collection, congestion pricing, traveler information, geometric design treatments, truck and other heavy vehicle treatments, and incident and work zone management on roadway capacity and performance (57). Ongoing FHWA research is supporting the development of this chapter of the HCM. In addition, SHRP 2 Project L08, *Incorporation of Travel Time Reliability into the Highway Capacity Manual*, is working to express reliability performance measures in a method that can be used within the HCM.

### Use with Travel Demand Models

Recent research projects in the United States have focused on using available data and analytical procedures to develop post-processing methods to estimate travel time reliability performance measures. Mobility monitoring program (58) data from more than 20 metropolitan freeway systems were used to develop an equation to estimate delay for the Texas Department of Transportation (DOT) and the state's MPOs (59). The equation indicated a reasonably direct but non-linear relationship between average congestion and the buffer index. The study processed travel-demand-model output using a technique similar to that used in mobile source emissions modeling, estimating free-flow travel speeds based on model outputs, and then calculating delay and reliability measures relative to the free-flow speed. The buffer index calculation was designed to assist planners who were beginning to address the reliability issue; the index values were used in explanations of future congestion levels, in phrases such as "Average travel time from work to home would be X minutes, but for a very important trip, Y minutes would have to be planned for."

Reliability measure estimates have been refined in several efforts for the National Cooperative Highway Research Program (NCHRP) and SHRP 2 reliability programs. NCHRP Report 618 developed a travel time estimation procedure for use in corridor studies and as a basis for post-processing travel demand model outputs. The report also documented a few useful, simple reliability estimation equations (60).

Previous research suggests a strong relationship between the 95th percentile travel time index (TTI)—the planning-time index—and the mean TTI, implying that reliability can be predicted if the mean TTI is available via modeling or sampling. SHRP 2 L03 researchers developed reliability reduction factors for selected strategies and two predictive equations to predict and forecast reliability (43). The first equation predicts the 95th percentile TTI as a linear and slightly exponential relationship of the mean TTI; as the mean TTI increases, the 95th percentile TTI increases even faster.

The second equation is used when the mean TTI is not available—which is typical—and must be estimated. Most

travel-demand models used to predict future travel conditions only estimate recurring congestion and do not include nonrecurring sources of congestion (e.g., incidents, weather). To predict reliability, it is first necessary to predict the mean TTI. The second equation estimates the mean TTI based on the maximum volume-to-capacity ratio predicted for a given highway section and the expected lane-hours lost because of incidents (based on estimated crash rates). The equation was validated using actual travel time distributions where the occurrence of incidents, weather, and work zones—including those on immediately downstream sections—are removed.

Kouwenhoven et al. used an empirical model and speed-detector (induction-loop) data and developed "a simple and pragmatic" tool to forecast the level of travel time reliability (61). The research used outputs from national and regional models that predict future traffic demand and congestion under different scenarios and input to the reliability prediction tool. They developed empirical relationships for four reliability indicators: the probability of a trip being on time, the probability of a trip not being too long (i.e., not arriving late), and the 10th and 90th percentiles of the speed distribution. Thresholds of on time and too long were defined as within 10 min of expected travel time for a 50-min trip and otherwise within 20% of expected travel time. The method is also capable of predicting reliability impacts for a range of exogenous factors, like accidents, road works, and weather conditions.

Teye-Ali and Davidson proposed a statistical technique for estimating probability distributions of route travel times (62). The techniques can be used to identify routes that are vulnerable to long travel times caused by unexpected events and day-to-day variations in the travel demand. The reliability measures (buffer index and the shape of the travel time distribution) show the extent of variability and robustness of the network in coping with variable demand under normal and abnormal (e.g., natural disaster) situations. Vulnerable network links were identified by adjusting the capacity of each link and measuring the impact of that link on system-wide travel time reliability. The study found that the most heavily traveled routes were not necessarily the most vulnerable. The study results might be used within route choice models to estimate the value of time that travelers have for unreliability.

Hu et al. presented a travel time reliability-based traffic assignment model to study daily demand variation (63). In the model, path travel times were viewed as random variables. The paper proposed a travel time reliability-based user equilibrium principle to characterize travelers' path choice behavior when travel times were uncertain because of demand variation. It employed a heuristic solution algorithm for solving what was termed a *variation inequality* problem.

Mehran and Nakamura presented a methodology to estimate travel time reliability by modeling travel time variations

as a function of demand, capacity, and weather conditions (64). They used Monte-Carlo simulation to generate patterns of demand and capacity (based on randomly generated collisions) for an expressway segment. The model was able to predict travel times, reliability, and collisions based on conditions. They used the model to evaluate two alternative congestion-relief strategies and to estimate the reduction in collisions and improvement in reliability.

### Use with Simulation Models

Bates et al. developed a framework and model to incorporate travel time reliability into simulation models (65). It appears that their techniques successfully predict travel time distributions and could become the basis for simulation model components. The research indicates that there is an achievable role for reliability analyses in simulation models that might be useful for operations and planning purposes. The research divided the journey-time variability into two components: incident-related variability and day-to-day variability, which can be further divided into unpredictable variations in demand and random fluctuations in capacity, as represented in the following paragraph.

The research modeled two traffic regimes: when demand is below capacity and when demand exceeds capacity. It confirmed that journey-time variability on a stretch of motorway is strongly, but not linearly, related to capacity utilization. It distinguished two key contributions to unreliability: incidents and the ratio of demand to capacity. With no incidents and low demand relative to capacity, journey-time variability is low, essentially a function of variation in capacity. When the ratio of demand to capacity reaches the equivalent of the breakpoint on the standard speed-flow curve (a value of 0.65 in this report), the combined effect of variation in demand and capacity starts to increase. The researchers used an average demand profile, as well as the day-to-day variation in demand (which appeared to be low based on the four weeks of data used for the study), to model when demand exceeded capacity. Day-to-day travel time variability values of up to a coefficient of variation of 0.4 were reported.

### Travel Time Reliability and Economic Analysis

Transportation agencies establish monetary values for travel time to capture the economic impacts of transportation investments. Congestion and delay on the transportation system have an economic cost to the people and shippers traveling to work or businesses. Investments that allow people or goods to move more quickly and efficiently allow people to spend more time productively, reduce the amount of inventory businesses have to maintain, and have other similar positive economic benefits to workers and businesses.

Many transportation agencies use benefit-cost analysis to capture the expected benefits of transportation investments. Benefit-cost analysis assesses the user and agency benefits of projects and programs in comparison to their costs. It normally includes all direct user and agency costs and benefits that the agency is able to estimate, including operating costs, travel time costs, and often other impacts such as crash costs and pollution costs.

Benefit-cost analysis is used for transportation project and program evaluations that relate to users and agencies. It differs from economic impact analysis, which generally attempts to estimate the economic impacts of investments on the overall economy. Benefit-cost analysis is typically applied in transportation studies to identify the net present value (NPV) of the societal benefits that can be associated with a project or program, net of the investment costs. This includes benefits that are not reflected in any monetary transaction. For example, the estimated value of personal-time saving benefits, of vehicle operating costs, of safety impacts, and of environmental improvement (or degradation) benefits are included in benefit-cost analysis, although these benefits typically are not reflected by any corresponding change in the flow of monetary income or monetary cost. Both benefits and costs are discounted over time to arrive at an NPV.

To enable benefit-cost analysis, an agency needs to monetize the benefits that accrue to the public, including, for example, average travel time benefits through reduced delay and reliability benefits through increased predictability of travel. Other economic analysis techniques, such as life-cycle cost analysis models and management systems, also can benefit from monetized estimates of benefits. Most transportation agencies provide a monetary value for average travel time, but few have examined the relationship between travel time reliability and this valuation. Transportation professionals have asked how the value of travel time varies for unreliable travel time; are unexpected delays worth more to travelers and shippers than known or expected ones?

Over the past two decades, researchers have developed estimates of the value of unreliable travel time. Historically, these estimates were based on stated-preference survey data, but recent implementations of managed lanes, high-occupancy toll (HOT) lanes, and express lanes make it possible to measure the value directly through revealed-preference data.

Like the value of travel time itself, the value of travel time reliability varies by traveler and time of day. Most recent estimates suggest that the average value of travel time reliability is comparable to the average value of travel time. A recent synthesis of estimates from several studies suggests that reliability can reasonably be valued at 0.8 times the value of average travel time (66). For travelers with inflexible arrival or departure constraints, the value of travel time reliability is considerably higher than the value of average time. Several factors influence

the stated value of travel time reliability, including roadway congestion, risk-aversion, and sociodemographic factors.

Brownstone and Small estimate the value of reliability as between 95% and 140% of the median travel time value using the data from the high-occupancy toll lanes on SR-91 and I-15 in California (67). They measured reliability as the difference between the 90th and the 50th percentile travel times.

By comparison, Small et al. conducted a stated-preference survey of travelers along the SR-91 corridor and observed from the survey results that the value of reliability, estimated as \$12.60 per hour, was more than twice the overall value of time, which was estimated as \$5.30 per hour (13). The value of reliability was estimated to be greater than three times the value of average travel time for work trips made by people of income greater than \$45,000 per year.

Bhat and Sardesai used stated-preference and revealed-preference surveys in Austin, Texas and observed that the value of reliability was 27% of the value of travel for those with flexible work schedules and 50% of the value of travel time for those with fixed work schedules (68). They measured travel time reliability as the additional time required to reach the work place due to the uncertainty of traffic conditions. Small et al. used revealed-preference study data of travelers in Los Angeles and calculated the median value of reliability as 85% of the average wage rate (\$19.56/hour). They measured reliability as the difference between the 75th and 25th percentile travel times (79). Tilahun and Levinson used stated-preference route-choice survey data from University of Minnesota employees; they compared the value of travel time with the value of travel time reliability, using several models, and found the values to be almost equal (70).

After a synthesis of research on the value of reliability, Concas and Kolpakov recommended that reliability be valued at between 80% and 100% of the value of time under ordinary circumstances with no major constraints (71). However, in the presence of inflexible arrival/departure constraints, they recommended valuing reliability up to three times that of average travel time. They suggested using the difference between the 95th and 50th percentile travel times as the measure of reliability. They observed that road value pricing can be successful even in areas of low prevailing wage rate if the travelers highly value the reliability of travel time.

Research from other countries suggests comparable valuation of travel time reliability, as in domestic research. The British Department for Transport estimated monetized benefits of changes in variability of travel time as 0.8 for private vehicles and 1.4 for public transport (72). They monetized travel time reliability as the value of the standard deviation of travel time divided by the value of travel time.

On the basis of stated-preference survey data gathered in London, Black and Towriss estimated the value of reliability to be 0.55 to 0.70 times the value of time (6). Using

stated-preference survey data for long-distance car travel (three hours) in New Zealand, Hensher calculated the value of travel time savings for free flow travel time to be NZ\$3.60 (U.S. \$3.70) per hour and the value of reliability to be NZ\$5.00 (U.S. \$4.90) per hour, about 1.4 times more valuable (73). On the basis of a survey of Spanish drivers, Asensio and Matas observed that they were willing to pay more than twice as much to avoid arriving late, as they would pay for reduction in mean travel time (74). Li et al. observed that Australians valued not being late greater than being early or mean travel time savings (75). Commuters valued reliability at \$40.39 per hour.

Batley and Ibáñez observed that the value of reliability was more than twice the value of time in the United Kingdom (UK) for rail commuters (76). Kouwenhoven et al. also obtained similar results from their stated-preference study on Paris rail commuters (77). The Paris rail commuters also indicated that the disutility from the first delayed train is the highest, and disutility decreases with each delayed train.

### Other Factors Affecting the Value of Travel Time Reliability

Lam and Small observed that women value reliability nearly twice as much as men, based on revealed-preference survey data and travel time data from 1998 on SR-91 (78). They defined reliability as the difference between the 90th percentile and the median travel time.

Socioeconomic factors also contribute to the importance of travel time reliability. From a stated-preference survey of Dutch commuters, Tseng et al. observed that the lower-income groups and commuters without a lot of flexibility about arrival time place a higher value on not being late than on being early (12). Reliability of travel time was also valued at half of the value of average travel time, which was estimated as €5.30 per hour. Reliability was measured as the difference between early/late arrival time and preferred arrival time.

Table 2.4 summarizes the value of travel time and reliability studies.

### Summary

This section summarizes the literature on reliability performance measurement and the use of travel time reliability within the planning process. The literature contains information about how to implement reliability in the planning process; however, success in accomplishing this is rare other than with the selection of measures. Key findings from the literature review include the following:

- *Highway users care about reliability.* Reliability issues and concerns are frequently expressed by the public and decision makers during comment periods, and the literature



**Table 2.4. Summary of Value of Time and Value of Reliability Studies**

Study	Value of Time (per hour)	Value of Reliability (per hour)	Study Method
Small et al. (1999), U.S. (13)	\$5.30	\$12.60; measured as the standard deviation of travel time.	SP survey
Ghosh (2001), U.S. (11)	\$36.06	\$47.51; measured as the difference between 90th and 50th percentile travel times.	SP and RP survey
Brownstone and Small (2003), U.S. (67)	\$20	95–140% of median VOT; measured as difference between 90th and 50th percentile travel times.	RP survey
Small et al. (2005), U.S. (69)	\$21.5	85% of average wage rate (\$19.56 per hour); measured as difference between 75th and 25th percentile travel times.	RP survey
Bhat and Sardesai (2006), U.S. (68)	\$12.2	\$3.3 (with flexible arrival time) \$6.1 (with fixed arrival time).	SP and RP survey
Tilahun and Levinson (2006), U.S., (70)	\$7 to \$8	Equivalent to VOT; measured as difference between actual late arrival and usual (mode) travel time.	SP survey
Black and Towriss (1993), UK (6)	—	55% to 70% of the VOT; measured as the standard deviation of travel time.	SP survey
Hensher (2001), New Zealand (73)	\$8.7	\$5; measured as uncertainty using a multinomial logit model.	SP survey
Batley and Ibáñez (2009), UK (76)	£15.4	£31.8; measured as mean lateness at departure or arrival.	SP survey
Tseng et al. (2005), Netherlands (12)	€5.3	50% of the VOT; measured as the difference between early/late arrival time and preferred arrival time.	SP survey
Li et al. (2010), Australia (75)	\$28.28	\$40.39; measured as the probability of arriving early/late.	SP and RP survey
Bates et al. (2001), UK (23)	—	£68.2; measured as the expected value of SDL.	SP survey
Asensio and Matas (2008), Spain (74)	€14.7	€34.4 for normal late arrival, €51 when commuters cannot arrive more than 10 min late; measured as SDL.	SP survey

Note: SP = stated preference, RP = Revealed preference, VOT = value of travel time, and SDL = schedule delay late.

finds that drivers place significant value on reliability when making travel decisions. Some regions are responding to this by providing a variety of regional, project, and program reports on reliability, but there remains a gap between the concern over reliability and the use of the concept in planning. The L05 project targets this gap.

- *Reliability is important to freight shippers.* A reliable transportation system allows for just-in-time delivery and consistent delivery time, unloading capacity, and inventory requirements. The L05 guide incorporates freight reliability needs into the planning process by encouraging planners to consider freight users explicitly when determining how to construct performance measures.
- *Agencies monitor travel time reliability but do not yet use it in planning.* Travel time reliability monitoring and reporting efforts are detailed and used by many transportation agencies but are not commonly used in formal transportation planning. The L05 guide will explain how to incorporate travel time reliability into the transportation planning and programming process.
- *Several sources of travel time data estimate reliability performance measures.* The emergence of continuous speed monitoring, including by the private sector, has made traffic speed data available to more agencies. Agencies can combine these

speeds with traffic volume and roadway inventory databases to measure multiple facets of traveler mobility, including reliability. As agencies become more familiar working with travel time data sources, they can turn to available procedures to calculate reliability measures. The L05 technical reference will explain how to find, collect, and analyze travel time data to estimate performance measures.

- *Long-range transportation planning models can forecast reliability.* There is little experience using long-range transportation planning models to estimate reliability directly. Recent research (e.g., SHRP 2 L03) developed post-processing techniques that can be used to estimate travel time, congestion, and reliability performance measures. These methods can be implemented without significant modifications to existing models and would allow planners to project future reliability, similar to the way other performance measures can be projected. The L05 technical reference will explain how to use transportation-planning models and analysis techniques to forecast reliability performance measures.
- *Operations can be incorporated into the planning process.* FHWA and others have developed several guidebooks for incorporating management and operations projects into a performance-driven metropolitan transportation planning process. The approach is built to help MPOs to

construct transportation improvement programs that include management and operations projects to help fulfill federal requirements.

- *Reliability can be monetized.* This may be a promising method for incorporating travel time reliability into the transportation planning process and, in particular, into benefit-cost analysis. Results of several research studies suggest the value of unreliable travel time is between one and 1.5 times the value of average travel time. This implies that reliability should be considered alongside travel time in the planning process. The L05 guide and technical reference explain how to incorporate the monetized value into the transportation planning process.

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## CHAPTER 3

# State of the Practice

Incorporating reliability performance measures into the transportation planning and programming process requires an understanding of the state of the practice to ensure that the guidance will be useful to the transportation agencies and practitioners who will be responsible for the integration. A state of the practice survey was conducted in October and November 2010 to gather information about the identification of travel time reliability as an issue, the collection of travel time data, the calculation of reliability performance measures, and the challenges and issues agencies face in this area. This chapter describes the approach to the survey and findings. This information will be used both to help shape the material being developed for the guide and to identify potential candidates for the validation case studies to be conducted in Phase 2 of this research.

### Approach

The research team developed a short on-line survey to identify the depth of knowledge and level of sophistication of travel time reliability; performance measures; travel time data collection and availability; reliability valuation; use of reliability in planning and programming; institutional relationships; and staff capacity. The survey instrument is provided in Appendix A.

The survey was distributed to DOTs and MPOs through all available channels. For state DOTs, the survey was distributed through the American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Planning (SCOP), Standing Committee on Performance Management (SCOPM), and Subcommittee on System Operations and Management (SSOM). For MPOs, the survey was distributed through research team contacts with individual MPOs and MPO organizations in several states.

The survey responses were reviewed and cleaned to ensure that there were no duplicate responses. Some DOTs and MPOs did provide multiple responses, typically from different

divisions, and these responses were usually retained. In cases in which one respondent from an agency appeared to have more information, this information was used. For example, one respondent from an agency might have answered “I don’t know” to a question that another respondent from the same agency answered with more specific information.

The data were identified by agency so that various comparisons could be made about the data, including area population, geographic location, and others. For the purposes of the findings presented, large agencies include states with more than five million people or regions with more than one million people. Small agencies are states with fewer than five million and regions with fewer than one million.

## Findings

### Response Rate

There is significant interest in travel time reliability among transportation agencies. There were 92 responses were received, with responses from 29 state DOTs and 39 MPOs. In several cases, multiple responses were received from the same agency. Note that the findings only include names of agencies that gave explicit approval to use their information; all other agencies are included in aggregate.

There are 50 states and 384 MPOs in the United States. Figure 3.1 presents the response rate by size of agency. Larger states and MPOs were more likely to respond to the survey, although states of all sizes responded. MPO responses were much more heavily concentrated among the agencies representing relatively large populations. Because the challenge of reliability is likely to impact larger urban areas more significantly than medium and small areas, it is useful to have a high response rate (50%) of these larger agencies.

Figure 3.2 presents the geographic distribution of responses across five regions of the United States. For state DOTs, a reasonable response rate was achieved from each region (at least 40% of states in each region responded to the

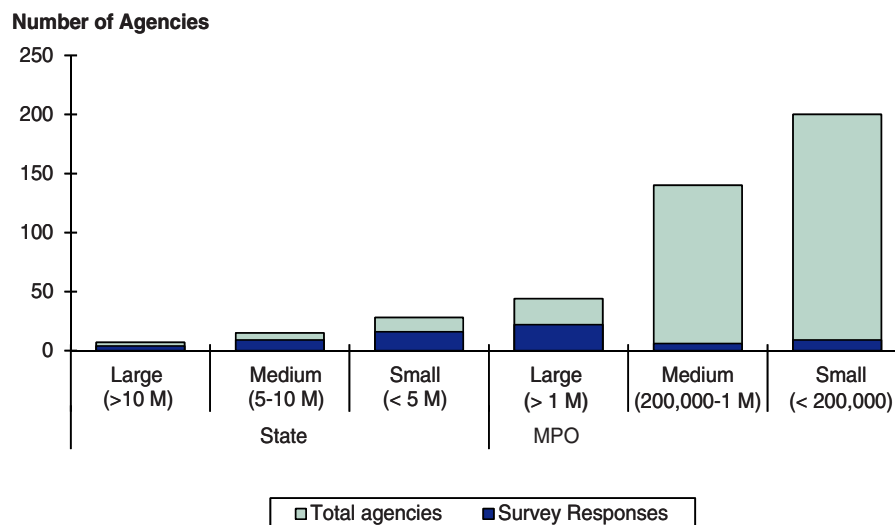


Figure 3.1. Number of survey respondents by agency type and size.

survey) and 75% of midwestern and southwestern states responded. For MPOs, a roughly equal number of responses were received from each region, but percentages are lower for the Southeast (5%) and Midwest (8%) and higher for the Southwest (22%). This may be in part because of the larger number of single county MPOs in states like Florida; only 7% of MPOs in the Southeast region are over one million in population.

### Key Findings

#### Definition of Travel Time Reliability

Of the organizations surveyed, 25% have developed an established definition of travel time reliability. Large agencies are far more likely to have developed a formal definition (35%) than small agencies (7%). MPOs and DOTs have established definitions at approximately the same rate.

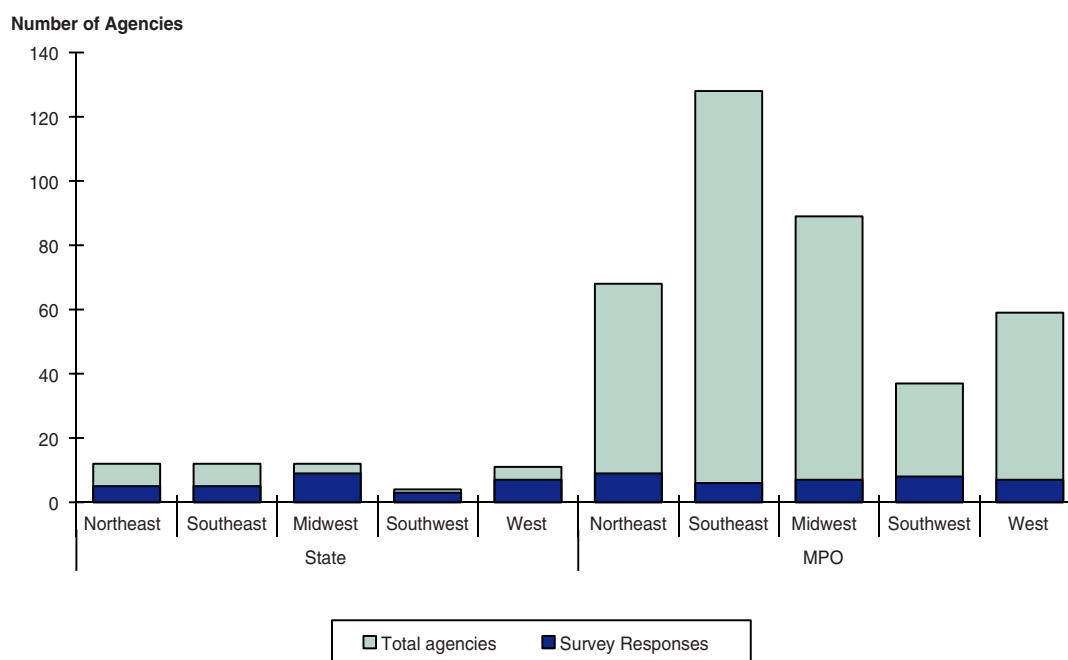
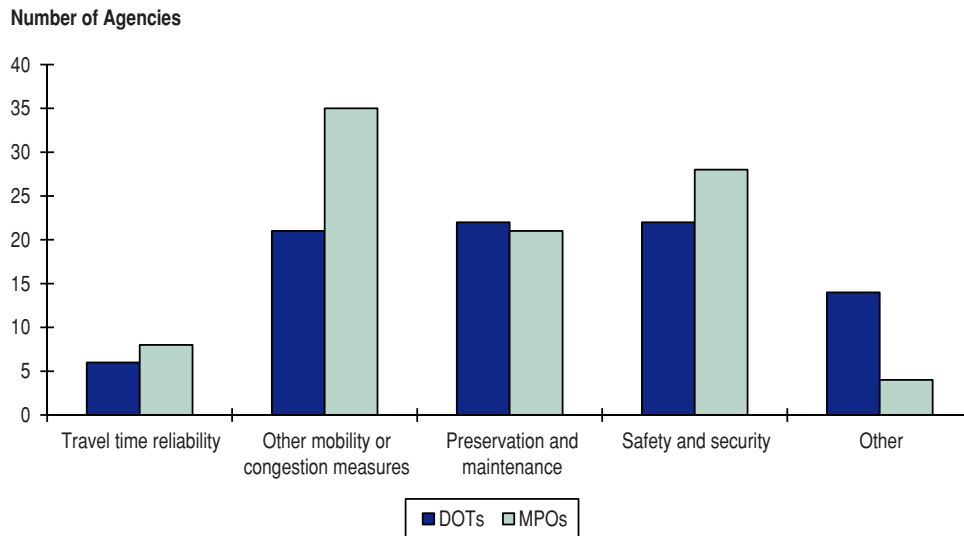


Figure 3.2. Number of survey respondents by agency type and geography.



**Figure 3.3. Performance measures reported by DOTs and MPOs.**

### Tracking Reliability Performance Measures

Many of the agencies that responded to the survey indicated that they are using performance measures, but only about 25% reported performance measures for tracking travel time reliability. Figure 3.3 presents the number of DOTs and MPOs that are tracking travel time reliability and other performance measures. Nearly all of the MPOs track mobility measures and over half track preservation and safety measures. About two-thirds of states track each of these measures.

Among agencies that do not track travel time reliability, 40% plan to begin within the next 3 years, while the remaining respondents were not sure or do not plan to do so within the next three years. Large agencies are far more likely to track reliability measures (33%) than small agencies (10%). Among agencies that report tracking travel time reliability, roughly equal numbers track the 95th or 90th percentile travel times (eight respondents), the planning-time index (seven respondents), and the buffer index (six respondents). Notably, many of these respondents (5) indicated that they track two or three of these measures, and one respondent noted tracking additional points of the travel time distribution (i.e., 50th and 80th percentiles in addition to 90th and 95th).

### Data Collection

Most agencies collect travel time data and do so mostly on urban freeways. Nearly all large agencies collect some form of travel time data (over 90%), while just under two-thirds of small agencies collect any travel time data. Loop detectors are the most common way to collect travel time data, with DOTs

much more likely to indicate that they use detectors than MPOs. Because DOTs typically own these detectors, MPO responses to this question may indicate DOT data to which they have access. MPOs are most likely to use floating car runs to validate their models. Fewer agencies use intelligent transportation system (ITS) detectors (such as loops, radar, or video imaging) and purchased private travel time data (e.g., INRIX, Traffic.com, or Trafficast). Figure 3.4 summarizes the data collection methods used by respondents to the survey.

Among agencies that collect travel time data, most collect data on most or all of their urban freeway segments, and all agencies collect travel time data on some of their urban freeway segments (Figure 3.5). DOTs commonly collect data on rural freeway segments, but very few agencies collect data for urban arterials. Only a few MPOs collect data for rural arterials, collector, or local streets. Among agencies that collect travel time data, more than half of the agencies use operations data from traffic management centers to support planning efforts. While about two-thirds of DOTs make use of the TMC operations data, fewer than half of the MPOs do.

### Monetization of Reliability

Relatively few agencies (fewer than 25%) responded that they monetize reliable travel time differently than average travel time. Respondents who said they monetized reliable travel time were asked for a value. The responses to this question generally indicated that agencies are only monetizing reliable travel time. Only one respondent provided an actual value (1.3 times the average value of travel time), and the respondent indicated that the agency only used it for occasional purposes, not on an ongoing basis.

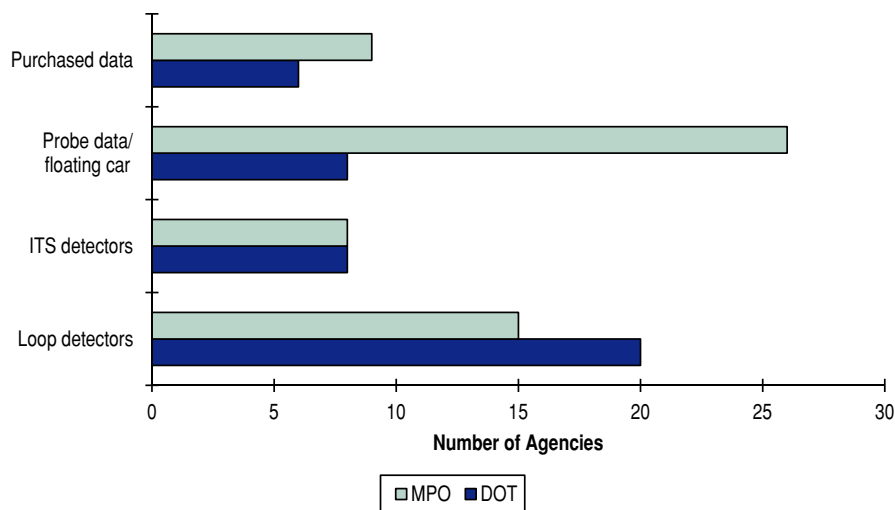


Figure 3.4. Data collection methods by agency type.

### Use of Reliability in Planning

For recently completed or upcoming planning studies, survey respondents were asked if reliability was incorporated in the planning process. For a range of planning efforts, respondents were asked if they “include reliability as a goal or address as an issue,” “identify reliability deficiencies or needs,” and/or “use reliability results to help evaluate or prioritize projects.” Findings by level of integration include the following:

- *Goal/issue.* Agencies commonly appear to identify reliability as a goal, with 54% of agencies identifying a reliability-related goal for at least one planning effort. More do so for long-range plans and CMPs (22 and 19 agencies, respectively) and

somewhat fewer for State Transportation Improvement Programs (STIPs) and Transportation Improvement Programs (TIPs), corridor plans, operation planning, and project plans (10 to 12 agencies).

- *Needs and deficiencies.* Just under half of agencies responding to the survey examine reliability needs and deficiencies in one or more planning product. These are identified most commonly within CMPs (19 agencies), which is not surprising, considering the intended role for CMPs in addressing these issues. Agencies claim to address reliability needs somewhat less frequently in long-range planning and operations plans (12 agencies) and project plans (15 agencies). Only 9 address reliability needs in a STIP/TIP and 12 in a corridor or area plan.

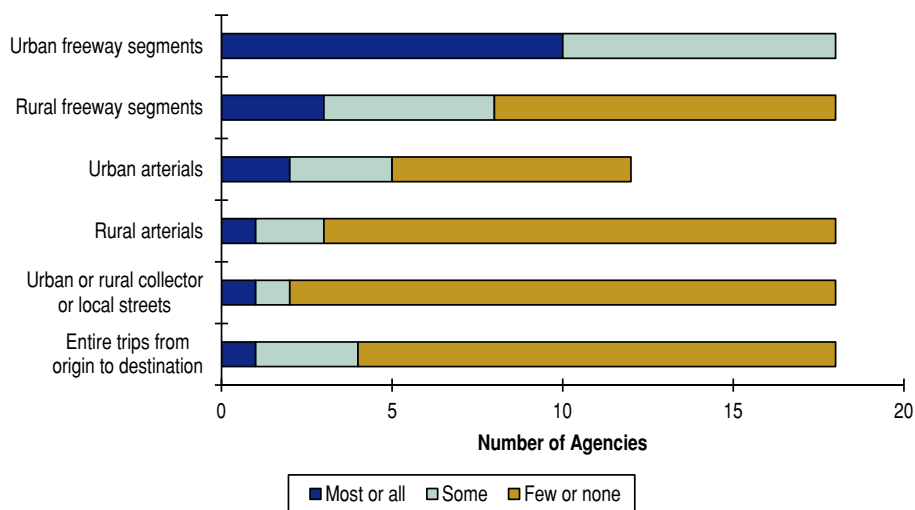
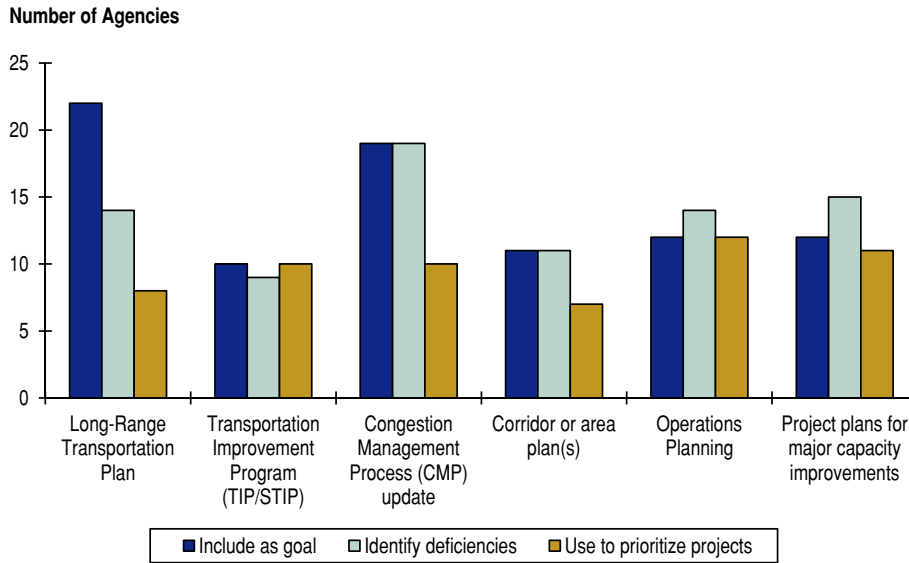


Figure 3.5. Travel time data collection by facility type.





**Figure 3.6. Agency uses of reliability in the planning process.**

- *Project prioritization.* Agencies report using reliability to support project prioritization least frequently (38% across all planning products). This was least common in long-range plans and corridor/area plans (8 and 7 agencies, respectively) and most common in operations planning and project plans (12 and 11 agencies, respectively).

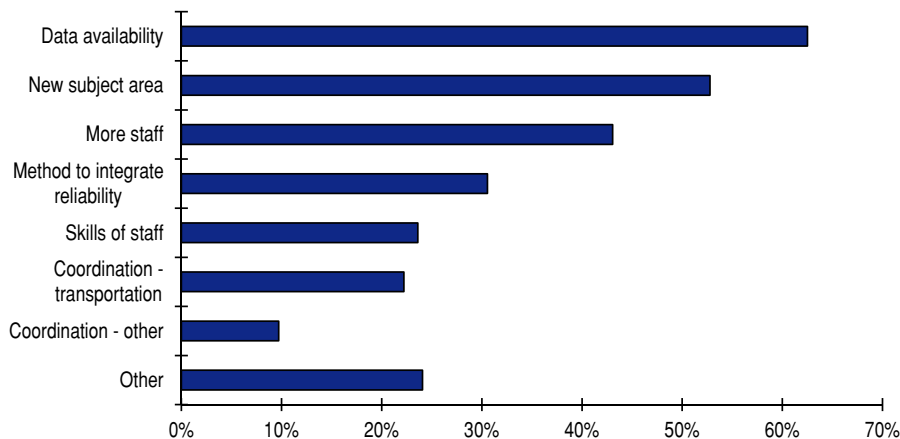
Figure 3.6 indicates agency uses of reliability in the planning process.

Agencies identified several challenges to incorporating reliability into planning and programming, including lack of data, newness of the subject material, or lack of staff (Figure 3.7). More than 60% of agencies saw lack of data availability as a challenge; more than 50% of agencies said that the newness of the subject is a challenge; and nearly 45% of responding

agencies indicated they do not have enough staff (note that this is a bigger issue among small agencies). About one-third of agencies said that there is “no clear way to link reliability with planning and programming process.” Lack of skills in current staff and coordination with other organizations were less frequently mentioned as challenges by survey respondents.

Respondents also listed a number of additional challenges, including the following:

- Lack of internal coordination;
- Data quality and managing large volumes of available data;
- Inability to predict future travel time reliability;
- Highway focus of reliability; and
- Cost to address reliability, including any impact on other initiatives.



**Figure 3.7. Challenges to incorporating reliability in planning and programming.**

**Coordination**

Coordination with other agencies on transportation system operations or reliability issues is most common through ongoing committee and stakeholder outreach with transportation planning and operations staff at DOTs and MPOs. Respondents noted that transit agencies are commonly involved, nearly equally through stakeholder outreach, ongoing committees, or planning study committees. Public safety and emergency response agencies are most commonly involved in addressing reliability or operations issues through stakeholder outreach and, in many cases, they participate in an ongoing committee. Toll authorities, towing companies, and shippers or freight carriers are less commonly involved, and when they are, it is through stakeholder outreach. It is not common among responding agencies to have staff colocated at a traffic management center. Figure 3.8 identifies the primary methods of coordination identified by respondents for various stakeholder groups.

**Upcoming Planning Efforts**

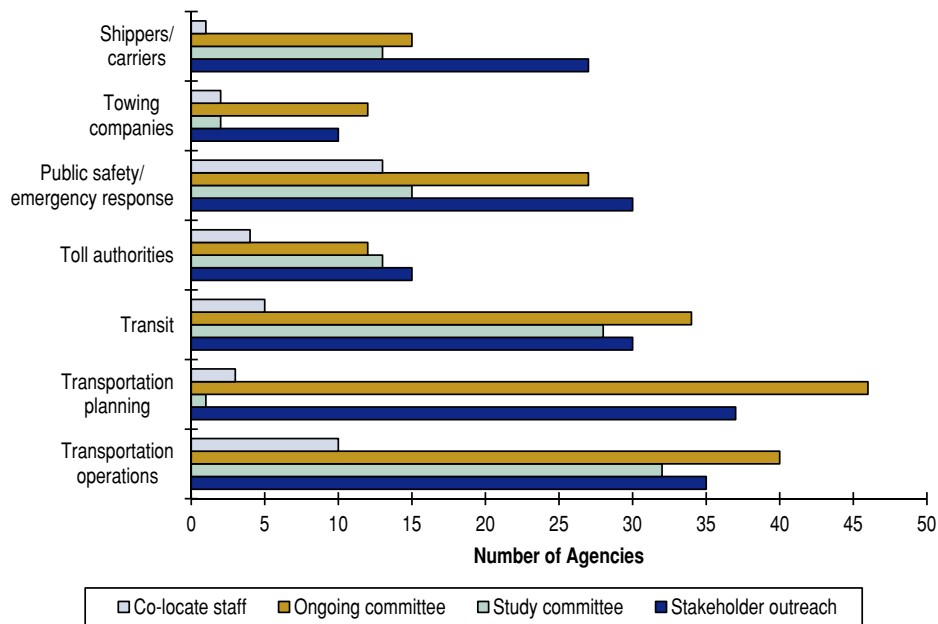
Finally, respondents were asked about upcoming planning efforts to help identify where potential opportunities exist to perform validation case studies. Most agencies will be working on planning products in the coming year. Of the 68 responding agencies, 39 will be producing a Long-Range Transportation Plan (LRTP) in the next year, and 45 will be working on their Transportation Improvement Program (TIP). Forty agencies plan to conduct corridor or area plans; 31 agencies

will update their congestion management process (CMP); 26 agencies will conduct major capacity improvements plans; and 27 will conduct operations planning. Information on upcoming planning efforts has been integrated into the case study selection effort described in Chapter 4.

**Summary**

The state of the practice survey provides a useful examination of where agencies stand in terms of their efforts to address and to measure travel time reliability, the data they need to measure, and the efforts they are making to integrate reliability as an issue within the transportation planning and programming process. By examining all of the responses together, a general continuum of sophistication in reliability measurement and application can be ascertained. The components of this continuum include the following:

- *Leaders and innovators.* Five DOTs and seven MPOs have established a definition of reliability and are currently tracking travel time reliability performance measures. Most of these are agencies with large populations in their jurisdictions, including DOTs from Florida, New York, and Wisconsin, and MPOs from Seattle, Washington, and Philadelphia, Pennsylvania. Note that throughout the summary, examples of agencies that have indicated an interest in participating in the study effort are given. Many responses to the survey were given anonymously. Some of these agencies are in relatively lower population jurisdictions, such as the MPO in Gary, Indiana.



**Figure 3.8. Coordination around reliability by stakeholder group.**

- *Unrealized opportunities.* Six large DOTs and 13 large MPOs are likely to have reliability problems (by virtue of population size). They track other performance measures and collect travel time data but do not track travel time reliability performance measures. This group includes DOTs in Colorado, Maryland, and Texas, and MPOs in Atlanta, Georgia; Detroit, Michigan; Dallas-Fort Worth, Texas; Pittsburgh, Pennsylvania; and Tucson, Arizona, among others.
- *Planning ahead.* Seven small DOTs and six small MPOs that are less likely to have ongoing reliability problems do track other performance measures and do collect travel time data but do not track travel time reliability performance measures. This group includes DOTs in Idaho and Iowa, as well as the Lake Tahoe, California MPO.
- *In need of a reliability primer.* A small number of larger agencies claim to not collect travel time data (though it is possible that respondents are simply not aware of what other parts of the agency are doing). Eleven smaller agencies also said they do not collect travel time data.

The information from the survey was an important input into the development of the guide. The survey helped identify which challenges the research team should focus on and what information holds interest for the primary audience. The survey makes clear that the audience for the guide has varying levels of sophistication and ability to take on the measurement and use of reliability within their planning processes. The methods in the guide will speak to these various audiences.

### **Conclusions and Lessons Learned**

The case study resulted in the following conclusions and lessons learned for MPOs in updating their CMP:

- In a survey of 20 MPOs representing most of the major metropolitan areas in the United States, only five are accounting for travel time reliability in some significant way in their transportation plans. Several of the larger metropolitan area MPOs (including Metro in Los Angeles County, Central Transportation Planning Staff [CTPS] in Boston, Chicago Metropolitan Agency for Planning [CMAP] in Chicago, Puget Sound Regional Council [PSRC] in Seattle) mention reliability only in the context of transit planning or freight movement.

- Those agencies that do not use reliability measures all agreed that it would be “nice” or “wish they could do it,” but resource limitations prevented them from doing so. These resource limitations include lack of sufficiently high-quality data and inadequate technical expertise.
- Calculating reliability performance measures requires robust amounts and sources of traffic data. Alternative data sources such as integrated corridor management (ICM) simulation modeling, regional 5-1-1 systems, and private sector data sources should be considered when developing data collection plans for reliability.
- Corridor-level reliability measures are recommended based on MWCOG experience.
- Effective report graphics are essential for presentation of the indices.
- No significant resistance to adopting and incorporating reliability measures into the CMP was encountered at the MPO Policy Board, stakeholder, or public involvement level at the five agencies. However, MPOs should consider developing explanations of travel time reliability indices that can be easily understood by multiple audiences.
- None of the five agencies using reliability exhibited significant differences in adoption and usage of the measures, regardless of the number of jurisdictions or institutional history or structure. This could bode well for MPOs with multiple jurisdictions or other factors that can complicate regional planning efforts.
- A performance measurement working group should be created with membership consisting of agency staff, technical and policy board members, local stakeholders, and the public. This will serve MPOs in CMP development and other initiatives.
- As a result of this case study, NCTCOG is already making efforts to acquire and incorporate additional sources of traffic data for use in their planning processes. This includes US-75 ICM data and continuous travel time data received as part of its regional 5-1-1 project. In conducting their CMP update, NCTCOG plans to report on reliability at the corridor level. NCTCOG staff members will focus on reporting reliability on highways for the current update and then work toward adding major arterials in the next update. The approach will allow them to set realistic goals for the first update, using the additional data and incorporating reliability measures. Once experience is gained using these resources and analysis approach, they will strengthen their planning techniques even further.

## CHAPTER 4

# Validation Case Studies

This chapter describes the approach used for selecting and conducting case studies that support the guide and the technical reference. From the state of the practice survey, 13 MPOs, 19 DOTs, and two transportation authorities expressed interest in participating in a more detailed case study. In addition, respondents identified planning products they expect to be working on in the next year, which is a key element of the proposed approach.

### Approach

The case studies for the SHRP 2 L05 project are unique in that they are validation case studies and not best practices case studies. Because the case studies validate reliability processes, the case studies are for areas that may not necessarily be fully incorporating reliability into their planning and operations processes. In general, case study agencies have at least begun to think about reliability but have not fully incorporated it into planning. The case studies provide an opportunity to test the methods presented in the guide and technical reference for incorporating reliability.

Project L05 identified a specific planning task (e.g., prioritizing projects, identifying reliability deficiencies and needs) and assisted the case study site by collecting and analyzing data. The project team and case study participants worked together to accomplish a specific desired outcome; the lessons learned were incorporated into the guide and technical reference. The validation case studies revolved around one or two of the following major planning and programming products.

- State and metropolitan Long-Range Transportation Plans (LRTP), which include a range of approaches, especially for states;
- Congestion management processes (CMP);
- Corridor, area, modal, and other similar studies that examine one portion of the transportation system;

- State Transportation Improvement Programs (STIP) or MPO Transportation Improvement Programs (TIP);
- State or regional efforts to plan for operations generally or to plan for special events, extreme weather, and other similar efforts;
- Project development processes (i.e., design);
- Environmental review;
- Project construction and work zone planning; and
- System operations and management.

### Selection Criteria

The team has defined multiple criteria for selecting validation case study sites. The team selected validation case study sites meeting as many of the following criteria as possible.

- *Understanding of reliability.* While the guide is intended to be applied at MPOs and DOTs at different levels of sophistication facing different levels of reliability problems, it is important that validation take place at agencies that have some conceptual understanding of reliability and face real reliability challenges. It is also useful to work with agencies that have been considering operations within the planning process, even if not explicitly measuring and tracking operations-oriented performance measures. All levels of sophistication are addressed, adapting the four levels of sophistication identified in Chapter 3 (i.e., sections on leaders and innovators, unrealized opportunities, planning ahead, and in need of a primer).
- *Area size.* Because of the need to have broad applicability, it is important to study metropolitan areas ranging in population size. The case studies include medium and large metropolitan areas because they are the most likely to have experienced travel time reliability problems.
- *Agency type.* It is important to study both state DOTs and MPOs. This ensures that both perspectives are accounted for in the guide and technical reference.

- *Work product.* Each case study validation site was organized around specific planning products or processes. Case study sites were selected in such a way that most work products and processes are accounted for.
- *Geographic coverage.* The case studies draw from agencies from across the United States representing various geographies and land-use development patterns. Case studies should include regions with dense urban areas and regions with more disperse suburban-style development. These areas are likely to have unique issues and unique solutions.
- *Willingness to participate.* Willingness to participate is important with any case study effort.

## Case Studies

The team identified validation case study locations from a combination of research team experience and the findings of the state of the practice survey described in Chapter 3. This chapter includes summaries of each case study developed in this research effort. Full write-ups of each case study can be found in the technical reference. Key findings from the case study results are referenced throughout the guide and technical reference and are summarized in Table 4.1

### Knoxville Region Transportation Planning Organization

The primary objective of the case study is to develop a process for estimating reliability performance measures and identifying reliability deficiencies based on traffic flow and incident duration data, as well as estimating the impacts of operations projects for the Knoxville Regional Transportation Planning Organization (TPO). The TPO has begun to carry out the update of the Long-Range Transportation Plan (LRTP) for the region and is undertaking Planning for Operations. This case study documents the incorporation of reliability into the agency's transportation planning process.

The case study also provides validation for the following steps in the guide.

- Measuring and tracking reliability;
- Incorporating reliability in policy statements; and
- Incorporating reliability measures into program and project investment decisions.

The case study was successful in establishing an initial framework for an ongoing reliability performance monitoring system. It demonstrated how various reliability performance indices and incident duration can be calculated using archived traffic volume, speed, and incident data from a regional ITS freeway management system. This is a critical first step in identifying reliability deficiencies on freeway segments and

potential traffic operations strategies for improving reliability on these segments.

It also demonstrated how agencies can formulate travel time reliability and incident duration goals and set specific targets for their region based on reliability and incident duration analysis results. These can be incorporated as criteria in the long-range transportation plan development process as well as in operations planning.

Finally, the case study showed how agencies can use sketch-planning methods and the data poor reliability prediction equations from SHRP 2 L03 to assess the reliability benefits for operations strategies within a regional ITS architecture and then build a roster of operations projects for inclusion in the LRTP.

### Florida Department of Transportation

The objective of the case study is to document Florida DOT's efforts to incorporate travel time reliability into their planning and programming process. Florida has developed reliability measures for both planning (system focused) and operations (corridor focused). These measures are being incorporated into Florida DOT's short-range decision support tool, the Strategic Investment Tool (SIT), which is used to prioritize projects for inclusion in the State Transportation Improvement Program (STIP). The planning office has also developed modeling techniques for predicting the impact of projects on travel time reliability. In addition, both offices are very interested in the economic value of projects and return on investment of operations improvements.

The case study documents these activities and provides validation for the following steps in the guide.

- Measuring and tracking reliability;
- Incorporating reliability in policy statements; and
- Incorporating reliability measures into program and project investment decisions.

The Florida DOT case study revealed that incorporating reliability (specifically operations projects) into the programming process is a challenging process for most state DOTs. It requires locating a specific funding category to cover operations improvements, although statutory requirements may limit the types of projects that can be funded with existing funding categories. Two basic funding models could be considered: (1) allocating separate funding for operations projects; or (2) allocating a portion of existing capacity funding for operations projects. This has important implications for the SHRP 2 L05 project, as it appears that many states would benefit from guidance on determining eligibility of funding operations improvements under specific silos or funding categories or making the required policy changes to set up

**Table 4.1. Key Findings and Lessons from Validation Case Studies**

Case Study	Objectives	Key Findings/Lessons	References
Colorado DOT	Conduct a before-and-after analysis and benefits study of a pilot traffic operations project being conducted by Colorado DOT in Denver. One of the key themes of SHRP 2 L05 and other efforts is an attempt to mainstream operations planning within the broader planning process. This validation case study identifies methods to better achieve that objective.	Documents the process for conducting an arterial before-and-after analysis with emphasis on travel time reliability. Benefits of operations strategies in improving travel time reliability. Steps to incorporating reliability performance measures into the LRTP at CDOT. The findings validate the operations planning phase of the planning process.	Technical reference: Section 2.2, Appendix D Technical reference: Chapter 6, Appendix B, Appendix C Technical reference: na
Florida DOT	Document FDOT's efforts to incorporate travel time reliability into their planning and programming process, including incorporating reliability into their short range decision support tool (Strategic Investment Tool) and modeling techniques for predicting the impact of projects on reliability.	Incorporating reliability into the programming process is a challenge due to lack of specific funding categories and challenges due to statutory requirements regarding the types of projects that can be funded. The case study documented many success factors for incorporating reliability into the planning and programming process. The findings validate the programming phase of the planning process.	Guide: Chapter 3 Technical reference: Chapters 2, 3
Knoxville, TN MPO	Demonstrate how reliability can be incorporated into the ITS/operations element of the region's upcoming LRTP and assist MPO staff in incorporating reliability performance measures in plan development, project identification, and project prioritization processes.	Developed a reliability objective for inclusion in the Congestion Management Process. Calculated reliability performance measures along freeways and incident prone locations. Developed a method for incorporating reliability into the project selection process. The findings validate tools for quantifying travel time reliability using somewhat less sophisticated modeling and other tools.	Technical reference: na Guide: Chapter 3 Technical reference: Chapter 5, Appendix D Technical reference: Chapters 3, 5
LAMTA (Los Angeles)	Document the development of an arterial performance monitoring system, which will be used to prioritize arterial operations projects for funding.	Recommends approach for using alternative data sources to support an arterial performance monitoring system. Preliminary findings suggest that multi-modal reliability measures can be calculated from alternative data sources, although data source consistency is critical.	Technical reference: Chapter 2, Appendix D
NCTCOG (Dallas-Fort Worth)	Identify best practices on how other MPOs are incorporating reliability into their Congestion Management Process and provide recommendations on how NCTCOG can incorporate reliability into their planning process.	Only a limited number of MPOs have incorporated reliability into their CMP. Success factors include having robust amounts and sources of traffic data, using corridor-level measures and effective reporting graphics, defining reliability in a way that can be easily understood by multiple audiences, and having a performance measurement working group consisting of agency staff, technical and policy board members, local stakeholders, and the public.	Technical reference: Chapters 2, 5, Appendix D
SEMCOG (Detroit)	Identify reliability performance measures for assessing highway operations and develop a method for incorporating reliability into SEMCOG's performance-based program trade-off process.	Reliability can be incorporated in the trade-off analysis process and will likely impact the results of the prioritization process; the use of representative corridors can be effective in conducting a regional analysis; assessments of reliability can be conducted even in situations with limited data availability. The findings validate incorporation of reliability into a program-level trade-off analysis.	Guide: Chapter 5 Technical reference: Chapters 5, 6, Appendix C
Washington State DOT	Incorporate reliability into identifying deficiencies and investments in a corridor.	Establishes a methodology for examining reliability deficiencies for WSDOT corridor studies.	Guide: Chapter 2. Technical reference: Chapter 3

Note: na = not applicable.

a dedicated funding mechanism. However, because different state DOTs have different programming priorities and processes, it may be difficult to identify a good decision-making model for the long term.

The case study validated the following success factors for incorporating reliability into the planning and programming process:

- Reliability needs to be specifically addressed in the vision, mission, and goals of a plan. These policy statements define the long-term direction of an agency and provide the foundation on which to select reliability performance measures and make the right choices and trade-offs when setting funding levels and selecting projects.
- Reliability needs to be a well-defined measure with supporting data. Well-defined reliability performance measures define an important, but often overlooked, aspect of customer needs. The measures help to support the development of policy language and are critical to making reasoned choices and balanced trade-offs.
- Reliability needs to be used to estimate and predict transportation needs and deficiencies including the development and analysis of project and scenario alternatives. Estimating reliability deficiencies using well-defined measures helps to define the size and source of the reliability problem and can be used to inform policy makers about how the reliability of the system has been changing over time and how it is expected to change in the future. The maps, charts, and figures provide critical background when making choices and trade-offs.
- Reliability needs to be used in program level trade-offs. Bringing reliability into the discussion brings clarity to the issue of balancing operations and capacity funding. Without the consideration of reliability, the trade-off nearly always tilts toward capacity projects.
- Reliability needs to be an integral component of priority setting and decision making at the project level. Incorporating reliability into project prioritization and programming brings clarity to the issue of choosing the appropriate balance of operations and capacity strategies.

State DOTs would benefit from a maturity model that defines various levels of organizational capability with respect to these success factors. State DOTs could use the maturity model as a tool for (1) assessing where they stand with respect to incorporating reliability into all components of the planning and programming process; (2) assisting them in understanding common concepts related to the process; and (3) assisting them in identifying next steps to achieve success toward an ultimate goal state. The maturity model should be a living document that is continually refined based on agency capabilities.

## Los Angeles Metropolitan Transit Authority

The objective of the Los Angeles (LA) County Arterial Performance Monitoring case study is to develop the preliminary framework for an arterial performance monitoring system, which is being developed by the Los Angeles Metropolitan Transit Authority (LAMTA) as an improved mechanism for prioritizing arterial operations projects for funding.

As part of the 2009 Long-Range Transportation Plan (LRTP), LAMTA continues to focus on improving arterial traffic flow through the implementation of transportation system management (TSM) projects, including intelligent transportation systems (ITS), coordinated signal timing, and bus signal priority. Historically, LAMTA has programmed over \$30 million per year to meet regional and subregional needs for projects of this nature. Due to a number of financial constraints, the 2009 LRTP Strategic Plan calls for a 50% reduction in TSM funding over the next 30 years. They have annual solicitations for agencies in LA County to apply for funding to improve arterial operations.

LAMTA's current process for prioritizing arterial operations projects involves conducting before and after evaluations. Data are collected using floating car surveys and spot counts. It is currently a reactive approach in response to incidents and complaints received from the traveling public. The basis for this approach is local level evaluation using optimization.

This case study documented the development of a preliminary framework for an arterial performance monitoring system. The case study results show that arterial reliability measures require robust data sets that provide sufficient data points on each roadway of interest during all times of interest. Although it is possible to calculate arterial reliability measures from a variety of multimodal data sources, there is a challenge in collecting large enough samples both spatially and temporally. Data source consistency is critical.

## Southeast Michigan Council of Governments

The Southeast Michigan Council of Governments (SEMCOG) is the metropolitan planning organization (MPO) for the Detroit region. As in many regions, the identified need for infrastructure improvements greatly outweighs the available funding levels, so a logical and effective process is needed to assist SEMCOG in setting program funding levels. They developed such a process while preparing their 2035 regional transportation plan (RTP) that allows them to trade off among several program areas, including pavement, bridge, highway capacity, safety, transit, and non-motorized modes. This case study updates that process to assess funding levels required for SEMCOG's roadway operations program by assessing total delay, including nonrecurring delay, the main cause of unreliable travel.

The case study provides validation for the “Incorporating Reliability into Program and Project Investment Decisions” step in the guide.

The comparison of the benefits estimated both with and without considering reliability shows several interesting results. Key findings include the following results.

As expected, when nonrecurring delay is considered in the analysis, the overall delay estimates are much greater (with the baseline delay more than doubling from 2.4 to 6.8 hours of delay per 1,000 vehicle miles traveled [VMT]).

Investments in roadway operations strategies were shown to yield a much greater impact on total hours of delay, particularly at the lower investment levels. Small investments in these strategies result in a steep curve of reducing delay levels.

Similar to the analysis, which does not consider reliability, there is a declining utility to higher investment levels, and increased investment brings about lower incremental improvement for each dollar spent.

In addition to the actual analysis results, several lessons were learned throughout the case study.

- Reliability can be relatively easily incorporated in the trade-off analysis process. Consideration of reliability will likely have an impact on the results of the prioritization process.
- The use of representative corridors can be effective in conducting a regional analysis within reasonable budget and schedule requirements.
- Even in situations with limited data availability, assessments of reliability can be performed efficiently, providing much needed consideration of these factors within the overall assessment of tradeoffs regarding investment priorities.

The analysis approach represented in this case study represents a first step in the overall incorporation of reliability performance measures in the investment prioritization process. Improvements and enhancements to this process may include the following.

- Application of nonrecurring congestion measurement within the analysis of highway capacity improvements to make the comparison of capacity and operations improvements more equitable (e.g., capture the reliability benefits of increasing capacity).
- Inclusion of a greater variety of representative corridors in the analysis.
- Development of automated routines to allow the estimation of incident-related delay and total delay (recurring and nonrecurring) within the travel demand model itself, thus allowing the more detailed regional assessment of these measures.

- Separating the various roadway operations improvements within the analysis to allow each strategy to be analyzed individually.

### **Colorado Department of Transportation (DOT) and Denver Regional Council of Governments**

This case study establishes baseline conditions for a pilot corridor and lays the groundwork for conducting a before-and-after analysis to assess benefits of operations strategies using an arterial performance monitoring system. It documents the steps to planning and funding an operations project intended to improve travel time reliability. Finally, the case study documents the Colorado Department of Transportation’s (CDOT) efforts in selecting and incorporating operations (including reliability) performance measures into their long-range planning process.

This case study provides validation for the following steps in the guide: (1) measuring and tracking reliability and (2) incorporating reliability measures into program and project investment decisions.

The pilot project on Hampden Avenue in Denver proved that reliability data can be calculated with a small amount of equipment (in this case three Bluetooth readers) over a relatively short period of time (two months). The use of this portable detection and monitoring system indicates to other agencies that corridor reliability studies and operations improvements benefits analysis can be conducted inexpensively.

CDOT is actively pursuing collection of reliability data. The purchase of Navteq data statewide and the portable detection and monitoring system have both proven to be valuable assets in obtaining reliability data. CDOT’s experience in their LRTP update process indicates that reliability data can provide transportation agencies with opportunities to enhance several steps within the statewide transportation plan development process, including

- Assessing program or strategy performance toward meeting mobility goals and objectives;
- Determining needs-based investment levels for corridors;
- Determining and evaluating the strategies that are best suited to improve travel in a corridor;
- Selecting and prioritizing projects for inclusion in the STIP; and
- Providing detailed data used in the design of specific projects.

CDOT modified their previous LRTP and STIP development processes to incorporate a process that is performance-driven and needs-based for this plan update cycle. They determined that reliability was one of the most important



factors in both evaluating system and project performance and assessing corridor needs. Developing plans based on performance data provides decision makers, taxpayers and users with assurances that implemented projects will meet performance goals, will be a high priority based on performance, and will provide users with specific benefits. Continuous monitoring of corridor and network performance will provide decision makers, taxpayers, and users with quantifiable information on both specific projects and on the sum of all improvements made to the corridor or network. Performance data, including reliability, provides accountability for investments to decision makers, taxpayers and users. Performance data also enables calculations of specific benefits and benefit-cost ratios that allow easy comparison with more traditional transportation improvements, such as capacity addition.

### **Washington State Department of Transportation**

The objective of this case study is to identify reliability deficiencies along a key segment of the Interstate 5 (I-5) corridor near the Joint Base Lewis-McChord military base and apply sketch-planning methods to assess the impacts of implementing a package of reliability mitigation strategies within the corridor.

The case study provides validation for the “Evaluating Reliability Needs and Deficiencies” and “Incorporating Reliability Measures into Program and Project Investment Decisions” steps in the guide.

The case study was successful in demonstrating how agencies can use sketch-planning methods to assess the reliability impacts for a package of operations strategies within a corridor and then advance these projects into the region’s long-range transportation plan. The case study demonstrated

- The process for collecting data and selecting appropriate analytical techniques from among several available options.
- How to divide the entire corridor into subsections. This allowed the analysis to be completed in a timely and resource-conscious manner without washing out the differences in performance that would have likely occurred if the corridor was treated as a whole.
- How to identify reliability deficiencies in a corridor using reliability thresholds.
- How a relatively low-cost set of operations investments can improve travel time reliability in a corridor.
- How agencies can apply sketch-planning methods using travel-demand-model data and the SHRP 2 L03 data poor reliability prediction equations within a spreadsheet environment.

## CHAPTER 5

# Summary of Technical Reference

The Strategic Highway Research Program (SHRP) 2 Project L05 technical reference, *Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes: Technical Reference*, provides guidance for transportation planning agencies to help them incorporate travel time reliability performance measures and strategies into the transportation planning and programming process. Strategies are discussed more fully in the guide. The technical reference will allow operational improvements to be considered alongside more traditional types of capital improvements and ensure that transportation funds are being used as effectively as possible.

The technical reference for incorporating reliability performance measures into the planning and programming process provides a how-to for technical staff to select and calculate the appropriate performance measures to support the development of key planning products, including the following:

- Long-range transportation plans;
- Transportation programs (STIPs and TIPs);
- Congestion management process;
- Corridor planning; and
- Operations planning.

The technical reference document is organized as follows:

- *Chapter 2: Overview of Travel Time Reliability.* This chapter summarizes foundational research on reliability, including a practical definition, how to measure reliability, why reliability is important, and strategies for improving reliability. It is based on previous work in the SHRP 2 Reliability Program.
- *Chapter 3: Description of Tools and Methods for Estimating Reliability.* This chapter summarizes the types of

tools and methods that may be used to estimate reliability measures, including sketch planning, model post-processing, simulation or multiresolution, and monitoring and management.

- *Chapter 4: Tool and Method Selection Process.* This chapter provides processes for selecting a reliability analysis tool or method and guidance for setting up the analysis.
- *Chapter 5: Conducting a Reliability Analysis.* This chapter provides systematic guidance in applying reliability analysis methods and tools.
- *Chapter 6: Benefit-Cost Analysis.* This chapter provides guidance on incorporating the results of the reliability analysis into a benefit-cost analysis.
- *Chapter 7: Improving Planning and Programming Capability.* This chapter describes a capability maturity model (CMM) approach for incorporating travel time reliability into planning and programming.

Selected relevant material from outside sources is in supplemental appendices.

- *Appendix A: Additional Resources.* This appendix provides annotated descriptions of references and other resources where the user may obtain additional relevant information, including descriptions of other parallel ongoing efforts related to performance measurement, analysis tools and the planning process.
- *Appendix B: Trends in Reliability.* This appendix presents an excerpt from the SHRP 2 L03 report, *Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies*, which provides an illustrative example of the challenges in interpreting the varied results of a reliability analysis.
- *Appendix C: IDAS Travel Time Reliability Rates.* This appendix presents the look-up tables from the ITS Deployment

Analysis System (IDAS) tool, which are required for some of the analysis methods.

- *Appendix D: Benefits and Costs of Full Operations and ITS Deployment: Technical Appendix.* This appendix presents additional information on completing a multi-scenario post-processing method.
- *Appendix E: Data Collection Methods.* This appendix presents an overview of various types of traffic data and describes technologies and methods for collecting the data.
- *Appendix F: U.S. DOT Guidance on Performance Measures.* This appendix presents guidance on how to calculate various reliability measures from simulation model outputs.
- *Appendix G: Guidance to Improve Transportation System Management and Operations (TSM&O) Planning and Programming Capability.* This appendix presents guidance on the types of actions needed to improve an agency's capability in the seven critical dimensions of TSM&O planning and programming.

## CHAPTER 6

# Incorporating Reliability into Planning and Programming

This chapter describes a framework for incorporating reliability into the planning and programming process. The framework addresses

- *The flexibility of the existing planning process.* The concepts reported in this framework for incorporating reliability are based on the long-standing, traditional, standard, federally mandated planning model. The framework provides guidance while allowing for the wide variation in how this model is applied in the real world.
- *Incorporation of reliability into technical processes.* The framework provides guidance for transportation agencies to learn the technical aspects of travel time reliability performance measurement (i.e., data collection and modeling); the development and evaluation of non-capacity improvement options; and how to incorporate the technical findings into transportation planning.
- *Integration of planning for operations into traditional planning.* The traditional continuing, cooperative, and comprehensive (3C) planning process focuses on capacity improvements and does not address the full menu of reliability-oriented strategies, especially operational improvements. This process, for example, does not include operations improvements that target incidents and other nonrecurring traffic disruptions that cause unreliable travel. Operations investments often include procedural changes (e.g., change to an agency's approach incident response) that may not have any capital cost and include staff from agencies that are entirely outside the conventional state-wide and metropolitan planning process. The framework provides guidance for incorporating operations in the traditional planning process.
- *Audiences with different levels of experience with performance measures.* Implicitly, the SHRP 2 L05 project assumes that agencies use some performance measures in transportation planning. In practice, many states and MPOs are only beginning to use performance measures and may have limited experience with the data, tools, and techniques required

to measure reliability and incorporate it into their planning process. This fact substantially impacts the ability of the planning process to deal with operational improvements whose justification and design features are substantially related to impacts on reliability. The framework provides guidance for many types of transportation agencies, not just those that have experience with performance measures and reliability.

## Framework for Incorporating Reliability into Planning and Programming

Given the extensive resources the second Strategic Highway Research Program (SHRP 2) has put toward developing the PlanWorks (formerly known as Transportation for Communities: Advancing Projects through Partnerships [TCAPP]) framework, the SHRP 2 L05 framework has been designed to align with the PlanWorks framework. PlanWorks provides a representation of the key decision points (KDPs) that are used as a model in the overall transportation planning and programming process, primarily for major capital investments. These KDPs are organized around four phases of transportation planning and project development.

- Long-range planning;
- Corridor planning (COR) (including subarea and other similar planning efforts);
- Programming; and
- A merged environmental review and permitting process.

While the PlanWorks process is focused on major capital investments, the assumption of the guide is that the transportation planning process is flexible enough to accommodate new concepts and approaches. From the perspective of SHRP 2 Project L05, two planning efforts are not explicitly addressed.

- *Operations planning.* SHRP 2 L05 examines the broad range of strategies that have the potential to improve travel time

reliability, including capacity, operations, and travel demand strategies; strategies that address the full range of travel modes; and strategies for both passenger and freight movements. Because PlanWorks focuses on capacity projects, it naturally does not address operations and related strategies, and only tangentially considers transit. Systems operations and management strategies improve nonrecurring congestion rather than the recurring congestion addressed by capacity strategies. Agencies may wish to directly incorporate operations into the PlanWorks process or set up a parallel process for operations. Either way, it is important for this framework to provide guidance for estimating the impact of operations investments on reliability.

- *Congestion management process.* The congestion management process (CMP) is intended to be a key place for consideration of the full range of strategies to address congestion and, by extension, reliability. The CMP is designed to develop and evaluate options for alleviating congestion using an ongoing process that does not necessarily result in a product (unlike a long-range transportation plan or a state or regional transportation improvement program). The framework identifies KDPs used in the CMP, drawing from recent work by the FHWA to provide guidance on the CMP for the transportation agencies that are required to use this process.

The framework for incorporating reliability performance measures into the planning and programming process includes four key steps.

1. *Measuring and Tracking Reliability Performance.* Agencies must first understand the reliability of their transportation systems. Doing so requires tracking and monitoring reliability based on quality supporting data. Well-defined reliability performance measures define an important, but often overlooked, aspect of customer needs. The measures help to support the development of policy language and are critical to making reasoned choices.
2. *Incorporating Reliability in Policy Statements.* Use reliability performance measures and concepts to draft policy statements (vision, mission, goals, and objectives), define the long-term direction of the agency, and make choices when setting program funding levels and prioritizing projects.
3. *Evaluating Reliability Needs and Deficiencies.* Use reliability to estimate and predict transportation needs and deficiencies and to develop lists of projects to address reliability. Estimating reliability deficiencies using well-defined measures will help to define the size and source of the reliability problem and to inform policy. The outputs of this process (maps, charts, and figures) will provide background when

developing policies, setting the size of the reliability program, and prioritizing projects.

4. *Using Reliability Performance Measurement to Inform Investment Decisions.* Use reliability performance to set reliability program funding levels and targets. Also, use reliability performance to set the right funding levels for other programs. Without considering reliability, it is more likely that capacity projects will be funded over operations and management projects.

The steps are described in detail in the accompanying guide. The remainder of this chapter summarizes how these steps relate to the PlanWorks framework. Appendix B provides an in-depth examination of the linkages between reliability performance and the PlanWorks framework. Figure 6.1 presents the PlanWorks framework with KDPs colored to reflect the activities appropriate for each KDP. The following sections describe how reliability is incorporated into the four PlanWorks phases, as well as operations planning and the congestion management process.

## Long-Range Planning

Long-range transportation planning is the phase of the transportation planning process that typically includes setting strategic priorities for the transportation system, identifying and understanding needs and deficiencies, and in some cases identifying solutions, including specific projects. The long-range planning (LRP) process described by PlanWorks focuses on the MPO long-range planning process because current federal regulations are more prescriptive for MPOs, requiring fiscal constraint and air quality conformity, than they are for states.

Table 6.1 describes how reliability can be incorporated into the long-range planning process.

## Programming

Programming (PRO) is the process of selecting specific transportation projects for development or construction, depending on the phase of the project. The outcome of the programming process is a STIP or TIP, depending on agency type, but the programming process is typically an on-going process that is continually updated as needs are identified, projects are scoped and designed, and revenue sources fluctuate. Reliability is most usefully considered within the programming process as a potential means to help prioritize potential future investments.

Table 6.2 identifies the specific KDPs within PlanWorks that are important for incorporating reliability into the programming process.

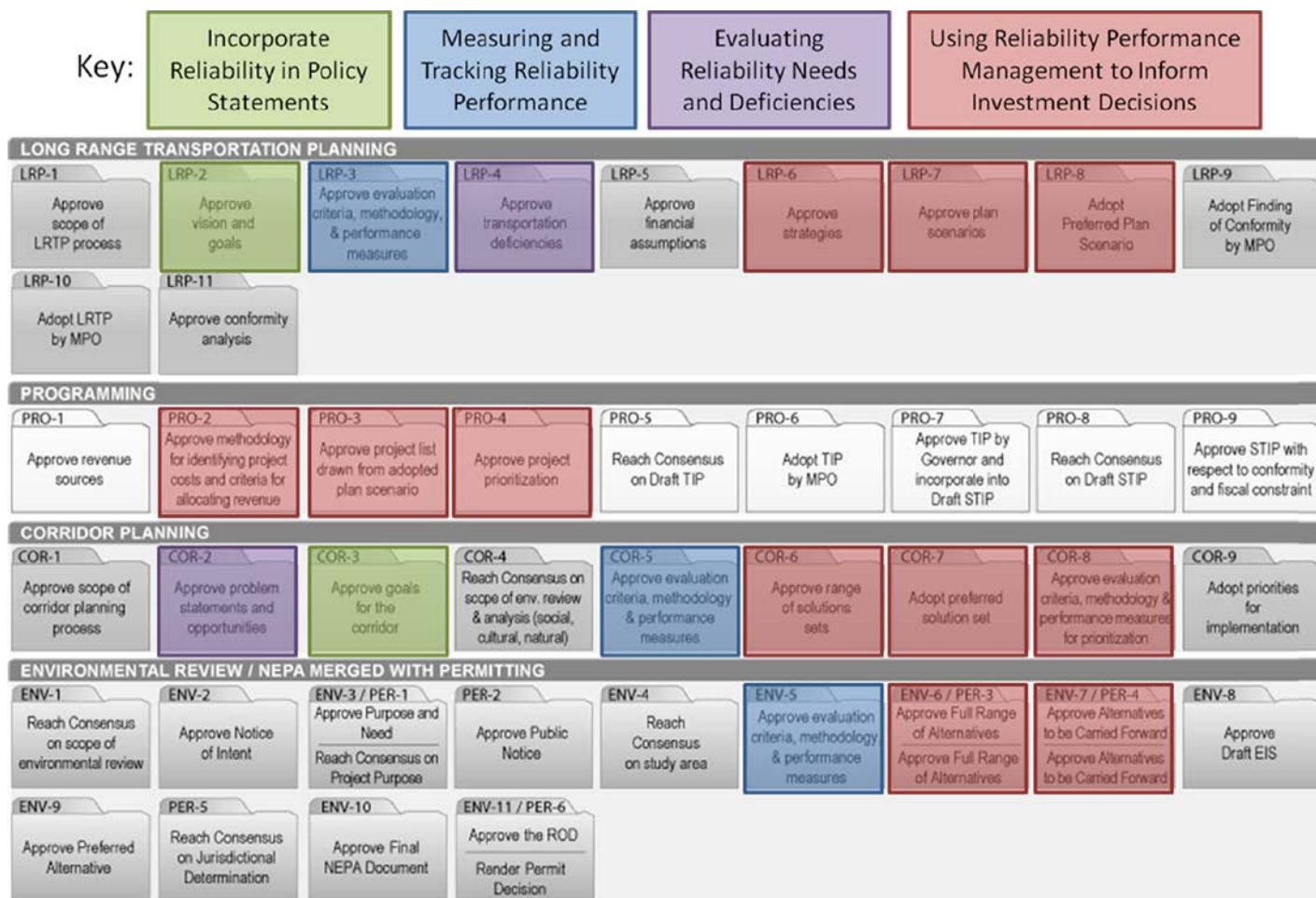


Figure 6.1. Incorporating reliability into the PlanWorks framework.

### Corridor Planning

Corridor planning is not required, but it is commonly used by transportation agencies to focus on the transportation needs of a specific corridor or area. Corridor planning is relevant for multiple types of investments and provides a way to consider trade-offs among investment types. At the corridor level, it is possible to consider the fit of a given investment type (e.g., a corridor may not have room for expansion), and it is easier to engage specifically relevant stakeholders (e.g., the residents and business located along the corridor, as well as the people and business who use a corridor). Defining the extent of a corridor under study is critical because improvements or changes to one corridor have the potential to shift traffic to others.

Table 6.3 identifies how reliability would be incorporated into the PlanWorks framework for corridor planning.

### Merged Environmental Review and Permitting

The final phase of PlanWorks is a merged environmental review and permitting (ENV/PER) phase. Reliability is related

to these phases of planning and project development in a more indirect way, though there may be elements of project design that might appropriately be influenced by reliability considerations. The specific KDPs in which reliability should be incorporated into environmental review and planning are described in Table 6.4.

### Congestion Management Process (CMP)

All metropolitan areas with more than 200,000 residents are officially defined as transportation management areas (TMA) and are required by MAP-21 to develop a congestion management process (CMP). The CMP is “a systematic and regionally accepted approach for managing congestion that provides accurate, up-to-date information on transportation system performance and assesses alternative strategies for congestion management that meet state and local needs. The CMP is intended to move these congestion management strategies into the funding and implementation stages.” (1)

Because the CMP is intended to help integrate operations strategies into metropolitan long-range transportation plans

**Table 6.1. Incorporating Reliability into Long-Range Planning**

LRP KDP	Description	Incorporating Reliability
2: Approve vision and goals	Community values articulated into transport-specific vision and goals	<i>Incorporating Reliability in Policy Statements.</i> At this KDP, an analysis of reliability and gathering of information from stakeholders and the public can help an agency determine how to educate the public regarding the relevance of reliability to their travel and whether reliability should be a goal or objective for the transportation system.
3: Approve evaluation criteria, methodology, and performance measures	Develop evaluation criteria, methodology, and performance measures for the LRTP in order to compare scenarios to each other and to the vision and goals	<i>Measuring and Tracking Reliability Performance.</i> At this KDP, transportation planners will identify the appropriate reliability measures to use in evaluating long-range plan scenarios. These measures will depend on the goals and objectives set in LRP-2.
4: Approve transportation deficiencies	Identify transportation deficiencies within the planning area that should be addressed in the LRTP	<i>Evaluating Reliability Needs and Deficiencies.</i> At this KDP, planners will classify corridors or locations now and in the future in which travel time reliability fails to meet acceptable thresholds using the performance measures identified in LRP-3.
6: Approve strategies	Develop and evaluate groups of strategies relative to stated needs	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, planners will ensure that the full range of strategies, including operations, are considered in developing plan scenarios.
7: Approve plan scenarios	Identify plan scenarios for testing and comparison in order to select a preferred plan scenario for the region	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, planners will make use of reliability and other performance measures to help compare and package together scenarios that include a range of strategies (both short and long term). This step will require significant analytic capabilities to provide a robust analysis of the impacts of various scenarios on travel time reliability.
8: Adopt preferred plan scenario	Evaluate proposed scenarios in order to identify the locally preferred scenario that addresses the deficiencies while supporting the vision and goals	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, planners will refine and expand the analysis conducted in LRP-7 to develop a preferred scenario. This scenario will include both long- and short-term improvement measures.

**Table 6.2. Incorporating Reliability into Programming**

PRO KDP	Description	Incorporating Reliability
2: Approve methodology for identifying project costs and criteria for allocating revenue	Establishes a consistent methodology for estimating project costs for both the long-range transportation plan and the TIP. It also documents the specific requirements and restrictions associated with each funding source	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, transportation planners will ensure that the full range of strategies is included. This step requires understanding what funding sources can be used for operations strategies, having approaches to support projects using a combination of funding sources, and understanding different implementation timeframes. Operations strategies typically have no dedicated source of funding; establishing a dedicated source might help to ensure that the full range of strategies are addressed.
3: Approve project list drawn from adopted plan scenario	Establishes the list of projects drawn from the long-range plan or corridor-planning process that will be considered for funding in the TIP	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, planners will ensure that all the strategies are considered in the project evaluation, including operations. This step might require evaluating how projects are scoped (i.e., does a project include the right set of strategies for the location?) and ensuring that operations strategies are considered for programming more generally. This step is intended to be linked to a long-range plan but may also be linked to operations planning (see section on operations planning).
4: Approve project prioritization	The approved project list is prioritized using the methodology previously developed	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, transportation planners will include reliability and other performance measures to help compare and rank projects.

**Table 6.3. Incorporating Reliability into Corridor Planning**

COR KDP	Description	Incorporating Reliability
2: Approve problem statements and opportunities	The full range of deficiencies and opportunities within a corridor are defined.	<i>Evaluating Reliability Needs and Deficiencies.</i> At this KDP, planners will evaluate the travel time distribution for the corridor and examine locations where travel time reliability exceeds a threshold or target value.
3: Approve goals for the corridor	Adopt the comprehensive set of goals for the corridor.	<i>Incorporating Reliability in Policy Statements.</i> At this KDP, planners will analyze reliability and gather information from stakeholders to determine what level of reliability to target for the corridor.
5: Approve evaluation criteria, methodology, and performance measures	Define a methodology that includes criteria to enable a comparison and selection of solutions that address the corridor's opportunities and deficiencies and that address the approved goals.	<i>Measuring and Tracking Reliability Performance.</i> At this KDP, transportation planners will identify the appropriate reliability measures to use in evaluating corridor scenarios. This step also will involve setting targets for reliability and other measures.
6: Approve range of solution sets	Determine a range of solutions for the identified problems and opportunities.	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, planners will ensure that the full range of strategies, including operations, is considered in developing corridor scenarios.
7: Adopt preferred solution set	Select a preferred solution set from the full range of solutions.	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, planners will make use of reliability and other performance measures to help compare proposed solution sets for the corridor.
8: Approve evaluation criteria, methodology, and performance measures for prioritization	Identify the evaluation methodology, criteria, and performance measures for prioritizing the implementation of the solution set for the corridor.	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, transportation planners will identify and include reliability and other performance measures to help compare and rank projects.

and is performance-based, it is a natural process for addressing and using reliability performance measures. To be consistent with the overall framework described above, a set of KDPs has been developed from the CMP actions described in the FHWA's *Congestion Management Process: A Guidebook (1)*. Not every action in that step is considered a key decision point, because not all actions require one or multiple agency to make specific decisions. In developing a set of KDPs for the CMP, the research

team has made every attempt to stay true to the intent of the SHRP 2 program in developing PlanWorks.

Table 6.5 presents a proposed set of KDPs for the CMP and describes how reliability would be integrated into these KDPs. The CMP is required but the CMP does not result in formal documentation at many transportation agencies. The importance of this process for addressing congestion makes it valuable to address how reliability will be incorporated.

**Table 6.4. Incorporating Reliability into Environmental Review and Permitting**

ENV/PER KDP	Description	Incorporating Reliability
ENV-5: Approve evaluation criteria, methodology, and performance measures	Define evaluation criteria, methodology and performance measures to compare how alternatives meet the purpose and need.	<i>Measuring and Tracking Reliability Performance.</i> At this KDP, transportation planners will identify the appropriate reliability measures to use in evaluating corridor scenarios.
ENV-6/PER-3: Approve full range of alternatives	Identify a range of alternatives that meet the project purpose and need.	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, transportation planners will identify operations strategies that either stand alone as alternatives or complement other strategies.
ENV-7/PER-4: Approve alternatives to be carried forward	Narrow the alternatives for detailed analysis. For permitting, alternatives should be narrowed to those that avoid and minimize resource impacts to the greatest extent practicable.	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, transportation planners will use reliability and other performance measures to help compare and rank alternatives.



**Table 6.5. Congestion Management Process Key Decision Points**

<b>CMP KDP</b>	<b>Description</b>	<b>Incorporating Reliability</b>
1: Approve objectives for congestion management	Objectives should draw from the community values articulated in the regional vision and goals identified in the MPO's LRTP.	<i>Incorporating Reliability in Policy Statements.</i> At this KDP, planners will analyze reliability and gather information from stakeholders and the public to determine if reliability should be a goal or objective for the transportation system.
2: Approve CMP network	Define both the geographic scope and the system elements (e.g., freeways, major arterials, transit routes) that will be analyzed in the CMP.	<i>Incorporating Reliability in Policy Statements.</i> At this KDP, planners will think proactively about the network where travel is likely to be unreliable.
3: Approve multimodal performance measures	Develop performance measures to identify, assess, and communicate congestion.	<i>Measuring and Tracking Reliability Performance.</i> At this KDP, transportation planners will identify the appropriate reliability measures to use in evaluating congestion. These measures will depend on the goals and objectives set in CMP KDP-1.
4: Approve congestion problems and needs	Identify congestion deficiencies and sources within the approved CMP network that should be addressed in the CMP.	<i>Evaluating Reliability Needs and Deficiencies.</i> At this KDP, planners will classify corridors or locations where travel time reliability exceeds some threshold or target value using the performance measures identified in CMP KDP-3.
5: Approve strategies	Identify and assess groups of strategies relative to stated needs.	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> At this KDP, planners will ensure that the full range of strategies, including operations, are considered.

**Table 6.6. Key Decision Points for Operations Planning**

<b>OPS KDP</b>	<b>Description</b>	<b>Relationship to Reliability</b>
1: Adopt regional ITS architecture	Develop and maintain the regional ITS architecture in conformance with the National ITS Architecture requirements.	<i>Incorporating Reliability in Policy Statements.</i> Planners will include data collection and reporting capabilities for reliability in the regional architecture.
2: Adopt project level concept of operations (ConOps) and systems engineering management plan (SEMP)	Develop project ConOps and SEMP.	<i>Incorporating Reliability in Policy Statements.</i> Planners will include a methodology to enable data collection and reporting of reliability.
3: Approve scope of the operations plan	Identify the mode, facility type and range of cost and schedule for the operations plan.	<i>Incorporating Reliability in Policy Statements.</i> Planners will use reliability performance to define the general scope of the problem to be addressed.
4: Approve operations problem statements and opportunities	Identify specific locations, problem type, and solution opportunities, including identifying a wide range of deficiencies.	<i>Evaluating Reliability Needs and Deficiencies.</i> Planners will use reliability data to identify problem locations, including their duration and extent. At this step, planners also will review the reliability status of current operational deployments.
6: Approve operations evaluation criteria, methodology, and performance measures	Identify specific performance criteria, methodology, and measures that will be used for the operation planning evaluation process.	<i>Measuring and Tracking Reliability Performance.</i> Planners will use reliability performance to evaluate operations projects.
7: Approve range of solution sets	Identify potential solutions that will meet goals of the operations plan.	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> Planners will evaluate solutions using reliability performance.
8: Adopt preferred solution set	Evaluate the solutions using the performance criteria and methodology and define preferred solutions.	<i>Using Reliability Performance Measurement to Inform Investment Decisions.</i> Planners will adopt solutions sets using reliability performance.

## Operations Planning

The existing PlanWorks process was developed for capital investment planning. Operations planning (OPS), however, has little relationship to this process. Operations investments typically are short range, low capital, and often management-focused. They are designed for a real-time environment. Incorporating reliability into the planning and programming process could proceed along two tracks. The first track would focus on mainstreaming operations within the broader, traditional planning process. In this track, planners would treat operations and planning projects together using technical methods to compare projects directly. The second track focuses on a parallel operations planning process, on the assumption that, for

many agencies, operations and capacity planning may remain in separate silos.

This section describes a parallel operations planning track, identifying a set of key decision points for operations planning. These KDPs are intended to provide for flexibility in application, allowing agencies to combine them in different configurations to fit with their operations planning process. Table 6.6 presents a set of KDPs for operations planning.

## Reference

1. *Congestion Management Process: A Guidebook*, Federal Highway Administration, U.S. Department of Transportation, 2011.

## APPENDIX A

# State of the Practice Survey

This appendix provides the state of the practice survey.

### Introduction

Thank you for taking time to answer some questions about the emerging use of travel-time reliability performance measures in transportation. On behalf of the National Academies of Science, Cambridge Systematics, Inc., is conducting this survey to identify current uses of travel time reliability—how consistent travel conditions are from day-to-day—in transportation planning, programming, and budgeting processes.

Reliable travel, something drivers seek, is defined by a consistency or dependability in travel times, as measured from day-to-day or across different-times of day. Drivers want to know that a trip will take a half-hour today, a half-hour tomorrow, and so on.

This survey is designed to take 5 to 10 minutes to complete.

Your responses will be used in aggregate unless you indicate that you and your organization would be interested in participating in a more detailed case study with the project team. A link with details of the Strategic Highway Research Program is available on the ‘Thank You’ page at the end of the survey. Our contact information also is available on the ‘Thank You’ page if you would like to discuss this project further.

### Questions

1. Respondent Information

- Name:
- Organization Name:
- Division/Group within Organization:
- E-mail Address:
- Phone Number:

2. Is your organization an MPO or DOT?

- MPO
- DOT
- Other

3. Are transportation congestion and travel-time reliability significant issues in your region?
  - Yes
  - No
  - Not Sure
4. Has your organization established a definition of travel-time reliability?
  - Yes (please describe)
  - No
  - Not Sure
5. Does your organization track and/or report performance measures in any of the following areas? (Check all that apply)
  - Travel-time reliability (Note: If a respondent indicated that they do measure travel-time reliability, they skipped questions 6 and 7. If a respondent indicated that they do not measure travel-time reliability, they skipped questions 8, 9, 10, and 11.)
  - Other mobility or congestion measures
  - Preservation and maintenance
  - Safety and security
  - Other (please specify):
6. Do you plan to report on travel-time reliability in the next three years?
  - Yes
  - No
  - Not Sure
7. How does your organization collect your travel-time data? (Check all that apply)
  - No travel-time data collected
  - Detectors (loop, microwave, infrared, etc.)
  - Probe data (toll tags, Bluetooth, license plate readers, etc.)
  - Purchased private travel-time data (e.g., INRIX, Traffic.com, Trafficast)
  - Floating car or other travel-time runs
  - Other (please specify)

8. Which travel-time reliability performance measures does your organization track and/or report? (Check all that apply)
- 90th or 95th percentile travel-times
  - Buffer Index
  - Planning-Time Index
  - Other (please specify)

9. How are the travel-time data collected? (Check all that apply)
- Loop detectors
  - ITS detectors (e.g., radar, license plate readers, electronic toll tags)
  - Probe data (toll tags, Bluetooth, floating cars)
  - Purchased private travel-time data (INRIX, Traffic.com, Trafficast)
  - Other (please specify)

10. For what facilities and to what extent are travel-time data collected? (Check all that apply)

	most/all	some	very few/none
Urban freeway segments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rural freeway segments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Urban arterials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rural arterials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Urban or rural collector or local streets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Entire trips from origin to destination	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. For use in modeling, benefit-cost and other purposes, many organizations use a dollar value for travel-time. Does your organization use a different dollar value for travel-time lost due to unreliable conditions?
- Yes—What is it and how did you determine it?
  - No
  - Not Sure
12. Will your organization be producing any of the following plans or programs during the coming year? (Check all that apply)
- Long-Range Transportation Plan
  - Transportation Improvement Program (TIP)

- Congestion Management Process (CMP) update
- Corridor or area plan(s)
- Operations Plans
- Project plans for major capacity improvements
- Other (please specify)

13. For recently completed or upcoming planning studies, did you or do you plan to (Check all that apply)

	<b>... include reliability as a goal or address as an issue?</b>	<b>... identify reliability deficiencies or needs?</b>	<b>... use reliability results to help evaluate or prioritize projects?</b>
Long-Range Transportation Plan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Transportation Improvement Program (TIP/STIP)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Congestion Management Process (CMP) update	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Corridor or area plan(s)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Operations planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Project plans for major capacity improvement projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify):	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

14. Do you face any of the following challenges to incorporating reliability in your planning and programming processes? (Check all that apply)

- New subject area
- Not enough staff
- Lack of skills in current staff
- No clear way to link reliability with planning and programming process
- Lack of data availability
- Lack of coordination with other transportation organizations
- Lack of coordination with other non-transportation organizations
- Other (please specify)

15. How do you coordinate with other agencies on transportation system operations or reliability issues? (Check all that apply)

	<b>Through stakeholder outreach in planning studies</b>	<b>Participate in a committee for a planning study</b>	<b>Participate in an ongoing committee</b>	<b>Staff colocated at a traffic management center</b>
Transportation operations staff (DOT or MPO)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Transportation planning staff (DOT or MPO)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Transit agencies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Toll authorities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Public safety and emergency response	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Towing companies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shippers or freight carriers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify):	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

16. Does your agency make use of operations data (real-time or archived) from traffic management centers to support planning efforts?

- Yes
- No
- Not Sure

17. Are there other individuals, positions, and/or divisions/groups within your organization that perform (or would perform) reliability analysis or utilize reliability data that you think we should follow up with?

18. If you have any additional input or comments, please include them here.

19. Would you be interested in participating in a more detailed case study as the project progresses?

- Yes
- No
- (If yes, please enter Name, Title, E-mail, and Phone Number)

## APPENDIX B

# Incorporating Reliability into PlanWorks

This appendix provides detailed information about incorporating reliability performance measures into the key decision points of the PlanWorks (formerly known as Transportation for Communities—Advancing Projects through Partnerships [TCAPP]) planning and programming framework.

PlanWorks provides a representation of the key decision points (KDPs) that are used as a model in the overall transportation planning and programming process, primarily for major capital investments. These KDPs are organized around four phases of transportation planning and project development.

- Long-range planning;
- Corridor planning (including subarea and other similar planning efforts);
- Programming; and
- A merged environmental review and permitting (ENV/PER) process.

While the PlanWorks process focuses on major capital investments, the assumption of the guide is that the transportation planning process is flexible enough to accommodate new concepts and approaches. From the perspective of SHRP 2 Project L05, two planning efforts are explicitly not addressed:

- *Operations Planning.* SHRP 2 L05 is examining the broad range of strategies that have the potential to improve travel time reliability, including capacity, operations, and travel demand strategies; strategies that address the full range of travel modes; and strategies for both passenger and freight movements. Because PlanWorks has focused on capacity projects, it naturally does not address operations and related strategies, and only tangentially considers transit. Systems operations and management (SO&M) improvements focus in particular on nonrecurring congestion, rather than on the recurring congestion that is the focus of the capacity improvements that are typically part of the traditional planning process. Agencies may wish to directly incorporate operations

into the PlanWorks process or set up a parallel process for operations. Either way, it is important for this framework to provide a path to estimating the impact of operations investments on reliability.

- *Congestion management process.* The congestion management process (CMP) is intended to be a key place for consideration of the full range of strategies to address congestion and, by extension, reliability. The CMP is designed to develop and evaluate options for alleviating congestion using an ongoing process that does not necessarily result in a product (unlike a long-range transportation plan or a state or regional transportation improvement program). The framework identifies KDPs used in the CMP, drawing from recent work by the FHWA to provide guidance on the CMP for the transportation agencies that are required to use this process.

The remainder of this appendix describes in detail the steps for incorporating reliability into planning and programming. It first describes how institutional arrangements support incorporation and then walks through each of the processes—the four from PlanWorks and the two described here. These latter sections describe how reliability can be incorporated into relevant key decision points (KDP). Only relevant KDPs are described.

## How Institutions Help Incorporate Reliability

Well-functioning institutional arrangements can ensure that transportation decisions include reliability as a key consideration. A variety of participants and stakeholders must work together to plan, design, implement, and manage transportation system investments. When agencies work together to proactively develop a set of transportation system management and operations (TSM&O) strategies for various scenarios (e.g., a multivehicle accident, severe weather, or a large sporting event), and they also have the coordination mechanisms in



place to successfully implement, monitor, and adjust these strategies as necessary, it is more likely that customer expectations for a reliable transportation system will be met.

Understanding the institutional arrangements needed to incorporate reliability into the planning and programming process requires identifying the groups and organizations that should participate in the process and defining the specific roles they play at various stages of the process. Note that coordination with key legislative decision makers and policy makers also can help to incorporate reliability into transportation policy at the federal or state level. The actors are organized into three categories:

- *Owners* include those responsible for planning, building, operating, and maintaining the transportation system. Owners make decisions about funding system improvements that can affect reliability, and they are responsible for engaging stakeholders in the planning process. These may include DOTs, transit agencies, and other public entities, as well as private transportation owners, operators, and service providers.
- *Influencers* are those whose actions are intended to affect either the reliability of the transportation system or user behavior, or both. Emergency responders, towing companies, and information service providers fall into this category. In addition, major employers and major event organizers (e.g., sporting events, conventions, concerts) make decisions regarding the timing of the ingress and egress of the workers and patrons who have a significant influence on the reliability of the transportation network. Influencers should be included in the planning process, because they have firsthand knowledge of the causes of reliability problems.
- *Users* include the customers who create demand for transportation facilities and services and who experience the impacts of changes in reliability. A broad definition of “users” can include drivers of passenger and commercial vehicles as well as fleet dispatchers, freight forwarders, and logistics providers who determine where and when freight moves.

Given the intermodal, interconnected nature of the transportation system, it is critical that these groups communicate and share information among each other. Each agency or organization brings something different to the table—perspective, expertise, and the mechanisms to change or enforce policies and regulations, implement operational strategies, and make investments and improvements that can affect reliability. The ways in which these groups interact has an impact on the quality of the collaboration and subsequently the effectiveness of the outcomes. Specific information for the actors within each of these groups, how they affect reliability, and why it is important to include them in a collaborative planning process is provided.

## Owners

### *State Departments of Transportation*

State DOTs are the owners of much of the transportation infrastructure that is the focus of this guide. State DOTs plan, build, operate, and maintain state highway systems and the National System of Interstate and Defense Highways, and in various states, the state DOT also may be responsible for operating and maintaining county and local roadways, passenger rail, freight rail, transit, airports, and seaports. The DOT’s role in improving reliability is to manage and operate the transportation system, to fund and oversee transportation system improvements, including both TSM&O strategies and capital improvements, and to measure and track systemwide reliability performance. As owners of the system and statewide planning responsibilities, it is the DOT’s responsibility to coordinate with the other stakeholders. By coordinating with the DOT, MPOs and other stakeholders will have an opportunity to share local knowledge about appropriate strategies for improving reliability, potentially gain additional access to expertise and travel time data, and coordinate on drafting goals and objectives.

State DOTs have multiple functions that often are divided among divisions or offices within the organizational framework, and sometimes responsibilities are divided among a central office and various regional or district offices. It is best not to consider state DOTs as a single, monolithic participant in improving reliability, but as a group of participants and stakeholders with a variety of functions. The following is a representative list of offices that reflects the range of functions of a typical state DOT.

- Policy and Long-Range Planning Office
  - *Role in planning process:* The policy and long-range planning office owns the statewide long-range plan (LRP) that sets policy objectives for the entire state and includes reliability as a goal and/or objective. In addition, the policy office requests funding increases to support the goals and objectives. The office uses reliability performance measures to support these requests.
  - *Role in improving reliability:* The policy and long-range planning office develops, tracks, and reports reliability performance measures; prepares forecasts of population, employment, and other factors that drive travel demand; estimates future reliability deficiencies based on travel demand forecasts; and coordinates planning activities with other owners, influencers, and users. In addition, the office conducts trade-off analyses of operations, management, and capital strategies. This office often includes the data collection section, which houses travel time data for reliability analyses.
  - *Why coordinate? (DOT perspective.)* As a system owner and owner of the LRP, the policy office is responsible for

coordinating with all stakeholders to ensure that reliability is appropriately included in the plan. (*MPO perspective.*) MPOs should coordinate with the policy and planning office to develop goals and objectives that reflect regional reliability deficiencies and share local knowledge of reliability deficiencies and strategies to improve reliability.

- Programming Office

- *Role in the planning process:* The programming office owns the programming process and is responsible for coordinating input for the development of the statewide or metropolitan region transportation improvement program (STIP or TIP).

- *Role in improving reliability:* The programming office develops investment policies and evaluation criteria for prioritizing transportation improvement strategies, including operations and capital strategies aimed at improving current and future reliability. Sometimes, separate finance and budget offices coordinate with the state legislature and other executive branches to allocate funding to transportation overall and to specific transportation programs affecting reliability.

- *Why coordinate? (DOT perspective.)* As a system owner and the owner of the programming process, the programming office is responsible for coordinating with a specific group of key executive stakeholders to ensure that funding decisions support statewide goals and objectives and provide a set of future investments that can be delivered within available resources. (*MPO perspective.*) MPOs must coordinate with programming offices to ensure consistency of investments across the transportation network.

- Operations Office

- *Role in the planning process:* The Operations Office is responsible for the day-to-day operation and management of the transportation system (e.g., responding to incidents and other day-to-day challenges) and typically owns the operations planning process.

- *Role in improving reliability:* To coordinate a state's operations strategies, including intelligent transportation system (ITS) and TSM&O strategies, on the state-owned elements of the transportation system; to operate or oversee contracted operations of freeway service patrols that respond to and quickly clear disabled vehicles from a roadway before they create significant reliability problems; and to coordinate with local signal timing agencies with respect to arterial operations.

- *Why coordinate? (DOT perspective.)* As a system owner and the owner of the operations planning process, the operations office is responsible for coordinating with statewide and regional planning and operations stakeholders to support goals and objectives and to build support for

appropriate funding levels. (*MPO perspective.*) MPOs can share travel time data and analysis; ensure that operational strategies are considered in their plans; and ensure that their strategies are accurately reflected in statewide plans.

- Mode-specific offices (e.g., public transportation, rail, aviation, maritime, nonmotorized transportation, freight)

- *Role in the planning process:* These offices typically develop modal plans that support the long-range transportation plan and provide detailed feedback about mode-specific deficiencies.

- *Role in improving reliability:* To provide a focused perspective on mode-specific reliability needs or improvements; to develop a deeper understanding of the needs of specific user groups; to play a role in operating the modal systems through coordination with modal entities (e.g., ports, airports, freight operators); and to work with highway planners and operators to manage demand among all modes.

- *Why coordinate? (DOT perspective.)* The modal offices develop focused plans and studies that ensure that reliability is incorporated into planning, design, construction, operations, and maintenance of nonhighway infrastructure. They also consider the role of highway infrastructure in supporting the reliable movement of people and goods by all transportation modes. (*MPO perspective.*) To ensure that demand is properly managed, to share region-specific information, and to gather statewide perspective for certain user groups.

- Maintenance Office

- *Role in the planning process:* The maintenance office develops and enforces standards for the condition and design of roadways (e.g., pavement, markings, signs, signals), bridges, and other state-owned infrastructure.

- *Role in improving reliability:* Infrastructure in poor condition can affect the reliability of the system, causing an increase in scheduled maintenance, delay, crashes, and other issues. The maintenance office is responsible for using available funding to maintain a state of good repair throughout the system. Further, the maintenance office may determine standards for things like access management and curb cuts that can have significant impacts on the reliability of a roadway.

- *Why coordinate? (DOT perspective.)* Maintenance projects can improve system reliability but maintenance typically competes with operations and capital for overall transportation funding. Close coordination among the maintenance offices and other DOT offices can help the programming office develop an overall transportation program that effectively supports all statewide goals and objectives. (*MPO perspective.*) MPOs typically do not coordinate directly with maintenance offices.

- Design and Construction Office
  - *Role in the planning process:* To implement the physical system improvements planned by other offices. Design and construction offices often are not responsible for making system improvement decisions (i.e., which investments to make), but they make many decisions about the design and scope of a project that ultimately influence reliability.
  - *Role in improving reliability:* To ensure that improvements are designed to address reliability, as appropriate, and to improve construction scheduling and work zones around construction areas to improve system reliability.
  - *Why coordinate? (DOT/MPO perspective.)* Design and construction offices ensure that design and construction practices support statewide and regional goals and objectives; provide information to engineers, designers, and DOT staff responsible for construction scheduling so they understand the impacts of their decisions on reliability; and provide them with the information and tools to make both strategic and tactical decisions that improve reliability.
- Safety Office
  - *Role in the planning process:* In some states, safety offices are freestanding, and in others, safety responsibilities may be part of an operations, maintenance, or design division or office. The safety office is often responsible for developing the Strategic Highway Safety Plan (SHSP) and the Highway Safety Program (HSP) in accordance with the statewide long-range plan.
  - *Role in improving reliability:* To reduce vehicle crashes and fatalities. Crashes are a common source of nonrecurring congestion that can have a significant impact on transportation system reliability.
  - *Why coordinate? (DOT/MPO perspective.)* The safety office ensures that reliability is considered as a goal of safety improvements and that safety is considered when addressing reliability.
- Commercial Vehicle Permitting Office
  - *Role in the planning process:* The commercial vehicle permitting office may be a part of operations offices or may be freestanding. Commercial vehicle permitting offices are not responsible for making system improvement but their decisions do influence reliability.
  - *Role in improving reliability:* To ensure that overdimensional loads use appropriate routes (avoiding bridge strikes that can affect system reliability) and that all commercial vehicles are operated in a manner that will not impact safety, systems operations, or reliability.
  - *Why coordinate? (DOT perspective.)* The commercial vehicle permitting office ensures that the permitting decisions support statewide and regional goals for improving reliability. (*MPO perspective.*) MPOs typically do not coordinate directly with vehicle permitting offices.

For many DOTs, some or all of these functions are located or also exist within regional or district offices. These offices, being closer to the infrastructure that is owned and operated by the DOT, play a critical role in ensuring that reliability is taken into account in the planning, design, operation, and maintenance of the transportation system. Compared to central office staff, regional and district staff also tend to have stronger relationships with the regional and local agencies that are responsible for ensuring the reliability of nonstate transportation assets.

### **Metropolitan Planning Organizations (MPOs)**

- *Role in the planning process:* MPOs rarely own specific infrastructure, but do “own” several planning processes, including the regional LRP; the regional TIP; air quality planning process; the CMP; and often corridor plans discussed in this guide.
- *Role in improving reliability:* To plan and program projects that improve reliability; to coordinate capital, operations, and management projects to address regional congestion; to track reliability on a regional level and perform tradeoff analysis of operations, management, and capital projects through corridor planning and congestion management processes; and to develop regional operations plans to help ensure that the set of operational and management strategies deployed in their region address reliability.
- *Why coordinate? (DOT perspective.)* MPOs can develop an in depth perspective on user understanding of reliability deficiencies and potential strategies within their region. DOTs must coordinate with MPOs to ensure consistency with the goals and objectives outlined in the statewide LRP. Also, STIPs typically are constructed by compiling strategies identified in regional plans and TIPs; coordination among these plans is critical to ensure proper representation from operations, management, and capital projects.

### **Other Regional and Local Agencies**

- *Role in the planning process:* Other regional and local agencies include local municipal planning and zoning departments (which set local development policy and make land-use decisions that affect transportation system demand and operations), highway and public works departments (which often operate traffic signals and plan, design, operate, and maintain local roadways that feed or act as alternate routes to parallel, state-controlled arterials and freeways), public transportation departments (which plan, design, operate, and maintain transit vehicles and transit infrastructure), independent toll road operators, and departments responsible for airports, seaports, and other transportation infrastructure and services not under the control of state DOTs. Local and

regional agencies work closely with legislative branches of local government, including city councils, county legislatures, and planning boards and others responsible for permitting and approval processes.

- *Role in improving reliability:* To implement strategies to improve reliability at smaller geographic levels than state or regional agencies.
- *Why coordinate? (DOT perspective.)* Regional and local agencies can provide feedback about system deficiencies. System owners also play a critical role in delivering transportation systems and service and in providing a reliable transportation system. (*MPO perspective.*) These groups can provide MPOs with developing corridor plans or by working through congestion management processes to provide a geographically or modally detailed perspective on needs and potential strategies for improvement.

### **Transportation Authorities**

- *Role in the planning process:* A second category of system owners, authorities may include some transit agencies, port authorities, airport authorities, toll road and bridge authorities, and other quasi-public entities that often have their own funding sources, regulations, procedures, standards, and so on. These agencies may conduct independent planning for the facilities they own, as well as participating in larger-scale planning that includes their facilities and those of others.
- *Role in improving reliability:* To plan and program projects on their infrastructure and to implement operational, management, or capital improvements to improve reliability.
- *Why coordinate? (DOT/MPO perspective.)* Many of the functions listed above may be duplicated in larger authorities, again necessitating separate outreach and coordination efforts involving specific offices that are responsible in some way for reliability. As is the case with state DOTs, it may not be sufficient to depend on a single contact within a single office at an authority to be responsible for reliability-related planning, programming, design, operations, and maintenance decisions.
  - At a transit authority, for example, bus or rail operations and dispatching personnel are concerned with reliability (typically measured in terms of on-time performance), as well as vehicle maintenance staff (mean time or distance between failure of equipment), planners (determining where route and schedule changes might improve reliability), and so on. Airport and port authorities are concerned with reliability not only on their facilities but also on multimodal access routes outside their boundaries. For longer-distance trips involving multiple transfers en route, users consider the reliability of a complete end-to-end trip. Thus, reliability directly affects an

airport's or seaport's competitiveness, and the operators of these facilities should be involved in discussions and decisions that affect transportation system reliability.

### **Private Sector Transportation System Owners and Operators**

- *Role in the planning process:* Private system owners and operators include the companies that own and operate most of the country's freight rail network, private intercity and commuter bus operators, passenger and freight airlines, and companies that own, lease, and/or operate airport and seaport terminals and other infrastructure.
- *Role in improving reliability:* To plan and program projects on their infrastructure and to implement operational, management, or capital improvements to improve reliability.
- *Why coordinate? (DOT/MPO perspective.)* Deterioration in transportation system reliability now increasingly impacts private sector transportation system owners and operators directly, even though they often do not control the sources of congestion and uncertainty. For example, a seaport terminal operator may have the ability to control the speed and reliability of transferring freight from a ship to a drayage vehicle to a container stack to a long-haul truck, but once that truck passes through the port gate, congestion and a lack of reliability on regional highways can influence shipping and logistics firms' decisions about whether to route shipments through that port or a competing port up the coast.
  - The private sector has formed closer relationships with the public and quasi-public entities listed above because capital to fund improvements has become scarce, and it has become apparent that the private sector can no longer afford to simply budget for transportation system congestion and pass costs along to customers. Private sector owners and operators often have a seat at the table in statewide planning efforts, and, increasingly, they are invited to participate in MPO planning and programming decisions as active stakeholders.

### **Influencers**

#### **Towing Companies and Emergency Responders**

- *Role in the planning process:* Towing companies and emergency responders, including fire, police, and emergency medical services can provide feedback to DOTs and MPOs through their planning processes. In addition, DOTs and MPOs can develop goals and objectives to improve utilization of these entities to improve reliability.
- *Role in improving reliability:* To improve incident response times, to improve the operating procedures to ensure safety at an incident site (e.g., an operating perimeter that results in closed lanes, closure of the entire roadway, and possible

closure of adjacent transportation facilities like rail lines), and to improve the time needed to clear an incident.

- *Why coordinate?* Emergency responders and towing companies have staff on-site at traffic management centers to facilitate coordination with other participants in operating the transportation system. Further, these entities provide services that improve reliability.

### **Regulatory and Enforcement Agencies**

- *Role in the planning process:* Regulatory and enforcement agencies may include federal, state, and local police; commercial vehicle inspection and permitting agencies (who may be part of state DOTs or local agencies); the Federal Motor Carrier Safety Administration (FMCSA), the National Transportation Safety Board (NTSB), and regulatory and enforcement arms of the Federal Railroad Administration (FRA) and the Surface Transportation Board (STB), the Federal Aviation Administration (FAA), the Federal Transit Administration (FTA), the Maritime Administration (MARAD), and other federal and state government agencies. These agencies are often involved in policy and planning decisions at the federal, state, regional, and local levels.
- *Role in improving reliability:* To prevent incidents that can cause nonrecurring congestion.
- *Why coordinate? (DOT/MPO perspective.)* The regulatory and enforcement agencies ensure coordination among state, regional, and federal goals, objectives, and standards.

### **Information Service Providers**

- *Role in the planning process:* Information service providers is a broad category that may include state 511 and highway advisory radio systems; variable message screens and monitors installed on roadways, in passenger terminals, and on vehicles; public address systems in passenger terminals and onboard vehicles; news media ranging from television stations to radios to privately maintained traffic information websites; and private “concierge” style services like on-call. Information service providers may collocate with operations and emergency response staff at traffic management centers, or they may have direct data feeds provided by public- and private-sector system operators. The services can be funded in the programming process or on an ad hoc basis.
- *Role in improving reliability:* To influence transportation system reliability by informing passengers and transporters of freight about incidents and recurring congestion so that the entire transportation system is used more efficiently. Passengers and freight sometimes have flexibility to reroute around an incident or retime a trip to avoid congestion and improve the likelihood that a trip can be made more reliably.

- *Why coordinate?* Information service providers ensure that travel time data recorded by service providers is included in the state and regional transportation planning process and ensure that strategies to influence demand through management include provisions for information dissemination.

## **Users**

### **Passenger and Commercial Vehicle Operators**

- *Role in the planning process:* Passenger and commercial vehicle operators are the most direct users of the transportation system. Agencies plan the systems to provide access and mobility to serve commerce, commuting, and personal travel needs. They typically have no formal role in the planning process but are given an opportunity to provide feedback as plans are developed.
- *Role in improving reliability:* To make real-time decisions about departure times, route choices, mode choices, and operational practices (e.g., aggressive or defensive driving techniques) that can have immediate impacts on transportation system reliability. Also, to make longer-term housing, warehousing, and modal decisions that can have a lasting and long-term impact on system demand and reliability.
- *Why coordinate?* Passenger and commercial vehicle operators are users with reliability needs. It is also useful for all users to understand their role in meeting the overall goals and to be vested in them.

### **Fleet Managers and Dispatchers**

- *Role in the planning process:* Although not directly operating transportation vehicles, fleet managers and dispatchers are nonetheless an important subset of users. Managers and dispatchers for companies such as Wal-Mart, JB Hunt, or taxi companies make fleetwide decisions about warehouse location, routing, and scheduling to meet the needs of their customers. They typically have no defined role in the planning process.
- *Role in improving reliability:* To impact reliability and respond to events that affect reliability in real time by rerouting trucks, transit vehicles, taxis, and other vehicles that have the flexibility to avoid congestion and to maintain the reliability of trips across a fleet. The perceptions or observations of their customers regarding the reliability of travel times can directly affect their firms’ bottom lines.
- *Why coordinate?* Fleet managers and dispatchers are users with reliability needs. Further, since system reliability affects these companies’ bottom line, they are likely to have a more fully developed understanding of systemwide reliability issues and needs. They may also have information or data they are willing to provide to the planning process.

### **Freight Logistics Coordinators and Brokers**

- *Role in the planning process:* Freight logistics coordinators and brokers make decisions about how, where, and when freight moves around the globe. They have no defined role in the planning process. The private sector lobbies state and federal legislators directly to make policy changes and obtain transportation funding earmarks for independent projects that may or may not be linked to a broader set of strategies to improve systemwide reliability.
- *Role in improving reliability:* Like fleet managers and dispatchers, they do not directly use the system, but their decisions about routes, modes, and departure and arrival times can be influenced by and, in turn, influence, transportation system reliability.
- *Why coordinate?* Freight logistics coordinators and brokers are users with reliability needs. Further, since system reliability impacts these companies' bottom line, they are likely to have a more fully developed understanding of systemwide reliability issues and needs.

### **Shippers and Receivers of Freight**

- *Role in the planning process:* Shippers and receivers of freight include manufacturers and food processors that depend on a reliable transportation system to access supplies and raw materials and to distribute finished products to customers; warehouses and distribution centers that receive bulk shipments and ship out truckloads of goods to retailers; consumers who order goods on the web, over the phone, or by mail; and service-oriented businesses who depend on timely and expedited shipments of small parcels and letters. They have no defined role in the planning process. Most often, their involvement is limited to the reliability-related education and outreach that public sector agencies undertake as part of long-range planning, corridor planning, and other planning processes. Otherwise, the private sector lobbies state and federal legislators directly to make policy changes and obtain transportation funding earmarks for independent projects that may or may not be linked to a broader set of strategies to improve systemwide reliability.
- *Role in improving reliability:* Reliability often is priced into the services offered by carriers like the U.S. Postal Service, UPS, and FedEx, with greater reliability or certainty in delivery times costing much more than bulk mail shipments. Thus, with the exception of some retailers and manufacturers that ship large volumes of freight and can negotiate directly with transportation providers (or those who own their own fleets and make their own operational decisions), reliability often affects shippers and receivers of freight in ways that are difficult for them to perceive.

- *Why coordinate?* Coordination must be done in a way that protects proprietary information and competitive position, but, like fleet managers and dispatchers, shippers and receivers of freight are customers with reliability needs. Further, since system reliability impacts these companies' bottom line, they are likely to have a more fully developed understanding of systemwide reliability issues and needs.

## **Long-Range Planning**

### **Introduction**

The long-range transportation plan, in any of its several forms and formats, sets the direction for transportation investment in the state or region for at least the next 25 years. Reliability must be addressed in the long-range planning process to ensure that it is included in other transportation planning documents and processes (i.e., programming, corridor planning, the congestion management process, and operations planning). To determine how reliability impacts travel in the state or region, consider the influence of the different causes of unreliable travel on system users. Unreliable travel is caused by

- Traffic incidents (crashes, turned-over truck trailers);
- More demand for travel than available capacity to handle that travel (common in urban areas);
- Demand variability (seasonal travel);
- Special events (e.g., concerts, seasonal events, fairs, festivals);
- Traffic signals (controls);
- Inclement weather (e.g., fog, snow, wind, rain, freezing conditions); and
- Work zones.

Table B.1 summarizes the steps for incorporating reliability into the long-range planning process.

### **LRP-1: Approve Scope of LRTP**

At this KDP, develop a common understanding and reach agreement on the LRP process, including stakeholders to engage; roles and responsibilities; tools and data sources to be used; timeframes; and a public involvement plan. To develop a scope that includes reliability, use the following work steps.

- *Gather scoping input from operations managers and planners.* Develop the scope of the LRP in consultation with transportation system owners responsible for managing and operating the system by gathering feedback from standing committees, especially committees who are responsible for operations and management decisions. If standing

**Table B.1. Incorporating Reliability into Long-Range Planning**

Key Decision Point (KDP)	Description	How to Incorporate Reliability
LRP-1: Approve scope of LRTP process	Set the stage for LRTP; assess data, decisions, and relationships needed for entire process.	<i>Consider reliability as an issue.</i> At this KDP, planners will identify how reliability should be included in the scope of the LRTP development, which has implications for data and stakeholder involvement. Some analysis may be required to help determine how reliability should be addressed.
LRP-2: Approve vision and goals	Community values articulated into transport-specific vision and goals.	<i>Consider reliability as an issue.</i> At this KDP, an analysis of reliability and information from stakeholders and the public can help an agency determine whether reliability should be a goal or objective for the transportation system.
LRP-3: Approve evaluation criteria, methodology, and performance measures	Develop evaluation criteria, methodology, and performance measures for the LRTP in order to compare scenarios to each other and to the vision and goals.	<i>Identify reliability measures.</i> At this KDP, transportation planners will identify the appropriate reliability measures to use in evaluating long-range plan scenarios. These measures will depend on the goals and objectives set in LRP-2.
LRP-4: Approve transportation deficiencies	Identify transportation deficiencies within the planning area that should be addressed in the LRTP.	<i>Use reliability measures to estimate deficiencies.</i> At this KDP, planners will classify corridors or locations now and in the future where travel time reliability fails to meet acceptable thresholds using the performance measures identified in LRP-3.
LRP-5: Approve Financial Assumptions	At this key decision information from the programming/fiscal constraint phase is introduced into the LRTP process.	<i>Consider reliability in the programming phase, and use reliability to support the long-range fiscal constraint analysis to be conducted in this KDP.</i>
LRP-6: Approve strategies	Develop and evaluate groups of strategies relative to stated needs.	<i>Consider operations strategies.</i> At this KDP, planners should ensure that the full range of strategies, including operations, is considered in developing plan scenarios.
LRP-7: Approve plan scenarios	Identify plan scenarios for testing and comparison in order to select a preferred plan scenario for the region.	<i>Include reliability strategies in trade-off analysis.</i> At this KDP, planners will make use of reliability and other performance measures to help compare and package scenarios that include a range of strategies (both short- and long-term). This step requires significant analytic capability to analyze the impacts of scenarios on travel time reliability.
LRP-8: Adopt preferred plan scenario	Evaluate proposed scenarios in order to identify the locally preferred scenario that addresses the deficiencies while supporting the vision and goals.	<i>Include reliability strategies in trade-off analysis.</i> At this KDP, planners will refine and expand the analysis conducted in LRP-7 to develop a preferred scenario. This scenario would logically include both long- and short-term improvement measures.
LRP-9: Adopt finding of conformity by MPO	Air quality conformity analysis is done within the air quality process to validate the preferred scenario.	No additional actions related to reliability need to be taken in this KDP.
LRP-10: Adopt LRTP by MPO	At this key decision a final plan is adopted by the MPO board.	No additional actions related to reliability need to be taken in this KDP.
LRP-11: Adopt conformity analysis	This is a legally required decision consisting of the federal approval of conformity of the LRTP.	No additional actions related to reliability need to be taken in this KDP.

committees have not been formed, reach out to the management at regional or state offices of operations, traffic management centers, and other operations system owners. Ask them how they feel reliability impacts mobility for the region's users.

- *Determine the form of your plan.* Long-range plans typically set strategic and investment priorities through vision and goal statements for the transportation system; identify

needs and deficiencies in the system; and, in some cases, identify strategies and specific projects. States and MPOs use the LRP process to focus regional and statewide transportation investments on projects that support the needs of the users and improve mobility, maintain and preserve the system, improve safety, improve the vitality of the economy, and protect the environment. LRPs provide an opportunity to balance the improvement of travel time reliability, one

of several dimensions of mobility, against improvements in other areas. How reliability will be incorporated will depend on the form of the plan. Typical forms include the following:

- *Policy Plan*: Every long-range plan includes the elements of a policy plan. Develop a clear set of priorities for your state or region by articulating a vision and goals that address reliability. In addition, your agency might develop reliability performance measures, identify reliability deficiencies, and approve strategies for improving the deficiencies, reaching your goals, and achieving your vision. On rare occasions, your agency might perform a more rigorous scenario analysis to support your goal-setting activities.
- *Program-Level Investment Plan*: The program-level investment plan includes the elements of a policy plan and results of a funding program-level trade-off analysis. To develop a program-level investment plan, define a scope, approve a vision and goals, measure reliability performance, measure reliability deficiencies, develop strategies relative to reliability needs, compare scenarios based on those strategies, and adopting a fiscally constrained preferred scenario. Note that the strategies and scenarios in a program-level investment plan will relate to policy-level decisions that support setting program funding levels; these analyses include tradeoffs among different programs based on overall policy direction.
- *Strategy-Level Investment Plan*: The strategy-level investment plan includes the elements of a policy plan and results of a project-level tradeoff analysis. To develop a strategy-level investment plan, you will need to define a scope, approve a vision and goals, measure reliability performance, measure reliability deficiencies, develop strategies relative to needs, compare scenarios based on those strategies, and adopt a fiscally constrained preferred plan scenario. Note that the strategies and scenarios in a strategy-level investment plan will relate to project-level decisions based on project prioritization.

Each form of the plan builds on the steps of other, more general plans. All forms of the LRP have aspects of a policy plan, and all strategy-level investment plans have aspects of a program-level investment plan. But not all plans require the same level of detailed analysis. For example, a program-level investment plan will not typically include project-level prioritization.

## LRP-2: Approve Vision and Goals

At this KDP, develop a set of values articulated as vision and goal statements, building on input from key stakeholders, including reliability-specific vision and goals. No matter how

formal your vision, answer these four questions: Where are we now? Where are we going? Where do we want to be? How will we get there? To identify how reliability should be included in the vision and goals, follow these work steps.

- *Answer “Where are we now?”* If they are available, use existing reliability performance measures to develop reliability trend charts that indicate how reliability has been changing over time. For the best assessment of travel time reliability trends for your state or region, look to your own or third-party direct-observation travel time data first to generate the most accurate picture of travel time variability (for more detail on data collection methods, see Chapter 6 of the technical reference). If you have travel time data but no reliability measures, store these data for later use in developing performance measures. In addition, use existing measures of the key sources of reliability deficiencies (e.g., crashes, incidents, special events, incident response time, weather) to support your reliability findings.
- *Answer “Where are we now?” with stakeholder input.* Gather feedback from key stakeholder groups regarding the current state of reliability in your system. Use information-gathering methods to present the stakeholders with the following questions as guidelines.
  - Director, DOT design and construction office: Do your design and construction practices affect the reliability of the system?
  - Transportation authorities: How reliable is travel in your facility? How does unreliable travel affect the competitiveness of your facility?
  - Private sector transportation system owners and operators: How does congestion and reliability in one metro area compare to others that you operate in? How does congestion/reliability in an area affect when you operate, make deliveries, and so forth?
  - Emergency responders: What do you see as the underlying cause of unreliable travel? What types of traffic/congestion problems do you encounter responding to calls? How consistent are response times?
  - Passenger and commercial vehicle operators: How much time do you allot for travel to work each day? What are your best and worst travel times? How often do you encounter unexpected congestion?
  - Fleet managers and dispatchers; freight logistics coordinators and brokers; and shippers and receivers of freight: How does system reliability affect your shipping, warehousing, and logistics decisions? How does this uncertainty affect business planning and operations?
- *Answer “Where are we going?”* Gather “business as usual” reliability projections from existing performance reports, needs assessments, congestion management plans, corridor plans, operations plans, or other modal or subarea plans to support



discussion with your stakeholders. If none exists, then gather existing projections of the key sources of reliability deficiencies (e.g., crashes, incidents, special events, incident response time, weather). The result will help stakeholders imagine how reliable travel will be in the future and help them to develop a clear understanding of reliability goals moving forward. Use existing analysis and established performance measures to begin the iterative long-range planning process.

- *Answer “Where do we want to be?”* Answer this question to draft the vision and goal statements. Within the project team, define goals for improving reliability in the region or state. This could be qualitative, for example, “reliable connectivity for people and goods” or “freight trucks should have reliable travel through urban areas.” Use the answers from the “Where are we going?” exercise to frame the reliability issue moving forward. In the same way, defining goals will turn into setting targets through iteration. For example, use deficiencies to update the qualitative goal of “reliable connectivity for people and goods” to the quantitative target of “buffer index of X or better on all roadways carrying X vehicles per day and Y tons of freight per day” by considering financial constraint and available strategies for improving reliability. Provide additional context for target setting by identifying examples of how other regions or states have achieved “good” reliability even in a congested environment.
- *Refine vision and goals statements.* Refine your vision and goal statements from the “where do we want to be?” question to help focus future reliability investment. For example, determine if your agency should focus reliability investment on interstates or major arterials. Similarly, should your agency focus on key corridors connecting population and economic centers and traffic generators? On priority routes? On freight routes? On key commuter routes? Making these difficult decisions will help to draft clear vision and goal statements that will provide the first steps toward improving reliability of the system.
- *Build consensus around your vision and goals through implementation of your public involvement plan.* Craft simple, consistent messages from your historical and projected reliability trends to inform stakeholders of future trends and policy choices for improving reliability. Outreach should actively inform and engage stakeholders by providing information about possibilities for the future. Inform your stakeholders with visuals of trends and engage them with tailored questions about reliability needs. Help them balance reliability needs against the needs of other goals such as safety, economy, preservation, and environment. Ultimately, gather an understanding of how much the stakeholders value reliability and how strongly these values should be written into the LRP vision and goal statements. Conduct reliability-focused stakeholder outreach consistently throughout the long-range planning phase.

### LRP-3: Approve Evaluation Criteria, Methodology, and Performance Measures

At this KDP, develop reliability evaluation criteria, methods, and performance measures to support comparison of groups of projects and policies to the vision and goals and to one another. The evaluation criteria, methods and measures used in long-range transportation planning lay a consistent framework for measuring reliability in corridor planning, the congestion management process, programming, and operations planning.

- *Develop a weighting scheme.* Later in the development of a strategy-level investment plan, you will weight and balance the performance measures. In this step, develop the scheme to support later efforts. The long-range plan will identify performance measures for each goal area. In this step, develop an approach for ensuring that each performance measure is given its proper level of importance when compared across all performance measures. This will be used in subsequent KDPs to evaluate and prioritize strategies and scenarios. Options for balancing performance measures against one another include
  - *Scoring.* For each project, estimate all performance measures. Approaches to scoring performance measures include
    - *Straight scoring.* All projects are given a score ranging from  $-X$  to  $+X$  based on how much the project degrades or improves reliability.
    - *Normalized scoring.* All projects are given a score of 0 (for the project with the smallest improvement in reliability performance) to 100 (project with the largest improvement in reliability performance).
  - *Combining.* Score each project based on a combination of performance measures. Approaches to combining measures may include
    - *Weighting goal areas.* Each goal area is given a weight. For example, for five goal areas with 100 points to spread among them, equally important goals would result in equal goal area weights of 20 points each. However, if improving reliability is critical for your state or region, weight the reliability goal area with 40 points, leaving 60 points for the remaining four goal areas.
    - *Weighting performance measures.* Each performance measure is given a weight. Divide up 100 points among the performance measures to identify which area of performance is most important.
    - *Weighting both goal areas and performance measures.* Multiply the goal area weight by the performance measure weight to develop a composite weight that identifies the importance of a performance measure within a goal area and the importance of the goal area in the plan as a whole.

- *Include monetized benefits and costs.* Convert reliability benefits to monetized benefits using a value you estimate or a national average of 80% of the value of average travel time. Then determine how best to combine these costs with your weighting and scoring scheme. Benefit and cost measures can be incorporated and weighted similar to other performance measures, can be used as another dimension (e.g., combined project score on the  $x$ -axis and benefit-cost on the  $y$ -axis), can be treated as informational, or can be used to rank projects on their own. This information can be used to develop a benefit-cost ratio. Cost effectiveness can be estimated more simply by dividing project scores by cost.
- *Collect travel time data.* Collect existing travel time data from the appropriate department within your agency or ask your data provider to provide test samples of the real travel time data.
- *Select a preliminary reliability performance measure.* Select among different types of reliability performance measures, including measures that compare to average conditions (travel time index), free-flow conditions (buffer index or planning-time index), worst case conditions (99th percentile travel time or failure indices), or distribution of congestion sources. Reliability comparisons to average or free-flow conditions tend to match users' expectations for travel time reliability more closely than others and can help stakeholders instinctively understand how to interpret the data.
- *Validate performance measures, estimation methods, and data sources.* Develop a sketch-planning or post-processing tool from post-processing methods, or acquire an off-the-shelf post-processing tool, such as IDAS, that meets the needs of the study outlined above. Estimate the preliminary performance measures and bring the draft results to the scoping team to get a feel for how to communicate the results and how quickly they understand the measures. Also discuss with your internal data providers the efficacy of tracking all of these measures year to year going forward; consider whether the technology or process for collecting, processing, and reporting travel time data will be changing in the future and how that will impact your estimates.
- *Refine the scope of the performance measures.* Use the results from the preliminary performance measure analysis to refine the scope of your measures in support of the vision and goals. Estimate the refined measures for the region or state. For example, develop maps showing ranges of reliability and identify the types of roadways where the users are experiencing reliability problems. Develop a list of the primary geographical problem spots (e.g., interstates, arterials, urban, rural); the primary travel patterns (e.g., major origin–destination [O-D] pairs, subareas); the primary causes of unreliable travel (e.g., incidents, weather); and the primary impacted stakeholders in your region (e.g.,

commuters, freight trucks, transit) based on the qualitative feedback you received through the scoping, vision, and goal setting exercises.

For example, if travel on the interstates in your urban areas is becoming increasingly unreliable for freight trucks due to wintry conditions and the businesses are threatening to relocate out of the area, focus on measuring reliability of the key freight corridors. Or, if a particular origin–destination commute pattern is becoming increasingly unreliable due to increasing demand, you might focus on measuring the percentage of these trips that arrive late.

In their 2011 Congestion Report, Washington State DOT reports that 17 of the 36 high-demand commutes in Puget Sound saw modest changes (less than or equal to 2 min) in 95% reliable travel time between 2008 and 2010. Fourteen commutes saw reliable travel times worsen between 3 and 10 min, while reliable travel times improved on five commutes ranging from 3 min to 11 min.

#### **LRP-4: Approve Transportation Deficiencies**

At this KDP, identify reliability deficiencies within the planning area that should be addressed in the LRP. Transportation deficiencies occur when the current or future system is expected to experience reliability problems. The steps to incorporate reliability into this KDP include the following:

- *Set thresholds for identifying reliability problem spots.* Use the refined performance measures to test different thresholds for identifying reliability deficiencies. Identify the deficiencies for each threshold and coordinate with stakeholders to determine whether it matches their judgment of how reliable travel is in the region. It can be extremely helpful to show options as a set of maps that highlight the unreliable travel trouble spots. For example, if you are measuring the areawide buffer index for all traffic at the segment level, you could identify any segment with a buffer index over 40% as unreliable; rank the segments by buffer index; or categorize as reliability tiers such as 0% to 10% as reliable; 10% to 30% as moderately unreliable; and 30% plus as unreliable. The thresholds also can be different for urban and rural; for different functional classes; or for different modes.
- *Identify current and future deficiencies.* Once you have settled on thresholds, apply them to your systemwide estimates of reliability for the current year to identify existing trouble spots (again, this should reasonably match professional and stakeholder judgment) and, for future years, to identify where future reliability trouble spots are likely to arise.
- *Develop weights for your performance measures.* Given the scheme developed in LRP-2, consider how the stakeholders feel about reliability as an issue in your region and how to

balance the reliability needs across modes. Convene working groups to discuss how important improving a reliability measure is compared to the other measures you have selected for the other goal areas. The result will be a project score that includes reliability.

- *Set performance targets.* Set reasonable targets based on deficiency thresholds and financial projections. Targets for improving reliability should be realistically achieved given the expected investment level. For example, a target would be “Improve reliability in urban areas by 10% by 2030.” Useful references for setting targets include (1) NCHRP Report 666: *Target Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies*, and (2) PlanWorks (formerly TCAPP) LRP-5 (not discussed in this guide), which describes how to set fiscal constraints in long-range plans.

### LRP-6: Approve Strategies

At this KDP, develop strategies to address the deficiencies. A strategy can be a specific tactic or policy used by an organization.

- *Collect capital and operational strategies and policies from CMP, corridor plans, and operations plans.* Review all relevant preexisting plans to ensure inclusion of the full range of capital, operational, and management improvement projects and policies. Many relevant strategies to improve reliability will be identified in the CMP. Consider describing operations strategies, for long-range planning purposes, as project groups rather than unique projects to allow for flexibility in deployment. For example, an operations strategy might be to “optimize arterial signal timing.”
- *Coordinate with operations staff to ensure all strategies not listed in these plans are included.* Since much of operations planning is often done on an ad hoc basis, coordinate with the office of operations, TMCs, and others responsible for implementing operations strategies to complete the list of potential strategies.
- *Develop new strategies.* Work with your stakeholders using the methods described in the institutional arrangements chapter to gather ideas for new strategies not already identified in previous planning studies. For example, hold a high-level meeting with your technical advisory group to develop some high-level policies; and glean ideas from other stakeholders through working groups and other passive comments. Strategies can include capital and operational strategies and policies. Otherwise, discuss with your stakeholders the laundry list of potential strategies.
- *Evaluate the effectiveness of the strategies.* Use the scoped approach for estimating reliability to evaluate how strategies will improve reliability. Calculate the improvement in

reliability performance measures by using one of several approaches for estimating the effectiveness of reliability strategies. Agencies may require project sponsors to estimate effectiveness or to estimate benefits using region- or state-specific before-and-after studies, national estimates, or sketch planning or model post-processing techniques.

- *Develop monetized benefits for the strategies.* Convert the reliability effectiveness estimates to benefits in dollars to facilitate benefit-cost analysis. In general, one hour of delay caused by unreliable traffic is worth approximately the same dollar value as recurring delay (results of several research studies suggest the value of unreliable travel time is approximately 80% of the value of average travel time). Use the same value of time for nonrecurring delay as for recurring delay in your benefit estimation.
- *Develop costs for the strategies.* These costs can include per lane-mile costs, per project costs, right-of-way costs, and operating and maintenance costs. Ensure that project sponsors that submit projects into the universe of projects use this cost-estimating technique. Doing so will allow you to make apples-to-apples comparisons of projects.

### LRP-7: Approve Plan Scenarios

At this KDP, identify plan scenarios for testing and comparison in order to select a preferred plan scenario. The scenarios are designed to address the approved deficiencies using the approved strategies. This begins the iterative analysis that is conducted for a full understanding of the trade-off decisions necessary to identify the preferred plan scenario. Scenarios should be identified in terms that can be easily understood by decision makers, planning partners, and stakeholders. The steps for incorporating reliability into this KDP include the following:

- *Develop scenarios or packages of projects and policies.* Group mutually supportive strategies into logical packages or “scenarios.” Scenarios might include things like the “operations and management scenario” in which capital improvements are kept to a bare minimum but all recommended operations strategies are implemented; the “operations and capital strategy mix scenario” in which there is a balanced approach to implementing capital and operations strategies, perhaps represented through a percentage distribution of funding (e.g., the scenario is to have 30% of funds allocated to operations); a more mode-specific scenario that packages critical projects together along key freight corridors; or an area-specific scenario that packages urban or rural projects together. Build these logical groupings with projects, policies, or both. Iterate and refine the packages as you conduct your analysis.
- *Prioritize projects within each scenario.* Select a prioritized list of projects from the complete list of projects within

each package based on the fiscal constraint. Develop a composite score for each strategy by combining effectiveness of the strategies (e.g., how much the strategy is expected to improve the buffer index) and the performance measure weights (e.g., improving the buffer index by 10% is worth three points). Develop a composite score for each strategy by summing the score for each strategy across all measures for all goal areas. It can be useful to combine a benefit-cost estimate along with the composite score when selecting from among the universe of projects within each scenario.

- *Evaluate the effectiveness of each scenario.* At this stage, the degree to which each individual strategy will improve reliability is known and these projects can be prioritized based on each strategy's own performance. In this step, sum the performance scores for all projects within a given scenario, and then compare across scenarios to select the scenario with the best overall score. Also, consider analyzing the combined impacts of all strategies within the scenario to eliminate any double counting or to capture the way that projects, when combined, can improve reliability more than each could independently.
- *Develop benefits for reliability projects.* For each operations and capital strategy, estimate reliability benefits. The most expensive and technical approach is to conduct several before-and-after studies to identify the range of travel time reliability benefits you should expect to get when implementing an operations or capital strategy. As another option, use sketch-planning results from other national research studies, including SHRP 2 L03, to develop an order-of-magnitude estimate of reliability improvement from specific strategies. As the final option, allow applicants to submit reliability benefit estimates themselves when proposing a project (in this case, consider developing estimation guidelines to strive for consistency of results). Use the guidance from the case studies report on the value of travel time reliability savings to convert the travel time reliability benefits into dollars to allow comparison with other strategies. In general, improving the reliability of travel time by one minute is worth approximately the same as improving travel time by one minute.
- *Identify funding by program area.* Identify the percentage of the total budget to allocate to improve reliability, keeping in balance with other programmatic goals. Use the vision and goal statements to set this percentage. Perform program-level trade-off analysis to answer the question "If funding increases in the reliability program, how will that impact the performance of the other programs (e.g., safety, preservation, and economic development)?" This is a high-level discussion that requires the executive decision makers from the various system owner stakeholders to have decision-making power, so employ a standing executive committee or an

executive committee that you have formed for the purposes of the LRP process to make these decisions. It is possible to arrive at these conclusions through open discourse, but it will be useful to quantify the consequences of the program decisions. To quantify the consequences of program-level funding, develop curves for each program area that relate funding to performance.

## LRP-8: Adopt Preferred Plan Scenario

At this KDP, compare the impacts of proposed scenarios and vet with stakeholders and decision makers in order to identify the locally preferred scenario that addresses the deficiencies while supporting the vision and goals. The steps for incorporating reliability into this KDP include the following:

- *Determine the preferred scenario.* Communicate the impact of the various packages of strategies to the many stakeholders and gather input to gain a consensus on the preferred scenario. From a reliability perspective, ensure that reliability performance and ranking is broken out for interested stakeholders and decision makers to understand how reliability impacts contribute to total project and scenario performance. It is important to understand that the quantitative evaluation in the KDPs above is not intended to be a black box that provides a final answer; it is intended to help inform better decision making. If reliability is a strong concern in a region or state, decision makers may want to consider scenarios with strong reliability impacts as potential preferred scenarios. Other concerns, such as geographic and social equity, funding availability, and synergies with already programmed improvements which cannot be easily quantified, can be considered by decision makers and stakeholders at this point.

## Programming

### Introduction

Programming is the process of selecting specific transportation projects for development or construction over the next four or more years. Often similar types of projects are grouped into program areas that correspond to an agency's vision and goals or to the funding sources used to implement the projects. The list of projects in these program areas collectively make up an MPO's TIP or a state DOT's STIP.

*Allocation of funds programs.* Federal and many state transportation funding sources include rules and restrictions defining how the funds can be applied to projects. For example, Congestion Mitigation and Air Quality Improvement Program (CMAQ) funds can be spent only on projects intended to improve air quality in a metro region. The current federal Highway Trust Fund (HTF) includes multiple funding programs,

each with its own rules. Fundamental to a performance-based approach is the recognition that agencies should first identify projects that are consistent with their goals and performance targets, and then determine the appropriate funding source for those projects. Unlike a traditional programming and budgeting process that identifies funding sources first, this approach first identifies the set of projects that best help the agency meet its goals or targets.

*Relationship of KDPs for TIPs and STIPs.* States and MPOs follow similar programming processes. In both processes the agency evaluates, prioritizes, and selects projects using the agency's vision and goals, performance evaluation criteria, and available programmatic funding levels. The STIP includes the projects in an MPO TIP along with projects serving non-metropolitan areas. The KDPs listed in Table B.2 describe the complete programming process for both MPOs and states,

**Table B.2. Incorporating Reliability into the Key Decision Points for Programming**

Key Decision Point (KDP)	Description	How to Incorporate Reliability
PRO-1: Approve revenue sources	Establishes the revenue basis for the fiscal constraint of the long-range plan and funding sources for the TIP.	<i>Identify operations funding sources.</i> At this KDP, identify dedicated sources for funding for operations projects and make overall budget requests using reliability performance measures as supporting evidence. Operations strategies typically have no dedicated source of funding; establishing a dedicated source may be valuable to ensure that the full range of strategies is addressed.
PRO-2: Approve methodology for identifying project costs and criteria for allocating revenue	Establishes a consistent methodology for estimating project costs for both the long-range transportation plan and the TIP. It also documents the specific requirements and restrictions associated with each funding source.	<i>Consider operations strategies.</i> At this KDP, transportation planners should ensure that the full range of strategies is included. This step requires understanding what funding sources can be used for operations strategies and having approaches available to support projects using a combination of funding sources and understanding different implementation timeframes.
PRO-3: Approve project list drawn from adopted plan scenario or solution set	Establishes the list of projects drawn from the long-range plan or corridor-planning process that will be considered for funding in the TIP.	<i>Consider operations strategies.</i> At this KDP, planners should ensure that all strategies, including operations, are considered in the project evaluation. This may mean evaluating how projects are scoped (i.e., does a project include the right set of strategies for the location) and ensuring that operations strategies are considered for programming more generally. This step may be linked to a long-range plan or an operations plan.
PRO-4: Approve project prioritization	The approved project list is prioritized using the methodology previously developed.	<i>Project prioritization includes reliability measures.</i> At this KDP, transportation planners will include reliability and other performance measures to help compare and rank projects.
PRO-5: Reach consensus on draft TIP	Identify projects from the prioritized list based on funding restrictions and agreements, actual available revenue, and project readiness.	<i>Include operations stakeholders in outreach.</i> Include operations stakeholder. These stakeholders will know the details and intricacies of available revenue sources and how ready certain things are for implementation.
PRO-6: Adopt TIP by MPO	Address comments on the draft TIP and produce a final TIP.	No additional actions related to reliability need to be taken in this KDP.
PRO-7: Approve TIP by governor and incorporate into draft STIP	The Governor or designee should ensure that the TIP meets other state and federal requirements so that the TIP can be incorporated into and be in agreement with the STIP.	No additional actions related to reliability need to be taken in this KDP.
PRO-8: Reach consensus on draft STIP	Release draft STIP for public comment.	<i>Include operations stakeholders in outreach.</i> Include operations stakeholders because these stakeholders will know the details and intricacies of available revenue sources, how ready certain things are for implementation, and how one strategy can be packaged with something else for construction.
PRO-9: Approve STIP with respect to conformity and fiscal constraint	Validate that the approved TIP/STIP meets requirements related to air quality conformity and fiscal constraint, where required.	No additional actions related to reliability need to be taken in this KDP.

starting with the MPO approving revenue sources and finishing with approval of the STIP. In reality, states and MPOs both will make key decisions at PRO-1, -2, -3, and -4, whereas only the MPO will make TIP-specific key decisions (PRO-5, -6, and -7) and only the state will make STIP-specific key decisions (PRO-8, -9).

The outcome of the programming process is a STIP or TIP. These programs typically are updated on an annual cycle to include additional needs identified in corridor plans, congestion management plans, operations plans, and other subarea or modal plans; projects are scoped and designed; and revenue sources fluctuate. Reliability is most usefully considered within the programming process as a potential means to help prioritize potential future investments at the project level, but it can also be useful when identifying potential funding streams or making legislative budget requests. Table B.2 summarizes the steps for incorporating reliability in the programming process.

### PRO-1: Approve Revenue Sources

At this KDP, establish the revenue basis for operations funding sources for the TIP or STIP and the fiscal constraint of the LRP, for plans requiring fiscal constraint. The steps for incorporating reliability into this KDP include the following:

- *Identify dedicated sources for operations funding.* Identify existing dedicated sources of funding for operations projects and consider creating new revenue sources to support an operations and management program area. Examples of dedicated funding for operations projects might include earmarks from the general fund or dedication of specific funds from any discretionary source of funding (e.g., a surface transportation program). Examples of new revenue streams for operations projects might include sales tax, tolling, or other user fees. Use reliability performance measures to help support requests for increasing tax rates or other initiatives. For example, voters have approved the tax increases in metropolitan regions because MPOs have successfully demonstrated the expected investments from, and the benefits of, a new sales tax.
- *Determine the overall size of your legislative budget request.* To set the budget, the governor's and budget offices will likely provide broad direction; will adopt an official revenue forecast; will submit recommendations for an upcoming budget; will submit recommendations to the governor; and eventually will have the budget adopted by the legislature. To include reliability performance in a legislative request, build a curve that shows the cost of improving reliability by comparing the cost of reliability on the  $y$ -axis with reliability performance on the  $x$ -axis. Build the curve based on individual strategies or based on the scenarios (complementary packages of strategies) identified in LRP-7. An iterative

process, resulting from PRO-2A, will help add context to the budget request by identifying the right mix of capital and operations investments to improve reliability and identifying any federal and state funding constraints.

Supporting legislative budget requests with performance measures has been shown to be effective in Utah and Kansas where the DOTs have received more funds than they had originally asked for due to their clear description of needs.

### PRO-2: Approve Criteria for Allocating Revenue

#### *Approve Criteria for Allocating Revenue*

Because they often are short-term investments with limited capital components, operations activities are often funded outside the STIP or TIP. While the capital investments needed to support operations (such as roadway sensors, message signs, and other ITS investments) do end up in a STIP or TIP, other aspects do not (e.g., service patrols, ongoing maintenance of ITS infrastructure, and others). Combine information on both capital and operations to have a complete perspective of the investment priorities of the transportation agency and the expected future performance of both types of investments. In many states, operations and maintenance activities are funded from completely separate budgets, but for thinking about reliability performance, it will be useful to evaluate these various funding sources together and to identify the appropriate split between actual capital and operations investments to achieve a level of future performance. Perform the following steps:

- *Review program area funding guidelines.* Review the LRP to identify how much funding should be allocated to the programs that will support improving reliability. For example, the LRP might have identified that reliability improvement represents a significant need in your area and set a target over the long term that the agency should invest 40% of the total budget on strategies to improve it. In this way, the LRP defines the policy direction of the programming process.
- *Identify discretionary funds to support the mainstreaming of operations funding.* Many states have constitutional or legislative restrictions that control how the state distributes certain funding sources—such as gasoline taxes, vehicle license fees, and others. Review all funding sources to identify whether the funds are flexible and can be used on operations strategies or on projects that include operations improvements.
- *Develop a process for matching funding sources to goal areas.* Develop a crosswalk of funding programs to the goal areas defined in LRP-2 and explicitly include reliability or operational improvements among them. For example, the Highway Safety Improvement Program (HSIP) funds can only be spent on safety projects while the surface transportation

fund typically can be spent on multiple types of improvement. In this case, the safety program maps to the safety goal area only, but the surface transportation fund will map to the safety goal area as well as the reliability and operations, preservation, and economic development goal areas.

- *Develop a process for matching funding sources to strategies.* Use the crosswalk of funding sources to goal areas to distribute funds to specific projects supporting that goal area. For example, large comprehensive improvement projects might include safety, preservation, capital, and operations strategies. These projects would be eligible for funding through several different pots of funding. Develop a framework for allocating the eligible funding sources, based on their restrictions, to different project components.

### **Approve Methodology for Identifying Project Costs**

This part of PRO-2 requires establishing a consistent methodology for estimating project costs for the TIP and STIP. The results of the costing analysis will provide a starting point for building long-term revenue forecasts that allow for adding fiscal constraint in the LRP process. This should occur prior to the identification of specific deficiencies and potential solutions so that criteria are not targeted toward particular projects. The steps include the following:

- *Develop cost estimates for reliability projects.* Determine whether to perform costing in-house using sketch planning-level techniques to ensure consistency among reliability strategies or collect project costs as assessed by project sponsors using statewide or regionwide costing guidelines. For each strategy, define costs in specific terms, such as dollars per lane-mile (for linear operations projects, including managed lane projects) or dollars per unit (for stand-alone operations projects, including ramp meters). If collecting project costs as assessed by project sponsors, communicate the cost-estimating techniques to the MPOs in the state or to the towns in the region so that projects entering the TIP and STIP process are comparable. Estimate all costs as the net present value (NPV) to ensure that capital projects, which typically take several years to complete, compare on equal footing with operations projects, which typically can be completed relatively rapidly.
- *Track the cost of operations projects.* Track the aggregate cost of proposed operations and management projects across the entire program. Since many operations strategies currently are implemented on an ad hoc basis, coordinate closely with the implementing agencies in your state or region (TMAs, towns, and the state operations offices) through a standing committee if one exists, or through several conversations. Collect information on the design, scope, and cost for each

project in a consistent manner. Construct a database of projects and costs. Update the database periodically, as new operations projects are constructed.

### **PRO-3: Approve Project List Drawn from Adopted Plan Scenario**

At this key decision point, establish the list of projects drawn from the LRTP/RTP, corridor, CMP, and operations planning processes for consideration for funding in the TIP/STIP. The steps include the following:

- *Collect the universe of projects.* The LRP will have identified an approved list of strategies as part of the preferred plan scenario identified in LRP-8. This list represents the long-term strategy of the agency and is the starting point the programming process. The program will begin with these and add additional considerations, such as whether a project is shovel-ready, for example. In addition, because the LRP is developed once every four or five years and the TIP/STIP must be produced annually, it is important to update and refresh the list of strategies before beginning the programming process. Develop a complete list, or universe, of strategies by compiling the strategies identified in the LRP adopted plan scenario with those identified in the CMP, corridor, and operations planning processes.

While all MPOs develop strategy-level investment plans, states have more discretion and can develop policy plans, program-level investment plans, or strategy-level investment plans. A state that developed a policy plan will not have a priority strategy list from which to draw; a program-level investment plan may provide “buckets” of strategy types or funding allocations. In these cases, the state might build the universe of projects based on those identified in the CMP, corridor, and operations planning processes; these should be consistent with policies and goals set forth in the LRP.

### **PRO-4: Approve Project Prioritization**

At this KDP, the approved project list is prioritized using the methodology previously developed in LRP-3. Using the LRP as the basis for priority strategies and performance measures in the programming process saves time (much of the analysis already has been completed in the LRP) and promotes consistency among statewide and regional planning efforts (while measures and projects change, the consistent starting point keeps final measures similar). The project list should include associated costs, sequencing, and applicable revenue considerations for immediate programming as funds become available. By strengthening the link between a state’s or region’s vision, goals, objectives, performance measures, and prioritization criteria, your agency can demonstrate that investment decisions

are truly driven by policies and strategic plans. The steps include the following:

- *Develop project evaluation criteria.* Refine project evaluation criteria by beginning with the performance measures and weights identified in the LRP-3, adding any practical considerations for implementation listed later in this step.
- *Evaluate and prioritize projects.* Ensure that the universe of projects is evaluated for reliability improvements and that the costs and implementation horizons for operations projects are accurately reflected. All operations and capital projects should indicate some reliability benefit. Further, ensure that operations projects are given accurate “readiness” scores, since these projects typically can be completed much more quickly than large capital projects. Develop project scores by applying weights to the evaluation criteria and prioritize projects based on the project score in the fashion described in LRP-3.
- *Apply funds to strategies.* Distribute funds to the final list of prioritized strategies using the process described in PRO-2A. For each strategy, identify the appropriate funding source and level.
- *Identify practical considerations for implementation.* Balance the priority strategies based on the timing and availability of funding (especially considering that certain pots of money can only be used for certain types of projects); opportunities related to other projects (for example, if a major resurfacing is already programmed for next year and a managed lane is one of the priority strategies, then include the priced dynamic shoulder lane with active traffic management technologies along with the resurfacing project, making those items a priority, although they may not have performed as well as other solutions); and geographic equity or other political considerations that are not captured in the measures and cannot be accounted for in the weighting scheme.
- *Ensure consistency of overall spending with the targets set in the LRP.* Sum the total funding for the reliability goal area over the four- or five-year horizon of the TIP or STIP and ensure that it is consistent with the targets for reliability spending set out in LRP-7. If it is not consistent, revise the list of priority strategies and identify larger or different pots of funding for operations projects. Also, consider ways to influence the project universe in the appropriate direction.

### **PRO-5–8: Reach Consensus on Draft TIP/STIP**

In these KDPs, include operations stakeholders in outreach efforts, because these stakeholders will know the details and intricacies of available revenue sources, how ready certain things are for implementation, and how one strategy can be packaged with something else for construction.

## **Corridor Planning**

### **Introduction**

Corridor planning complements the federally required planning process by focusing on the transportation needs and improvement strategies of a specific corridor or area. Planning processes, such as National Environmental Policy Act (NEPA), encourage the use of corridor planning to assist in scoping, project and cumulative assessments, and alternatives analysis. When these elements are performed to NEPA standards as part of a corridor-planning process, it can greatly streamline the NEPA process itself. The purpose of corridor planning is to identify and implement a set of mutually supportive strategies to maintain and address access, mobility, reliability, safety, economic development, and environmental quality throughout the corridor. While reliability is often just one of several performance areas considered during the development of a corridor study, there are a variety of ways to incorporate reliability into each stage of the corridor-planning process. Table B.3 summarizes how to incorporate reliability into the corridor-planning process.

Corridor planning allows for a comprehensive assessment of all modes as well as the impacts of growth patterns and local land use decisions on traffic conditions and travel demand. It is also relevant for multiple types of investments, including noncapital-intensive strategies (such as operational improvements, access management, or land use policies) as an alternative to expensive transportation capital investments. When considering reliability, agencies should consider the potential for multimodal solutions alongside a full suite of operational improvement strategies.

From a reliability perspective, corridor planning should encompass a comprehensive understanding of the transportation dynamics and interacting influences within the corridor. These could include the impacts of variables such as traffic incidents (crashes, overturned truck trailers), demand exceeding capacity, demand variability (seasonal travel), special events (e.g., concerts, seasonal events, fairs, festivals), traffic signals (controls), inclement weather (e.g., fog, snow, wind, rain, freezing conditions), work zones, and other similar phenomenon on nonrecurring congestion and travel time reliability. As such, incorporating reliability into corridor planning requires the involvement of nontraditional stakeholders [e.g., law enforcement, emergency services, private towing and recovery entities, and traffic management center (TMC) operators] and special interest operators in the corridor (e.g., military, freight delivery), in addition to the transportation system owners, transit operators, residents, businesses, and land owners that are traditionally involved in the corridor-planning process. Developed through a collaborative process, the recommended strategies for the corridor should balance reliability alongside other corridor needs and objectives.



**Table B.3. Incorporating Reliability into the Corridor-Planning Process**

Key Decision Point (KDP)	Description	How to Incorporate Reliability
COR-1: Approve scope of corridor-planning process	Assessment of what data, decisions and relationships need to be considered, acquired, or made throughout corridor planning.	<i>Consider reliability as an issue.</i> At this KDP, planners will identify how reliability should be included in the scope of the corridor-planning process, which will have implications for the data and stakeholders to be involved. Some lightweight analysis may be required to help determine if reliability should be addressed.
COR-2: Approve problem statements and opportunities	Define the full range of deficiencies and opportunities within a corridor.	<i>Use reliability measure to estimate deficiencies.</i> At this KDP, planners will evaluate the travel time distribution for the corridor and examine locations where travel time reliability exceeds a threshold value.
COR-3: Approve goals for the corridor	Adopt the comprehensive set of goals for the corridor.	<i>Consider reliability as an issue.</i> At this KDP, an analysis of reliability and gathering of information from stakeholders and the public can help an agency determine what level of reliability to target for the corridor.
COR-4: Reach consensus on scope of environmental review and analysis	Determine the data, decisions, and level of analysis needed for the environmental review.	No additional actions related to reliability need to be taken in this KDP.
COR-5: Approve evaluation criteria, methodology, and performance measures	Define a methodology that includes criteria to enable a comparison and selection of solutions that address the corridor's opportunities and deficiencies and that address the approved goals.	<i>Identify reliability measures.</i> At this KDP, transportation planners will identify the appropriate reliability measures to use in evaluating corridor scenarios. This step will also involve setting targets for reliability and other measures.
COR-6: Approve range of solutions sets	Determine a range of solutions for the identified problems and opportunities.	<i>Consider operations strategies.</i> At this KDP, planners should ensure that the full range of strategies, including operations, is considered in developing corridor scenarios.
COR-7: Adopt preferred solution set	Select a preferred solution set from the full range of solutions.	<i>Trade-off analysis includes reliability.</i> At this KDP, planners will make use of reliability and other performance measures to help compare proposed solution sets for the corridor. This step requires significant use of analytic capabilities to provide a robust analysis of the impacts of various scenarios on travel time reliability.
COR-8: Approve evaluation criteria, methodology, and performance measures for prioritization	Identify the evaluation methodology, criteria, and performance measures for prioritizing the implementation of the solution set for the corridor.	<i>Project prioritization includes reliability.</i> At this KDP, transportation planners will identify and include reliability and other performance measures to help compare and rank projects.
COR-9: Adopt priorities for implementation	Recommend phasing and priorities for implementing the solutions for the corridor.	No additional actions related to reliability need to be taken in this KDP.

### **COR-1: Approve Scope of Corridor-Planning Process**

At this KDP, assess what travel time data, reliability decisions, and reliability-related relationships need to be considered, acquired, or made throughout the corridor-planning process. Some lightweight analysis may be required to help determine at a sketch planning level the types and extent of reliability issues in a corridor. The steps within this KDP are likely to be performed in an iterative fashion.

- *Establish the geographic boundary of the corridor and identify all relevant modes.* Corridors are often defined around specific routes. However, reliability within a corridor may be influenced by the availability of parallel

routes or investments in alternative modes. The reliability of highly constrained corridors can sometimes be improved by adjusting the operations of parallel routes, encouraging the segregation of use types (e.g., local versus through traffic), or other investments that are not on the corridor itself. Similarly, improving transit service is another approach to managing travel time reliability in a corridor and may reduce (or create) the need for other types of investments. For these reasons, include in the study area all facilities and modes that can reasonably be anticipated to impact the operations of the corridor. The corridor should be defined as several sections or segments that are adjacent and travel in approximately parallel directions (e.g., freeway and arterial street, arterial street and rail line). From

a transit perspective, transit operating on dedicated right-of-way has the potential to have a bigger influence on reliability than transit operating in mixed traffic. Be sure to include all transit facilities that serve the approximate origins and destinations of the primary freeway or arterial route under consideration.

At the early stages of a corridor-planning process, the study will benefit from broad inclusion of facilities, modes, and geography. Use relatively straightforward and simplistic analysis to narrow the scope of the study, as opposed to excluding reasonable alternatives or stakeholders at the beginning. Defining the facilities to be included will limit the scope of transportation data collection and strategy analysis.

- *Identify the relevant stakeholders and transportation providers responsible for management and operations within the corridor.* As described previously, the key stakeholders required to incorporate reliability into the corridor-planning process can be categorized into three categories: owners, influencers, and users. Traditional stakeholders in the corridor-planning process include system owners and operators (state DOTs, MPOs, local transportation departments, transit agencies) and users (residents and businesses). When incorporating reliability, however, include influencers as stakeholders as well, including law enforcement, emergency services, private towing and recovery entities, and private TMC operators. Emergency responders influence reliability through their incident response times, the operating procedures they use to ensure safety at an incident site, and the time needed to clear an incident. Regulatory and enforcement agencies work to prevent incidents that can cause non-recurring congestion. Private TMC operators can influence reliability by informing passengers and freight carriers about incidents and recurring congestion so that they may choose to reroute around an incident or retime their trip to avoid congestion and improve the likelihood that the trip can be made more reliably.

The appropriate method of communication and engagement varies based on the stakeholder's role as an owner, influencer, or user in specific corridor-planning processes.

- *Assess the degree to which reliability affects mobility in the corridor and its causes.* Engage a steering committee, if one exists, in the scoping process by asking committee members to characterize existing reliability in the corridor. Is travel time reliability an issue? Has reliability in the corridor changed over time? If so, what seems to be the underlying causes of reliability problems (e.g., incidents, weather, infrastructure conditions, special events, variable demand)? While this step will support the scoping process to determine the extent to which reliability should be considered throughout the corridor-planning process, you will solicit feedback from a broader group of stakeholders later on in COR-2 and COR-3.

- *Scope out appropriate data, analytical methods, and tools necessary to quantify the corridor's reliability deficiencies.* Inventory the data available and identify data gaps to influence how rigorous your reliability assessment can/will need to be. Sketch-planning, model post-processing, simulation or multiresolution, monitoring and management tools and methods, and multi-scenario analysis methods may be used, based on the available tools, data requirements, and the type of analysis being conducted.

## **COR-2: Approve Problem Statement and Opportunities**

At this KDP, use information from the LRP or CMP, stakeholder feedback, and preexisting data to develop a high-level understanding of the corridor's reliability deficiencies and to identify potential strategies that can improve reliability in the corridor. To provide guidance for solution strategies, use additional explanation information as necessary to identify the causes of the reliability problems. For example, do weather conditions play a key role in corridor reliability, or are fluctuations in travel time attributed to other causes, such as demand variability, inadequate base capacity, incidents, traffic signals? The problem statements and opportunities resulting from this key decision are informed by the transportation deficiencies identified in long-range planning.

- *Review existing studies and historical data to identify locations and/or time periods with reliability deficiencies.* To develop a sketch-planning-level understanding of corridor reliability deficiencies at this stage in the process, compile a list of reliability deficiencies and strategies identified during previous planning efforts. This would include the CMP, previous corridor studies, the statewide LRP, and the regional LRP. Also use preexisting data, such as transit on-time performance and traffic/speed data that is collected and analyzed on a regular basis, to assess historical reliability trends and understand how reliability has been changing over time.
- *Gather feedback on corridor reliability from stakeholders and the public.* To supplement the information documented in previous plans, ask stakeholders for their opinions on reliability in the corridor. For example, ask shippers how corridor reliability affects their shipping and warehousing decisions. Ask emergency responders what they view as the underlying cause of unreliable travel. Ask TMC managers how the reliability of the system has been changing and what seem to be the underlying causes of reliability deficiencies (e.g., incidents, weather, infrastructure conditions, special events).
- *Assess the underlying cause(s) of reliability deficiencies and identify areas where opportunities to improve reliability exist.* Collect and analyze supplemental data such as weather

conditions, incident and crash reports, special event schedules, construction and maintenance logs, to assess whether reliability in the corridor is largely impacted by weather, incidents, special events, construction, congestion, or other identifiable causes. Use this information to assess opportunities to address the underlying causes of reliability in the corridor. For example, if incidents are a problem, there may be an opportunity to improve emergency response and incident clearance times. While this step requires a preliminary assessment of problems and opportunities, you will develop specific strategies to address these opportunities under COR-6.

### **COR-3: Approve Goals for the Corridor**

At this KDP, gather feedback from stakeholders and the public to determine what level of reliability to target for the corridor. Ensure that reliability goals are compatible with the comprehensive set of goals for the corridor, as goals will guide the selection of a set of solutions that address the corridor's opportunities and deficiencies. The steps include the following:

- *Engage stakeholders in building consensus around their expectations for reliability in the corridor.* To understand stakeholder expectations, present to them the historical reliability data compiled in COR-2, supplemented with maps and other visualization tools as necessary, and ask them to describe what “acceptable reliability” would look like to them. For example, ask shippers to describe what a reliable shipment route looks like or how often they experience delay in a month. Ask commuters how much travel time variability they are willing to tolerate on a day-to-day basis. Use existing reliability data to convey existing issues and to determine whether stakeholder perceptions of reliability deficiencies and their causes are consistent with the technical analysis conducted in COR-2. Ultimately, build consensus around stakeholder expectations and how much they value reliability compared with other needs in the corridor. Establish a reliability goal for the corridor that reflects this input.
- *Incorporate reliability into the goals for the corridor.* The process of establishing goals creates an opportunity for stakeholders to balance reliability needs against the other goals for the corridor. Goal setting at this stage is driven largely by the LRP, previous sketch-planning analysis, anecdotal evidence and stakeholder input, and community priorities. Travel time reliability may be a goal in and of itself, or reliability may be captured under a larger goal, such as “improve multimodal mobility.” Goals provide the foundation on which objectives, performance measures, and targets are established.

### **COR-5: Approve Evaluation Criteria, Methodology, and Performance Measures**

At this KDP, identify the appropriate reliability measures to use in evaluating corridor scenarios. This step also will involve setting targets for reliability and other measures. The steps include the following:

- *Develop reliability performance measure(s) appropriate for the corridor.* As a starting point, consider reliability performance measures that have been established at the state or regional level, if any, particularly through the LRP or CMP processes. Ensure that measures reflect the goals and objectives established for the corridor, are feasible with existing data and analysis tools (recognizing that some corridor-specific data may be collected to support the corridor study), are sensitive to the likely impacts of the capacity or operational projects under consideration, are understandable and resonate with the intended audience, and capture all modes operating in the corridor. In some cases, a steering committee may be responsible for approving the final list of measures.

Different measures are used at different levels within transportation agencies depending on how reliability is defined (e.g., overall reliability, delay by source) and the analysis tools selected for analysis (e.g., sketch-planning tools are unable to calculate the same measures as a simulation model). While the LRP and CMP consider reliability from a broad, regional perspective, corridor planning allows for a more focused analysis of the key travel markets that utilize the corridor. For example, developing performance measures at the origin–destination (O-D) level allows a market-based approach to target different activity centers, population groups, and modes operating within the corridor. It also provides a method to test the impact that improvements to transit operations or parallel arterials have on reliability in a given travel market.

- *Identify methods for establishing targets.* The thresholds for performance levels should be determined through the stakeholder feedback compiled during COR-3 as well as an assessment of available resources and other priorities within the corridor. Adjust targets over time to reflect financial and policy changes. Corridor-specific targets can be set for both the short and long term.
- *Develop or approve reliability targets.* Review the targets identified in the LRP and consider whether they are applicable for your corridor study or whether you need to further refine them to reflect the corridor-specific reliability issues voiced by stakeholders during the scoping process.
- *Develop a weighting scheme to balance reliability against other corridor priorities.* Consider how the issue of reliability stacks up against other corridor goals based on the stakeholder feedback compiled during COR-3. Convene working groups

to discuss how important improving a reliability measure is when compared to the other measures you have selected for the other goal areas. In this step, develop an approach for ensuring that each performance measure is given its proper level of importance when compared across all performance measures. This ultimately will be used in subsequent KDPs to evaluate and prioritize strategies and scenarios.

### **COR-6: Approve Range of Solutions**

At this KDP, ensure that the full range of strategies, including operations, is considered in developing corridor scenarios. The steps include the following:

- *Apply performance measures to refine reliability deficiencies.* Reevaluate the corridor's reliability deficiencies compiled in COR-2 using the performance measures identified in COR-5. This is of particular importance if the reliability measures are targeted at identifying or addressing a particular reliability issue. Refine the list of reliability deficiencies based on this reevaluation to provide stakeholders and planners with the information necessary to begin developing strategies to address these deficiencies.
- *Compile a list of capital and operational strategies and policies documented in existing plans.* The first step in identifying strategies is to compile a list of transportation improvement projects likely to influence reliability in the corridor that are currently underway, programmed, or have a high probability of moving forward. Pull from the LRP, CMP, operations plans, and other existing planning documents. This set of projects should serve as a baseline for the development of additional strategies.
- *Engage operations agencies and other stakeholders to add to the list of potential solutions.* Coordinate with your internal and external stakeholders to collect additional strategies that influence reliability. Categorize individual strategies by type (e.g., additional capacity, operational improvements, and demand management) to facilitate further screening and to consider possible strategies for all modes represented in the corridor. At this stage in the process, strategies may be conceptual in nature without specifying details. However, identify potential fatal flaws in proposed solutions and the level of support and/or a potential implementing sponsor for the individual solutions.
- *Develop a comprehensive list and add additional strategies as necessary.* Assess whether the range of solutions is broad enough to address the corridor's reliability goals. Develop screening criteria that can be used to eliminate unreasonable or unattainable strategies that are not worth investing any additional effort in analyzing. At this stage, the screening process will be largely qualitative in nature and will rely on judgment of the corridor-planning team members.

### **COR-7: Adopt Preferred Solution Set**

At this KDP, use reliability and other performance measures to compare proposed solution sets for the corridor. This step requires significant use of analytic capabilities to provide a robust analysis of the impacts of various scenarios on travel time reliability. The steps include the following:

- *Develop scenarios or packages of projects and policies.* Work with stakeholders to group the strategies into logical packages of mutually supportive solutions. For example, you would not want to include two strategies in the same solution set whose purpose is to solve a particular type of reliability deficiency at the same location, unless they are additive in some way. Develop separate strategy packages to address different funding or growth scenarios, as appropriate.
 

For example, Minnesota Department of Transportation (DOT) develops packages of mutually supportive solutions to address urban peak period recurring and nonrecurring delay-related reliability in the Twin Cities. A corridor strategy package may include a combination of a managed lane, active traffic management ITS technologies, electronic tolling to support congestion pricing, and express bus routing through the managed lane. Such a package's strategies are complementary and include managed capacity expansion, ITS, operations, and transit solutions.
- *Evaluate the effectiveness of each strategy or scenario on reliability.* Apply the technical approach developed in COR-5 for each strategy or bundle of strategies. Strategy evaluation using previously approved methodology should be based on considerations such as: the magnitude of the problem and its need to be addressed (major, moderate, minor); the certainty of need (existing/immediate, forecast and likely to occur, forecast but speculative); the cost-effectiveness of proposed solutions; the level of support for the strategy; the potential availability of adequate funding; and the negative impacts associated with the strategy. Prioritize strategies as high, medium, low, or not recommended based on their anticipated impact on travel time reliability.
- *Evaluate the trade-offs of reliability against other performance improvements.* Apply weighting developed on COR-5 to evaluate reliability against other performance improvements such as safety and corridor preservation. Ensure that reliability is addressed to an adequate extent in the preferred solution set based on established goals and objectives.
- *Develop consensus around a preferred scenario.* Document the rationale for eliminating solution sets and why a particular solution set is recommended. Use both qualitative and quantitative support, based on performance targets set previously and the approved goals and objectives for the corridor. Ensure that the established weighting scheme for the priorities of the corridor is supported by the preferred scenario. In selecting the preferred scenario, financial

constraints should also be considered: projects that will move forward into either the LRP or STIP/TIP will be subject to the fiscal constraints of those documents. If federal funds will be requested or used to implement the preferred scenario, and NEPA procedures were followed, this scenario may be considered a locally preferred alternative.

### **COR-8: Approve Evaluation Criteria, Methodology, and Performance Measures for Prioritization**

At this KDP, consider previous analysis and practical considerations to prioritize projects within the corridor solution set for implementation. Having completed the analysis of each strategy and solution set in COR-7 and evaluated the trade-offs of reliability against other performance improvements, this KDP considers that analysis to understand priorities in terms of how well they perform. The steps include the following:

- *Identify practical considerations for implementation as additional criteria for prioritizing implementation.* In addition to the performance scores of each project in the solution set, the prioritization of implementation for individual components should include the following:
  - Available financing, especially considering certain pots of money can only be used for certain types of projects;
  - Opportunity associated with other projects (for example, if a major resurfacing is already programmed for next year, and a managed lane is one of the projects in the preferred solution set, then consider including a priced dynamic shoulder lane with active traffic management technologies onto the resurfacing project, making those items a priority though they may not have performed as well as other solutions); and
  - Geographic equity or other political considerations that are not captured in the measures and cannot be accounted for in the weighting scheme.
- *Combine all of the performance measures to assess how the solution sets perform.* Reexamine the analysis of the individual strategies to determine the performance-based priorities within the solution set, and compare that to the practical considerations above. At this stage, it also may be necessary to break the individual strategies into smaller components based on funding or other practical considerations presented in this report (e.g., phasing), which may in turn require a second performance analysis of the individual components.

This reexamination may include a final benefit-cost index, cost-effectiveness index, or other combined score as determined in the methodology in COR-5; if reliability is a major concern in the corridor, the impact on reliability of each strategy should be clearly articulated.

- *Prioritize projects in the solution set to move forward to programming.* If the steps above adhere to NEPA standards and federal funds will be used, the preferred scenario of projects may be considered a locally preferred alternative, ready to move on to the NEPA phase.
- *Monitor the effectiveness of implemented strategies.* Following project completion, collect data to assess whether the implemented strategies addressed the reliability deficiencies to the extent expected. Use this information as an input to refine and enhance future LRP, CMP, and corridor-planning efforts in the region.

## **Congestion Management Process**

### **Introduction**

All metropolitan areas with a population greater than 200,000 residents are considered transportation management areas (TMA) and are required by the Safe, Accountable, Flexible, Efficient, Transportation Act: A Legacy for Users (SAFETEA-LU) to develop a congestion management process (CMP). As described in the FHWA *Congestion Management Process Guidebook*, a CMP is “a systematic and regionally accepted approach for managing congestion that provides accurate, up-to-date information on transportation system performance and assesses alternative strategies for congestion management that meet state and local needs. The CMP is intended to move these congestion management strategies into the funding and implementation stages” ([https://www.fhwa.dot.gov/planning/congestion\\_management\\_process/cmp\\_guidebook/chap01.cfm](https://www.fhwa.dot.gov/planning/congestion_management_process/cmp_guidebook/chap01.cfm)).

The CMP is not included in PlanWorks framework. For consistency, however, a set of KDPs has been identified for a typical CMP. Table B.4 summarizes how reliability can be incorporated into a set of KDPs for the CMP.

### **CMP-1: Approve Objectives for Congestion Management**

At this KDP, analyze reliability and gather information from stakeholders to help determine how to develop reliability objectives. The steps include the following:

- *Identify the relevant stakeholders and partnerships.* If the region has a robust and ongoing LRP process, many of the groups identified and formulated for the development of the LRP can be maintained and reengaged for the CMP, with particular focus on groups related to operations, system management, and users who are heavily impacted by reliability issues.

Depending on the geographic extent of the CMP network, stakeholders and partnerships may include MPOs,

**Table B.4. Incorporating Reliability into Key Decision Points for the Congestion Management Process**

Key Decision Point (KDP)	Description	How to Incorporate Reliability
CMP-1: Approve objectives for congestion management	Objectives should draw from the community values articulated in the regional vision and goals identified in the MPO's LRTP.	<i>Consider reliability an issue.</i> Reliability should be core. At this KDP, an analysis of reliability and gathering of information from stakeholders and the public can help an agency determine if reliability should be a goal or objective for the transportation system.
CMP-2: Approve CMP network	Define both the geographic scope and system elements (e.g., freeways, major arterials, transit routes) that will be analyzed in the CMP.	<i>Consider reliability an issue.</i> Ensure that components of the system that suffer (or are likely to suffer) from reliability issues are included. At this KDP, planners will think proactively about the network where travel is likely to be unreliable.
CMP-3: Approve multimodal performance measures	Develop performance measures to identify, assess, and communicate congestion.	<i>Identify reliability measures.</i> At this KDP, transportation planners will identify the appropriate reliability measures to use in evaluating congestion. These measures will depend on the goals and objectives set in CMP-1.
CMP-4: Approve congestion problems and needs	Identify congestion deficiencies and sources within the approved CMP network that should be addressed in the CMP.	<i>Estimate reliability deficiencies.</i> At this KDP, planners will classify corridors or locations where travel time reliability exceeds some threshold or target value using the performance measures identified in CMP-3.
CMP-5: Approve strategies	Identify and assess groups of strategies relative to stated needs.	<i>Consider operations strategies.</i> At this KDP, planners should ensure that the full range of strategies, including operations, is considered.

local transportation departments, and transit agencies from other areas. Although the CMP is the responsibility of the MPO, the involvement of transportation operations managers is important for evaluating congestion mitigation strategies. Examples of roles for operations staff may include brainstorming mitigation strategies, identifying congestion sources and measurement techniques, developing performance measures, and identifying approaches to strategy implementation. The appropriate method of communication will depend on the stakeholder's role.

- *Gather information from stakeholders and the public to identify objectives.* Ensure that reliability objectives reflect existing visions and goals for congestion and mobility discussed in the LRP, corridor studies, and project related efforts. Develop surveys and engage stakeholders to identify how they feel congestion is managed. Identifying causes of congestion and the perceived and real costs of travel time unreliability can help you to select a CMP network and define performance measures and strategies. Stakeholders may provide feedback related to personal and commercial travel, corridors and regions where travel time is unpredictable, and the associated costs of unreliability. For example, ask key stakeholders how they feel reliability impacts mobility for the corridor's users.
- *Identify objective(s) to be included in CMP.* Objectives should be focused on the desired outcome of the CMP, as it relates to overall objectives for the region based on other planning activities and on reliability-related

feedback from stakeholders and the public. It may not be feasible or desirable to try to eliminate all congestion, and so it is important to define objectives for congestion management that achieve the desired outcome. Reliability objectives may be tied to overarching operations-oriented objectives for the region, such as reducing incident-based delay, reducing travel delay associated with work zones or weather conditions, reducing emergency response times, improving transit system reliability, or improving access to travel time information. By including congestion management objectives that address reliability, the CMP will identify programs and strategies that more effectively address the causes and impacts of congestion.

- *Scope out necessary measures, data, and resources needed for approved objectives.* An examination of the availability of data sources may require collaboration with data suppliers within the MPO such as traffic counting staff, geographic information system (GIS) staff, and others.

### **CMP-2: Approve CMP Network**

At this KDP, think proactively about the network where travel is likely to be unreliable. This includes areas of recurring congestion (e.g., bottleneck locations where capacity is constricted or where merging and weaving patterns cause conflicts) and nonrecurring congestion (e.g., crash hotspots, special events, or construction). Either type will require analysis at the corridor or facility level to pinpoint problem

locations or to identify and evaluate congestion mitigation strategies. The steps include

- *Use model roadway networks of travel demand models to inform baselines for CMP roadway networks.* Looking at model output will provide a good basis of information related to congestion and reliability. When identifying the CMP network, consider the availability of supporting historical data. To the degree possible, the CMP network should be multimodal in nature, taking into account the interactions among various modes of transportation and the effect they could have on reliability. Also, consider how corridor-wide land use patterns, employment, transit, and population centers could affect reliability. To construct the network, use available multi-modal data to select roadway segments and elements of the transit system. For example, select highway segments based on the functional classification (e.g., select “all collectors or above”) or based on segments over certain reliability thresholds (e.g., a travel time index above 1.35).
- *Refine and update the CMP network.* Neighboring MPOs may choose to partner in the development of a joint CMP. Extend the geographic extent of the CMP network to include regional metropolitan land use, employment, transit, and population centers. For example, identify employment and commute patterns to identify key inter-regional corridors to include as part of the CMP network that may extend beyond MPO boundaries.
- *Identify the regional definition of “congested.”* Review existing studies for the state and regional working definition of congestion and reliability. A well-rounded understanding of congestion will be multidimensional in nature and will include travel time reliability. As described in the introduction, the four dimensions of congestion include spatial (how much of the system is congested); temporal (how long congestion lasts); severity (how much delay there is or how low travel speeds are); and variability (how congestion changes from day to day). Ensure that the reliability (variability) component is used to identify corridors and portions of the network to include in the CMP. In regions where the highway network is very dense, this can help limit data collection and analysis to the most congested facilities.
- *Define the system elements that will be analyzed under the CMP.* The availability and sophistication of model data and analysis of travel patterns and regions will help determine the appropriate system elements to be analyzed under the CMP. Reliability for each included system element will be considered separately depending on the regional definition of congestion agreed upon above. Reliability may be measured differently between different system elements (e.g., freeways, major arterials, transit routes). The reliability of certain system elements may be prioritized based on the

severity of the problem, the amount of travel occurring on the element, or the location of the element relative to the entire study region.

### **CMP-3: Approve Multimodal Performance Measures**

At this KDP, identify appropriate reliability measures to use in evaluating congestion. These measures will directly correspond to the reliability-based congestion management goals and objectives set in CMP-1.

- *Develop performance measures to identify, assess, and communicate congestion.* Use the performance measures developed in the LRP and PRO processes; this will reaffirm the efficacy of public input and provide a basis for further analysis. Tailor the LRP and PRO measures for the CMP based on the objectives set in CMP-1. Identify relevant performance measures already used in existing planning efforts as well as any reliability-related measures needed.
- The flexibility of these performance measures also is a notable consideration. For example, if actual or desired development patterns change (from growth and capacity expansion to higher density and multimodal options), will performance measures chosen be aligned with the new direction? Will they capture the impacts of those changes on performance, particularly reliability?
- *Identify source(s) of data related to performance measures.* Work with technical staff to ensure travel time data are available to estimate reliability performance measures. Current resources should be able to track the performance of each of these measures. If data are not currently available, consider hiring a consultant to collect the data. Other transportation agencies may serve as partners in data collection and analysis efforts.
- *Analyze current conditions.* Some agencies report reliability conditions in an annual performance report. If no reports exist, estimate new measures based on techniques described in the technical reference. Current conditions should help to confirm anecdotal information received from stakeholders. To the degree possible, collaborate with transportation operators, facility owners, and related agencies to leverage existing data for analysis. This is particularly true of multimodal data that may be available from transit agencies, bicycle groups, or local governments.

### **CMP-4: Approve Congestion Problems and Needs**

At this KDP, classify corridors or locations where travel time reliability exceeds some threshold or target value using the performance measures identified in CMP-3. Reliability problems

can also be reported as a ranking of corridors throughout the region based on reliability results or an analysis of how well the region as a whole is meeting established reliability objectives. The steps include

- *Review reliability deficiencies and problems from other studies.* Compile reliability deficiencies and problems collected from other planning efforts. These will be compared to the analysis of current conditions conducted in CMP-3 to ensure all identified deficiencies throughout the CMP network are addressed.
- *Set thresholds identifying reliability problem spots.* Using the performance measures developed in CMP-3, test different thresholds for identifying reliability problems. Identify the deficiencies for each threshold and determine whether it matches stakeholder judgment of how reliable travel is in the CMP network. It can be extremely helpful to show your options as a set of maps that highlight the unreliable travel trouble spots. For example, if measuring the areawide buffer index for all traffic at the segment level, identify any segment with a buffer index over 40% as unreliable. Alternatively, rank the segments by buffer index. A third option is to categorize segments into reliability tiers; for example, 0% to 10% would be characterized as reliable; 10% to 30% as moderately unreliable; and 30% or more would be considered unreliable. The thresholds also can be different for urban and rural areas; different functional classifications; or different modes.
- *Identify current and future deficiencies.* Determine reliability deficiencies by identifying network segments that exceed reliability performance thresholds. These segments indicate where future reliability trouble spots are likely to arise. These deficiencies will make up a portion of all congestion problems and needs identified through other planning efforts, stakeholder input, and analysis of approved performance measures.
- *Develop weights for your performance measures.* Develop a weighting scheme to balance reliability against other performance measures. This will ultimately be used in CMP-5 to evaluate and prioritize strategies.
- *Ensure that problems and needs align with input received from stakeholders and the public.* Compare reliability problems and needs to input received from stakeholders from other regional or statewide planning efforts. The alignment of regional goals, input received, and data analysis help to identify and prioritize strategies later in the CMP process.

### **CMP-5: Approve Strategies**

At this KDP, identify and assess groups of strategies relative to stated needs. Some regions may consider a hierarchy of congestion management strategies based on regional policy

goals, in which priority is given to strategies that eliminate or reduce travel first, followed by operations strategies, and then considering capacity expansion as a last resort.

- *Collect existing strategies and develop new strategies.* Strategies may come from a variety of different sources, including the LRP, COR, and OPS processes, and should be focused on the problems and needs identified in CMP-4. Work with stakeholders using the methods described in the institutional arrangements chapter to gather ideas for new strategies not already identified in previous planning studies. For example, hold a high-level meeting with a steering committee to develop high-level policy strategies and to glean ideas from other stakeholders through working groups and other passive comments. Strategies can include capital and operational strategies and policies. Examples of strategies include congestion pricing, high occupancy vehicle (HOV) lanes, incident management (e.g., emergency response teams and centralized traffic management centers), and ramp metering, among others. The decision should be made based on group consensus among committee members, and strategies should be consistent with those identified in the long-range planning process.
- *Evaluate the effectiveness of the strategies.* Assess how strategies support the congestion management objectives agreed upon in CMP-1. Use the approach for estimating reliability to evaluate how these strategies would improve reliability by calculating the measures selected above. Also consider how reliability-focused strategies contribute to other goals and objectives of the transportation system, such as safety, economic vitality, system preservation, and air quality.
- *Identify who has jurisdiction over implementation of CMP strategies.* This could include state DOTs, transit agencies, and local governments. MPO staff can support implementing agencies during the congestion management project design process by providing them with information from their travel demand model.
- *Rank and select strategies.* Ensure support for strategies. Identify potential project sponsors and implementing authorities to inform a prioritization of potential projects. Information from implemented strategies can be helpful in evaluating individual strategies. Tools and methods for assessing strategies include travel demand models, sketch-planning tools, past experience, analytical/deterministic tools (HCM-based), and simulation models.
- *Convert the reliability effectiveness estimates to benefits in dollars to facilitate benefit-cost analysis.* In general, one hour of delay due to unreliable traffic is worth approximately the same dollar value as recurring delay (results of several research studies suggest the value of unreliable travel time is between 0.8 and 1.5 times greater than the value of average travel time).



- *Develop costs for the strategies.* These costs can include per lane-mile costs, per project costs, right-of-way costs, and operating and maintenance costs. Ensure that project sponsors that submit projects into the universe of projects use this cost-estimating technique. Doing so will allow you to make apples to apples comparisons of projects.

## Operations Planning

### Introduction

FHWA defines Planning for Operations as “a set of activities that takes place within the context of an agency, jurisdiction, and/or regional entity with the intent of establishing and carrying out plans, policies, and procedures that enable and improve the management and operation of transportation systems” (<http://plan4operations.dot.gov/glossary.htm>). Operational strategies include many activities such as traffic signal timing, managed lanes, reversible lanes, ramp metering, variable speed limits, active traffic management strategies, incident management activities, service patrols and traffic management center (TMC) operations. The use of reliability data while analyzing these activities allows the operations practitioner to evaluate the impacts of the implemented strategies or to simulate the effects of strategies prior to implementation.

In terms of incorporating reliability into planning and programming, operations planning may have different components depending on whether it is being applied within a DOT planning office, a DOT operations office, or an MPO. Consequently, the use and application of reliability varies among these different stakeholders. For example, a DOT planning office may adopt travel time reliability as an official measure within its long- and short-term planning processes. As reliability becomes incorporated into the modeling and data collection processes, congestion (including nonrecurring congestion) can be better quantified. As a result, strategies intended to address this type of congestion—such as real-time travel time (traveler information), managed lanes, ramp metering (traffic management) and incident management applications (incident management)—begin to be included in short- and long-term plans.

This section covers operations planning within an operations office. Within an operations office, operations planning can take several forms, including developing the ITS architecture or consideration of performance measures such as reliability to compare and select operations type projects. Operations projects are directly linked to reliability. Operations planning heavily relies on reliability data and systemic improvements to reliability require the implementation of operations strategies.

Operations planning also can be a joint effort between operations and planning that encompasses the important institutional underpinnings needed for effective regional

transportation systems management and operations. In this context, operations planning includes three important aspects:

1. Regional transportation operations collaboration and coordination activity that facilitates regional transportation systems management and operations;
2. Management and operations considerations within the context of the ongoing regional transportation planning and investment process; and
3. The opportunities for linkage between regional operations collaboration and regional transportation planning.

These three elements are fostered and accomplished, at least in part, through the development of the regional ITS architecture, including regularly scheduled meetings to maintain, discuss status and update the architecture. In addition, regional planning agencies generally develop regional ITS strategic plans and ITS implementation plans in conjunction with development of the regional ITS architecture.

At each level of operations planning (local, regional, state-wide, and multiregion and multistate) agencies have a different method of using reliability data and incorporating reliability into the processes.

- *Local level:* An operating agency such as a state DOT district traffic management center (TMC) or a city TMC will conduct what often is referred to as operations planning, which is planning for spot improvements using management techniques or low-cost geometric changes. This planning is usually done within the agency without outside collaboration and within the agency operations budget.
- *Regional level:* This level of planning is usually within a metropolitan area regional planning agency, often the MPO or occasionally a regional operating agency (e.g., the Freeway and Arterial System of Transportation [FAST] in Las Vegas), or a DOT district or regional office. Regional planning is commonly accomplished through a management and operations committee of the MPO and requires collaboration among a large number of stakeholders, including many that are not traditionally part of the MPO process (such as public safety, emergency management, and special events managers).
- *Statewide level:* Planning that is conducted at a DOT central office that will enable the allocation of funds to maintenance and/or operations budgets or prioritize operations improvements identified at the district level.
- *Multiregion and multistate regional operating agencies:* Planning that enables coordination, resource sharing and information sharing among a group of operating agencies, authorities and state DOTs (e.g., the I-95 Corridor Coalition).

Operations planning is not included in the PlanWorks framework, but for consistency, a set of KDPs has been developed for this section. Operations investments typically are short-range, low-capital, often management-focused for a real-time environment. Operations projects typically are funded through maintenance and/or operations budgets, while capital projects have dedicated funding. The previous sections have identified approaches for integrating operations investments into the planning process; this section focuses on how to plan for operations investments themselves, recognizing that many state DOTs and other transportation agencies likely will continue to separate operations activities from capital investments.

The KDPs for operations planning are intended to provide for flexibility in application, allowing agencies to combine them, as they deem appropriate to fit with their planning process. They capture the range of decisions that take place as part of operations planning. Some of the steps take place only occasionally, such as adopting the ITS regional architecture, while others may be skipped when being developed by a single agency. The goal of the KDPs is to identify problem areas and potential operations solutions, evaluate the potential solutions, and adopt a defined solution project or set of projects. Table B.5 summarizes how to incorporate reliability into operations planning.

**Table B.5. Incorporating Reliability into Key Decision Points for Operations Planning**

Key Decision Point (KDP)	Description	How to Incorporate Reliability
OPS-1: Approve scope of the operations plan	Identify the mode, facility type, network level, range of cost and schedule for the operations plan.	<i>Consider reliability as an issue when developing the plan scope.</i> Reliability data will help define the general scope of the problem to be addressed.
OPS-2: Approve operations goals, evaluation criteria, methodology, and performance measures	Identify specific goals, performance criteria, methodology and measures that will be used in the operation planning evaluation process.	<i>Identify reliability measures when developing methodology and measures.</i> Reliability data will be part of the evaluation criteria for operations projects, the evaluation methodology will assess reliability, and reliability will be a goal and a performance measure.
OPS-3: Approve operations problem statements, deficiencies, and opportunities	Identify specific locations, problem types, and solution opportunities, including identifying a wide range of deficiencies.	<i>Estimate reliability deficiencies when defining problem areas.</i> Reliability data will help identify problem locations, duration, and extent. At this step, it is also appropriate to review the status of current operational deployments.
OPS-4: Develop a range of solution sets	Identify potential solutions that will meet goals of the operations plan.	<i>Include reliability in trade-off analysis.</i> Evaluation of solutions will include reliability data and reliability calculations. This step will also require identifying the range of capital, staffing, technology, training, and maintenance requirements or operations deployments.
OPS-5: Adopt preferred solution set	Evaluate the solutions using the performance criteria and methodology and define preferred solutions.	<i>Include reliability in trade-off analysis.</i> Evaluation of solutions will include reliability data and reliability calculations. This step also includes coordination with other agencies, including developing requirements for copartnering memoranda of understanding (MOUs) with public safety agencies and others for agreement on procedures and protocols.
OPS-6: Update the regional ITS architecture (optional)	Review the regional ITS architecture to ensure it is compatible with the preferred solution set and update if needed.	<i>Consider reliability as an issue when developing the ITS architecture.</i> Data collection and reporting capabilities for reliability data should be included in the regional architecture. The architecture must accommodate providing reliability data to support the KDPs.
OPS-7: Develop a project level concept of operations, systems engineering management plan, and configuration management plans (optional)	Develop project ConOps, SEMP, and CMP if needed.	<i>Consider reliability as an issue when developing the ConOps, SEMP, and CMP.</i> ConOps, SEMP, and CMP should include methodology to enable data collection and reporting of reliability. The ConOps must accommodate providing reliability data in to support the KDPs.
OPS-8: Assess benefits of implemented projects and provide feedback	Evaluate the project after implementation to assess the benefits and impacts. Provide feedback to the problem evaluation step (OPS-4) or the ITS architecture step (OPS-6).	<i>Include reliability in the benefits assessment.</i> The benefits analysis will include reliability data and reliability calculations.

### OPS-1: Approve Scope of the Operations Plan

The purpose of this KDP, which is part of the typical planning process, is to identify the modes, facility types, network levels, range of costs and schedules for the operations plan.

- *Gather scoping input from operations managers and planners.* Develop the scope of the operations plan in consultation with transportation system owners responsible for managing and operating the system by gathering feedback from standing committees, especially committees who are responsible for operations. If standing committees have not been formed, reach out to the management at regional or state offices of operations, traffic management centers, and other operations system owners. Ask them how they feel reliability affects transportation operations in the region.
- *Define the study area and scope.* Before the planning effort begins, define the study area and scope of the operations plan. This definition of the study should include the following:
  - *Mode:* highway, transit, bicycle, pedestrian;
  - *Facility type:* freeway, arterial, managed lanes, bus, rail;
  - *Network level:* interchange or intersection, segment, corridor, area, region;
  - *Range of cost:* low-cost, improvements within existing right-of-way only, major reconstruction; and
  - *Schedule:* short-term (1 to 2 years to completion), mid-term (2 to 5 years), long-term (more than 5 years).

Use available reliability data to help in problem scoping and in defining the study parameters. Reliability data will help define the mode and facility type of the problem area and the scale of the problem. Typically, factors such as budget and urgency of the need will drive the range of cost and schedule of the project.

- *Scope out necessary measures, data, and resources needed for approved objectives.* An examination of the availability of data sources may require collaboration with data suppliers within the MPO such as traffic counting staff, GIS staff, and others.

These steps will be different for each of the levels of planning:

- *Local:* Operations divisions typically address smaller, shorter-term projects under the purview of that division (freeways, arterials, or transit). This assumes that the project can be implemented within the existing budget and implemented within the operations division's resources, so this step normally is skipped.
- *Regional:* Stakeholder participation and coordination is critical to project scoping. Coordination with operators is essential.

- *Statewide:* Identification of funding is a major issue in scoping for statewide plans. The project scope will also determine whether the project must be included in the regional planning process.
- *Multiregion and multistate:* Both stakeholder participation and funding are significant issues. The scoping step will determine which agencies need to be involved in the planning process and what their role may be, as some agencies may be responsible for funding, while others may just need to coordinate with the planning process.

### OPS-2: Approve Operations Goals, Evaluation Criteria Methodology, and Performance Measures

At this KDP, identify specific goals, performance criteria, methodology and measures that will be used in an operations planning evaluation process. Once the scope of the project is defined in OPS-1, then the goals of the project, the criteria to be used in the evaluation, the evaluation methodologies, and the measures of performance for the projects must be defined. Depending on the agencies involved and the project scope, these items may have already been defined for operations projects, and therefore this step could be skipped. The steps include

- *Approve operations goals.* Build on input from key stakeholders to identify reliability-specific operations goals. The goals should be consistent with regional goals expressed in regional planning documents. Operations goals can be defined by answering the following four questions: Where are we now? Where are we going? Where do we want to be? How will we get there? Follow the work steps described in LRP-2 to answer these questions.
- *Approve evaluation criteria, methodology, and performance measures.* Follow the work steps described in LRP-3 to identify the evaluation criteria, methodology, and reliability performance measures to be used in the project development. Consider reliability by including reliability data in the evaluation criteria for operations projects; identify evaluation methodologies that are capable of assessing reliability; and identify reliability performance measures along with a specific goal and target. While it is important in any of the planning processes (e.g., LRP and COR) that reliability measures be sensitive to all types of potential projects, it is particularly important here that the reliability measures be sensitive to the vast array of operational improvements that are likely to be considered.

These steps may be different for each planning level; however, if the goals, criteria, methodologies, and measures are already defined, then this step can be skipped for any of

the four levels. Differences at each level may include the following.

- *Local*: This step normally is skipped as goals, criteria, methodologies, and measures typically are in place.
- *Regional*: Some agencies already have established evaluation criteria, methodologies, and measures in place for operations projects.
- *Statewide*: Some DOTs already have established evaluation methodologies in place for operations projects.
- *Multiregion and multistate*: Stakeholder participation is important in developing evaluation criteria and methodologies. Different agencies have different goals, criteria, methodologies, and measures, and these differences will need to be resolved to conduct project planning.

### **OPS-3: Approve Operations Problem Statements, Deficiencies, and Opportunities**

At this KDP, you will identify reliability deficiencies that should be addressed by planning for operations. Transportation deficiencies are where the current or future system is expected to experience reliability problems. This step is the same as a step in any typical planning process.

- *Identify reliability deficiencies*. Reliability plays a key role in problem identification by enabling estimation of reliability deficiencies on the network. Identify locations of reliability deficiencies using reliability data and the measures identified in OPS-2 to identify problem locations and duration by time of day, length of time, and geographic extent of the problem.

These steps are necessary for operations planning at all levels but may vary by planning level.

- *Local*: Some agencies have a consistent and ongoing process for deficiency analysis and use after-action reports by operators and planners who may or may not be involved in the planning process. Many agencies have an ad hoc process to identify problems.
- *Regional*: The current lack of reliability data (or lack of use of the data) often makes this an ideal—rather than real—step. Other congestion measures are often used in place of reliability to identify problems. Maintenance and operations committees are useful for identifying reliability problems.
- *Statewide*: Planning divisions must work with operations staff to identify problem areas. Operations staff is familiar with geometric or operational deficiencies and can provide valuable input to define the problem type, location, and scope.
- *Multiregion and multistate*: Stakeholder participation is important in identifying common problems and cross-jurisdictional problem areas.

### **OPS-4: Develop a Range of Solution Sets**

At this KDP, identify potential operations solutions that meet the goals of the operations plan, address the deficiencies identified in OPS-3, exceed the evaluation criteria established in OPS-2, and optimize network performance. This KDP also will require identifying the range of capital, staffing, technology, training, and maintenance requirements of operations deployments.

- *Review current operational deployments*. The evaluation of operations problems should begin with a review of the status of current operational deployments to determine their effectiveness and identify the need for technology upgrades and improved systems integration.
- *Develop a range of solution sets*. Identify potential operations strategies that meet the goals of the operations plan. Consult current plans and documents such as the congestion management process and the regional ITS architecture to identify needs and potential operations strategies. Work with the stakeholders to gather ideas for new strategies not already identified in previous planning studies (and eliminate those with fatal flaws from the beginning). Since much of operations planning is often accomplished on an ad hoc basis, coordinate with the office of operations, TMCs, and others responsible for implementing operations strategies to complete the list of potential solution sets.
- *Evaluate the effectiveness of solution sets*. Conduct a trade-off analysis among potential solutions using reliability data and performance measures to assess how each individual strategy will improve reliability. The analysis should review major recurring and nonrecurring congestion problems (e.g., recurring congestion and nonrecurring congestion, bottlenecks, peaking, incidents, weather, safety, construction, special events) and match problems to functional (work, recreation, freight), regional (urban and rural), corridor (thoroughfare, interstate), and network (freeways, arterials, transit) intensity and significance. Prioritize the solution sets based on performance using the prioritization process described in LRP-7.

These steps are necessary in operations planning at all levels.

Table B.6 provides examples of using reliability data in evaluating different operations strategies, the potential partners that may use the data, and the products of the analysis.

### **OPS-5: Adopt Preferred Solution Set**

At this KDP, complete the evaluation of the proposed solutions using the adopted performance criteria and methodology and then identify the preferred solutions that address the

**Table B.6. Examples of Operations Strategies and Reliability Data**

Operations Strategy	Uses of Reliability Data	Example Products	Potential Partners
Traffic signal timing	Input for signal timing tools, monitoring of signal system performance	Signal timing analysis, before-and-after studies, performance reports	Traffic engineering departments, regional traffic operations agencies, state DOTs
Managed lanes	Analysis input, performance monitoring, pricing calculation	Alternatives analysis, performance reports, real-time pricing	State DOTs, toll authorities
Ramp metering	Analysis input, performance monitoring, meter signal timing	Real-time meter signal timing, performance reports	State DOTs, toll authorities
Variable speed limits	Analysis input, performance monitoring, speed limit calculation	Speed limits, real-time speeds, performance reports	State DOTs, toll authorities
Active traffic management	Analysis input, performance monitoring, speed limit calculation, lane use calculation	Real-time lane usage and speed calculations, performance reports	State DOTs, toll authorities
Incident management	Incident duration analysis, incidents by road segment analysis	Incident impact analysis	State DOTs, toll authorities, highway patrol, local police, local fire, EMS, HAZMAT agencies
Service patrols	Incident duration analysis, incidents by road segment analysis	Incident impact analysis	State DOTs, toll authorities, highway patrol, local police, local fire, EMS, HAZMAT agencies
TMC operations	Analysis input, performance monitoring	Incident impact analysis, alternatives analysis, performance reports	State DOTs, toll authorities

deficiencies while supporting the vision and goals. The steps include the following:

- *Approve preferred solution set.* Communicate the impact of the various solution sets (especially relative to reliability) to stakeholders and gather input to gain a consensus on the preferred scenario. Coordinate with other agencies to explore ways to take advantage of economies of scale and to leverage resources. Develop requirements for co-partnering with public safety agencies and other agencies and come to agreement on procedures and protocols. Develop and implement MOUs or other agreements to document these requirements.
- *Implement preferred solution set.* After the steps are completed and the preferred operations solution project or set of projects is adopted, proceed with implementation in one of the following ways. If the solution is a project that can be implemented by a single agency operations division, then the project will be designed, budgeted, scheduled and implemented within the operations division purview.

These steps may be different for each planning level.

- *Local:* Low-cost projects often can be funded and implemented within existing budgets and detailed implementation plans may not be required. Since the projects are usually low-cost improvements at this level, the evaluation is simplified.

- *All levels:* While an operations planning process may produce a prioritized list of operational investments, often these investments compete in the broader planning process, requiring modifications to that process as described in previous sections of this document. This may occur at the program level (i.e., identifying a broad level of funding for operations) or at the project level (i.e., selecting individual operations investments to be funded). The solution should include capital, staffing, technology, training, and maintenance requirements. Coordination with other key service delivery participants is needed. Funding options should be identified.

### **OPS-6: Update the Regional ITS Architecture (Optional)**

At this KDP, review the regional ITS architecture to ensure it is compatible with the preferred solution set. Architecture development and maintenance is not a requirement for operations planning activities since much of the utility of data are independent of the architecture itself; however, the architecture should include data collection and reporting capabilities to support reliability. If it does not include these capabilities, the regional ITS architecture should be updated in conformance with the National ITS Architecture requirements.

This is an occasional step (typically completed once every five years) and thus is normally skipped for all four levels (local, regional, statewide, and multiregion and multistate)

when conducting typical planning activities. The steps include

- *Develop and maintain a regional ITS architecture.* If a regional ITS architecture is not already in place, develop one in conformance with the National ITS Architecture requirements. This is a requirement for any ITS project to receive federal funds. Update the regional ITS architecture every few years (typically five years) to remain in conformance with national requirements. The update should take into account the region's existing ITS capabilities, proposed projects not currently included in the architecture, and any new services added to the National ITS Architecture that were not originally considered.
- *Consider reliability as an issue when developing or updating the ITS architecture.* To accomplish this, include travel time data collection and reporting capabilities in the regional ITS architecture.

### **OPS-7: Develop a Project-Level Concept of Operations, Systems Engineering Management Plan, and Configuration Management Plans (Optional)**

This KDP refers to the systems engineering process, which includes developing a project concept of operations (ConOps), systems engineering management plan (SEMP), and a configuration management plan (CMP). Conduct this KDP only when a new major ITS project is proposed. Review the adopted solution set and develop systems engineering documents for any major projects that are proposed. Also review the systems engineering documents for any current or future projects to ensure they include methodologies that enable data collection, archiving, and reporting of reliability measures.

This is an occasional step and thus normally is skipped for all four levels (local, regional, statewide, multiregion and multistate) when conducting typical planning activities. The steps include the following.

- *Develop and maintain a ConOps, SEMP, and CMP.* Develop a ConOps, SEMP, and CMP for any ITS project that receives federal funds. This provides for the systematic, structured development of complex projects and provides assurance to project stakeholders that the project will

operate properly and will be compatible within the existing system environment. At this KDP, ensure that the project is consistent with the regional ITS strategic plan and/or ITS implementation plan.

Several agencies, Colorado DOT, for example, have determined that although the SEMP is only required for ITS projects that use federal funds, it should be applied to all ITS projects and/or applications regardless of type of funds and is performed commensurate with the approved risk assessment level of the ITS project and/or application. This helps an agency track all ITS projects within the respective regional ITS architecture and to update those Architectures in an ongoing process.

- *Consider reliability as an issue when developing the ConOps, SEMP, and CMP for current and future projects.* This can be done by including methodologies in the ConOps, SEMP, and CMP that enable data collection, archiving, and reporting of reliability measures.

### **OPS-8: Assess Benefits of Implemented Projects and Provide Feedback**

This KDP involves assessing the benefits and impacts of projects after implementation, which can lead to the identification of additional problem areas and new solutions for other problem area studies. The feedback step will improve the operations planning process also.

- *Assess project benefits.* Assess the benefits and impacts of implemented operations projects using reliability data and performance measures. The benefits analysis will be helpful in identifying both recurring and nonrecurring problem areas and determining if additional projects or services are needed. In addition, the benefits analysis could identify solutions for other problem areas and provide data to justify projects and operations funding.
- *Complete the feedback cycle.* Use the benefits results to complete the feedback cycle for two KDPs: (1) the evaluation step (OPS-4) for refinements to an analysis of a problem is underway; or (2) the ITS architecture step (OPS-6) when a study is being initiated.

These steps are necessary in operations planning at all levels.

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**Jeffrey F. Paniati**, *Executive Director, Federal Highway Administration*  
**John Pearson**, *Program Director, Council of Deputy Ministers Responsible for Transportation and Highway Safety, Canada*  
**Michael F. Trentacoste**, *Associate Administrator, Research, Development, and Technology, Federal Highway Administration*

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\* Membership as of July 2014.

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**Andrew Beal**, *Manager, Traffic Office, Highway Standards Branch, Ontario Ministry of Transportation*

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\* Membership as of April 2013.

## Related SHRP 2 Research

Establishing Monitoring Programs for Travel Time Reliability (L02)

Analytical Procedures for Determining the Impacts of Reliability  
Mitigation Strategies (L03)

Institutional Architectures to Improve Systems Operations  
and Management (L06)

Identification and Evaluation of the Cost-Effectiveness of Highway  
Design Features to Reduce Nonrecurrent Congestion (L07)

Evaluating Alternative Operations Strategies to Improve Travel  
Time Reliability (L11)