SHRP 2 Reliability Project L05

Guide to Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes

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SHRP 2
STRATEGIC HIGHWAY RESEARCH PROGRAM
Accelerating solutions for highway safety, renewal, reliability, and capacity

TRANSPORTATION RESEARCH BOARD
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Contract No. SHRP L-05

Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes

A Guide

prepared for

Strategic Highway Research Program

authors

Cambridge Systematics, Inc.

date

March 2013

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Executive Summary

Incorporating Reliability into the Planning and Programming Process is intended to be a high-level reference document for transportation planners, operators, and system managers. The reliability of the transportation system refers to the uncertainty or variability that system users experience in the time it takes to travel from one place to another – from home to work, from producer to consumer, and from any location to another. This *Guide* will help planning, programming, and operations managers to apply the concept of travel-time reliability to balance investment in programs and projects.

This *Guide* has been developed at a time of significant changes in the transportation planning and programming process. The Moving Ahead for Progress in the 21st Century Act (MAP-21) transportation bill requires transportation agencies to use a performance-based approach to planning and programming. Reliability and congestion reduction are explicit goals of the bill, though the specifics of how agencies are expected to implement these requirements remains to be seen. At the same time, significant research on data and tools to evaluate reliability is helping agencies better understand and predict the variability of travel time.

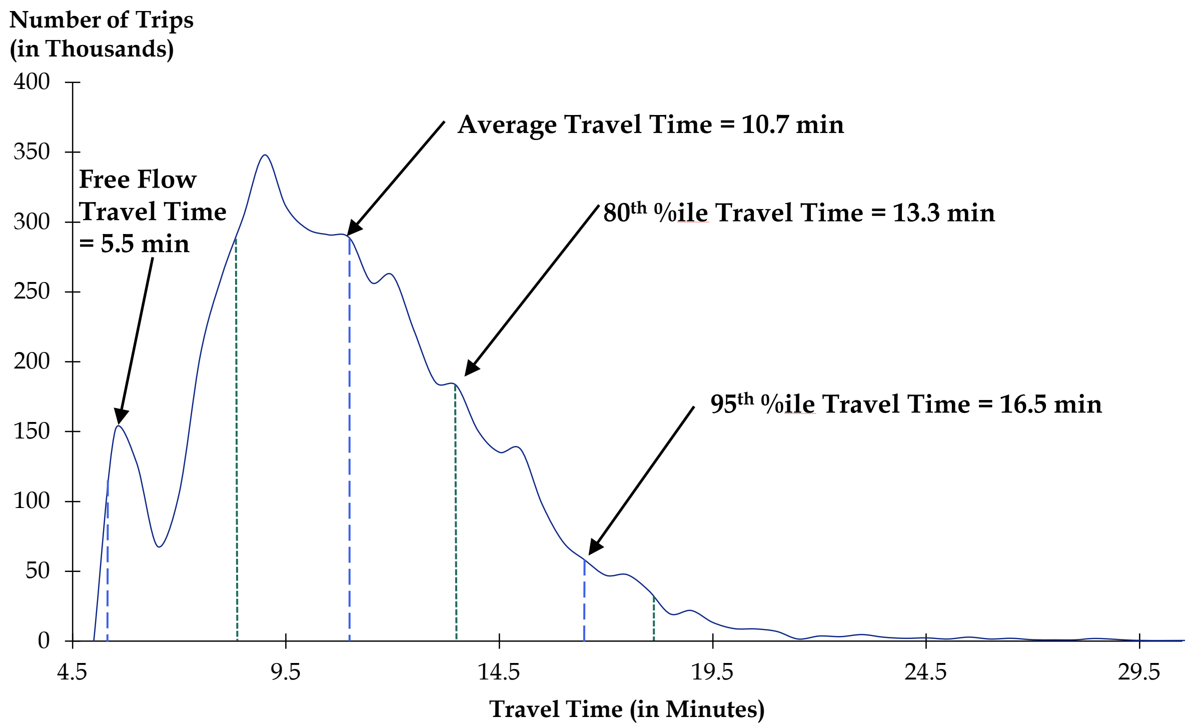
The purpose of this *Guide* is to help agencies wherever they are in the process of using reliability performance measurement to (1) understand and communicate reliability; (2) identify the tools and methods to help them track transportation system reliability; (3) begin to incorporate reliability into their existing analysis tools; and (4) identify emerging analysis tools that will better help them evaluate reliability and make program and project investment choices that address the reliability of the system.

What Do We Mean by Reliability

Reliability is a measure of the variability of travel times. When a system is reliable, it means people and goods get to their destinations on-time, nearly every time. It means a traveler leaving for the airport and knowing that they will catch their flight. It means not paying another late fee at daycare. It means leaving for work in the morning at 7:15 a.m., like usual, and getting into the office at 8:00 A.M. nearly every day. It means reducing the stress of traveling, knowing better when you will arrive at your destination. Reliability is important to commuters and businesses. Consistently, research shows that commuters value reliability in similar measure to how they value overall travel time and shippers routinely value being able to specify when shipments will arrive at their destination.

The measurement of reliability is based on an understanding that for any road segment or corridor or any trip, it is possible to examine travel times across multiple times of day, days of the week, seasons, weather conditions, presence or absence of crashes and other incidents, and other factors that influence how long it takes to travel. Figure ES.1-1 presents a distribution of travel times for a single roadway segment. Several points of the distribution are pointed out to help describe travel conditions. While traveling on this segment in free flow only takes 5.5 minutes, on average it takes nearly twice that time. To be on time to a destination 80 percent of the time (e.g., late to work one day a week) requires over 13 minutes of travel, and 95 percent of the time requires 16.5 minutes. These statistics and others are combined to estimate a variety of reliability performance measures that are at the core of this *Guide*. The *Guide* provides advice on developing these measures and communicating them to the public and decision makers.

Figure ES.1-1 Distribution of Travel Times for a Single Roadway Segment

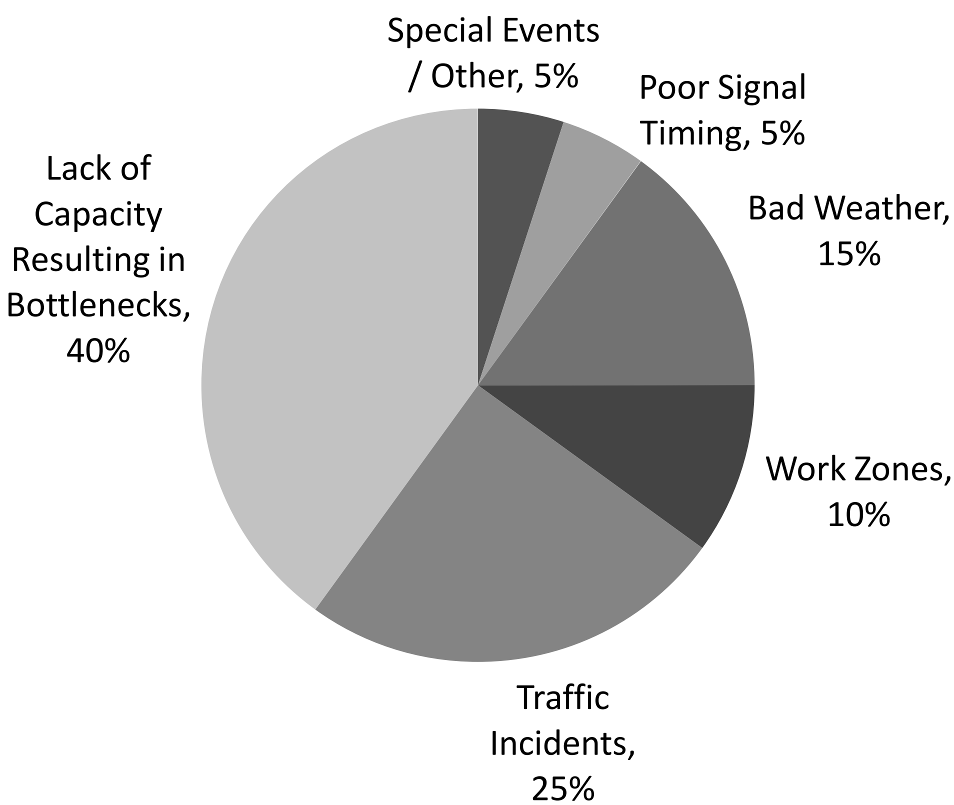


INCORPORATING RELIABILITY INTO PLANNING AND PROGRAMMING

This variability in travel times comes from several sources, and understanding those sources can be as useful to the planning process as understanding the variability in travel time. Figure ES.1-2 presents a distribution of causes of travel delay. In 2005, only 40 percent of delay was a result of a lack of capacity. The remaining delay was from lack of system reliability due to traffic incidents, work zones, weather, poor signal timing and special events. Addressing these types of delay in the planning process requires thinking carefully about the solutions – adding only capacity will not always make sense.

Understanding reliability performance is a critical first step to incorporating it into the planning and programming process. Reliability is different from most performance measures that agencies report on today, because it is a measure of variability. Most performance measures such as fatalities, pavement and bridge condition, and others change year-to-year but not day-to-day or hour-to-hour. The tools that agencies have used to examine system performance (four step travel demand models, management systems, and the like) typically examine average annual conditions. As reliability becomes a more significant issue, different tools will be needed to directly measure and forecast the type of variability that agencies face.

Figure ES.1-2 The Causes of Travel Delay



Incorporating reliability into the planning and programming process requires different data and tools than are typically used to examine and predict future performance. This *Guide* and the associated Technical Reference can help agency planners and system operators identify the data, tools, and methodologies for examining reliability. These include emerging analysis tools that can directly estimate or forecast reliability, as well as tools and methodologies that can help an agency begin to bridge the gap. The guidance is based on several key principles, including:

1. **A collaborative approach to planning**. The guidance provided here is based on an approach to planning and programming that includes substantial collaboration and coordination with stakeholders and system users. To collaboratively address reliability requires partnering with key system supporters, such as emergency response personnel, and tow truck operators, that can impact the overall reliability of the transportation system by responding and clearing incidents quickly. The SHRP 2 Capacity program has identified

a collaborative and performance-based framework to support decision making. http://www.transportationforcommunities.org.

2. **A performance-based approach to investment decision making**. MAP-21 has begun the process of crystallizing requirements around performance-based planning and programming, but many agencies are already using performance measures to help inform decision making. This *Guide* is built around these concepts, reliability being one of several measures that an agency may use to evaluate the performance of the system and make investment decisions at both the program and project levels.

3. **A balanced approach to improving reliability that considers all project types on a level playing field**. Because reliability is impacted by a variety of transportation challenges – incidents, weather, bottlenecks, and others – agencies should consider a wide range of solutions when attempting to improve reliability. These include operations and management strategies (typically targeted at improving the reliability of the system) in addition to capacity additions, safety, and other investments. Because operations and management strategies occur at different time frames than capacity projects, examining the full life cycle cost of investments (and their benefits) is especially critical to ensure the efficient use of limited resources.

The guidance provided tackles four key areas needed to incorporate reliability into the planning and programming process, including:

- **Developing and Tracking a Reliability Performance Measure.** Well-defined reliability measures based on quality supporting data are critical for understanding and communicating how the transportation system is performing.
- **Incorporating Reliability in Policy Statements.** To incorporate reliability, agencies must establish that reliability is among the core strategic goals or objectives the agency strives to achieve.
- **Evaluating Reliability Needs and Deficiencies.** Like any goal area, one first valuable step is to understand the extent of reliability deficiencies and needs. Where are travel times least predictable? What would it cost to address the deficiencies that exist? 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.
- **Incorporating Reliability into Investment Decision Making**. One key goal of the planning process is to help inform agency investment decisions. This part of the *Guide* addresses how to incorporate reliability into tradeoffs across investment types (capacity, operations, safety, preservation, etc.) and project prioritization.

The *Guide* is accompanied by an in depth ***Technical Reference*** that provides detailed background and instruction describing how to collect travel-time data and select and evaluate reliability performance measures using the full range of available analytical tools and methods.

Detailed case studies were also developed as part of the L05 project to develop and validate the guidance and techniques presented in the *Guide* and the *Technical Reference*. The ***Case Study Technical Memorandum***, available electronically, describes the detailed findings from each of the case studies.

A ***Final Report***, available electronically, summarizes the research that was conducted as part of this project. It includes a summary of a literature review, state of the practice survey, and validation case studies conducted to test the concepts and methods evaluated as part of this project. It also provides a detailed appendix that describes the linkage between this project and the Transportation for Communities – Advancing Projects through Partnership (TCAPP) project that is the keystone project of the Strategic Highway Research Program (SHRP) 2 Capacity program.

1.0 Introduction

This *Guide* describes, with as much flexibility as possible, how to incorporate reliability into transportation planning and programming. The *Guide* enables planning, programming, and operations managers to balance program funding project priorities.

This *Guide* is designed for planning, programming, and operations managers who will be leading planning efforts and making decisions about how the plans will be completed.

The introduction presents three key pieces of information to help users orient themselves to the information presented in the *Guide*.

1. **Reliability is an Important Aspect of Traveler Experience.** Background on reliability and the strategies to address reliability.
2. **Performance-Based, Collaborative Planning.** A framework for incorporating reliability into the planning and programming process based around collaborative decision making and a performance-based approach.
3. **How to Use this *Guide*.** A description of how the *Guide* is organized.

1.1 Background – Reliability is an Important Aspect of Traveler Experience

Travel-time reliability, or simply *reliability*, is a measure of how consistent or predictable travel times are over time. Technically, reliability is the variation in travel time over time measured statistically using histograms, probability density functions, or cumulative distribution functions. Figure 1-1 describes what reliability is, its causes, and the ways that it can be reported. For the user, reliability means getting to daycare on-time for an evening pickup to avoid expensive late fees, arriving at an appointment on-time, and arriving at work on-time, nearly every time. Reliable travel means that weather, crashes, and construction work zones do not cause lengthy, unpredictable, and frustrating delays.

To improve reliability, we must be able to measure it. This *Guide* describes how to measure reliability and how to update agency-wide planning and programming processes to ensure that projects to address it are planned for and adequately funded.

Specific technical guidance related to the definition of travel-time reliability can be found in Chapter 2 of the *Technical Reference*.

Figure 1-1 Description of Reliability

Travel Time Reliability

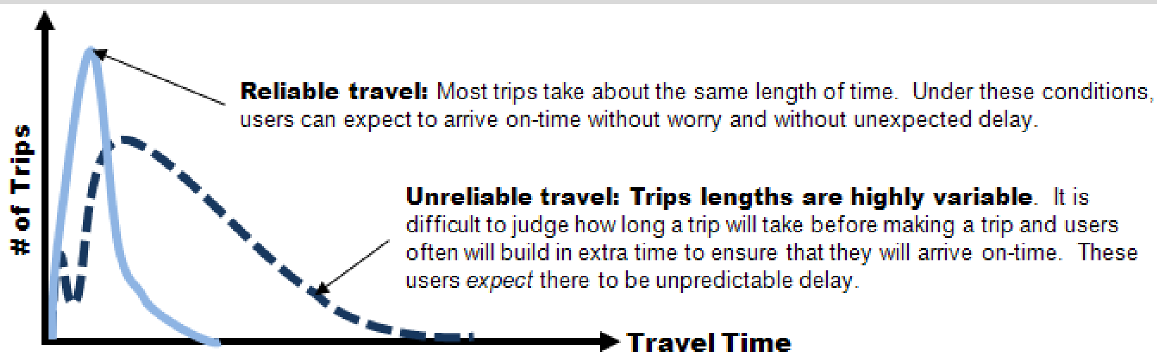
For the user, reliability means getting to daycare on-time for an evening pickup avoiding expensive late fees, arriving at an appointment on-time, and arriving at work on-time, nearly every time.

Reliable travel means that unpredictable circumstances do not cause lengthy, unpredictable, and frustrating delays.

Unpredictable Circumstances…

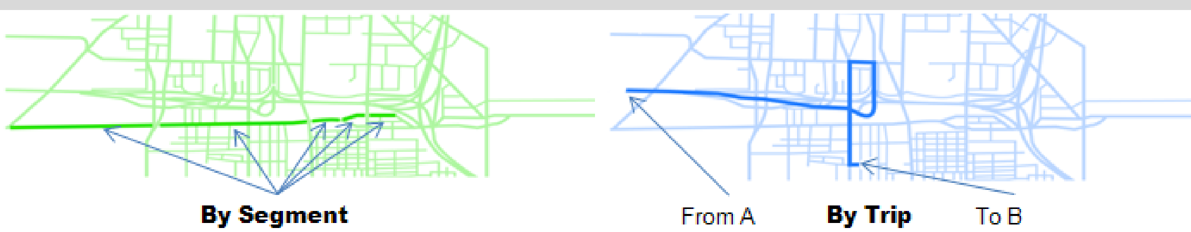
Inclement Weather	Fluctuations in Demand	Incidents and Crashes	Work Zones	Poorly Timed Traffic Signals

…Do Not Cause Unpredictable Delays.



There are Many Ways to Measure Reliability

By Travel Patterns



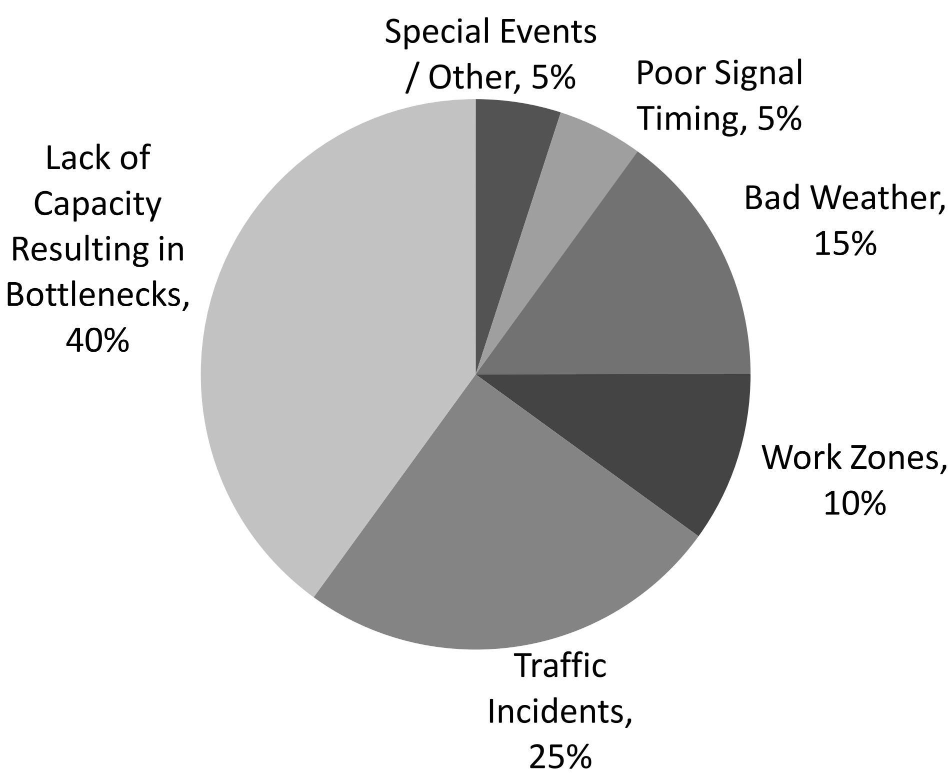
By Time Periods	By Roadway Types
Morning, evening, midday, weekend peak hour or peak period, etc.	Functional class, strategic highways, high volume roads, etc.
By User	**By Geography**
Commuter, personal, trucker, visitor, etc.	State, region, corridor, urban, rural, etc.

Use the Right Tools to Improve Reliability

The traditional planning and programming process is structured to plan for large capacity improvement projects, not to address smaller, "quick turnaround" operations and management investments that could provide significant and immediate relief to congestion and reliability. Over 50 percent of congestion is directly attributable to fluctuations in demand (due to special events), poor signal timing, traffic incidents, inclement weather, and work zones, rather than capacity related bottlenecks (Figure 1-2). These circumstances are less predictable and are the root cause of unreliable travel. Improving travel conditions during these circumstances will improve reliability. While capacity projects can improve reliability by improving the ability of the system to absorb unpredictable circumstances, they should not necessarily be an agency's only choice. Capacity projects include adding capacity such as the addition of lanes. Operations and management projects are specifically intended to address reliability, though only to the extent these investments are targeted at the root cause of unreliability (e.g., unreliability that is caused by crashes may be improved by an improved incident response program, but not necessarily by adjusting signal timing). Operations and management projects include coordinating signal timing, Intelligent Transportation Systems (ITS), incident response, and other similar efforts. This *Guide* describes how to plan and program projects targeted at improving reliability.

More technical guidance on the topic of measuring travel-time reliability is in Chapter 2 of the *Technical Reference*.

Figure 1-2 The Causes of Travel Delay (*1*)



1.2 FRAMEWORK – PERFORMANCE-BASED, COLLABORATIVE PLANNING

This chapter identifies the two foundational efforts that shape this *Guide*. The first of these - the SHRP 2 Capacity Program - has identified a **comprehensive approach to collaborative transportation planning** built around a set of key decision points (2). This *Guide* provides guidance on how to incorporate reliability into the most critical of these key decision points.

The second foundational effort for developing this *Guide* is the **national trend towards performance-based planning and programming**. Over the last decade or so, an increasing number of agencies have been managing their systems and organizations using performance measures. After strong support for performance management and performance-based planning, Moving Ahead for Progress in the 21st Century Act (MAP-21) has codified an approach that requires tracking and reporting performance in seven national goal areas, including safety, infrastructure condition, congestion reduction, **system reliability**, freight movement and economic vitality, environmental sustainability, and reduced project delivery delays.

Collaborative Planning – Institutional Arrangements and Stakeholder Engagement

Ensuring that reliability is addressed following a collaborative approach to planning requires developing sound institutional arrangements. The resources in Table 1-1 are intended to help transportation agencies work together improve reliability. The table includes the types of institutional arrangements that are important, why they are important, and resources that help define how to make the necessary arrangements.

Table 1-1 Institutional Arrangements That Support Planning and Programming for Reliability

What Arrangements Should Be Made?	Why Should It Be Done?	Resource Explaining How to Make Necessary Arrangements.
Define specific reliability goals, document current business processes and recommended changes, implement a process, measure outcomes against reliability goals, and institutionalize the process.	Organizing and institutionalizing the internal business process to account for reliability will set the stage for success in improving reliability.	*Guide to Integrating Business Processes to Improve Travel-Time Reliability (SHRP)* – The guide details steps for agencies to improve collecting and analyzing data; integrating travel-time reliability considerations into planning, programming, and project delivery; adopting innovative operational strategies and technologies; and modifying their institutional structures and business practices surrounding traffic operations. http://www.trb.org/Main/Blurbs/165284.aspx
Develop a collaborative and coordinated effort among many transportation organizations and within key units of a transportation organization.	Properly incorporating reliability into the planning process by figuring out who has the right data, how to get it from them, how to continue getting it from them, and how to analyze and report it will ensure that reliability performance measures can be developed and tracked.	*Institutional Architectures to Improve Systems Operations and Management (SHRP)* – The report identifies strategies by which transportation agencies can adjust their institutional architecture – including culture, organization and staffing, resource allocation, and partnerships – to support more effective systems operations and management (SO&M). http://www.trb.org/Publications/Blurbs/165285.aspx
Develop a rapport with first responders (fire, police, ambulance, etc.). These stakeholders are among those with the largest influence on reliability through incident management.	Knowing how to reach out to the first responders can help when building an early understanding of reliability deficiencies; begin to conceptualize how to improve them, and developing effective strategies for improving reliability.	*Training of Traffic Incident Responders (SHRP)* – A strong interdisciplinary traffic incident management program can significantly decrease incident duration and, when combined with traveler information, can increase peak-period freeway speeds, reduce crash rates, and improve trip-time reliability. http://www.trb.org/Main/Blurbs/166877.aspx
Collaborate with other agencies to achieve respective goals and objectives.	Collaborating among agencies regarding data, funding, communication, procedures, information, resources, and delivery of services will ensure that the most up-to date and relevant information on reliability performance is obtained.	*The Collaborative Advantage: Realizing the Tangible Benefits of Regional Transportation Operations Collaboration (FHWA)* – Agencies can realize a range of tangible benefits from participating in multi-agency collaborative efforts for regional transportation operations, including access to funding and other resources, improvements in agency operations and productivity, and outcomes that help agencies achieve their mobility and safety goals. http://ops.fhwa.dot.gov/index.asp *Statewide Opportunities for Integrating Operations, Safety and Multimodal Planning: A Reference Manual (FHWA)* – The document provides a "how to" guide 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. http://www.fhwa.dot.gov/planning/
Address differences in perspective, institutions, and funding between operators and planners.	Working together with operators and planners will help to effectively balance funding among needs to support a reliability policy.	*Incorporating ITS Into the Transportation Planning Process: An Integrated Planning Framework (ITS, M&O, Infrastructure) Executive Guidebook (FHWA)* – 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. This can encourage examining both arterial streets, transit, and their interrelationships to improve reliability, including providing signal pre-emption for transit. http://ops.fhwa.dot.gov/publications/moguidebook/index.htm

Incorporating Reliability into the Technical Process – Performance-Based Planning and Programming

One of the cornerstones of MAP-21's highway program transformation is a requirement that State DOTs and metropolitan planning organizations (MPOs) develop performance-based transportation plans and programs. This *Guide* builds on work completed by the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) to develop a framework for performance-based planning and programming. Table 1-2 presents this framework and identifies how the chapters of this *Guide* relate to the framework.

Table 1-2 Elements of Performance Management

Element	Description	Guidance
Goals and Objectives	Goals and objectives that capture an agency's strategic direction.	Incorporating Reliability into Policy Statements (see 2.0)
Performance Measures	Agreed on measures for goals and objectives.	Developing and Tracking a Reliability Performance Measure (see 3.0)
Identify Strategies	Strategies, policies, and investments that address transportation system needs within the identified goal areas.	Evaluating Reliability Needs and Deficiencies (see 4.0)
Strategy Evaluation	Evaluate strategies and define program-level system performance expectations.	Evaluating Reliability Needs and Deficiencies (see 4.0)
Targets/Trends	Established targets/trends for each goal/measure based on an understanding of a desirable future for each goal area and measure.	Sizing an Operations and Maintenance Program (see 5.0)
Resource Allocation	Identify the amount and mix of funding needed to achieve targets set to address performance goals within individual program areas.	Sizing an Operations and Maintenance Program (see 5.0) and Project Prioritization (see 6.0)
Evaluation	Identify improvements in analytics, process, etc. to improve the planning process.	Not addressed
Reporting and Monitoring	Reporting and monitoring progress on goals relative to targets and resource allocation efforts.	Developing and Tracking a Reliability Performance Measure (see 3.0)

The FHWA has developed the following guidance on performance-based planning and programming:

- The FHWA has developed a white paper that describes the elements of performance-based planning. This document provides background on the elements of performance-based plans and programs (*3*).
- The FHWA showcases opportunities to use an objectives-driven, performance-based approach to facilitate an objective allocation of resources, prioritize regional investments in management and operations, increase accountability, engage the community, and expand the focus of the metropolitan transportation plan to include both short- and long-range operations needs (4).

Incorporating Reliability Requires Leveling the Playing Field for All Projects

To effectively incorporate reliability into a performance-based planning and programming process, it is important to consider the full life-cycle costs and benefits of operations and management, capacity, and other types of investments. This includes considering transit investments (both operations and capital) in addition to highway and arterial investments, and the interrelationships among these types of investments. Agency costs and benefits can be estimated over three time periods: project-planning (site acquisition, planning and engineering), construction, and post-construction. Typically, capacity projects cost a great deal more to plan and build than operations projects. Operations projects, on the other hand, typically have much lower planning and construction costs.

Performance-Based Planning and the Color of Money – From Programming to Budgeting

All agencies have to address fundamental constraints set by Congress, State legislatures, and other sources on the use of funds for various types of projects. Because operations and management projects are important strategies to address reliability, these restrictions can limit an agency's flexibility in identifying and funding the appropriate set of strategies. Because of the range of circumstances within which agencies operate, and given the desire to focus this *Guide* on a performance-based approach, these issues are set aside following a key finding identified by FHWA and Federal Transit Administration (FTA):

> *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. (5)*

By first considering the performance implications of investment and resource allocation decisions, agencies can look for creative approaches to fund projects that are most needed to improve performance and can develop information to help shape how operations and management investments are funded in the future.

Barriers to Incorporating Reliability into Planning and Programming

This *Guide* is intended to help transportation planners incorporate reliability into their analysis of the transportation system and the selection of programs and projects. The research conducted as part of this project has identified several key barriers that agencies must address as they attempt to incorporate reliability into their planning and programming processes, including:

- Data. Many agencies see data availability as a major barrier to analyzing reliability. This *Guide* and the accompanying *Technical Reference* help to identify sources of data, but data required for incorporating reliability are likely to seem overwhelming to many.
- Analytic tools. Although research indicates reliability has a similar value as travel time, only a few states monetize reliability, meaning the value of reliability is not adequately reflected during decision making. The SHRP 2 reliability program has helped to develop

significant new tools and methodologies to evaluate and forecast reliability, but it will take time and investment in agency tools to incorporate these methodologies.

- Staff capacity. Evaluating data and implementing tools will require staff who understand reliability as a concept, can work with significant quantities of data, and develop or at least manipulate potentially complex models. Agencies will need to develop staff skills over time, starting with developing an understanding of reliability and building over time to encompass sophisticated analytic techniques.
- Color of money. Limits on how funding can be used are common and can limit an agency's ability to implement operational solutions and other strategies that may best improve reliability. This *Guide* is written from the perspective of how to identify the best strategies to improve reliability, but eventually all agencies and decision makers will have to tackle how to pay for these investments.
- Communicating with the public. While reliability is an intuitive concept – people like to be able to predict how long it takes them to get from point A to point B – explaining the sophisticated data capture and analysis that goes into estimating and forecasting reliability could create confusion. Many of the performance measures used to describe reliability may not be easily understood by the general public without converting them into formats or scales that make sense. Chapter 2 tackles both the question of how to measure and how to present information to the public.

1.3 HOW TO USE THIS *GUIDE*

Incorporating Reliability Performance Measures into the Planning and Programming Process 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. This chapter describes the overall organization of the *Guide* and the key issues addressed within each chapter.

The *Guide* is organized around a small number of key steps for incorporating reliability into the planning and programming process:

- **Chapter 2 – Measuring and Tracking Reliability Performance.** Create well-defined reliability measures 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.
- **Chapter 3 – 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 the right choices when setting program funding levels and prioritizing projects.
- **Chapter 4 – Evaluating Reliability Needs and Deficiencies.** Use reliability to estimate/ 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.

- **Chapter 5 – 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.

Each of these chapters provides guidance and examples of incorporating reliability into the planning process. Each chapter identifies key questions that must be addressed and provides guidance to help agencies answer those questions. Three companion documents provide additional information to support the implementation of the practices described in this *Guide*, including:

- The ***Technical Reference***, available in hard copy and electronically, provides more detail on calculation and estimation methods that are critical to support each chapter. It includes detailed descriptions of available analytic tools, including those that have been developed through the SHRP 2 Reliability program.
- The ***Final Report***, available electronically, summarizes the research that was conducted as part of this project. It includes a summary of a literature review, state of the practice survey, and validation case studies conducted to test the concepts and methods evaluated as part of this project. It also provides a detailed appendix that describes the linkage between this project and the Transportation for Communities – Advancing Projects through Partnership (TCAPP) project that is the keystone project of the SHRP 2 Capacity program.
- The ***Case Study Technical Memorandum***, available electronically, describes the detailed findings from each of the case studies conducted to validate the products of this research effort. Findings from the case studies are incorporated throughout the *Guide* and *Technical Reference*.

1.4 Acronym List

AHP	Analytical Hierarchy Process
CMP	Congestion Management Process
FITSEval	Florida ITS Evaluation
GRTA	Georgia Regional Transportation Authority
HERS-ST	Highway Economic Requirements System – State Version
IBC	Incremental Benefit Cost
IDAS	ITS Deployment Analysis System
ITS	Intelligent Transportation Systems
LRP	Long Range Plan
MAG	Maricopa Association of Government

MAP-21	Moving Ahead for Progress in the 21st Century Act
MOE	Measure of Effectiveness
NBIAS	National Bridge Investment Analysis System
NHS	National Highway System
NPV	Net Present Value
OMB	Office of Management and Budget
PTI	Planning Time Index
SEMCOG	Southeast Michigan Council of Government
STIP	Statewide Transportation Improvement Program
TCAPP	Transportation for Communities – Advancing Projects Through Partnership Project
TCAPP	Transportation for Communities Advancing Projects through Partnership
TDM	Travel Demand Management
TIP	Transportation Improvement Program
TOPS-BC	Tool for Operations Benefit/Cost
TPO	Transportation Planning Organization
TSM&O	Transportation Systems Management and Operations
TTI	Travel Time Index
VMT	Vehicle Miles Travelled

Reference List

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2. http://www.transportationforcommunities.com

3. http://www.fhwa.dot.gov/planning/performance_based_planning/resources/white_paper/wp00.cfm

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5. Performance-Based Planning and Programming – White Paper. FHWA and FTA. 2012.

2.0 Measuring and Tracking Reliability

Performance measures provide the technical basis for monitoring performance, setting program funding levels and prioritizing projects. Performance measures can support goal setting by demonstrating the significance of a given need and can be used to help set program funding levels or prioritize projects – the key steps of a performance-based process. Performance measures provide an opportunity to "level the field" or allow comparison of unlike programs or benefits (e.g., comparing capacity addition to operational or other programs) for the purposes of finding the right package of strategies to address transportation needs.

2.1 Key Questions

- What measures are available for monitoring reliability performance?
- How should the measures be tailored to reflect the reliability needs of the system?
- What is the best way to communicate performance measures to various audiences?

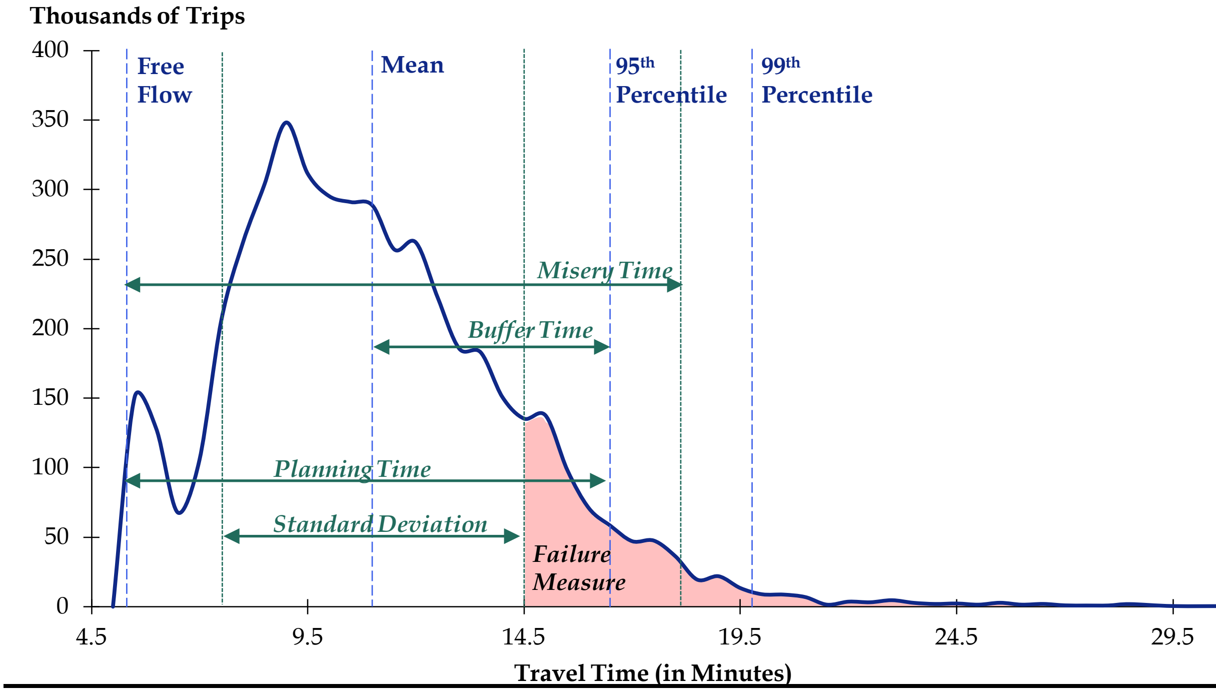
2.2 Selecting a Performance Measure

It is critical to select a performance measure that can help users understand how reliability impacts them on an intuitive level and to help planners and operators throughout the agency understand why reliability is important. Fundamentally, ***reliability measures variability in travel times***. There are several ways to capture this variability, and this chapter describes the meaning of these measures.

Figure 2-1 defines, describes, and illustrates the calculation of common measures used to describe travel time reliability. As the figure indicates, they are all based on the travel time distribution. Typically travel time data used to calculate these distributions are captured at a fine grained level (e.g., travel times on a facility every 5 minutes). Chapter 2 of the ***Technical Reference*** provides additional details on how to use travel time data to calculate reliability performance measures.

This guidance has been developed before FHWA has issued regulations on performance measures that will be required as part of MAP-21 implementation. When they become available, agencies should consult the regulations when selecting an appropriate performance measure.

Figure 2-1 The Travel-Time Distribution is the Basis for Defining Reliability Metrics



Measure	Calculation	Description
Planning Time Index* (PTI)	$\frac{95th\ Percentile\ of\ TT}{Free\ Flow\ TT}$	The extra time required to arrive at a destination 'on-time' 95 percent of the time. Can be calculated for trips, corridors, or segments. *The PTI is the recommended measure because it gives intuitive and consistent results.*
Buffer Time Index** (BI)	$\frac{95th\ \%tile\ of\ TT - Average\ TT}{Average\ TT}$ (could replace Average with Median TT)	The *extra* time required to arrive at a destination 'on-time' 95 percent of the time, compared to average or median travel time. A BI of 1.5 indicates that, 95 percent of the time, it will take you 50 percent more time to arrive at your destination than it would if it were uncongested.
Standard Deviation	$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(TT_i - Average\ TT)^2}$	The variation in travel time compared to the average. A standard deviation of 5 minutes indicates that it is not unlikely for it to take 5 minutes more to travel than it would during average congestion.
Semi-Standard Deviation	$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(TT_i - Free\ Flow\ TT)^2}$	The variation in travel time compared to free flow. A semi-standard deviation of 5 minutes indicates that it is not unlikely for it to take 5 minutes more to travel than it would during uncongested conditions.
Failure measure	$\frac{Trips\ with\ TT < 1.1 * Median}{Total\ Trips}$	The percent of trips arriving 'on-time.' A failure measure of 85 percent indicates that 85 percent of trips are arriving on-time.
Misery index	$\frac{Average\ of\ the\ Highest\ 5\ Percent\ of\ TT}{Free\ Flow\ TT}$	How much longer it takes to travel on the worst five percent of all trips. A misery index of 4 indicates that the worst trips take 4 times as long as they would if it were uncongested.

Note: * The travel time index (TTI) is the travel time for a point on the travel time distribution divided by the free flow travel time. The PTI is a specific instance of the Travel Time Index, calculated at the 95th percentile. A TTI value can be calculated at any percentile of the travel time distribution.

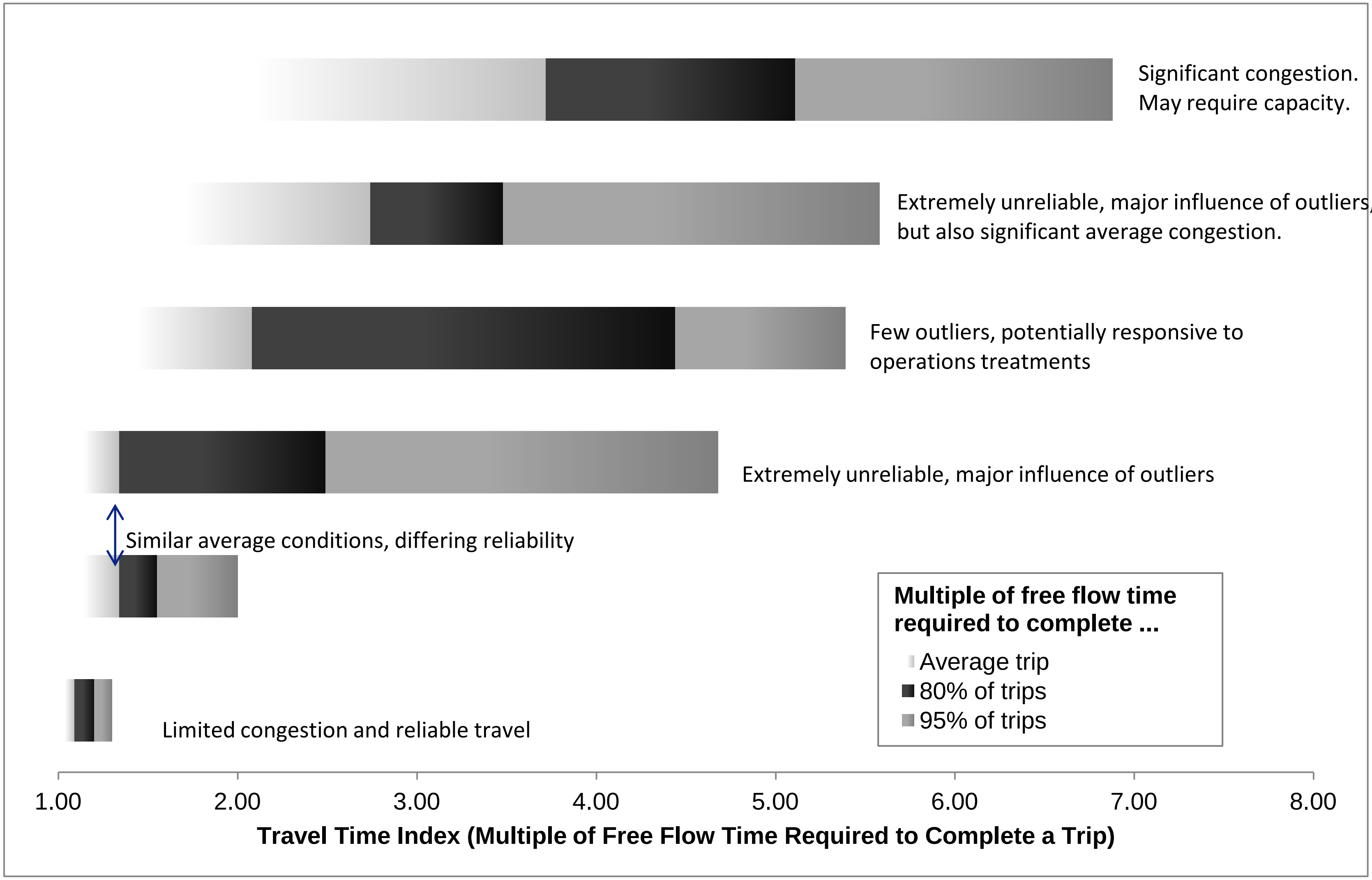
** Research has raised questions about the consistency and intuitiveness of the Buffer Time Index. This is explained in more detail in the Technical Reference.

Agencies are encouraged to estimate multiple reliability performance measures to provide a robust perspective on reliability. Individual measures capture different slices of the travel time distribution and may suggest different strategies to employ. Figure 2-2 illustrates this point, providing three points on the travel time distribution (average TTI, 80^{th} percentile TTI, 95^{th} percentile TTI) for several real corridors. Looking at these three points together provides additional perspective on the specific challenges each corridor faces and potentially some of the strategies to address these challenges. For example:

- Where the TTI_{mean}, TTI_{80}, and TTI_{95} are all clustered and low, there is limited congestion and generally reliable travel.
- Where TTI_{80} and TTI_{95} are higher than the TTI_{mean}, but close together, the corridor experiences reliability challenges, but sees limited outliers (i.e., extremely long travel times). Work conducted under SHRP 2 L03 has demonstrated that routine operations strategies, such as incident management, may be effective in addressing congestion in these corridors.
- Where TTI_{95} is higher than TTI_{80}, a corridor experiences significant influence of outliers. These may be due to extreme weather, special events, or major incidents that require closing the road. Challenges like extreme weather and special events may require specialized planning efforts.

Planners will need to experiment with these measures to determine which combination of measures best helps them understand the reliability of the system and evaluate strategies. Understanding the travel time distribution for individual corridors will help planners understand what they are planning for – day to day challenges, extreme events and outliers, or both. Chapters 4.0 and 5.0 identify potential strategies to evaluate and methods for evaluating those strategies.

Figure 2-2 Variation in Reliability Measures for Example Corridors (*1*)



Examples of Reliability Performance Measures in Use at Transportation Agencies

Knoxville Regional Transportation Planning Organization (TPO) CMP. In their Congestion Management Process (CMP), the Knoxville TPO measures the PTI for all users on freeways and major arterials in the region and plans to narrow the time period to a 'specific time period of the day.' In addition, the TPO has developed an incident management specific measure to support the overall reliability statistic: clearance time of traffic incidents on freeways and major arterials in the region.

Madison MPO CMP. The Madison MPO developed guidelines for the reliability measures that they will include in their CMP. They will include both peak and off-peak measures because 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. They also will include measures for the region and key sub-areas and corridors that reflect primary modal travel patterns.

2.3 SELECTING A METHOD TO ESTIMATE RELIABILITY

Selecting a measure is important, but estimating reliability performance often requires tools and methods. This Chapter describes how agencies can estimate reliability using several methods. The ***Technical Reference*** chapter 5 provides more details and examples of each of these analysis methods.

Monitoring Reliability

The simplest way to measure reliability is to monitor travel time. Because reliability measures variability of travel times, it has significant data requirements. Unlike average travel time, which can be calculated using a relatively small sample of travel times over a few days, accurately monitoring reliability requires capturing travel time data across a wide range of conditions – days of the week, times of day, seasons, weather conditions, and during the presence or absence of incidents.

Data for monitoring reliability can come from a variety of sources, including traditional travel monitoring sensors, ITS sensors (Bluetooth, cameras, induction loops, etc.), instrumented vehicles, and others. In addition to collecting data directly, several third party vendors use instrumented vehicles and other methods to provide data for purchase to agencies (e.g., Inrix and Navteq). These data can support both operations and planning.

In addition to travel time data, examining reliability benefits from understanding its causes, including data on crashes and other incidents, weather, variations in demand (i.e., travel volumes), special events, and others. These data can help measure the impact of circumstances on reliability.

As part of a reliability monitoring program, agencies should also keep track of the investments that have been made in the transportation system, both those that are specifically intended to improve reliability and those that may have been implemented for other reasons. Tracking reliability of the system over time allows for before and after comparison of investments in the transportation system. With sufficient system coverage, agencies can examine both localized improvements from individual investments and system improvements from packages of improvements over time.

The ***Technical Reference*** chapter 5 contains a detailed description of different travel-time data resources, how to set up a travel-time monitoring system, and how to estimate reliability using various sketch-planning methods.

SHRP 2 L02 provides guidance for developing a travel time reliability monitoring system (TTRMS) to monitor, assess, and communicate reliability to end users. SHRP 2 L02 discusses the various technologies available for collecting travel times, the foundation of a TTRMS, and distinguishes between roadway-based and vehicle-based equipment. Travel time data is preferred to be collected continuously so that travel time density functions can be developed. These are used to describe the reliability characteristics of a corridor or a trip. Augmenting travel times are data on nonrecurring disruptions: incidents, weather, work zones, and special events.

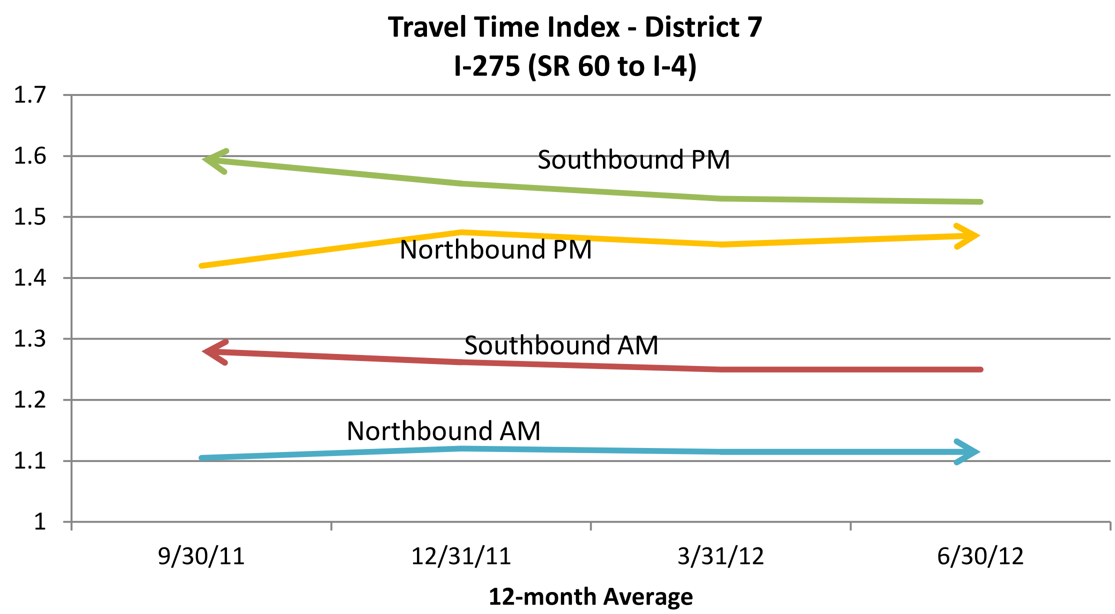
Modeling Reliability

Where travel time data are limited or when agencies need to forecast reliability (not just estimate current conditions), agencies can use tools that can help estimate reliability. Many of these tools can also be used to evaluate the impact of strategies on reliability. Because reliability is a function of the variability of travel times, the ideal tools for estimating reliability can estimate variability.

Typical planning analysis tools such as the standard four step travel demand model produce static estimates of travel times (potentially varying by time of day), making them a poor fit for estimating reliability. However, these are among the most common tools in use at transportation agencies; bridging the gap to more sophisticated tools will require using techniques to translate static estimates into reliability impacts, including:

- **Sketch Planning Methods.** Sketch planning methods provide a quick assessment of reliability using readily available data (travel times, volumes, etc.) as inputs. They are the least resource intensive of the analysis methods and produce order-of-magnitude results. It is typical to use a spreadsheet to build a sketch planning model.
- **Model Post-processing Methods.** These methods focus on applying customized analysis routines to more robust network supply and demand condition data from travel demand models to generate more specific estimates of travel-time reliability. Common tools to post-process model results include FHWA's ITS Deployment Analysis System (IDAS) and the Florida ITS Evaluation (FITSEval) tool. Figure 2-3 presents an example of the output developed by the Florida DOT using FITSEval and real travel time data to evaluate the TTI for all users on key segments of their Strategic Intermodal System.

Figure 2-3 Florida DOT's Performance Measure Annual Report Example

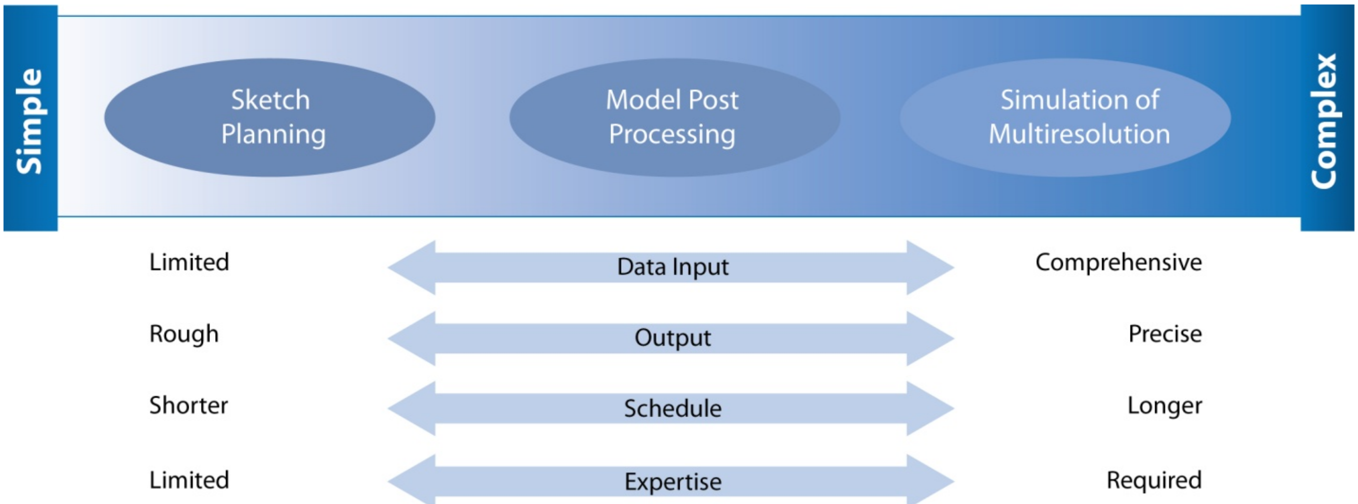


More sophisticated tools include:

- **Simulation.** These methods make use of advanced analytical models to assess driver behavior and their reactions to unpredictable circumstances. Simulation models can give modeled travel-time distributions from which reliability performance measures can be built.
- **Multiresolution methods.** These methods combine several other analysis methods to assess reliability through different lenses. Multiresolution methods take advantage of the integration of several standard analysis tools, (e.g., microsimulation and travel demand models) combining different tools' ability to assess shorter- and longer-range impacts of various congestion mitigation strategies.

Figure 2-4 describes the resources required to use each of these methods. Sketch planning methods require the fewest resources while simulation, multiresolution, and monitoring methods require the most.

Figure 2-4 Resources Required to Apply Different Tools and Methods to Evaluate Reliability Performance



2.4 COMMUNICATING RELIABILITY PERFORMANCE

This section presents thoughts on how to communicate reliability performance measures to the public and stakeholders. SHRP 2 L14 is also developing advice on how to communicate reliability performance measures.

Focus Reliability Measures on Key Issues

When crafting reliability measures, it can be useful to focus them on specific issues including:

- **Time periods.** Typical time periods include AM or PM peak hour or period. The measure should reflect the user's experience. For example, a reliability analysis focused on special events may select various evening and/or weekend midday periods to capture when issues are anticipated.
- **Travel patterns.** Reliability performance can be considered for trips or for segments and the selection can impact the choice of measure (in much of the reliability literature, segments are referred to as facilities). Travel-time data vendors are beginning to release data on individual trip-based travel times. These data can help identify key commuter patterns and their reliability traits.
- **Roadway types.** Appropriate thresholds (or measures) may vary by roadway types (i.e., functional class, levels of vehicle-miles-traveled, statewide roadway designations, etc.).
- **Users.** System users perceive reliability differently depending on their circumstances. When presenting reliability performance measures, it is important to consider these perceptions and incorporate them into the measures. For example:
  - **Freight Carriers** balance the need to pickup loads and the need to arrive on-time to avoid a penalty for being late. These users will likely be interested in the PTI or the 99th

percentile TTI. For freight-heavy segments (e.g., the roadway from the Miami Airport to the flower distribution center to its west), travel may be unreliable if the carrier is late once out of 1,000 times (i.e., the 99.9th percentile TTI).

- **Visitors and tourists** making a one-time pass through an area without time constraints will perceive travel time to be reliable if they are on time 6 times out of 10 (i.e., 60th percentile TTI).
- **Commuters** will perceive travel time to be reliable if they are on time 95 times out of 100 (e.g., late to work no more than once per month).

Developing Corridor Level Measures

Because reliability measures variability in travel times, corridors and roadway segments are a natural level to present information to users. However, presenting reliability at a corridor level requires developing thresholds that make reliability measures meaningful to system users. One simple way to do this is to **convert reliability performance into good/fair/poor categories.** This style of presentation is common for infrastructure performance measures (i.e., percent of pavement in 'good' condition).

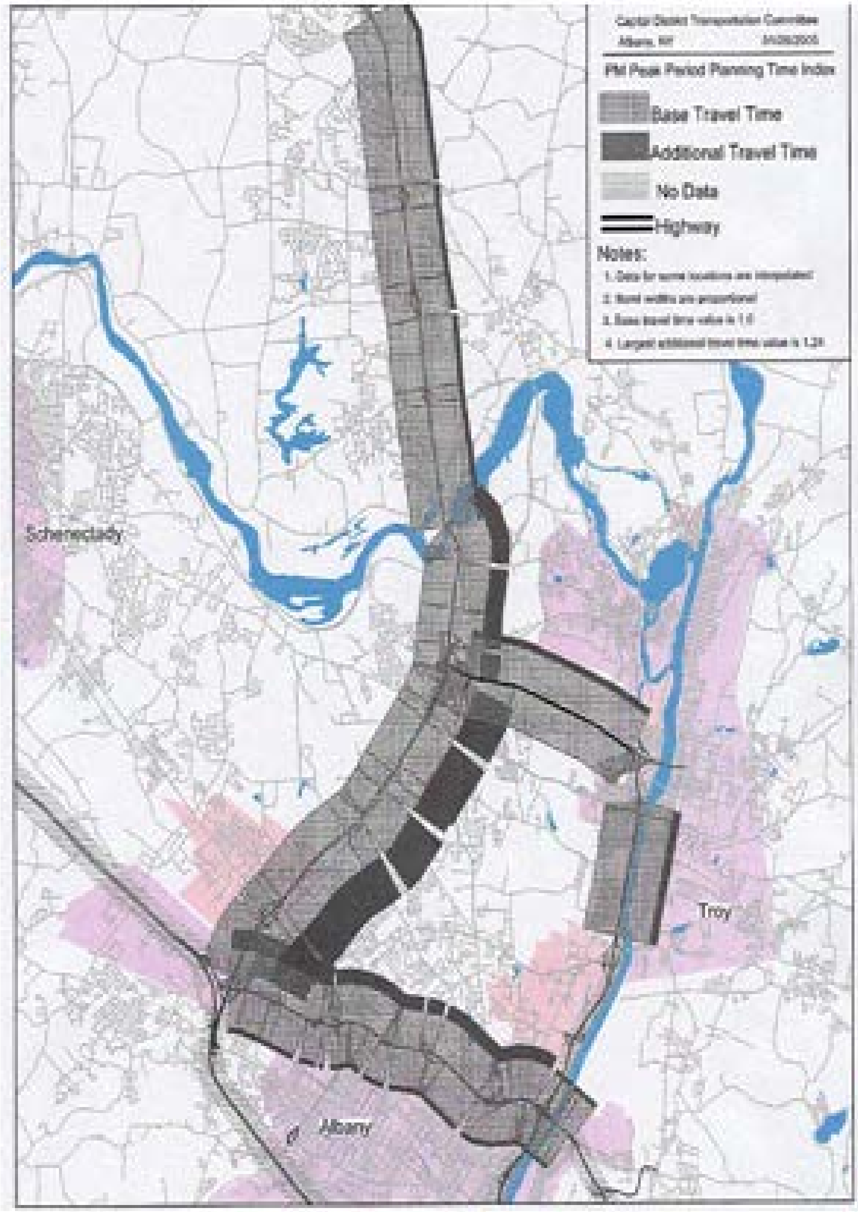
Appropriate thresholds will depend on the characteristics of the corridor or region. Chapter 4 of this *Guide* indicates a thorough explanation for how to tailor thresholds for the agency. Potential examples include:

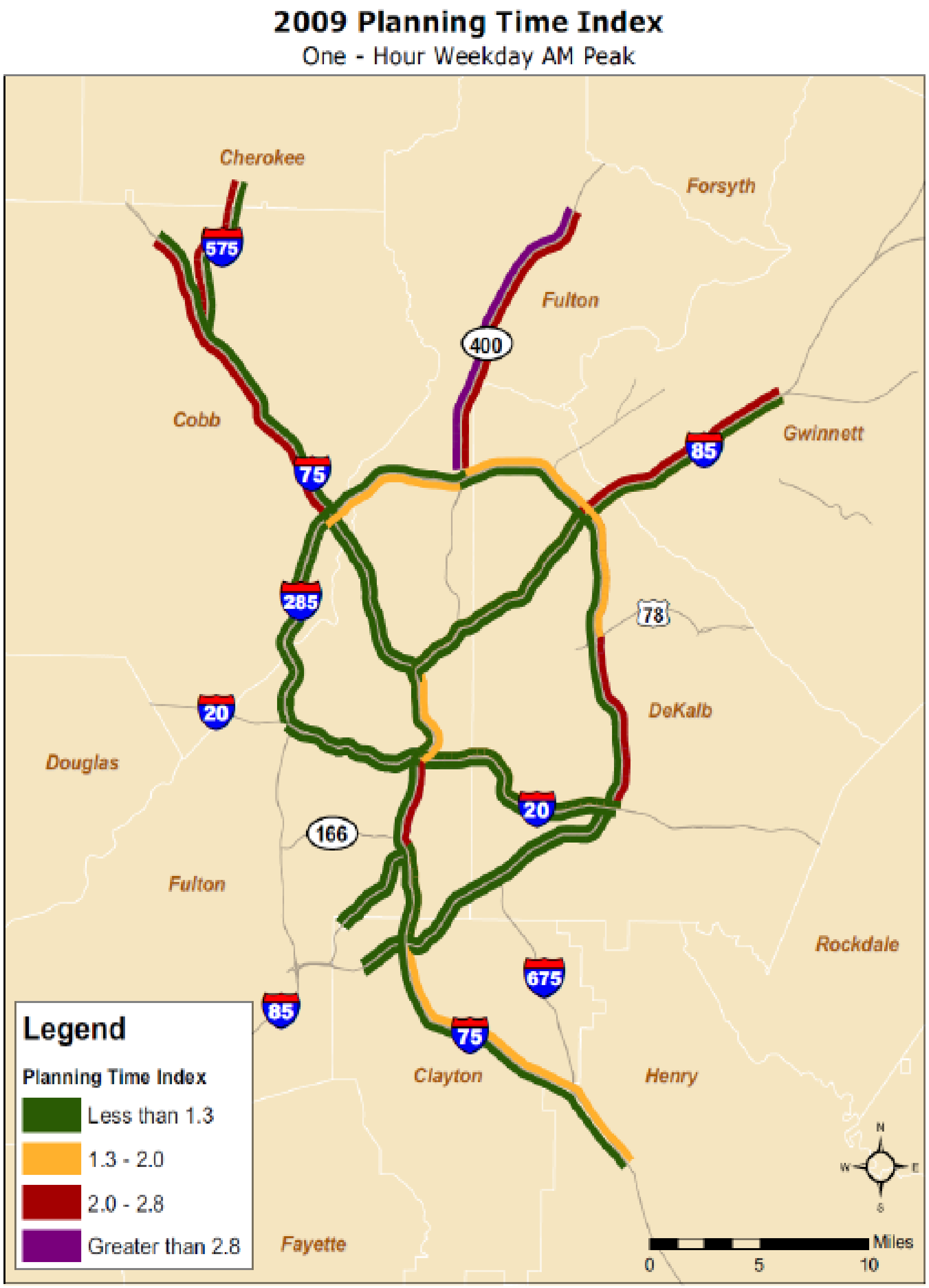
- **Good –** "Good" performance is when the PTI is less than 1.3 (PTI < 1.3);
- **Fair –** "Fair" performance is when the PTI is between 1.3 and 2 (1.3 < PTI < 2); and
- **Poor –** "Poor" performance is when the PTI is greater than 2 (2 < PTI).

Examples of Corridor Level Measures in Use at Transportation Agencies

Figure 2-5 provides examples of maps to communicate reliability performance. The first example, from the Capital District Transportation Committee (CDTC) in Albany, NY, presents the PTI (2). In this example, the width of the line represents free-flow (base) travel time and the dark line represents the 95th percentile travel time. The second map, from the Georgia Regional Transportation Authority, illustrates the segments that experience the worst reliability using the PTI (3). Red and purple segments have "poor" reliability, yellow segments have "fair" reliability, and green segments have "good" reliability according to the above definitions.

Figure 2-5 Examples of Communicating Travel-Time Reliability at the Corridor Level

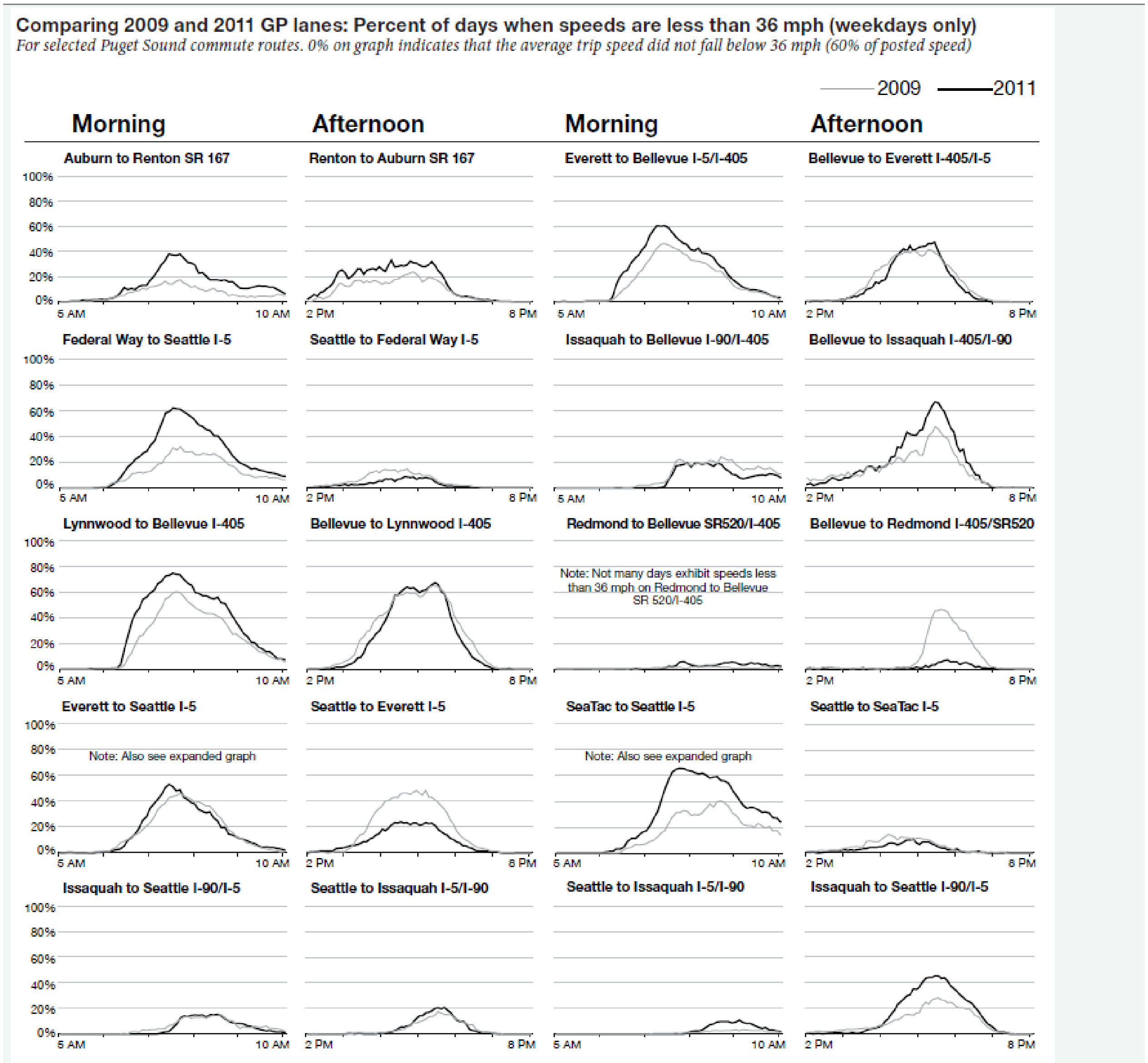




Note: Planning Time Index is expressed as the ratio of the planning time and free-flow travel time.
Planning time represents the amount of time needed to be on-time 95 percent of the time.
The Planning Time Index for GA 400 is based on 2004 data.

In the 2011 Congestion Report, Washington DOT reports that 17 of the 36 high-demand commutes in Puget Sound saw modest changes (less than or equal to 2 minutes) in 95 percent reliable travel time between 2008 and 2010. Fourteen commutes saw reliable travel times worsen between 3 and 10 minutes, while reliable travel times improved on five commutes ranging from 3 minutes to 11 minutes. Washington DOT uses 'stamp graphs' to help illustrate current performance and how performance is changing from 2009 (light grey lines) and 2011 (dark grey lines).

Figure 2-6 Washington DOT Tracking of Travel Times (*4*)



Developing System Level Measures

Many agencies use performance measures to present a summary of overall system performance. Tracking system performance over time can be a useful tool for communicating if performance is improving or worsening. Reducing reliability, a measure of variability, into a single number that can be tracked over time can be challenging. The simplest approach is to find a way to combine data from multiple corridors. Two basic ways to present such a measure include:

- A weighted average of the reliability measure. For example, the PTI for several corridors could be weighted by volume or another factor to generate a single PTI measure for the system; and
- The percent of travel that occurs at various reliability conditions. This type of measure examines all corridors (or a subset of corridors) and calculates the percent that are in 'good', 'fair', and 'poor' conditions.

Examples of System Level Measures in Use at Transportation Agencies

In their 2011 Congestion Report, the Washington DOT measured performance, described trends, and communicated reliability using the 95th percentile travel time (the numerator in the PTI) for segments along 'high demand commute' routes. To convey reliability trends, they categorized how much the 95th percentile of travel time had changed in the most recent two year period. They report that 17 of the 36 high-demand commutes in Puget Sound saw modest changes (less than or equal to 2 minutes) in 95 percent reliable travel time between 2008 and 2010. Fourteen commutes saw reliable travel times worsen between 3 and 10 minutes, while reliable travel times improved on five commutes ranging from 3 minutes to 11 minutes.

Table 2-1 Washington DOT Reliability Performance Measures

Performance Measure	Definition
95% Reliable travel time	Travel time with 95% certainty (i.e., on-time 19 out of 20 work days).
Maximum Throughput Travel Time Index (MT^3I)	The ratio of average peak travel time compared to maximum throughput speed travel time.
Percent of days when speeds are less than 36 mph	Percentage of days annually that observed speed for one or more five-minute intervals is less than 36 mph (severe congestion) on key highway segments.
HOV Lane Reliability	An HOV lane is deemed "reliable" as long as it maintains an average speed of 45 mph for 90% of the peak hour.

Reference List

1. Texas Transportation Institute, 2011. Congested Corridors Report. http://mobility.tamu.edu/corridors/

2. http://www.fhwa.dot.gov/planning/congestion_management_process/case_studies/cdtc.cfm.

3. http://www.grta.org/tran_map/2010_Transportation_MAP_Report.pdf.

4. http://www.wsdot.wa.gov/Accountability/Congestion/2011

3.0 Incorporating Reliability in Policy Statements

Policy statements provide the platform and foundation for making all choices in the planning process.

Transportation agencies draft policy statements to provide direction for the organization. As agency staff become familiar with reliability as a performance measure, the next logical step is to address reliability within these policy statements. For the purposes of this *Guide*, the term policy statements is used broadly to include all strategic statements that direct an agency's investments in the transportation system.

Ensuring that reliability is addressed in policy statements is a critical step towards incorporating reliability into planning and programming. Addressing reliability as a policy issue requires some technical analysis (i.e., what is the extent of unreliable travel conditions in a corridor, region, or State?) and public and stakeholder coordination (i.e., to what extent do various users of the transportation system identify reliability as an issue?). Working with a wide range of stakeholders is critical to ensure that agency goals address user needs.

3.1 Key Questions

- What's the appropriate level to incorporate reliability into an agency's policy statements?
- How can an agency's goals and objectives be tailored to include reliability in a way that matters to system users?
- What are the chief causes of poor reliability in a State or region?

3.2 Identify the Appropriate Level for Incorporation

The part of an agency's strategic direction addresses reliability will depend on the significance of the reliability issues faced by a State or region, the resources available to the agency, and the agency's experience with various types of investment. The typical levels of policy development and a summary of how reliability may be incorporated are described in Figure 3-1. The figure can be used to guide the inclusion of reliability into the development of policy elements.

Figure 3-1 Incorporating Reliability into Various Levels of Policy Statements

Description	Element	Approach to Incorporating Reliability
Broadest statement. Identifies the purpose of the organization	*Vision*	Reliability included only if it is a top agency priority
Broad statement that identifies how an agency delivers the vision	*Mission*	Reliability may be included if it is a major issue impeding the agency
Short statements describing a small set of the most critical issues that an agency is addressing	*Goals*	Reliability included if a significant issue
Additional specificity for the goals	*Objectives*	Reliability commonly addressed
Steps to implement the goals and objectives	*Policies, Strategies, Actions*	Actions to address reliability included

3.3 Incorporating Reliability into Vision and Mission Statements

Vision and mission statements are the broadest statements of strategic direction that transportation agencies use to communicate their priorities. They should be developed collaboratively with the appropriate stakeholders, including those that may be focused on reliability, such as businesses and others. These statements are meant to convey the overall direction for the entire organization and the transportation system and should guide goals, objectives, and actions. For transportation systems that include significant reliability issues, it will be appropriate to either incorporate reliability or focus primarily on system reliability within these statements.

Examples of Reliability in Vision and Mission Statements

The following are examples of how agencies have incorporated reliability into their vision and mission statements:

- Massachusetts DOT (MassDOT) Mission: The MassDOT mission is "Deliver excellent customer service to people who travel in the Commonwealth, and to provide our nation's safest and most reliable transportation system in a way that strengthens our economy and quality of life." The mission sits above the goal level and sets the direction for the entire agency.
- Washington DOT's vision for transportation investment, developed as part of Moving Washington, "combines three essential transportation strategies to achieve and align our objectives and those of our partners:" Operate efficiently, manage demand, and add capacity strategically.

3.4 Incorporate Reliability into Goals and Objectives

At the level of goals and objectives, reliability statements can begin to become more specific. For the above, it may be sufficient to know that the transportation system faces issues of reliability. For goals and objectives, it is important to begin to closely examine the performance measures (from Chapter 2) to ensure that these statements relate to the fundamental issues faced by an agency. A common approach to selecting objectives is the 'SMART' process, which suggests objectives that are Specific, Measurable, Attainable, Realistic, and Time-bound.

The goal setting process can be strengthened by using a collaborative process that includes key stakeholders and provides the right type of information to help facilitate these discussions. This includes:

- **Presenting existing reliability conditions.** Summarize existing travel time data from other sources (CMPs, Operations plans, etc.) to identify the current reliability of the system.
- **Develop reliability trends.** If data are available, presenting reliability trends can show how reliability has changed over time and will help the agency, partners and stakeholders to develop an understanding of reliability issues in the area. Because few agencies have a long history of collecting extensive travel-time data, this may be challenging. Some agencies may find it worthwhile to estimate historical reliability trends using travel demand model post processors or sketch planning techniques. While these techniques have their drawbacks, they are relatively straightforward to implement and can be useful for an agency attempting to get a handle on the reliability issue.
- **Engage with stakeholders**. In addition to quantitative estimates of reliability, stakeholders can provide qualitative understanding of reliability issues in a State, region, or corridor. Broadly reaching out to system users, including commuters, freight shippers and carriers, goods and service delivery providers, emergency response providers, and others can provide a broad understanding of the types of issues these agencies face, as well as identifying corridors that are a major challenge. This can further help an agency focus its data collection and analysis efforts.

Working with stakeholders to develop goals and objectives requires an understanding of the location and causes of reliability issues. As described in Chapter 2, it is valuable to look at reliability through different lenses, including:

- **Roadway types or key corridors** (by functional class, key commuter or freight routes, or other important roadway designation);
- **Geographies** (urban, rural, or key subareas);
- **Impacted stakeholders** (commuters, freight trucks, transit, etc.); and
- **Cause of unreliable travel** (incidents, inclement weather, etc.).

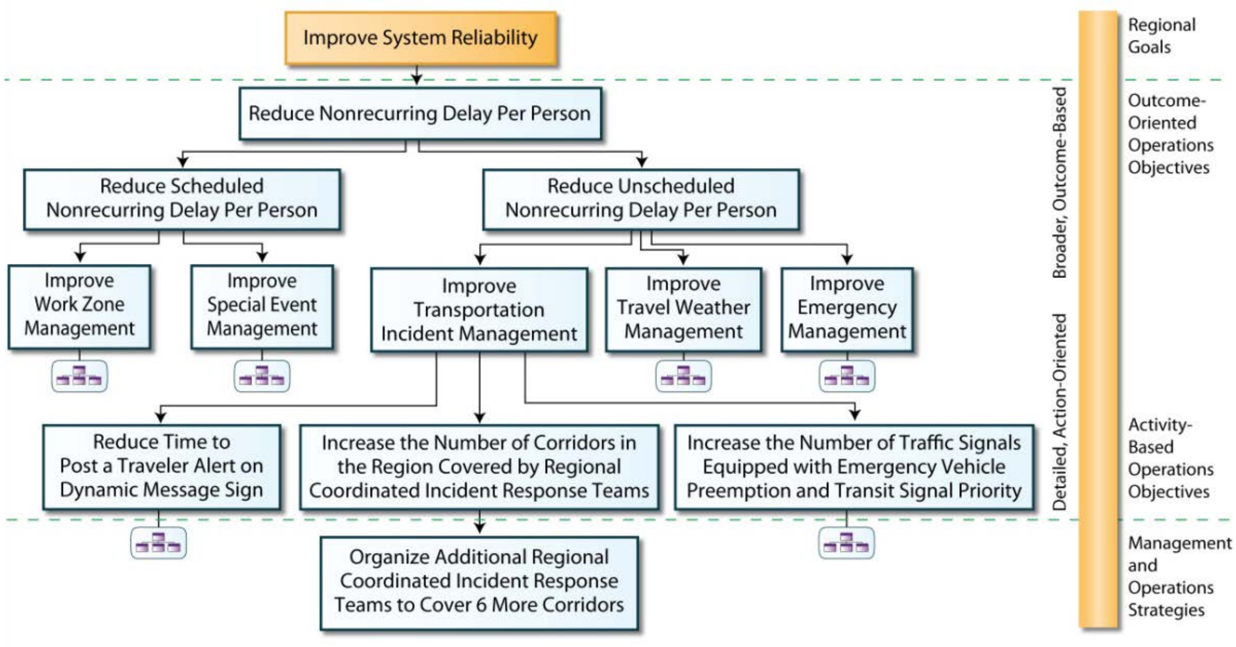
Having assembled relevant data and stakeholder input, reliability goals and objectives can be developed that focus on the specific reliability issues. Goals tend to be broad statements, such as 'Improve System Reliability', but objectives usually provide more specific descriptions of what improved system reliability would look like. Table 3-1 presents a selection of choices to consider when drafting objectives related to reliability.

Table 3-1 Key Choices for Drafting Reliability Objectives

Improve Reliability...			
...On...	...In...	...For...	...By...
...Interstates...	..Urban Areas...	...Freight...	…Improving Incident Management.
...Arterials...	...Rural Areas...	...Transit...	...Improving Storm Management.
...National Highway System...	...Key Subareas...	...Commuters...	…Improving Safety.
...Key Corridors...		...Visitors...	...Improving Work Zone Management.
...Key Routes or Corridors...			...Managing Demand.
			...Improving Special Event Management.
			...Improving Traffic Operations

Figure 3-2 presents a similar approach to identifying relevant objectives and strategies depending on the types of reliability issues an agency faces.

Figure 3-2 Reliability Objective Tree (*1*)



Example of Setting a Reliability Objective Using Stakeholder Input

For the 2060 Florida Transportation Plan, the Florida DOT worked with its partners to develop the strategic framework for the plan, including steering committee meetings, statewide webinars, regional workshops, statewide summit, web site, briefings and updates at regularly scheduled partner meetings, and public and partner review period for draft plan. The Florida DOT convened an advisory group focused on improving economic competitiveness that included members from the Florida Trucking Association, Economic Development Agencies, Business Associations, MPOs, and several businesses. These stakeholders identified that improved transportation reliability for freight and passenger trips would catalyze the State's future economic competitiveness. Their suggested objective, "Increase the efficiency and reliability of travel for people and freight," was incorporated into the plan under the goal, "Improve mobility and connectivity for people and freight." To track progress in the future, the advisory group recommended asking, "Are travel times consistent for people and freight?"

3.5 Incorporating Reliability into Complementary Planning Efforts

Visions, missions, goals, and objectives are typically set at the system level, either in separate strategic planning exercises or as part of long range transportation planning. Much of the data and information, however, will be derived from complementary planning efforts, such as CMPs, Operations plans, corridor plans, transit plans, and other similar efforts. Much of the material for setting objectives will likely be drawn from these plans, as they will provide significant detail on the types of reliability issues an agency faces.

Agencies also often set specific goals or objectives for these complementary planning efforts. The previously described approach to setting broad system level reliability issues can also be used for setting reliability objectives for these plans. Because these efforts delve more deeply into a specific issue (congestion), investment type (operations), or corridor, the objectives are likely to be more specific and detailed than at the broad, system level.

FHWA offers the following additional guidance on incorporating reliability into complementary planning efforts:

- FHWA describes how to integrate operations into the metropolitan transportation planning process to maximize the performance of the existing and planned system. They describe an approach to developing a regional 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) (*2*).
- FHWA also 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 regional transportation plan to illustrate the results of an objectives-driven, performance-based approach to planning for operations (*3*).

Appendix B in the Final Report provides additional information about incorporating reliability into the steps of the planning process as described in the Transportation for Communities – Advancing Projects through Partnership (TCAPP) framework developed by SHRP 2.

Agency Examples of Incorporating Reliability into Complementary Planning Efforts

Florida DOT District 4 TSM&O Defines Reliability Objectives

The TSM&O task team is developing a TSM&O program and includes reliability among its objectives, "Achieve peak period travel time reliability on critical arterial segments in the TSM&O network." The objective is structured similarly to that found in any other sort of plan, but is targeted to measure performance on their TSM&O network (*4*).

Knoxville TPO – Setting an Incident Clearance Time Goal

As part of its Operations plan, Knoxville TPO wants to include a goal of reducing the duration (clearance time) of incidents on the freeways. The results of an incident duration/clearance time analysis will be used to set a quantifiable objective for this goal. The goal can be accomplished by implementing improved response strategies by Tennessee DOT's incident management operation. Table 3-2 presents current information on incident clearance times in Knoxville.

Table 3-2 Incident Clearance Times in Knoxville

Type of Incident	Average Duration (Minutes)	Median Duration (Minutes)	Standard Deviation (Minutes)
Single Vehicle Crash	62.95	35	99.15

Type of Incident	Average Duration (Minutes)	Median Duration (Minutes)	Standard Deviation (Minutes)
Multi Vehicle Crash	49.38	43	35.57
Debris	13.07	7	21.02

Reference List

1. Advancing Metropolitan Planning for Operations, Federal Highway Administration http://www.ops.fhwa.dot.gov/publications/fhwahop10027/fhwahop10027.pdf

2. http://ops.fhwa.dot.gov/publications/fhwahop10026/index.htm

3. http://ops.fhwa.dot.gov/publications/fhwahop10027/index.htm.

4. http://www.dot.state.fl.us/trafficoperations/TSMO/documents/District_4/Broward%20County%20Q1%202010.pdf

4.0 Evaluating Reliability Needs and Deficiencies

Understanding the extent of reliability needs helps policy-makers and stakeholders draft policy statements with substance, set funding levels for operations and management programs, and properly prioritize projects.

Agencies define needs and deficiencies to describe the significance of their reliability challenges. An agency can define needs by comparing reliability performance to thresholds or simply by describing areas of poor performance to identify challenges. Three key terms are important to define for analyzing needs and deficiencies.

- **Reliability thresholds.** The point at which a segment or network is considered to have good, fair, or poor reliability. Thresholds can be used to identify needs and deficiencies.
- **Reliability deficiency.** A segment or trip that is unreliable. Unreliable travel is identified by comparing reliability performance to a threshold. When the performance is worse than the threshold, the segment is considered unreliable.
- **Reliability need.** The project necessary to ensure that a segment or trip is reliable. In financial terms, the need can be defined as the total cost to improve deficiencies to an acceptable level. The total need can help to support budget requests or identify the gap between *fundable* and *unfundable* needs.

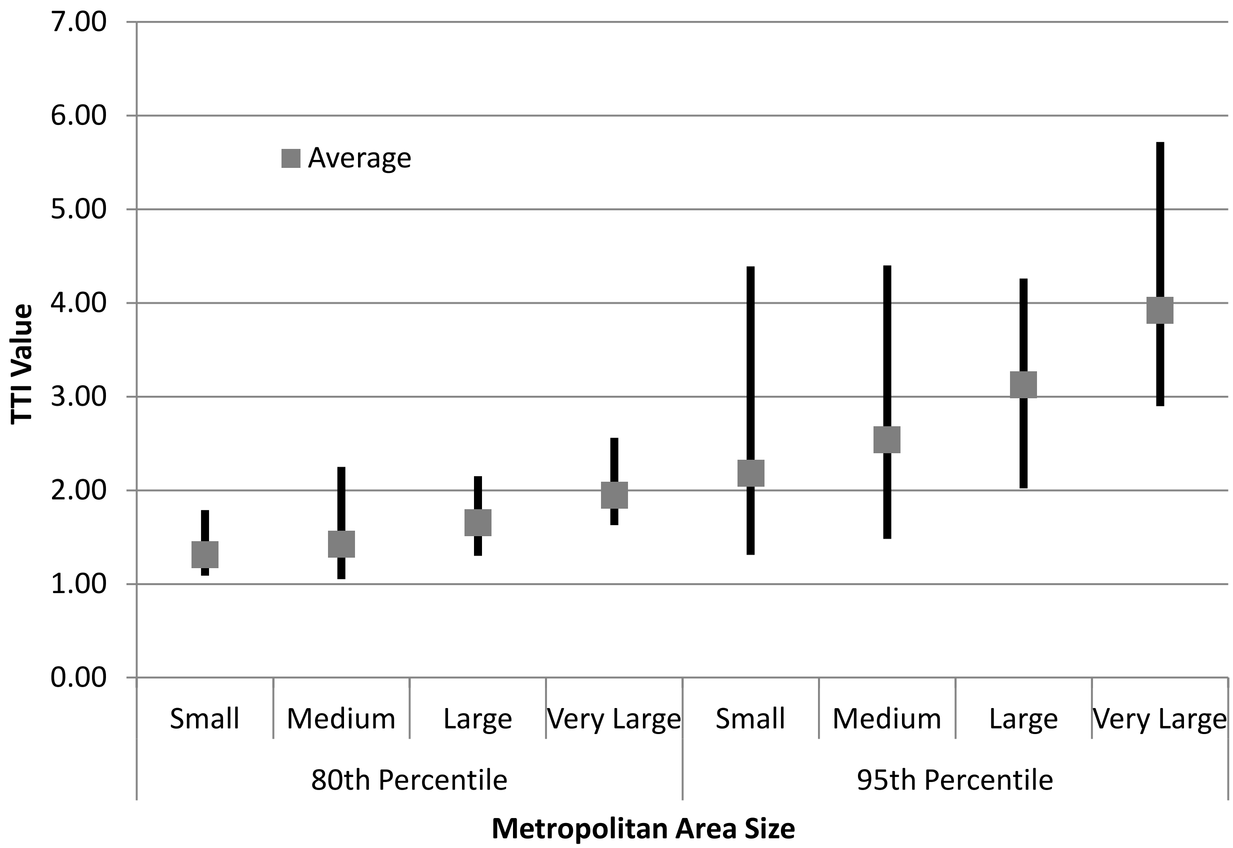
4.1 Key Questions

- How are reliability thresholds set?
- How can reliability deficiencies be identified?
- How should reliability deficiencies be translated into needs?

4.2 Setting Reliability Thresholds

Measuring performance can tell how the system is performing, but it cannot identify reliability issues. To do that, a threshold must be developed. Any segment or trip with reliability performance worse than this threshold may be considered to have a deficiency. Because reliability is a function of the perception of system users and varies significantly across locations, seasons, times of day and days of the week, there is no standard threshold that indicates when reliability is considered unacceptable. For example, Figure 4-1 illustrates how reliability varies by urban area size, using data from the Texas A&M Transportation Institute's Urban Mobility Report. The variance is shown across four sizes of metropolitan area for both the PTI (95th percentile of TTI) and the 80th percentile of TTI. The average increases across metropolitan area size, but some small and medium areas have as significant reliability challenges as the larger metropolitan areas.

Figure 4-1 Reliability Variation by Area Size (*1*)



Defining thresholds requires understanding user perceptions of reliable travel. It is recommended that an iterative approach is used to: set preliminary thresholds, make maps of reliability performance (described in Chapter 2), identify deficiencies, present the materials, discuss whether these materials match agency and stakeholder understanding of reliability deficiencies, and adjust the threshold up or down as needed. If good/fair/poor categories have been identified for the reliability performance measure, they should be used as the starting point and new thresholds fed back into the categories if changes are made.

Consider the following when developing thresholds:

- **Users.** Develop different thresholds for different users of the system. Depending on the specific issues, consider reliability for commuters, freight carriers, tourists, and other user groups.
- **Time Period.** Develop thresholds for travel at various time periods to reflect specific user expectations such as AM and PM peak periods, weekday midday, and weekend midday. Freight shippers, for example, may have more expectations for a reliable off-peak

transportation network, than for peak period conditions. Freight movers try to use the generally less congested off-peak periods, but transportation agencies often scale back incident management activities between the peaks. Given the important role of just-in-time manufacturing, however, the midday periods may be those when incident management is most important to the provision of reliable travel times.

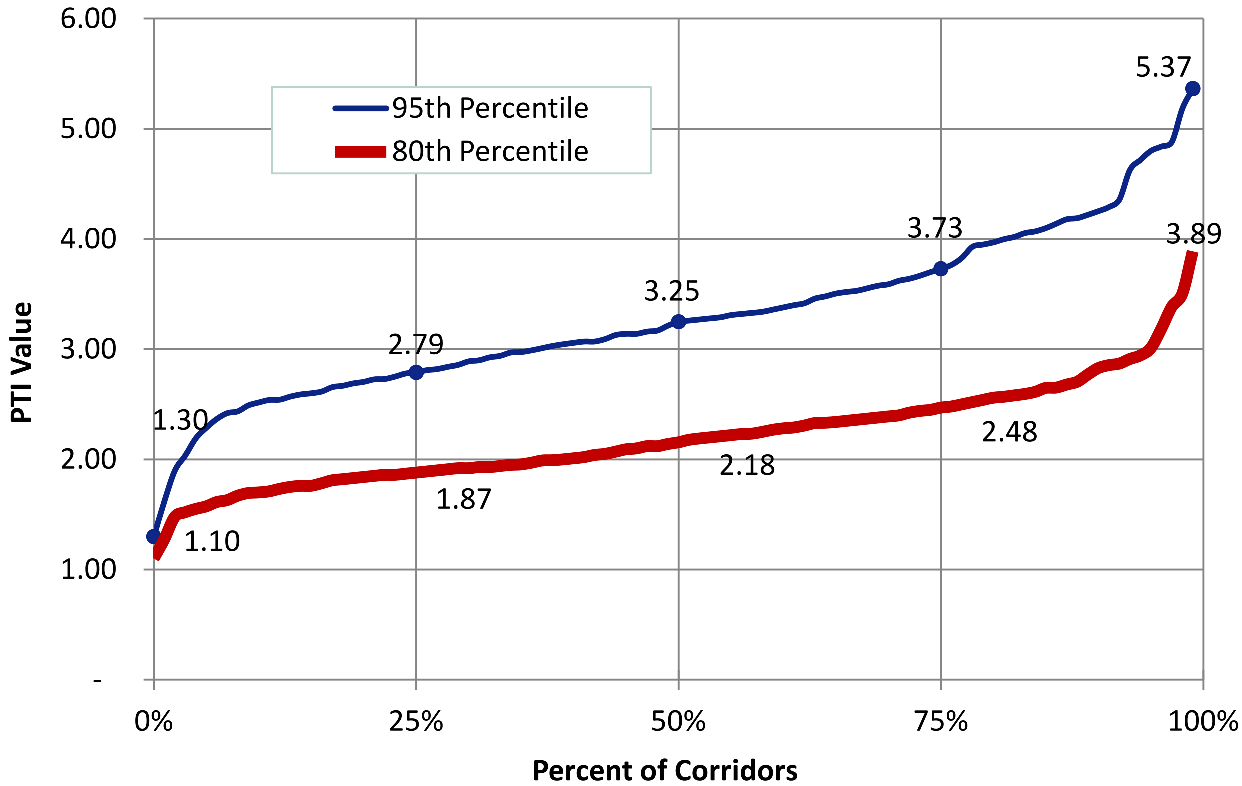
- **Roadway Types.** Develop thresholds for different roadway types to reflect specific conditions on those roadways, such as interstates, expressways, National Highway System (NHS) roads, major arterials, or principal transit, freight, or other modal corridors (e.g., those connecting critical economic centers).
- **Geography.** For all general geographies, including statewide, regional, corridor, and subarea, set thresholds that apply to all users who overall have a low to moderate tolerance for unreliable travel, such as different tolerances for urban and rural travelers.

One approach to setting thresholds may be to use data from other comparable corridors to establish acceptable thresholds. Figure 4-2 presents the distribution of PTI for the 328 most congested corridors in the U.S. from a study by the Texas A&M Transportation Institute. The worst corridors are close to or above a 95th percentile PTI of 3.75; almost all of these very congested corridors have a PTI above 2.50. For many, these values are likely to represent poor reliability performance.

Some agencies have examined research by the SHRP2-L03 project and identified the 80th percentile travel time as a point where long travel times are caused by large incidents – which might be reduced by aggressive incident management practices – as opposed to the 95th percentile, which is frequently the product of weather problems or very large special events – circumstances which are less affected by agency actions. Figure 4-2 shows the PTI80 line, with most corridors having a value greater than 1.75.

The TTI study includes all of the most congested corridors in the U.S. Conditions in these corridors should be avoided by other corridors and regions. Values above PTI_{95} of 2.50 and PTI_{80} of 1.75 indicate very unreliable conditions. Values of PTI_{95} =2.00 and PTI_{80} = 1.50 indicate unreliable conditions and should be considered as the beginning of serious problems.

Figure 4-2 Distribution of the PTI for the 328 Most Congested Corridors in the U.S. (*2*)



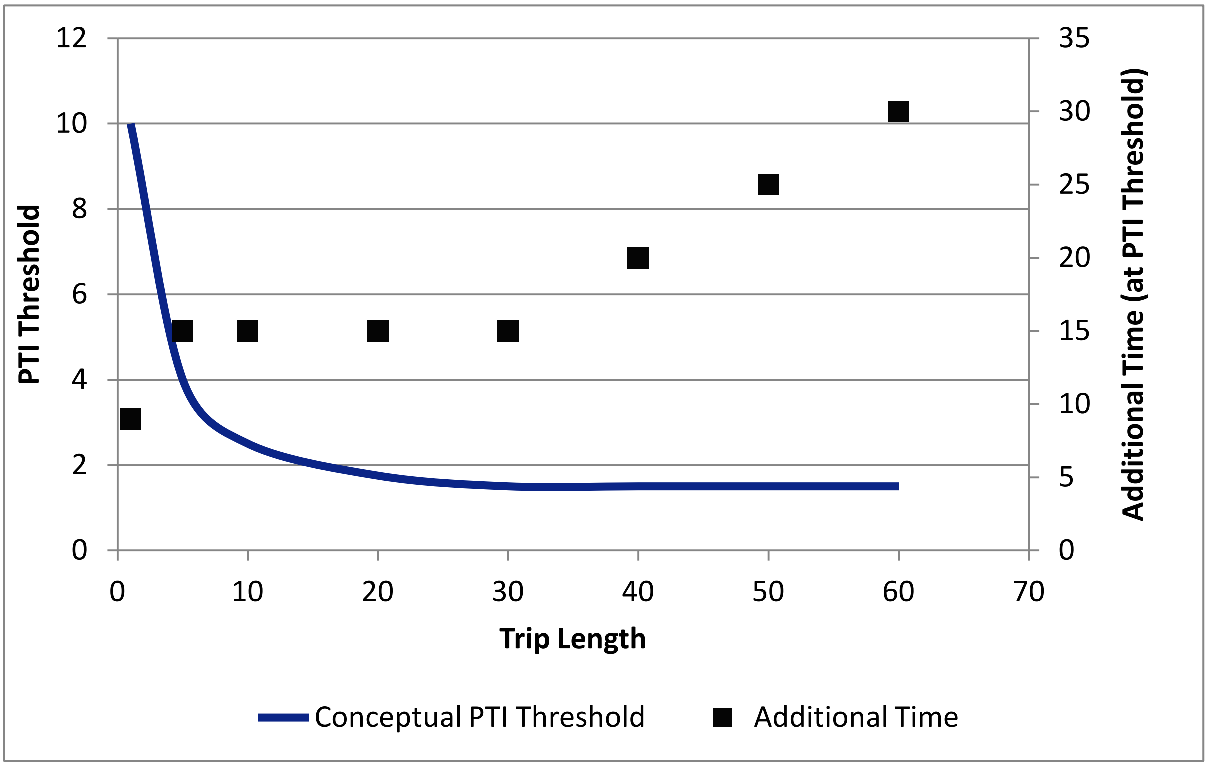
Setting Thresholds Relative to Expectations

Setting thresholds for a performance measure requires being able to clearly communicate what level of reliability or congestion is acceptable. Defining meaningful reliability thresholds is particularly challenging for two reasons:

- Congestion and reliability are a matter of perception. Is no congestion acceptable, some congestion, a lot? The most common reliability measure – the planning time index – assumes that it is acceptable to be late to work 1 day out of 20. Setting a threshold will depend on individual perceptions – 1 day a week may be acceptable for some, 1 day a month for others will not.
- Individual perception of system reliability depends on both the ratio of extra (unreliable) travel to free flow or average travel and the total amount of unreliable travel. For example, a 5 minute trip with a PTI of 3 takes 15 minutes to complete 95 percent of the time. That may be frustrating, but doesn't compare to a 15 minute trip with a PTI of 2.0 (30 minute trip 95 percent of the time).

Ideally, planners would have information available on the travel time for trips, not just roadway segments. Travel surveys that are conducted for travel demand models may provide a source to understand travelers' expectations, both for average acceptable travel, but for minimums and maximums as well. Figure 4-3 presents a conceptual relationship between trip length and PTI. As agencies continue to use reliability measures, it will be easier to understand which measures can be clearly communicated to the public and to ascertain which techniques are effective for capturing information about public perceptions of reliability.

Figure 4-3 Conceptual Relationship of Trip Length to PTI Threshold



Example of Setting a Reliability Threshold

In their CMP, the Madison, WI MPO defined a reliability threshold as: "The travel time index for the morning peak period should not exceed 175% of free flow travel time in the East Washington corridor." They defined the threshold for a specific time period and along a specific corridor. Any travel time index above this will be considered deficient.

4.3 DEFINING RELIABILITY DEFICIENCIES

Defining reliability deficiencies can be done by comparing trips or segments to threshold values and highlighting those segments that are worse than the threshold. If the thresholds do not tell a story that stakeholders and internal agency staff can understand intuitively (e.g., the segments or trips identified that do not feel deficient to them), it may be necessary to adjust them. Maps are a critical mechanism for communicating deficiencies. The GRTA example presented in Chapter 2 uses a map to illustrate reliability at the roadway segment using the PTI.

Example of Defining Reliability Deficiencies in Corridor Planning

The Washington DOT identified reliability deficiencies regarding a key segment of the Interstate 5 corridor Seattle/Tacoma/Olympia metropolitan region, adjacent to the Joint Base Lewis McChord military base. The corridor has significant existing recurring congestion due to high demand and limited capacity; however, travel time reliability often is the more significant issue, negatively impacted by major incidents, construction/maintenance work zones, and primarily by large spikes in demand caused by major troop and equipment movements in and out of the military base. Analysis confirmed a much higher than average baseline reliability issue in the corridor as measured using the Travel Time Index (estimated at nearly 1.3 for the corridor segment during peak periods).

4.4 DESCRIBING RELIABILITY NEEDS

Needs refer to the projects and/or investment levels needed to reduce or eliminate reliability deficiencies. As described in the thresholds section, a major challenge in identifying needs is the variability in expectations of acceptable travel time reliability. Needs can be defined based on constrained or unconstrained funding and can also be defined relative to performance and/or utility of the investment. This section describes three approaches to identifying needs:

- Identifying needs at the corridor or segment level;
- Using a performance-based approach to estimate program needs; and
- Using incremental benefit cost to estimate program needs.

Identifying Needs at the Corridor or Segment Level

At the corridor or segment level, needs are often thought of as the specific investments that would improve performance. To support the identification of these investments, it is useful to develop a 'toolbox' of strategies to draw from that can improve reliability. Strategies in the toolbox include capacity, operations and travel demand management (TDM) investments. This toolbox of strategies should be developed as part of the Congestion Management Process (CMP), a requirement of the Federal planning process for MPOs/transportation management areas (TMAs), and then used in other planning processes. Table 4-1 presents example strategies to consider in this toolbox. For each of these strategies, critical information will include:

- The relevant situations to which the strategy may be applied;
- The capital and operating cost for each strategy (expressed per mile or per unit); and
- Expected project benefits, such as average expected benefits by type of investment, a range of benefits from previous experience, or a methodology for calculating expected benefits.

Additional project characteristics that should be considered include whether the project is shovel-ready, whether it has political support, or whether it should be packaged with another project or groups of projects. These additional considerations will help you refine your priority list, find mutually supportive projects, and build investment programs (such as TIPs and STIPs).

Table 4-1 Example Strategies to Improve Reliability (*3*)

Improvement Type		Examples
Additional capacity	Highway	New or widened freeways/arterials, Toll roads and lanes and managed lanes
	Transit	New rail lines or bus routes (including busways/BRT), Additional service on existing lines/routes
	Freight	Truck only lanes, rail improvements
Operational Improvements	Arterial	Information systems, signal retiming and management, incident management, geometric or intersection improvements, access management, and parking restrictions
	Freeway	Information systems, incident management, work zone management, ITS, managed lanes, variable speed limits, ramp closures
	Transit	Vehicle tracking, signal priority, bypasses, express service, information
	Freight	Vehicle tracking, information, roadside electronic screening
Demand Management	Travel Alternatives	Telecommuting, alternate work/travel schedules,
	Land Use	Smart growth, transit oriented development, parking strategies
	Pricing	High Occupancy Toll lanes, pricing for time of day, activity centers, parking
	HOV	Rideshare matching, vanpools, guaranteed ride home
	Transit	Subsidized fares, trip itinerary planning
	Freight	Truck only toll lanes, delivery restrictions

SHRP 2 L02 recommends establishing 'Reliability Regimes' of travel time data as a way to categorize and understand the situation in a corridor or a system. By categorizing travel time data by key causal factor – demand, weather, incidents, events, work zones, and others – a better understanding can be developed of the specific situations to which various investment strategies can be applied (Table 4-2).

Table 4-2 Example Matrix for Categorizing Travel Time and Reliability Measures (*4*)

Congestion Level	Event					
	None	Weather	Incident	High Demand	Special Event	Work Zone
Uncongested						
Low						
Moderate						
High						

Table 4-3 presents project costs, benefits, and cost-effectiveness for operations and management projects in the Knoxville Transportation Planning Organization (TPO) region. While this list identified projects in various corridors and locations, a similar table could be assembled for each location to compare potential project alternatives (where multiple alternatives are feasible).

In addition, similar lists of projects could be identified that compare multiple types of projects, not all projects from a single program. See the ***Technical Reference*** Chapter 5 for how to estimate reliability using these methods and tools.

Table 4-3 Sample Operations Costs, Benefits, and Cost-Effectiveness for Knoxville

1.0 Project	2.0 Location	[redacted] PTI Improvement	Capital Cost * [redacted] (Dollars)	Cost-Effectiveness [redacted] (Dollars)
[redacted] Maryville and Alcoa CCTV Cameras	[redacted] U.S. 129 from Pellissippi Parkway to Hunt Rd	[redacted] 0.13	[redacted] 100,000	[redacted] 7,876
[redacted] Cities of Maryville and Alcoa CCTV Cameras	[redacted] U.S. 129 from Hunt Road to U.S. 411	[redacted] 0.12	[redacted] 100,000	[redacted] 8,312
[redacted] Oak Ridge Traffic Signal System Upgrades	[redacted] Illinois Ave from Tulane Ave to Lafayette Dr	[redacted] 0.19	[redacted] 180,000	[redacted] 9,457
[redacted] TDOT Ramp Metering	[redacted] I-40 from I-140 (Exit 376) to I-640 (Exit 385)	[redacted] 0.16	[redacted] 200,000	[redacted] 12,248
[redacted] Maryville and Alcoa CCTV Cameras	[redacted] SR 35 from U.S. 129 to U.S. 321	[redacted] 0.06	[redacted] 100,000	[redacted] 15,543
[redacted] Combined City of Pigeon Forge and Sevierville Adaptive Signal System	[redacted] U.S. 441 from Chapman Highway to Dollywood Lane	[redacted] 0.25	[redacted] 450,000	[redacted] 18,148
[redacted] Region 1 Incident Management Expansion – I-40 and I-75 West of Knoxville	[redacted] I-40/75 from I-40/75 Interchange (Exit 368) to near Lovell Road (Exit 374)	[redacted] 0.98	[redacted] 2,000,000	[redacted] 20,345
[redacted] Region 1 Incident Management Expansion – I-40 and I-75 West of Knoxville	[redacted] I-75 from U.S. 321 (Exit 81) to I-40/75 Interchange (Exit 84)	[redacted] 0.98	[redacted] 2,000,000	[redacted] 20,439
[redacted] Region 1 Incident Management Expansion – U.S. 129/SR 115 (Alcoa Hwy)	[redacted] I-140 to Gov John Sevier Hwy	[redacted] 1.04	[redacted] 2,250,000	[redacted] 21,622
[redacted] Region 1 Incident Management Expansion - U.S. 129/SR 115 (Alcoa Hwy)	[redacted] Gov John Sevier Hwy to near Cherokee Trail	[redacted] 1.00	[redacted] 2,250,000	[redacted] 22,499
[redacted] Region 1 Incident Management Expansion – I-140 South of Knoxville	[redacted] Near Westland Dr (Exit 3) to U.S. 129 (Exit 11)	[redacted] 0.97	[redacted] 3,600,000	[redacted] 37,020
[redacted] Oak Ridge DMS Deployment	[redacted] Solway to Illinois Ave	[redacted] 0.03	[redacted] 150,000	[redacted] 56,853
[redacted] Oak Ridge Traffic Signal System Upgrades	[redacted] Oak Ridge Turnpike from Illinois Ave to Florida Ave	[redacted] 0.03	[redacted] 180,000	[redacted] 62,033
[redacted] Region 1 Incident Management Expansion – I-75 North of Knoxville	[redacted] Merchant Dr (Exit 108) to Emory Road (Exit 112)	[redacted] 0.19	[redacted] 1,300,000	[redacted] 67,919
[redacted] Oak Ridge Traffic Signal System Upgrades	[redacted] Lafayette Dr from Oak Ridge Turnpike to Bear Creek Road	[redacted] 0.02	[redacted] 180,000	[redacted] 79,967

1.0 Project	2.0 Location	PTI Improvement	Capital Cost * (Dollars)	Cost-Effectiveness (Dollars)
Pigeon Forge and Sevierville Adaptive Signal System	U.S. 411 (Dolly Parton Parkway) from SR 66 to Veterans Blvd	0.05	450,000	84,107
Oak Ridge Traffic Signal System Upgrades	Illinois Ave from Robertsville Road to Tulane Ave	0.02	180,000	84,612
Pigeon Forge and Sevierville Adaptive Signal System	SR 66 from I-40 to Chapman Highway	0.05	450,000	84,894
Region 1 Incident Management Expansion – I-40 and I-75 West of Knoxville	I-40 from U.S. 321 (Exit 364) to I-40/75 Interchange (Exit 368)	0.17	2,000,000	119,003
Knoxville DMS Deployment	Kingston Parkway from Northshore Drive to Pellissippi Parkway	0.03	375,000	139,483

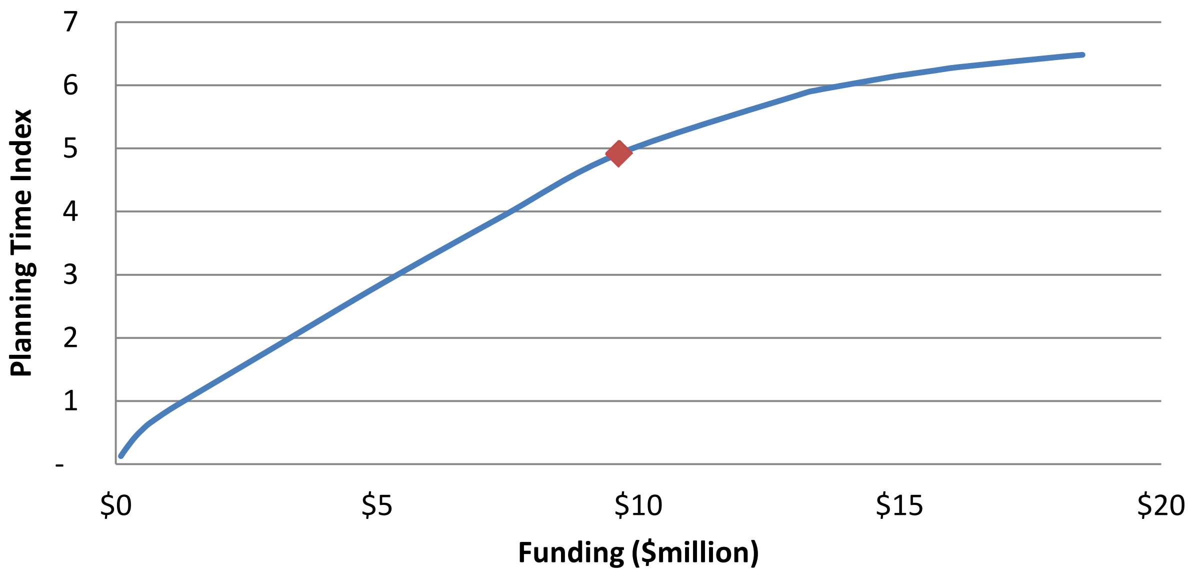
* Only capital costs were available for this analysis, not operations and maintenance costs. A comprehensive analysis would include all of these costs. Costs are based on professional judgment. Cost effectiveness is the cost per unit of PTI improvement.

Estimate Program Needs using a Performance-Based Approach

Shifting from individual corridor or segment needs to overall system needs shifts the focus from projects to dollars. In some program areas, management systems can provide a system level analysis of needs, but there are no existing management systems that can do this for operations and management investments. Deriving these estimates requires an approach to aggregate segment or corridor level information into a system level estimate of needs. Several approaches are possible, and more detailed examples of several approaches are provided in Chapter 5.

One approach to estimating system or program level needs is to build a performance curve based on the reliability benefits and costs estimated for individual investments. Using the Knoxville estimate, Figure 4-4 presents an example curve that compares the cumulative benefits (in improved PTI) and costs of investments in different programs. This curve could also be based on the weighted estimate of PTI improvement based on vehicle miles of travel, or the cost effectiveness of the investments identified. In this example for Knoxville, the first 10 million purchases about 5 points of change in PTI. The next 10 million only purchases 2 points of change in PTI. Based on this, the performance-based needs for Knoxville is 10 million. These figures can become especially useful when comparing and making tradeoffs in investments across multiple programs.

Figure 4-4 Example Reliability Performance Curve for Knoxville



Estimate Program Needs using Incremental Benefit Cost

An alternate approach to estimating program needs is to use incremental benefit cost. The incremental benefit cost (IBC) ratio is defined as:

$$\frac{Benefit\ Project\ 1 - Benefit\ Project\ 2}{Cost\ Project\ 1 - Cost\ Project\ 2}$$

Where project 1 is the more expensive of the two. Only projects with benefits greater than costs (or some other minimum threshold) should be included. The next cheapest project may be to do nothing.

Once the IBC ratio has been calculated for each project, the projects are rank-ordered by IBC ratio, allowing for the development of a similar performance curve as described above.

An Alternative Approach to Develop a Project List

The IBC ratio could also be used as an alternative approach to developing a project list or package of alternatives to improve a corridor. To do so, for each corridor in the system, package reliability projects together with all other projects into a good, better, best option for the corridor. Use IBC to select the appropriate package of projects for each corridor. Finally, use the project prioritization methods described in Chapter 6 to prioritize the packages of projects among corridors.

Reference List

1. Texas A&M Transportation Institute Urban Mobility Report. http://mobility.tamu.edu/ums/congestion-data/.

2. Texas Transportation Institute, 2011. Congested Corridors Report. http://mobility.tamu.edu/corridors/.

3. Adapted from Cambridge Systematics, Inc. "SHRP 2 Project L03 Final Report: Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies." SHRP 2, Transportation Research Board, February 2010.

4. SHRP 2 L02 Draft Final Report.

5.0 Incorporating Reliability Measures into Program and Project Investment Decisions

The previous chapters provide a foundation for understanding the reliability of the transportation system and establishing agency priorities that incorporate reliability. This section turns towards ***using reliability performance measures to support decision making***. Incorporating reliability performance measures into decision making occurs at three levels – program tradeoffs (how much funding to provide to each program), project prioritization (how to select from among many projects within or across programs), and project alternative selection (how to select the preferred alternative for a project in a specific location). Regardless of the level, practitioners need to be able to forecast reliability to be able to incorporate reliability performance measures alongside other performance measures. Detailed techniques for forecasting reliability are described in the *Technical Reference*.

At the program level, reliability performance measures can be used to help an agency evaluate how much emphasis to give to operations and management programs relative to preservation, safety, capacity expansion, and other programs. Reliability measures can also be used as a component in evaluating capacity expansion, safety, and other programs, but the most common use of a reliability performance measure will be for evaluating operations programs.

There are no widely used methods to set program funding levels. Many agencies distribute funding to programs based on federal and State funding requirements and historical practice. Performance measures can help answer the question, "How do I find the right level of funding for all programs so that I can best meet the various needs of users?" This process often takes place separately from the development of a specific plan or program, but can happen as part of a LRP or strategic plan and has a clear influence on STIPs and TIPs.

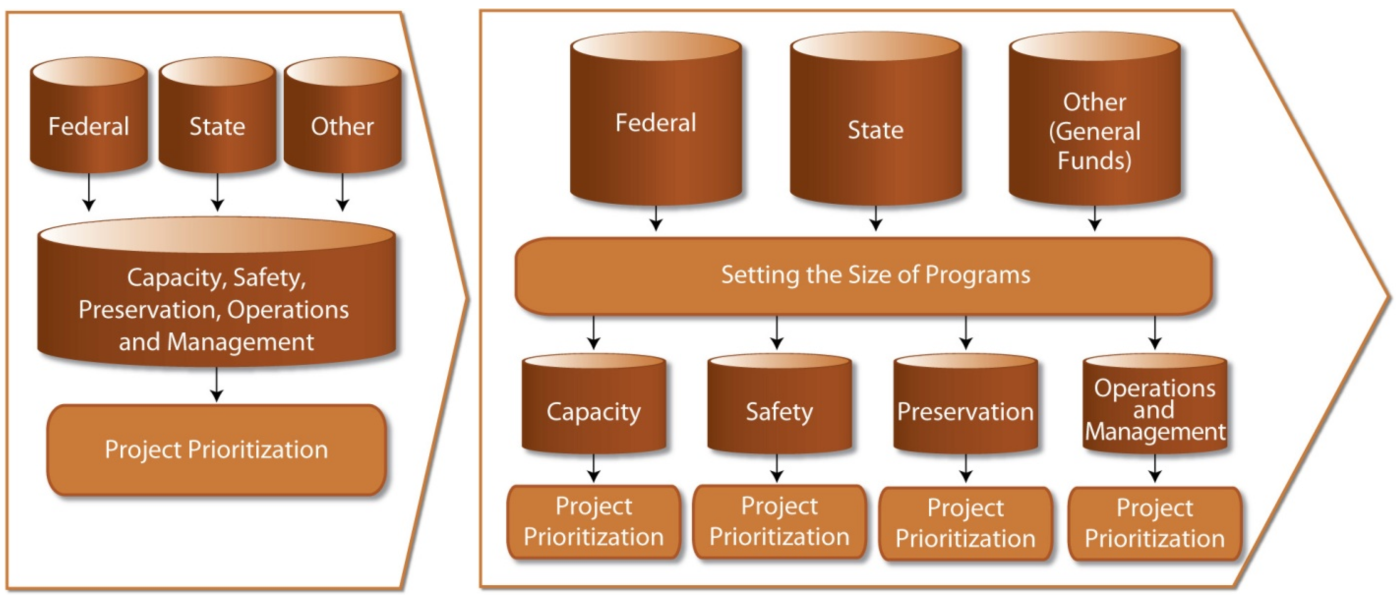
For project prioritization, reliability performance measures can be used alongside other measures to identify a preferred, constrained list of projects to be implemented, usually in the form of a TIP or a STIP. This includes prioritizing investments within one program (i.e., using reliability performance measures to help prioritize operations projects) or across program areas (i.e., using reliability as one of several measures to prioritize a range of project types), as well as using reliability performance measures within either a cost effectiveness analysis (i.e., developing a weighted score of project performance that includes reliability) or an economic analysis (i.e., estimating an economic value of reliability to use within benefit/cost analysis).

Finally, reliability performance measures can be used to support the evaluation of project alternatives. When selecting a particular investment for a transportation corridor or segment, reliability performance should be considered alongside other measures. This can help ensure that the selected preferred alternative addresses the full set of concerns.

In combination, these program, project, and project alternative decision points must fit within an overall framework of performance-based planning and programming. Incorporating reliability into the program and project level investment decisions requires that agencies use performance measures across all (or at least most) of their program areas. Measures from other areas – infrastructure, safety, capacity expansion, and others – must be used *in combination* with reliability performance measures to provide a robust analysis.

While all agencies make investment decisions at both program and project levels, there are multiple methods for moving from program to project decisions and linking these two sets of decisions. For the purposes of this *Guide*, two models are considered (Figure 5-1) and the implications discussed throughout this chapter. In the first model, all transportation funds are pooled into one bucket and all project types are prioritized together. In the second model, investment levels are set at the program level and projects are prioritized within separate funding programs. In this model, one can define which projects are allowed to compete with one another. Other combinations may be used as well – for example, some program areas may be prioritized together and others prioritized separately.

Figure 5-1 Two Approaches to Investment Planning and Project Prioritization



Using a performance-based approach asks the question, "Assuming no constraints on funding within individual programs, what are my ideal investments?" Taking an unconstrained approach to analysis allows agencies to compare the ideal investments against investments constrained by the "color of money".

Regardless of the approach used to make investment decisions, several key technical resources are needed, including:

- **Identify available funding.** In principle, program and project investment analyses can be conducted without constraining total revenue, but in practice, all agencies must work under a revenue constraint. Applying such a constraint from the beginning can help agencies both sharpen their focus on critical choices and create the opportunity to identify how additional funding may produce benefits.

- **Identify and exclude projects or programs that will not be analyzed.** This can include earmarked projects, legislative requirements, or projects that already are programmed in the TIP or STIP. It can also include programs that an agency determines cannot be easily analyzed using the methods below. From a technical perspective, funding 'earmarked' for specific projects or purposes can be removed from the total available funding.
- **Organize programs.** Decide whether and how to combine programs for analysis purposes. A common set of programs may include preservation, safety, capacity expansion/mobility, and operations and management. However, agencies can organize their programs to suit the way they make decisions. As described below, the purpose of a program is to define a type of investment with benefits that can be measured using a single (or multiple) measures of effectiveness.

5.1 Key Questions

- How can reliability performance measures and operations investments be incorporated into an analysis of program tradeoffs, specifically the relationship between investment in operations and management and reliability performance?
- How should reliability performance measures be used to support project prioritization for a single program (e.g., operations and management investments)?
- How can reliability be incorporated into a cost effectiveness analysis of multiple programs?
- How can reliability be incorporated into a benefit/cost analysis of multiple programs?

5.2 How To Use Reliability Performance Measures to Support Program Trade-Offs

Using the two-step approach requires first analyzing performance at the program level and then moving on to the project level. This subsection describes how to analyze program level performance and use this information to support tradeoff analysis. It builds on the performance-based approach to estimating needs described in Chapter 4.

At the program level, reliability performance measures are most likely to be useful to evaluate an operations and management program, though other program areas could include capacity expansion (either instead of or in addition to a more traditional mobility measure). The primary focus is on examples of evaluating operations and management programs. In general, the assumption is that this analysis would be conducted as part of either long range planning or to develop an investment plan that is used to inform capital programming (e.g., STIPs and TIPs). While investment plans are not a required product of the planning process, States in particular are increasingly using 10-year investment plans to consider program tradeoffs. This investment level of analysis uses traditional program silos, but helps agencies break them down by asking how investment in a given program area relates to overall performance. As noted, this may also include combining some silos. For example, agencies may wish to evaluate all operations and capacity investments together to evaluate how both impact system reliability. The steps in this process are described below.

Establish Measure of Effectiveness

The measure of effectiveness (MOE) is typically a single measure of performance attributed to reliability projects, but multiple measures can be used, either by generating a scale or by simply presenting results from multiple measures. While not as common for this type of analysis, a scale can be developed from multiple measures much as a single score can be generated for a project based on multiple performance measures (see Section 5.4 below). One disadvantage of this approach is that scales do not have an intuitive interpretation, limiting the ability to readily communicate the meaning of various investment levels.

Analyze the Relationship between Investment and Reliability Performance

The key step in this analysis is to build a performance curve that demonstrates the relationship between investment in operations and management and reliability performance. Unlike some other performance areas, there are no established management systems to estimate system performance of management and operations programs. However, the tools and techniques described here and in more detail in the associated *Technical Reference* can help to develop estimates of system performance. Generally speaking, the methods available to do this build up from individual projects or from corridor analyses. A range of methods could be used, but three potential types are described using examples from case studies conducted for this *Guide*:

- Aggregate project benefits and costs to the system level. This is the method used by the Knoxville TPO, described in detail in Chapter 4.
- Aggregate to the system level based on an analysis of representative corridors. See Detroit MPO example below.
- Estimate the expected benefits of operations investments based on the exposure of the system to reliability challenges and national and State or regional estimates of expected performance. See Georgia DOT example below.

Estimate Program Level Performance for Other Funding Programs

To consider investments at the program level, it is necessary to define the other program areas that an operations program would be compared against and to establish complementary measures for these programs. For example, there are well-developed tools for bridge, pavement, and general capacity adding programs. There are also proprietary tools (pavement management systems, travel demand models, and other tools) that may be helpful for estimating performance at the program level. There are a variety of Federal and AASHTO tools that can also produce this information, including the Pontis Bridge Management System and the National Bridge Investment Analysis System (NBIAS), the Highway Economic Requirements System – State Version (HERS-ST), and others. If these tools are not available, follow a similar process to that described in this chapter to develop performance versus cost curves for other programs.

Present Scenarios to Decision Makers

The final step is to combine the analysis results from several program areas into scenarios for decision makers. These scenarios should relate to agency policy statements and directly address key decisions. Example scenarios may be program focused (e.g., preservation or safety first), based on public and stakeholder input, or follow historic spending patterns. These scenarios can then be presented to decision makers and the resulting performance reviewed. Ideally, decision makers will be able to examine the implications of shifting funding across various program areas.

Examples of Using Reliability Performance Measures to Support Program Trade-offs

Detroit MPO Analysis of Typical Corridors to Estimate Reliability System Performance

The Detroit MPO, the Southeast Michigan Council of Governments (SEMCOG), wanted to incorporate reliability into their existing process for assessing the effectiveness of investment strategies on regional transportation benefits. Previously, this analysis examined hours of recurring delay per VMT. SEMCOG incorporated reliability by estimating non-recurring hours of congestion delay in addition to typical recurring hours of congestion delay. With limited resources and time to invest in the analysis, SEMCOG decided to apply sketch planning methods to estimate total delay in the corridor. They reduced the geographic scope of the analysis by using representative freeway corridors with operational characteristics (e.g., average traffic volume, interchange density, directional flows and surrounding land use) that are generally representative of other corridors throughout the Detroit region. The representative corridors included: 1) an urban radial (Interstate 96); 2) a suburban radial (Interstate 75); and 3) a suburban beltway (Interstate 275).

SEMCOG developed a region-wide analysis by identifying the representative corridor's percent of regional VMT. Based on historical traffic data, SEMCOG determined that urban radials carry 37 percent of regional VMT, suburban radials carry 30 percent of regional VMT, and suburban beltways carry 33 percent of regional VMT. SEMCOG used the delay rate from the representative corridors as a proxy for delay on all other similar corridors in the region.

SEMCOG's regional travel demand model provided input data on a link by link basis, including peak period volumes, capacities, number of lanes, VMT, and speeds (congested and posted). Link data were averaged across the representative corridors, while free flow and congested travel times were estimated by dividing the link lengths by the compiled travel speeds. SEMCOG calculated future recurring and nonrecurring delay and estimated the benefits of a set of strategies using the sketch planning methods described in the *Technical Reference*. Table 5-1 shows the base conditions and the future conditions with strategies implemented.

To estimate regional benefits, SEMCOG extrapolated the benefits of the study corridor to representative corridors and then to the region as a whole. This allowed them to develop an improved performance curve that compared funding levels to reliability performance in conjunction with average travel time performance.

Table 5-1 SEMCOG Forecasts of Reliability Performance Measures

Segment	Speed (MPH)	Travel Rate (Hours/Mile)	Recurring Delay (Hours)	Incident Delay (Hours)	Equivalent Delay (Hours/1000 VMT)	Equivalent Delay (Hours)
3.0 Baseline Speed and Delay Estimates						
Urban Radial	52	0.0192	0.0010	0.0012	4.06	99
Suburban Radial	45	0.0222	0.0040	0.0010	8.48	101
Suburban Beltway	52	0.0192	0.0025	0.0024	8.36	177
Improved Speed and Delay Estimates						
Urban Radial	54	0.0185	0.0003	0.0008	2.05	50
Suburban Radial	52	0.0192	0.0010	0.0006	3.06	36
Suburban Beltway	55	0.0182	0.0015	0.0002	5.37	114

Georgia DOT Estimate of System Level Operations Benefits Using FHWA Operations Benefit/Cost Desk Reference

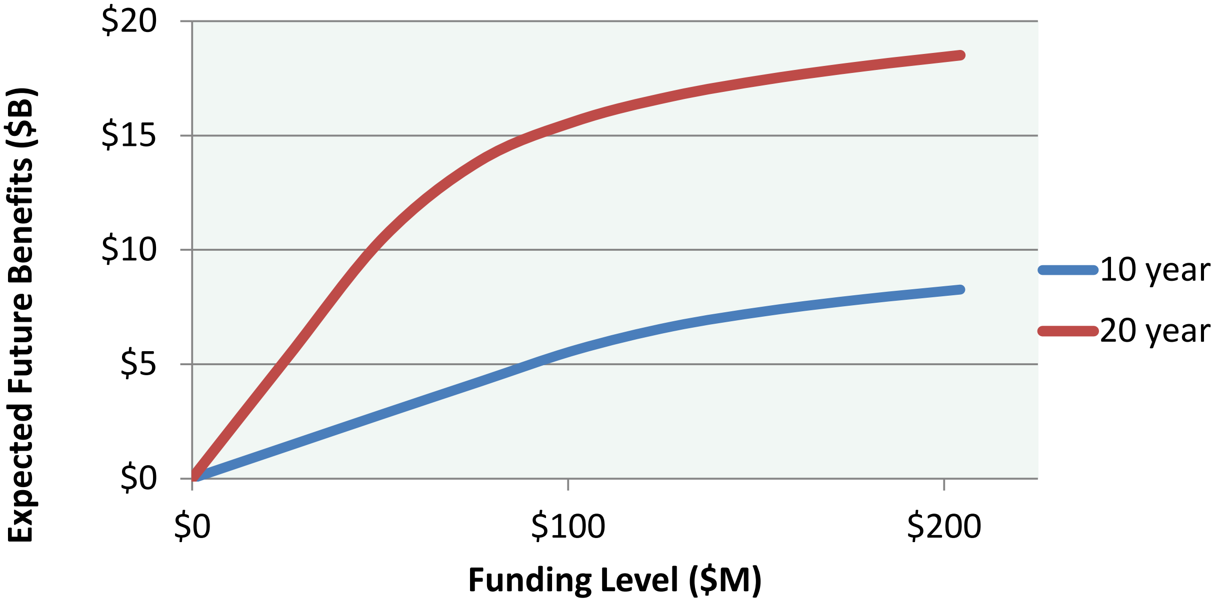
The Georgia DOT has examined the role that a performance-based approach can play in supporting investment decision making. Like many agencies, GDOT has traditionally relied on expertise in each of its program areas and guidance from decision makers to put together the program of projects. More recently, GDOT has attempted to develop a tradeoff analysis tool that can be used to illustrate major investment choices across program areas.

The GDOT tool includes five program areas – pavement, bridge, safety, capacity, and operations. For each of these program areas, GDOT estimated a performance curve that showed the relationship between investment and performance. These curves were developed based on a variety of State and national tools, including a State specific pavement management system (GPAMS), FHWA's National Bridge Investment Analysis System (NBIAS), a State project prioritization tool to examine capacity investments, and detailed analysis conducted by GDOT on operations and safety investments.

For operations, GDOT used the methods developed for the FHWA Operations Benefit/Cost Desk Reference, in combination with locally specific data, to estimate expected benefits from different levels of deployment of three types of strategies – ramp metering, incident response, and signal timing and coordination. GDOT has been actively pursuing strategies in each of these three areas and has been conducting detailed analysis of the effectiveness of these strategies, especially signal coordination. GDOT, along with its regional and local partners, has invested significant resources in developing coordinated and centrally controlled signal timing along most of the significantly congested arterials in the Atlanta metropolitan area.

The resulting outputs by year were aggregated across the three strategies. They are presented in Figure 5-2 for 10 year and 20 year intervals.

Figure 5-2 GDOT Estimate of the Relationship between Operations Investment and Future Reliability



More information on implementing this approach can be found at: http://www.ops.fhwa.dot.gov/publications/fhwahop12028/index.htm.

Arizona DOT Uses Open Discourse to Set Funding Levels

In their LRP, the Arizona DOT distributed funding to programs using stakeholder feedback through committee meetings. Based on feedback, they split funding across programs as follows: 10 percent on non-highway, 27 percent on highway expansion, 34 percent on highway preservation, and 29 percent on highway modernization (*1*).

Set Reliability (and Other) Targets

As decision makers review the expected performance benefits, they can set targets based on the final scenario selected. Typically, targets take the form of having a certain percent of the network achieve a certain level of performance by a certain year. For example, a reliability target might read "90 percent of urban arterials will have a "good" planning-time index by 2030." NCHRP Report 666, *Target-Setting Methods and Data Management to Support performance-based Resource Allocation by Transportation Agencies*, describes methods that managers of State DOTs and other agencies can use for setting performance targets to achieve multiple objectives and interact with multiple decision-makers and stakeholder groups(2).

5.3 How to Use Reliability Measures to Support Project Prioritization

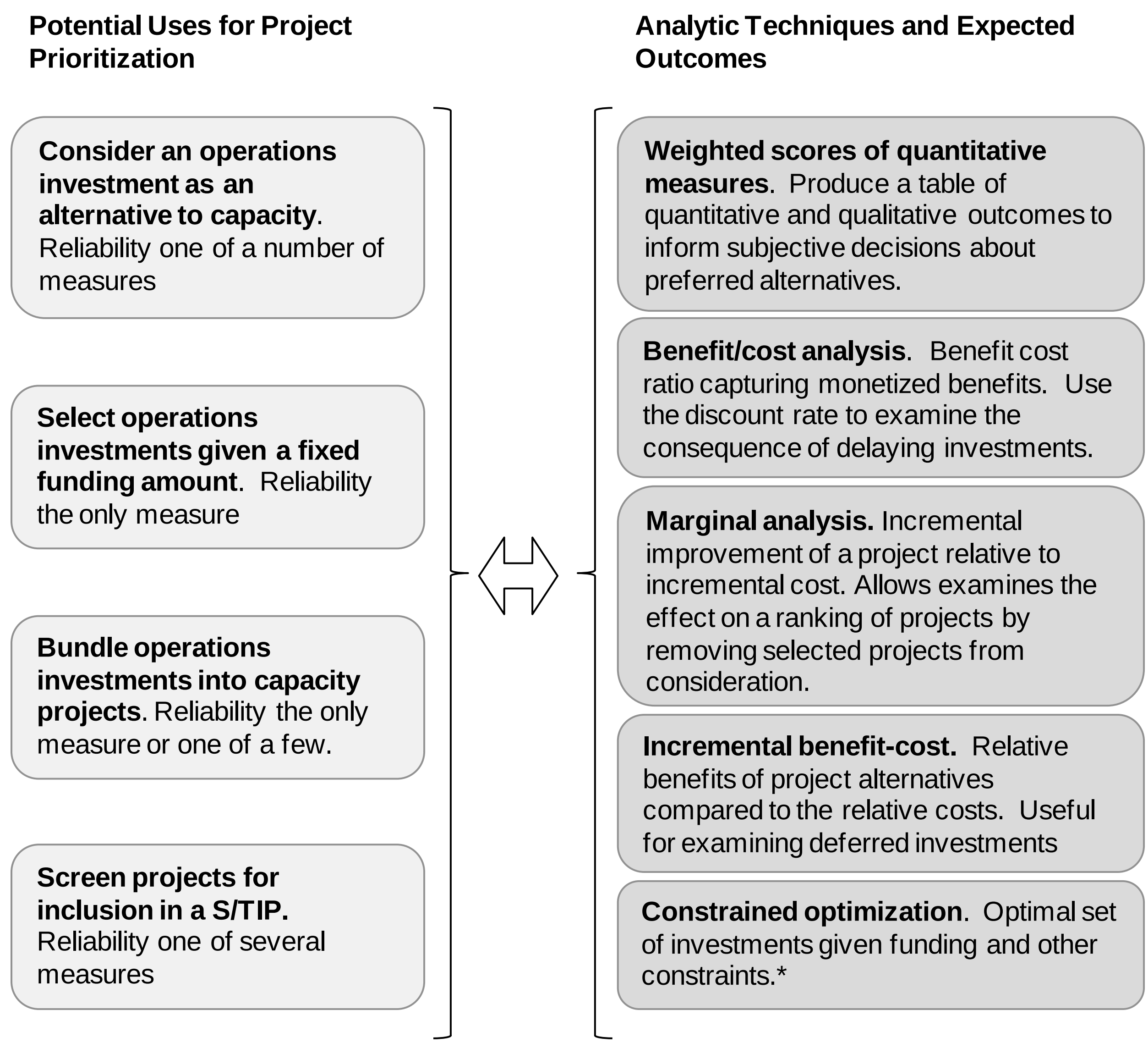
For both the one-step and two-step performance-based planning and programming approaches, project prioritization supports the identification of priority investments that are presented to decision makers. In the one-step approach, all or many types of projects are combined for prioritization. In the two-step approach, projects have already been separated into buckets and a decision or guidance may be available about the total funding available for each bucket. This *Guide* provides several specific examples of how to apply analysis approaches, but they are a subset of a more general set of uses of analytic methods for ranking and prioritizing projects. Figure 5.3 presents a summary of some of the likely key uses and how they relate to a corresponding set of potential analysis methods, including those that examine unconstrained and constrained funding amounts.

Prioritization of Operations and Management Investments in Isolation

The simplest application of reliability performance measures within project prioritization is to prioritize projects for a single program. If program funding levels have been established, projects can be prioritized within these funding buckets using one or more measures. For the purposes of this *Guide*, agencies will likely be most interested in prioritizing operations and management projects using reliability, but other investment types such as capacity expansion and safety may also consider reliability.

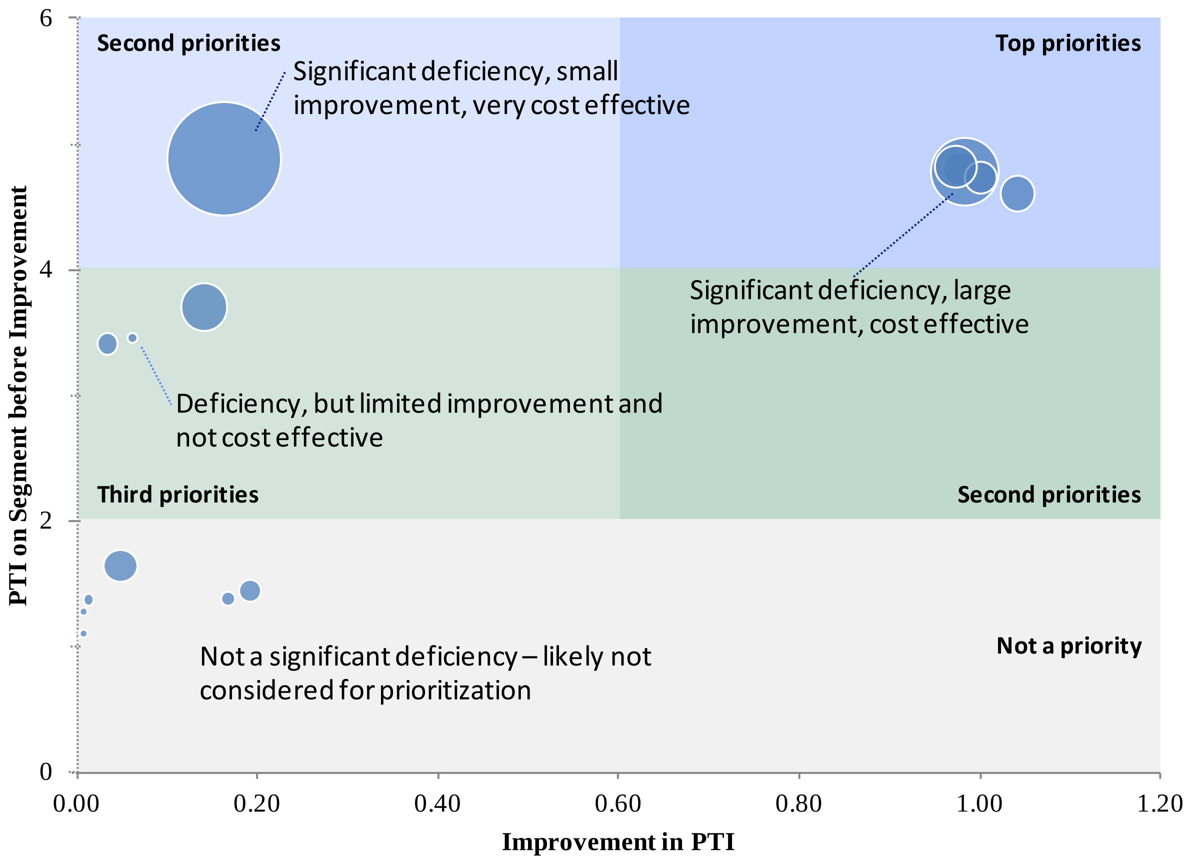
Projects can be prioritized simply, using a single measure such as improvement in the PTI or cost effectiveness (cost per unit of improvement). Projects can also be prioritized using multiple factors. Figure 5-4 presents an example framework for prioritizing projects in Knoxville, based on the data presented in Chapter 4. The chart shows the existing PTI (the deficiency), the expected improvement in PTI (the benefit), and the cost effectiveness of the investment (based on cost, benefit, and vehicle miles of travel). Projects in the top right of the figure (darker blue area) are likely to be prioritized first, as long as they reach some level of cost effectiveness. Projects at the bottom are in areas that do not have deficiencies and may be excluded from prioritization. In between, projects have lower levels of deficiency and make less of a difference. Among these projects, cost effectiveness is likely to be a primary consideration.

Figure 5.3 Incorporating Operations into the Planning Process – Use Cases and Analytic Techniques



* See NCHRP Report 590, *Multi-Objective Optimization for Bridge Management Systems* for more information on constrained optimization techniques.

Figure 5-4 Example Prioritization Scheme of Knoxville Operations and Management Investments



Note: bubbles are sized relative to the cost effectiveness of the proposed projects

Project Prioritization Using Cost Effectiveness

Many agencies look at cost effectiveness of projects across all or multiple program areas together and include reliability in that calculation to prioritize projects of multiple types. Other agencies use an approach where scores for individual projects are combined into a single project performance score. There are a variety of variations of these approaches that include:

- Qualitatively scoring projects based on data and judgment (i.e., ranking each project from zero for no improvement in reliability, to 5 for a substantial improvement in reliability).
- Estimate a weighted score from multiple performance measures and rank-order the projects from highest to lowest. Similar to the qualitative approach, this approach develops a weighted numerical value for each project. The approach requires estimating multiple performance measures for each project, normalizing scores across projects, and weighting measures to reflect their significance.
- Estimating the cost-effectiveness (/unit of benefit) of projects and rank-ordering them from the highest to the lowest cost-effectiveness. The unit of benefit is typically the weighted

project score. Cost-effectiveness analysis allows for the comparison of projects based on the cost required to purchase a package of performance benefits.

Tools for Estimating Reliability Benefits

Chapter 4 introduced the concept of estimating expected future improvements in reliability at the project or segment level. The ***Technical Reference*** chapters 3, 4, and 5 provide descriptions of tools for estimating the benefits of reliability projects, including:

- **Sketch planning.** These analysis methods provide a quick assessment of reliability (and the impacts of projects affecting reliability) using readily available data as inputs to the analysis.
- **Model post-processing.** These analysis methods apply customized analysis routines to more robust network supply and demand data from regional or State travel demand models to generate specific estimates of travel-time reliability.
- **Simulation.** These methods make use of an advanced traffic simulation model's ability to test and assess likely driver reactions to non-recurring circumstances. Use simulation method if a corridor study, CMP, or operations plan is being developed.
- **Multiresolution/multiscenario modeling.** These approaches integrate several standard analysis tools (e.g., microsimulation and travel demand models) to combine different tools' abilities to assess shorter- and longer-range impacts of various projects on reliability performance.

The FHWA Operations Benefit/Cost Analysis Desk Reference describes in detail the process for estimating the benefits and costs for operations projects. In addition, the project developed a spreadsheet tool that can be used to estimate B/C ratio of many operations projects (http://www.ops.fhwa.dot.gov/publications/fhwahop12028/index.htm). A brochure on the Operations Benefit/Cost Analysis Desk Reference is also available (3).

Estimating Cost Effectiveness

Estimating cost effectiveness requires taking estimates of benefits (in the units used to calculate them), normalizing these across several measures, developing a method to weight performance measures, and then calculating an overall cost effectiveness score. While the *Guide* only provides information specific to estimating reliability performance, a framework of performance measurement has been developed by the SHRP 2 Capacity program that provides useful information for selecting other measures (4).

The steps to estimate overall cost effectiveness include:

- **Normalizing measures**. One simple approach to normalize performance measures is to generate project points that reflect the relative benefits of the best and worst projects.

$$\frac{\boldsymbol{Project\ Effectiveness - Minimum\ Project\ Effectiveness}}{\boldsymbol{Mazimum\ Project\ Effectiveness - Minimum\ Project\ Effectiveness}} = \boldsymbol{Project\ Points}$$

- **Weights**. A simple method to calculate weights is to distribute 100 points among all measures. Distribute points based on stakeholder feedback, professional judgment, simple pair wise comparisons, or the quantifiable pair wise method called the Analytical Hierarchy Process (AHP) informed by structured stakeholder feedback (5).

- **Estimate cost effectiveness**. To estimate cost-effectiveness, divide the current year costs by current year reliability measure or project score, depending on how the programs are organized.

$$\frac{\textbf{Project Cost}}{\textbf{Change in Project Score}} = \textbf{Cost Effectiveness}$$

Incorporating Reliability Oriented Strategies into Other Projects

While most of this *Guide* has focused on directly analyzing how investments improve reliability, another approach may be to first identify and prioritize operations and management strategies that address reliability deficiencies, and then incorporate these investment into other projects when those projects become agency priorities. The Minnesota DOT uses this type of approach within the Twin Cities. The 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.

Examples of Prioritizing Projects Using Cost Effectiveness

The Maricopa Association of Governments (MAG), the MPO for the Phoenix metropolitan area, developed a project screening process for its CMP that includes reliability. The tool is intended to evaluate several projects all of the same type. The evaluation factors include:

- **Quantitative Criteria Based on Performance Measures.** The tool includes a CMP Toolbox with a selection of measures, including volume, crash rate, and congestion related measures to assess congestion reduction impacts.
- **Qualitative Criteria Based on Consistency with CMP Objectives.** Consistency with CMP objectives is evaluated qualitatively on a four point scale (1 = no impact, 4 = greatest impact). The CMP includes seven objectives: minimize delay and improve travel time, reduce travel time variability, improve system connectivity, increase alternative mode share, improve level of service/reduce congestion, reduce emissions and fuel consumption, and cost effectiveness. Table 5-2 shows the criteria for the 'reduce travel time variability' objective.
- Project/Mode Specific Criteria. Finally, candidate projects are evaluated based on project or mode specific qualitative criteria. These are a series of yes/no questions that depend on the specific mode and a score of 1 through 4 based on the number yes responses.

Weights for each factor are generated based on committee discussion of the relative importance of each of these factors. Bonus points are awarded if a project addresses more than one strategy type. An example is provided in Figure 5-5.

Table 5-2 MAG CMP Objectives and Evaluation Criteria

CMP Objectives	Evaluation Criteria	Addresses
Reduce Travel Time Variability	Travel Time Reliability (hours of unexpected delay)	Does the project reduce crash risk? Does the project reduce weave/merge conflicts?

Figure 5-5 Example Weighting Based on Quantitative and Qualitative Criteria

	CRITERIA	Weight	PROJECT NUMBER: 1	2	3	4	5	6	7
Quantitative	VOLUME/AADT	25%	2	1	5	3	6	4	7
Quantitative	CONGESTION / LOST PRODUCTIVITY GP	30%	6	1	2	3	4	4	7
Qualitative	CMP OBJECTIVES	25%	2.6	2.1	2.4	2.0	2.3	2.6	2.0
Qualitative	PROJECT/MODE SPECIFIC ASSESSMENT	20%	3.5	3.0	3.0	2.0	3.5	3.0	2.7
	Total Weighted Score:		1.3	1.1	1.2	0.9	1.3	1.2	1.0
	Bonus Points:		1	1	0	1	1	1	1
	Total Score:		4.6	2.7	3.1	3.6	5.0	4.4	5.9
	Rank Order:		3	7	6	5	2	4	1

Prioritize Projects Using Benefit/Cost Analysis

Where possible, agencies often look to benefit/cost analysis to come up with an economic valuation of a project. There are two general approaches to implementing benefit/cost analysis. The simple approach can be used when comparing projects or alternatives where the benefits of various alternatives generally accrue in the same years. This is described below as the **average annual** approach. This is useful for comparing projects with similar deployment and expected lifecycles. A more complex method may be considered if the projects and alternatives under consideration have substantially different expected lifecycles or the benefits or costs vary over the course of the project. This approach requires estimating the **net present value** (NPV) of benefits and costs. This approach is useful for normalizing the benefits received in different years. For example, the NPV approach would be useful for comparing an operations strategy, which could be deployed in the near term and start producing benefits immediately, with a longer term capital project, which may not produce benefits until many years in the future.

Regardless of the approach used, incorporating reliability into benefit/cost analysis requires two basic questions to be addressed:

- **What is the monetary value of reliability?** If a simple average annual approach is used, a future forecast year needs to be predicted where all analyzed alternatives/strategies are predicted to be in place and fully operational to provide for a meaningful comparison. If, on the other hand, the net present value approach is used, benefit/cost analysis is based on the notion that benefits can be valued in monetary terms, allowing for a direct comparison of benefits and costs. For reliability to be used within benefit/cost analysis, it is important to understand its value to travelers. Valuing travel time and delay is typically done through surveys of travelers, often as part of the development and calibration of a travel demand model. Using stated or revealed preferences, agencies can estimate not just how travelers of different types value average travel time, but also how they value reliable 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 (6). In other words, people are willing to pay a little less to avoid the possibility of being stuck in traffic due to a crash than they are to avoid being stuck in traffic due to normal everyday congestion. The U.S. DOT recommends using 18 per person-hour for average travel time for all purposes, in 2009 dollars (7). Based on this, reliability would be valued at 14.40 per person-hour (18 X 0.8 = 14.40).
- **What is the timeframe?** Benefit/cost is conducted over a planning horizon, often 20 years. Many agencies maintain their own procedures for conducting B/C analysis and can use their own timeframe. Otherwise, the time horizon should begin when the first expenditures on the first project begin (i.e., during the planning phase) and extend until the end of the useful life of the longest-lived alternative or at a future point when analysis no longer is meaningful (i.e., discount costs and benefits until they have nearly no value in today's dollars). Note that the longest-lived project within the reliability program will be shorter if the program excludes capacity projects. The timeframe should be the same for benefits and costs.

Using the average annual approach, typically a single year of benefits is estimated that captures an average improvement in reliability and used as an average benefit for the project. These benefits are then multiplied by the value of reliable travel time developed above to estimate the monetary benefit from improving reliability. Costs are simply estimated by amortizing the capital deployment costs across the average useful life of the strategy and then adding in an estimate of annual costs necessary to operate and maintain the deployment. For the average annual approach, the comparison between the average annual benefits and average annual (lifecycle) costs represents the conclusion of the analysis stage and provides the basis for project prioritization.

Because operations and management investments take place on different timeframes and scales than capacity improvements, the net present value approach may be useful to better capture not just average benefits, but the timing of benefits and disadvantages, particularly when comparing operations investments directly with more traditional capital (capacity increasing) projects. There are three distinct benefits to measure when considering reliability projects, listed below. See the ***Technical Reference Chapter 6*** for a step-by-step process for estimating reliability benefits and disadvantages.

- *Construction disadvantages.* Construction work zones are one of the leading causes of unreliable travel, causing 10 percent of total delay. Appendix C.4 of the ***Technical Reference*** describes additional analysis methods for estimating the impacts of work zones.
- *Operations and maintenance.* Ongoing operations and maintenance (O&M) costs of new projects should be considered along with the up-front capital cost of deployment to capture the full lifecycle costs of the project. This is particularly important for operations type projects as they may often experience a greater proportion of their overall costs as continuing O&M costs rather than up-front capital costs, as compared with more capital intensive capacity projects.
- *Project benefits.* For estimating reliability, it is important to estimate benefits carefully to properly value reliability for the B/C analysis. For benefit cost, agencies should measure the actual amount of unreliable travel time for valuing reliability. The current best-practice for estimating the amount of unreliable travel time is to estimate the difference between the 80^{th} percentile and 50^{th} percentile travel time

Once benefits are estimated, standard procedures for estimating net present value should be followed, including:

- **Select a discount rate.** The Office of Management and Budget (OMB) circular A-94 identifies a recommended discount rate that can be used for estimating benefits over time. This value fluctuates due to capital markets, so the OMB resource should be checked for the latest recommended value.
- **Estimate the net present value (NPV) of project costs and benefits.** For each project, estimate project-specific costs and benefits using the roster of costs over the analysis timeframe. Planning and construction costs typically accrue in the early years. Construction reliability disadvantages also accrue in the early years while reliability benefits begin accruing only after construction is complete.
- **Apply the discount rate and estimate the NPV.** Apply the discount rate for each year in the cost stream and sum the discounted costs to calculate the NPV of project costs.

$$NPV\ Costs = \sum_{1=0}^{n} Costs\ in\ Year\ i\ /\ (1 + Discount\ Rate)^{Year\ i}$$

- **Apply the discount rate and estimate the NPV.** Convert project benefits into dollars using the value of reliability. Sum the NPV of the total reliability benefits of the project over its full useful life.

$$NPV\ Benefits = \sum_{1=0}^{n} Benefits\ in\ Year\ i\ /\ (1 + Discount\ Rate)^{Year\ i}$$

Tools for Estimating Benefit/Cost Values for Operations and Reliability

The following tools are available for estimating benefit/cost values for operations and reliability:

- The FHWA Primer on Economic Analysis and the FHWA Operations Benefit-Cost Desk Reference both provide detailed instructions on how to perform benefit-cost analysis. The Operations Benefit-Cost Analysis Desk Reference includes a sketch-planning tool for estimating the benefit-cost ratio of operations projects called the Tool for Operations Benefit/Cost (TOPS-BC). The tool includes a lookup database of likely impacts of various strategies on various MOEs, including reliability. For each strategy and MOE, the tool displays a typical range of benefits. Many of the costs and benefits were derived from the ITS project cost and benefits database maintained by the US DOT ITS Joint Program Office at: http://www.benefitcost.its.dot.gov/.
- The SHRP program produced a white paper on valuing reliability that provides a valuable and detailed description of the ways that researchers have monetized reliability benefits and current trends in the literature. This research suggests that unreliable travel time be valued at about 80 percent the value of average travel time. Ongoing research in this area will help agencies incorporate reliability into benefit/cost analyses.
- Florida is building a B/C analysis tool that will compare the benefits and costs of projects costing more than 50 million. At times, agencies perform basic sketch level B/C analysis on large numbers of projects, but typically this is done with a more limited number of costs and benefits and with estimated using sketch planning tools.

Not All Users Value Time Equally

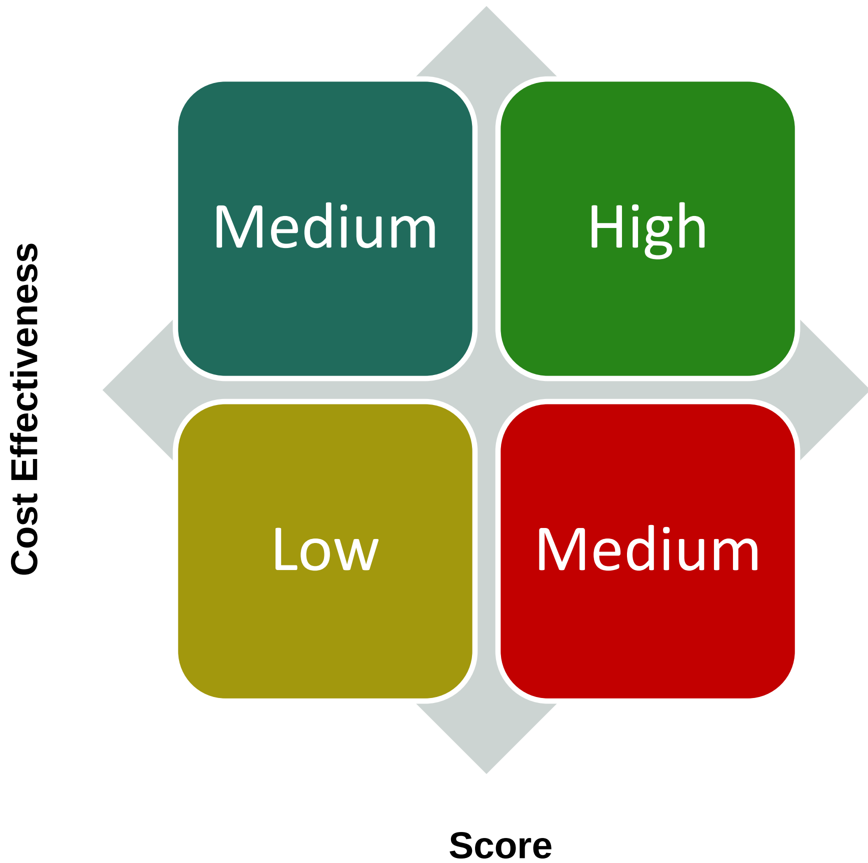
The value of reliability varies by user, time of day, and trip purpose. SHRP 2 Projects C04 and L04 derived an expansive set of values of reliability for combinations of trip type, income, and trip length. In general, the influence of these factors is:

- **Trip Type** – the Reliability Ratio for the trip to work is higher than the trip from work or non-work trips.
- **Income** – for the work trip, lower income groups have a higher Reliability Ratio (presumably because their work schedules are more rigidly fixed by employers).
- **Trip Length** – for the work trip, the Reliability Ratio decreases with trip distance.
- **Studies of How Freight Users Value Reliability Are Not as Plentiful as For Passenger Travel** – Some evidence exists that both the value of reliability and Reliability Ratio is higher than for passenger travel, but these values are highly dependent on the type and value of commodity.

Using a Hybrid Approach

In practice, agencies may wish to combine the above prioritization techniques. For example, combining cost/benefit ratio or cost-effectiveness with an overall project score supports decision-making from both economic and performance-based perspectives. Using multiple pieces of information allows easy organization of projects into tiers based on both dimensions. Figure 5-6 presents this concept graphically.

Figure 5-6 Example of a Hybrid Prioritization Scheme Comparing Cost-Effectiveness and Project Score



High (Tier 1): High benefit/cost ratio, high performance;

Medium (Tier 2): High benefit/cost ratio, mediocre performance OR high performance and mediocre benefit/cost ratio; and

Low (Tier 3): Mediocre performance and mediocre benefit/cost ratio

5.4 Programming and Budgeting

A fundamental assumption of the analysis presented here is that decisions will be based on performance – that better performance at the program and project level will take precedence over worse performance. However, all agencies must also take into account the funding constraints they face, particularly from specific funding sources. This is an especially significant issue for operations investments, because most Federal funding sources cannot be used on operations and some State's gas tax revenues are also similarly proscribed.

The consolidation and reorganization of Federal programs under MAP-21 may have implications for how funding can be used to support operations. But more fundamentally, it may encourage agencies to focus on identifying the investments that will improve performance and then figure out how various Federal, State, and other funding sources can most efficiently support those investments. This approach helps ensure that programming and budgeting decisions yield the best performance achievable given available resources.

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6.0 Conclusion

Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes provides guidance on how agencies can plan and make investment decisions that address fluctuations in travel time that result from variations in demand, incidents, weather, special events, and other factors. These fluctuations in travel time define the reliability of the system – the ability of its users to predict the amount of time it takes to make a trip or make a delivery.

Addressing reliability requires first understanding the locations and sources of travel time variability. This typically requires a significant amount of travel time data and, ideally, information about related conditions – incidents, weather, etc. SHRP 2 L02 provides guidance on developing a travel time reliability monitoring system that can help agencies identify the data needed to *measure* system reliability, as well as approaches to organizing and managing those data to help *understand* system reliability. Developing an understanding of reliability provides a foundation to using reliability within the planning and programming process. There are three key aspects of the planning process addressed in the *Guide*, including:

- Defining policy statements. Based on travel time and other data and stakeholder input, agencies can identify how reliability should be addressed among other agency goals and objectives.
- Estimate needs and deficiencies. Having established reliability as a priority, understanding needs requires setting threshold levels for acceptable and unacceptable system reliability (i.e., defining good, fair, and poor reliability) and estimating system needs. Needs can be defined by examining individual potential investments or categories of investments. Both performance-based and economic analysis approaches can be used, potentially in combination. Defining needs and deficiencies helps agencies understand the scope of their reliability challenges.
- Supporting investment decisions. Building on the understanding of system needs, agencies must determine how they are going to fund investments in operations and management programs relative to other program areas. Then agencies can use this information to help prioritize projects, either within or across program areas. Supporting decision making requires a performance-based approach and analytic tools that agencies can use to both estimate and forecast reliability performance and the impact of investment strategies on future performance. Traditional planning tools, such as four-step travel demand models, are not well suited to address reliability because they produce static estimates of travel times. The SHRP 2 Reliability program has developed a set of both sketch planning and more sophisticated methods to help agencies either use the tools they have or develop new tools to forecast future reliability.

Significant detail on the tools and methods can be found in the accompanying ***Technical Reference***, ***Case Study Technical Memorandum***, and ***Final Report.*** The *Technical Reference* provides up to date information on these tools and methods, but given the evolving state of the practice, emerging methods will continue to evolve, requiring revisiting these issues over the next 5 to 10 years. As agencies update their tools, they will be better positioned to tackle the reliability of the transportation system.