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Data Capture for Performance and Mobility Measures Reference Manual

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16. Abstract
The Guide to Transportation Management Center (TMC) Data Capture for Performance and Mobility Measures is a two-volume document consisting of a summary Guidebook and this Reference Manual. These documents provide technical guidance and recommended practices regarding concepts, methods, techniques, and procedures for collecting, analyzing, and archiving TMC operations data to develop measures of roadway and TMC performance, as well as documenting the benefits of TMC activities for a variety of stakeholders. This guide is designed to be used by TMC technical and management staff involved in developing, implementing, and/or refining a TMC performance monitoring program.

Effective performance monitoring efforts can assist the user in a variety of tasks including traffic performance monitoring, asset management, evaluation of TMC activities and strategies, and planning and decision-making. They can also provide persuasive data in support of continued or enhanced TMC programs; conversely, a lack of available data regarding the value of TMC programs can make agencies more vulnerable to budget reductions when resources are constrained and the remaining budgets are being allocated.

The contents of this guide are based on a literature survey, a survey of TMC Pooled-Fund Study (PFS) members, follow-up interviews, and the project study team's experience and judgment. The study team began with a literature survey of publications regarding TMC data, performance data, performance measures, performance analysis, and reporting. Next, a survey of the PFS members was performed to gain an understanding of the current state of the practice and to determine PFS member needs. The team conducted follow-up discussions with members as needed and then selected a core set of performance measures that would form the basis for this guide.

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Executive Summary

The Guide to Transportation Management Center (TMC) Data Capture for Performance and Mobility Measures is a two-volume document consisting of a summary Guidebook and a Reference Manual. These documents provide technical guidance and recommended practices regarding concepts, methods, techniques, and procedures for collecting, analyzing, and archiving TMC operations data to develop measures of roadway and TMC performance, as well as documenting the benefits of TMC activities for a variety of stakeholders. This guide is designed to be used by TMC technical and management staff involved in developing, implementing, and/or refining a TMC performance monitoring program.

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How to Use This Guide

The *Guide to TMC Data Capture for Performance and Mobility Measures* consists of two parts: The summary *Guidebook* and the more detailed *Reference Manual*. The *Guidebook* provides an overview of TMC performance monitoring guidelines, measures, and issues, with a focus on the “what” and the “why” (i.e., what are the primary metrics that TMCs should consider for their performance and mobility monitoring programs, and why should they be used?). The *Reference Manual* includes details on the “how” (i.e., how does a TMC implement a monitoring program using a given performance metric?). The *Reference Manual* also expands on the discussion in the *Guidebook* and provides a convenient synopsis of each performance measure (or group of related performance measures), including an overview of the measure’s usefulness, required data sources, primary calculation steps or equations, useful variations of the measure, issues or implementation considerations associated with the use of that measure, and example applications from TMCs around the country.

Readers are advised to begin with the summary *Guidebook*, which provides an overview of the core performance metrics that are the focus of this project, and make note of specific measures that are considered relevant and useful for the reader’s TMC. Then, the reader can use the *Reference Manual* to look up expanded discussions of the metrics of interest.

Many TMCs do not have responsibilities in all the functional areas described in this guide. A particular TMC may therefore choose to focus on selected performance measures so that its performance reports reflect the specific activities undertaken by that TMC. **TMCs are not expected to measure performance in areas in which they do not have functional responsibilities.** In those cases, performance reporting can be left to others until or unless those functions become a specific area of responsibility for that TMC.

How This Guide Is Organized

Both the *Guidebook* and the *Reference Manual* are organized around four basic categories of performance measures, each associated with a set of functions that are frequently performed by a TMC. Many TMCs do not have responsibilities in all four areas, and should only report performance in those areas for which they are responsible. The four categories of performance measures are—

1. **TMC Operations Measures.** TMC operations performance measures focus on statistics regarding TMC operations activities and assets, including number of devices, geographic coverage, level of usage of TMC equipment and services, operational status, staff performance and retention, special events response activities, etc.
2. **Incident Response Measures.** Incident response performance measures include traffic incident statistics (e.g., location, number, type, severity), incident event times (e.g., times of incident events ranging from incident occurrence to full roadway clearance), and statistics associated with the activities of safety service patrols and other incident responders and services.
3. **System Mobility Measures.** System mobility performance measures describe how many people and vehicles are using the system, and the delays—or lack of delay—those users are experiencing. Mobility is analyzed within the context of system usage (background traffic volumes), disruptions to the roadway network (e.g., crashes, debris, weather, special events), and TMC responses to roadway conditions (e.g., traffic control plans, incident response activities, traveler information systems).
4. **Cross-Cutting Measures.** Cross-cutting measures are metrics that combine data from two or more of the other three performance measurement categories described in this guide, sometimes in combination with other external data sets, to measure the effects of specific TMC programs and strategies on traveler mobility, and track the public's perception of those programs. Cross-cutting metrics help TMCs judge the effectiveness of TMC activities (based on changes in mobility), and are particularly useful and necessary if decision makers request numerical benefits resulting from TMC activities.

This guide is designed to address the needs of a broad range of TMCs that are at different stages in the development of their performance monitoring activities, ranging from those who are planning to establish a monitoring program, to those with well-established monitoring efforts that are looking to enhance their programs. In an effort to meet the needs of a broad range of TMCs of different sizes, with differing areas of functional specialization and varying resource levels, this guide includes performance monitoring metrics of varying complexity and specialization, beginning with *basic measures* that are recommended as a good foundation or starting point for all TMCs with responsibilities in a specific topic area, and provide the basis for more sophisticated monitoring activities in the future. Because these basic measures alone do not always meet the management needs of many TMCs, more advanced supplementary measures are also discussed. These *computed basic measures* extend the basic measures using additional analyses and/or data. *Advanced measures* include specialized metrics that might be relevant for a subset of TMCs with a particular focus (e.g., snow maintenance), and metrics that have additional data requirements or involve more complex methodologies.

There is not always a definitive distinction between basic and advanced measures. We recommend that TMCs new to performance monitoring start by implementing the basic measures, within the limits of their data and staffing resources. TMCs should then begin to incrementally adopt and report selected computed basic or advanced measures that meet their specific needs for managing their operations, meet the reporting requirements of their agency, or respond to information requests from their legislature or other decision makers. Many of the more advanced TMCs have already followed this incremental reporting trend. The evolution from basic to more advanced implementation of performance metrics and reporting often reflects the TMC's evolution from using metrics for basic monitoring activities, to using measures for evaluation of operational and capacity enhancement strategies, and then to actively managing its activities and resources.

Chapter 1. Introduction and Overview

As with all business activities, in order to efficiently manage a TMC it is necessary to collect, analyze and report data that describes the performance of the activities being performed by that center. This report provides guidance to TMC operators in the selection of those performance measures, identifies where the data needed to produce those measures can be obtained, and provides instructions on the steps necessary for converting those data to useful reporting statistics.

The Guide to Transportation Management Center Data Capture for Performance and Mobility Measures is a two-volume document consisting of a summary Guidebook and a Reference Manual. The summary Guidebook provides a broad overview of effective TMC performance measurement to executives and managers of TMCs. It focuses on the “what” and the “why,” that is, what are the primary metrics that TMCs should consider for their performance and mobility monitoring programs, and why those measures should be used.

In contrast, this *Reference Manual* provides details on the “how,” that is, how a TMC implements a monitoring program using a given performance metric or set of performance metrics. This *Reference Manual* expands on the discussions in the *Guidebook* and provides a convenient synopsis of each performance measure (or group of related performance measures), including an overview of the measure’s usefulness, required data sources, primary calculation steps or equations, useful variations of the measure, issues or implementation considerations associated with the use of that measure, and example applications from TMCs around the country.

Readers are advised to begin with the summary *Guidebook*, which provides an overview of the core performance metrics that are the focus of this project, and make note of specific measures that are considered relevant and useful for the reader’s TMC. Then, the reader can use this *Reference Manual* to look up expanded discussions of the metrics of interest.

1.1 Purpose and Objectives

The purpose of this document is to provide guidance to the operators of TMCs that need to improve their ability to compute and report performance measures. Those measures can both be used internally to manage TMC activities and resources, and published externally to inform executives and other decision makers about the activities being performed and the benefits those activities provide to freight shippers and the traveling public.

The *Guidebook* and *Reference Manual* are designed to be useful to TMCs that are just beginning to explore performance measures, to those that have been using performance measures for some time and are looking to compare their activities to those considered state-of-the-practice, and to those somewhere in-between these extremes.

To meet this latter objective, the project team reviewed the available literature, and surveyed TMCs around the country. Based on the data obtained from those activities, the project team developed a set of recommended performance measures for TMCs and an implementation strategy that guides TMCs of different sizes, types, and levels of sophistication to the set of performance measures most appropriate for them, as well as a path to continually enhance those reporting measures as each

TMC's needs call for those enhancements. These measures were then reviewed and approved by the TMC PFS member organizations.

It is important to note that the *TMC Data Capture for Performance and Mobility Measures Guidebook* is not a data collection instruction manual. This *Guidebook* assumes that the TMC is already collecting data from installed devices or other available methods, although it does describe sources of data for those measures for which data are not currently being collected.

1.2 Guidebook Context and Target Users

The summary *Guidebook* should be used as a tool for TMC management and other agency decision makers to gain an overview of TMC performance monitoring guidelines, measures, and issues. It will provide those leaders with an understanding of what the primary metrics are for their TMCs, as well as helping them understand why they should measure the performance of their operations and mobility programs.

This *Reference Manual* should then be used by the staff charged with implementing the performance monitoring and reporting process. It describes the detailed steps and calculations needed to produce the recommended measures.

Given space constraints, the reader should note that not every possible performance measure has been discussed in either the *Guidebook* or this *Reference Manual*. The number of possible performance measures needed to respond to specific questions is immense and their inclusion would have created an overwhelmingly large *Guidebook*. Consequently, only those measures selected by the project team and approved by the TMC PFS Technical Advisory Panel have been included in this *Guide*.

If you have questions about other measures, please consult the literature review references in the Appendices for other sources of information.

1.2.1 Why Do We Measure?

Performance measurement is a tool used to determine how a program or system is functioning over time. The measures reported often compare performance against specific goals and objectives, but can also simply be used to judge the outcome of specific activities being undertaken. The reporting tools used by TMCs often present performance through pictures, graphics, or charts in order to make the data being presented more easily interpreted. Current measures are often compared to a baseline or show historical performance in order to illustrate trends.

TMC performance measures are designed to answer three basic questions: (1) how the transportation system functioning, (2) what activities the TMC is performing as a result of what is happening on the transportation system, and (3) what effect the activities are having on the transportation system's performance. When analyzed in the context of the available resources and expected or desired performance, the answers to these questions can be used to effectively manage the TMCs resources and describe to decision makers the value of the TMC and the activities it performs.

This, in turn, allows TMCs to defend their budgets, justify the implementation of new operational strategies, or discontinue ineffective operational strategies.

1.2.2 What Do We Measure?

This document provides specific guidance for measures that are considered by the TMC Pooled Fund Study participants to be the best practices for TMCs across the country. The specific performance measures that are used at a TMC are a management decision. The measures to be reported are driven by the activities being performed by each TMC, because performance measurement is designed to help manage a TMC, providing information on what is and is not being done well, and whether those activities are affecting transportation system performance. Thus, this guide recommends that TMCs measure and report on the activities they are performing as well as the performance of the transportation system they are operating,

To reflect the differences in TMC responsibilities and activities across the nation, recommended measures are divided into four basic categories:

1. TMC Operations Measures
2. Incident Response Measures
3. System Mobility Measures
4. Cross-Cutting Measures

The first three categories relate to different areas of TMC operations that may be a responsibility of a specific TMC. A TMC should explore the recommended measures in one of these topic areas if they have responsibilities in that area of operations. The last category combines measures from the first three categories to determine how activities being performed by the TMC affect the performance of the transportation system.

Guidance is also provided to help TMCs get started in performance measurement, and then grow the use of those measures to effectively respond to questions and concerns of decision makers.

1.2.3 Goals for TMC Performance Measurement

Performance reporting attempts to answer questions about how the TMC program is working and whether the TMC is meeting the goals and objectives set in its mission statement. Consequently, gathering and reporting performance data should be directly linked to the motivation or goals of the TMC. The most common performance measurement motivations are to respond to legislative mandates and agency-wide performance initiatives. That is, TMC performance measures are designed to answer the question of whether the TMC is meeting the goals set out either by the legislature or by its own agency. Once the motivations are understood, the TMC management and agency decision makers need to tailor data collection and analysis to assist with reporting program outcomes. Reporting typically describes what the TMC is doing, how well the TMC is doing those activities, and what is happening on the roadway as a consequence of those activities. These same performance measures are excellent inputs to more effectively manage the staff and resources at the TMC, as they allow the TMC management to understand what is working and what is not, allowing management to more effectively deploy its limited resources.

These reports also provide justification for, or defense of, TMC activities. Effective reporting of performance measures allows the agency to demonstrate success, justify its programs and help build support for taking the next steps in advancing its programs. This is especially important when agencies are faced with decisions about funding road repairs, new construction, or providing funding for expanded TMC activities such as installing more closed-circuit television (CCTV) cameras, detection devices, or new adaptive signal control and active management systems.

1.2.4 Benefits of Performance Measurements

The TMC management staff benefits from performance measurements in many ways and those benefits change over time. Tracking the TMCs operational activities allows the TMC to report on the geographic and temporal distribution of the benefits its activities support. It also allows a quick response to decision maker questions, such as “What are we getting for our money?”

For example, performance measurement that supports incident response shows how working with the first responder community can quickly identify incidents and dispatch the correct response to the scene to save lives. Performance measures can also be used to “tune” those responses to enhance the effectiveness of the response, especially in the “golden hour,” while also increasing the safety of first responders by reducing the time they are on scene and improving the traffic flow around the incident scene. These same improvements to keep traffic moving also have large time, economic, and safety benefits to the traveling public.

System mobility describes how to report on general roadway performance, that is, the number of road users and the travel times and delays they experience. These measures describe the travel experiences of the public. They set the stage for describing why TMCs are necessary. Reducing delays and improving travel reliability (as well as safety) are the real end products and the reason TMCs exist. Performance reports that describe the mobility of the TMC region set the stage for why TMC activities are being undertaken—or need to be undertaken—as well as describing the ultimate effectiveness of those programs once they are implemented.

The chapter on cross-cutting measures explains how metrics from the previous three chapters can be related or combined. TMC managers and decision makers use these metrics to demonstrate how the actions taken by the TMC benefit the traffic network to reduce emissions, delay, and crashes, and to where new, larger, or different operational approaches need to be undertaken.

1.2.5 Targeted Guidebook Users

The target users for the *Guidebook* and *Reference Manual* are those individuals who operate and are responsible for TMCs in their jurisdictions. The data collection and performance measures noted in these two documents reflect the measures identified by the study team as being the most useful for the broadest audience.

The summary *Guidebook* is intended for managers and executives that need to understand the key aspects of performance measures and specifically how performance measures apply to TMCs. Conversely, this *Reference Manual* is intended for the key staff charged with implementing the performance monitoring system, as it includes the detailed instructions on how to complete the recommended measures.

It is expected that many readers will want to focus on specific chapters based on their duties and functions. The TMC Operations chapter looks at the operation of the TMC itself from a staffing and staff function perspective. The Incident Response chapter discusses measures that are applied to incident response functions, such as incident clearance times, and would be a good chapter for the freeway safety service patrol staff and other first responders to review. The System Mobility chapter provides metrics that give a broader look at the transportation network’s performance and is useful to decision makers when looking for problem areas that need to be addressed in future budget cycles or using alternative solutions. Finally, the Cross-Cutting Measures chapter combines measures from the first three chapters to look at the interplay of TMC activities, and how they ultimately affect transportation network performance. It also examines the public’s perception of the TMC’s activities, a key measure when looking for public support for those activities.

1.3 Research Methodology

The study team utilized the literature review to determine the amount and relevancy of the data and documentation currently available to TMC staff. The *Guidebook* does not attempt to be the only source for this information and the reader should review the documents referenced in the Appendices for additional details about performance measures and measurement.

The next step was to develop an initial list of potential performance measures from the more than 125 measures found in the literature for consideration in the *Guidebook*. This initial information was supplemented by the outcomes of a survey of TMC PFS members that asked about the metrics and measures that those organizations currently use. By combining the findings of these two efforts, the study team was able to select and sort a more limited set of key measures into related groups. The measures in these groups were then organized so that they could be effectively used by all TMCs, regardless of their current level of performance measurement and sophistication.

1.3.1 Literature Review

The study team's literature review confirmed the vast array of written material and information available regarding TMC operations and performance measurement. When reviewing available published material, the team started with the Federal Highway Administration (FHWA) Traffic Incident Management (TIM) website, then the FHWA Office of Operations website, followed by other sources, including the National Cooperative Highway Research Program (NCHRP), Transportation Research Board (TRB), American Association of State Highway and Transportation Officials (AASHTO), and other general web publications (e.g., Texas A&M University's *Urban Mobility Report*).

The literature review highlighted 45 separate references that are applicable to this *Guidebook*. The study team found many more documents in circulation that, while useful, are older and potentially outdated, but can still be useful to people exploring performance measurement of transportation systems. These smaller or outdated reports have not been included in the list of documents in the literature review for brevity.

The 45 highlighted documents were categorized into the following groups:

- Performance Monitoring Efforts
- Performing Data Integration
- Improving Data Quality
- Project / Program Evaluation
- Lessons Learned
- Project / Program Descriptions
- Other Guidebooks.

The study team reviewed the literature, analyzed the documents based on timeliness and usefulness, developed the preliminary list of TMC performance measures, and used the findings from that review, along with the results of the TMC panel survey and the project team's own professional experiences, to develop the recommended list of TMC performance measures. However, because the literature is so vast, these reports may be of interest to readers of this *Guide*. As a result, the Appendices contain a list of the primary documents reviewed for this project. Interested readers are encouraged to read documents in the Appendices that deal with their specific interest areas.

1.3.2 Synthesis / Overview

The amount and type of performance measurements currently in use today are based on three levels of TMC development. There are those that are very experienced with performance monitoring. That is, these agencies sit on “the bleeding edge” of performance measurement. Other agencies are just getting started with performance monitoring, while many TMCs are somewhere in the middle. Each of these groups has different current abilities and consequently different needs. Because of this wide range of TMC performance measurement skills and abilities, it was determined that this *Guidebook* needed to be written so that it could be used across a wide spectrum of TMC experience levels.

The literature also pointed out that it is important to remember why TMCs are reporting performance measures, as different TMCs approach performance measurement for different reasons. Some are responding to legislative mandates. Others are responding to larger agency-wide performance initiatives. Still others are using performance measures as part of business process reviews—particularly for operations (i.e., using data on equipment or staff performance to more effectively make business and resource allocation decisions). Others are using performance reporting to improve agency cooperation with other agencies, or to review and improve employee activities. Some agencies are using these measures to assist with planning future investments or changes in resource allocation.

Once the motivation for the reporting is understood, the reporting metrics need to be developed, whether these are designed to meet specific management needs or to quantify the general benefits of TMCs in order to assist in defense of program funding or assist in competition for additional funding with infrastructure projects.

In general, performance reporting attempts to answer the following questions:

- What we are doing?
- How well we are doing those activities?
- What is happening on the roadway?
- How do the things we do affect what is happening on the roadway?

In order to answer these performance questions some basic data need to be collected and then usefully summarized. For example, data are needed that—

- Describe activities occurring or being performed (e.g., number of incidents responded to by size of incident or number of messages posted by staff)
- Track the size and operational condition of equipment and staff
- Provide detailed quantification of activities being performed (e.g., detailed incident descriptions that allow for trend reporting, including data such as incident types, timestamps, and actions taken)
- Monitor volumes of vehicles on the road, the travel times and delays those vehicles experience, and the reliability of those travel times
- Identify the location and timing of congestion
- Determine revenue (high occupancy/toll [HOT] lanes) being collected
- Track and quantify the occurrence of severe weather and the agency response to those weather patterns.

As performance measurement advances, these and other basic data items are then converted to more informative metrics that examine the cause-and-effect relationships between these variables. This expanded view of TMC performance can then be used to effectively direct the resources of the TMC so that the public gains the most benefit from the TMC’s activities.

1.4 Organization of the Report

The Guide to Transportation Management Center Data Capture for Performance and Mobility Measures is a two-volume document consisting of a summary Guidebook and this Reference Manual. The summary Guidebook provides an overview of TMC performance monitoring guidelines, measures, and issues, with a focus on the “what” and the “why.” The Reference Manual includes details on how a TMC would implement a given performance metric. The Reference Manual expands on the discussion in the Guidebook and provides a synopsis of each performance measure (or group of related performance measures.)

Both the *Guidebook* and the *Reference Manual* are organized around four basic categories of performance measures, each associated with a set of functions that are frequently performed by a TMC. Many TMCs do not have responsibilities in all four areas, and should only report performance in those areas for which they are responsible. The four categories of performance measures are—

1. **TMC Operations.** TMC operations performance measures focus on statistics regarding TMC operations activities and assets, including number of devices, geographic coverage, level of usage of TMC equipment and services, operational status, and staff performance and retention, special events response activities.
2. **Incident Response.** Incident response performance measures include traffic incident statistics (e.g., location, number, type, severity), incident event times (e.g., times of incident events ranging from incident occurrence to full roadway clearance), and statistics associated with the activities of safety service patrols and other incident responders and services.
3. **System Mobility.** System mobility performance measures describe how many people and vehicles are using the system, and the delays—or lack of delay—those users are experiencing. Mobility is analyzed within the context of system usage (background traffic volumes), disruptions to the roadway network (crashes, debris, weather, special events, etc.), and TMC responses to roadway conditions (e.g., traffic control plans, incident response activities, traveler information systems).
4. **Cross-Cutting Measures.** Cross-cutting measures are metrics that combine data from two or more of the other three performance measurement categories described in this guide, sometimes in combination with other external data sets, to measure the effects of specific TMC programs and strategies on traveler mobility, and track the public’s perception of those programs. Cross-cutting metrics help TMCs judge the effectiveness of TMC activities (based on changes in mobility), and are particularly useful and necessary if decision makers request numerical benefits resulting from TMC activities.

Within each of these four categories, a variety of performance measures are recommended. In addition, the recommended measures are organized in subsections that allow for better clarity in understanding the measures and how they are used. To meet the different needs of TMCs of different sizes and levels of sophistication, the recommended performance measures start with *basic measures* that are recommended as a good starting point for all TMCs. Because these basic measures alone do not meet the reporting needs of many TMCs, more advanced supplementary measures are also discussed. These *computed basic measures* extend the basic measures using additional analyses and/or data. *Advanced measures* are then provided to meet the remaining performance monitoring needs relevant for a subset of TMCs with a particular focus (e.g., snow maintenance), or that require additional data or complex methodologies.

There is no definitive line between *basic* and more *advanced* measures. We expect that TMCs new to performance monitoring will start with the basic measures, and then slowly adopt and report more advanced measures in response to their own needs to manage their resources, meet the reporting requirements of their agency, or respond to information requests from their legislature or other political funding source. Many of the larger, more sophisticated TMCs have already followed this reporting trend.

The *Reference Manual* is set up so readers do not have to read the entire document in order to find what they are looking for. The chapters are developed to be read relatively stand alone. Some factors related to data and data collection are common to all chapters (such as speed or volume data collection using a collection device), so the discussion has been reduced to keep the document's overall size at a manageable level for readers.

Readers should look at the chapter titles to determine where they should look for additional information. Chapter 2 discusses TMC measures typically associated with internal items such as devices and staffing. Chapter 3 discusses external coordination issues typically associated with how TMCs work in the incident response arena and with external stakeholders. Chapter 4 looks at system level performance and how TMCs play a role in system managements. Chapter 5 discusses items considered to be cross-cutting or applicable to multiple topic areas. Finally, the appendices are provided as an excellent set of references if readers are interested in greater detail than can be provided in this document about specific aspects of measures such as specific data quality checks for data items being collected.

1.5 References

The Appendices include references from the literature search, including the bibliography.

Chapter 2. TMC Operations Performance Measures

This section summarizes the findings and recommendations developed throughout the study effort for TMC operations performance measures. It identifies which TMC operations performance measurement and reporting techniques best support the goals and objectives of the *Guidebook*.

2.1 Purpose and Need – TMC Operations Performance Measures

TMC operations performance measures generally measure the TMC's ability to meet goals and objectives related to performing its key functions of monitoring, operating, and maintaining traffic management and traveler information systems. The results of performance monitoring should feed into decision making processes to determine how selected strategies compare to other investments and to continuously improve agency operations. Performance measures are also needed to determine how effectively the TMC is performing in relation to historical norms. Routine and continued performance monitoring helps the agency identify and resolve problems quickly, limiting the impact and exposure to the public, which in turn improves public perception of the agency and places it in a better position to receive funding than if the agency did not track performance.

Performance monitoring and reporting will also lead to the identification of TMC operations or operational procedure deficiencies that can be addressed to improve TMC efficiency and optimize performance. For instance, after TMC operational procedures are implemented, they should be monitored at periodic intervals and adjusted, as necessary, for optimal performance. In addition, at these periodic intervals, the performance of the TMC can be reported to the public and local decision makers to provide clear accountability for how public funding is being used and to what extent benefits are being observed.

2.1.1 General Discussion of TMC Operations Performance Measures

The basic performance measures that describe TMC operational activities are divided into four sub-categories:

1. Intelligent Transportation Systems (ITS) Infrastructure and Traveler Information Services
2. TMC Operational Responsibilities
3. TMC Staff Performance
4. Specialized Operations.

2.1.2 Process for Selecting and Prioritizing TMC Operations Performance Measures

Prioritizing the development and publication of TMC operations performance measures is straightforward. The *Guidebook* recommends that TMCs start by publishing operations performance measures that are based on data they are currently collecting and have confidence in. When reporting operations measures, it is important that consideration be given to the goals and objectives of the individual agency.

2.2 Selected TMC Operations Performance Measures

This section describes the selected TMC Operations performance measures in detail.

2.2.1 ITS Infrastructure and Traveler Information Services Performance Measures

Freeway management systems are typically planned, designed, deployed, operated, and maintained with public funding. To this extent, it is the responsibility of the TMC to demonstrate its value and performance to be perceived as a critical entity/function worth allocating scarce public funds.

The basic “infrastructure coverage measures” are designed to describe the size of the infrastructure associated with the TMC. Reporting changes in these measures over time allows the TMC to describe how public funds are being used to expand the area covered by the TMC or, for example, how sensor density is being increased. In turn, this information can be used to demonstrate the effectiveness of potential/new ITS investment in addressing transportation needs and issues.

“Infrastructure performance measures,” on the other hand, are designed to describe the actual performance of the devices and services. These measures are part of a good asset management program and are designed to describe whether the equipment installed as a result of capital expenditures is operating as intended. They also describe whether the staff performance, given the available maintenance budget, is adequate to maintain the sensor/device/equipment purchase(s) that are installed in support of the TMC’s activities.

ITS Equipment – Number of Devices

By itself, the number of devices metric serves as a means to show what transportation agencies and TMCs are doing to fight congestion, improve safety and provide information to the motoring public. It is also used to track the growth of the system and individual types of devices over time. This provides a clear understanding of the pace of system growth and how its individual components have evolved over time. Figure 2-1 illustrates an example from the *Wisconsin Department of Transportation (WisDOT) Statewide Traffic Operations Center (STOC) 2011 Performance Measures Report* that summarizes the number of ITS devices at the end of the year and the percent expansion over the course of the year.

Figure 2-1: Field Equipment Summary

FIELD EQUIPMENT	CAMERAS	DETECTORS	DMS	PCMS	HAR	RAMP METERS
Devices as of Dec. 31, 2011	210	247	62	195	13	141
Percent Expansion	11%	7%	17%	10%	0%	2%

Source: WisDOT STOC 2011 Performance Measures Report

This metric can be presented in tandem with a host of other metrics, such as annual system funding and number of total incidents, to justify and advocate for additional funding for continued operations and maintenance or to demonstrate return on investment, respectively. For instance, if the agency reports that the number of devices under the center's control has grown but staffing levels have not, this may persuade upper management and elected officials to allocate funding streams to hire additional staff or to procure additional resources. To help upper management and decision makers, the agency can use this metric to quickly and accurately respond to funding requests when prompted to do so.

ITS Equipment – Coverage

In terms of performance measurement, the greater the coverage and data availability, the greater the understanding of impacts and conditions that are occurring throughout the network. In recent years, the extent by which data are becoming available has been increasing providing agencies the ability to better assess performance. Historically, coverage was limited to certain limited access facilities or defined corridors, requiring a separate detailed analysis to interpret performance on facilities where data wasn't available.

The coverage metric not only allows the agency to internally gauge the extent by which it can accurately assess performance of its facilities and devices, it also allows the agency to show accountability to upper management, elected officials, and the general public in terms of the actions it is taking to improve regional mobility and operations. It is not uncommon for these groups to inquire about the actions the agency has taken to address congestion, safety, and the overall quality of life of the traveling public. This metric can also provide a historical record of how freeway management systems have grown.

Coverage can be expressed in terms of area (i.e., number of highway miles covered), or in terms of motorists/vehicles receiving a service (i.e., number of motorists that pass by a dynamic message sign). This can help the agency assess the quality of service it is providing to the public and to self-assess where it is in meeting overall service goals. Consideration should be given to the desired level of coverage when establishing this measure. For example, although a TMC is located in a metro area that includes 100 miles of freeway, ITS deployment may only be planned/needed for a percentage of the system. Therefore, it may be more appropriate to report coverage in terms of identified need rather than the entire system.

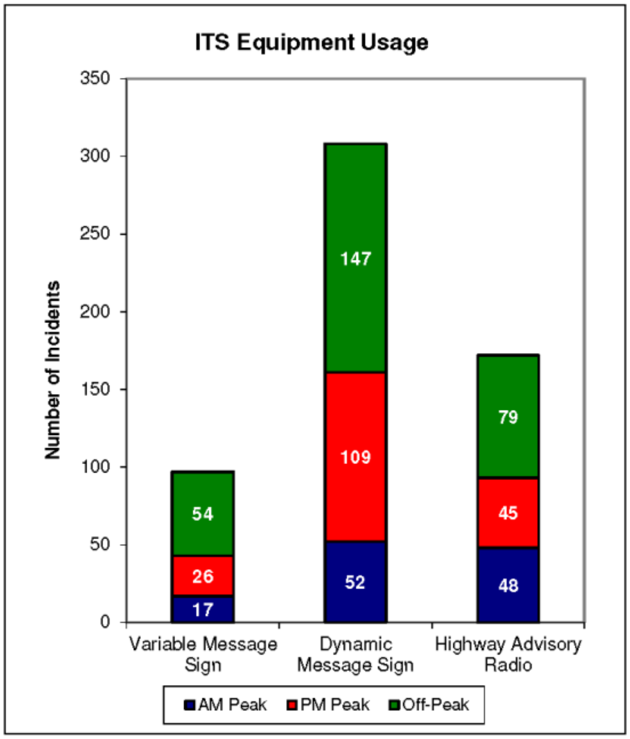
ITS Equipment – Usage

The number of times ITS equipment is used or activated by TMCs summarizes the operational activities of the TMC and provides insight into how the transportation network is performing. The number of messages posted to dynamic (variable) message signs or the number of floodgate messages posted to a 511 system are examples of usage reporting.

Similar to system growth, this metric can also be used to help analyze staff performance and workload. As ITS equipment usage increases, so does the workload of the individual TMC operator. If staffing levels remain steady and usage increases, staff workload should be reviewed and changed if necessary. Other factors to consider are how staff is assigned duties, whether they share the work across the coverage area or have designated zones/areas, as well as how much equipment each person has to utilize.

ITS equipment usage can also be aggregated across a number of secondary characteristics. For instance, monitoring the usage of ITS equipment by time of day may indicate trends related to when incidents occur that necessitate ITS equipment activation. For example, the Rhode Island Department of Transportation (RIDOT) TMC summarizes its ITS equipment usage by peak period in its quarterly reports, as illustrated in Figure 2-2.

Figure 2-2: ITS Equipment Usage



Source: RIDOT TMC Incident Statistics - 4/1/2012 to 6/30/2012

Similarly, activation can be tracked by roadway to determine the roadways where the most/least incidents are occurring. With that understanding, the transportation agency may undertake more regularly scheduled preventative maintenance on devices on more critical corridors where a device failure would be unacceptable. At a minimum, this information can be used to prioritize maintenance activities.

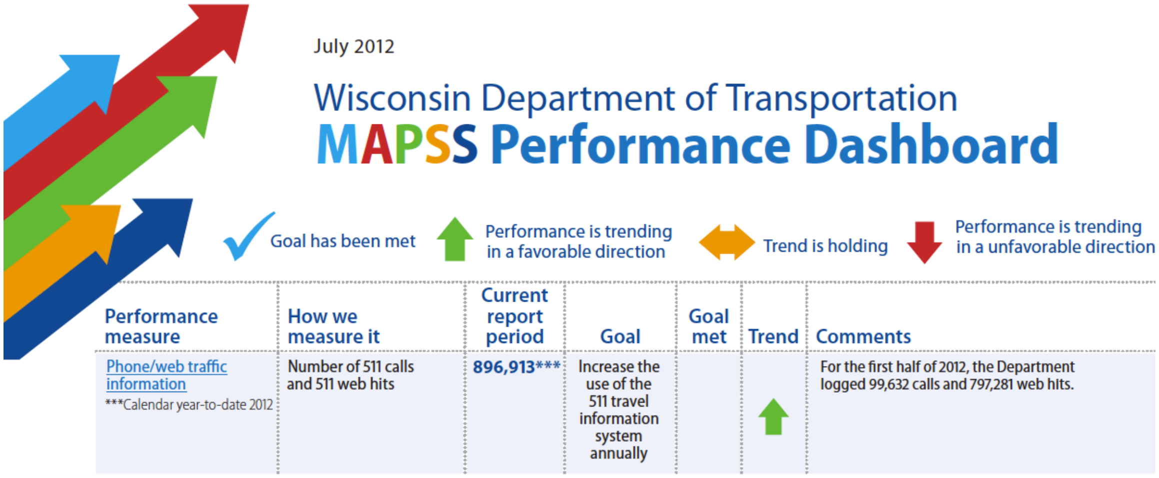
Beyond just tracking how many times a device is used, some TMCs are also recording what type of traveler information was provided. For example, message type categories might include traffic incident, construction, maintenance, adverse weather conditions, travel times, safety message or special message (i.e., AMBER Alert). In addition to providing operational insight, this information can support requests for additional or alternative funding sources. For instance, TMCs may be able to present a case for using outside funding to support the installation, operations, or maintenance of ITS equipment that is primarily being used to support construction activities.

Finally, this metric can also be used to review what type of return or value transportation investments are providing. However, it is important to recognize that low usage numbers do not necessarily indicate that the ITS equipment is not needed or not important.

Traveler Information Services Usage

Transportation agencies typically track how the public is using the traveler information services their TMCs are providing. For example, as part of its Mobility, Accountability, Preservation, Safety and Service (MAPSS) Performance Dashboard, WisDOT is tracking the number of 511 calls and 511 web hits, as illustrated in Figure 2-3.

Figure 2-3: 511 Phone/Web Usage



July 2012

Wisconsin Department of Transportation
MAPSS Performance Dashboard

✓ Goal has been met

⬆ Performance is trending in a favorable direction

⬌ Trend is holding

⬇ Performance is trending in a unfavorable direction

Performance measure	How we measure it	Current report period	Goal	Goal met	Trend	Comments
Phone/web traffic information ***Calendar year-to-date 2012	Number of 511 calls and 511 web hits	896,913***	Increase the use of the 511 travel information system annually		⬆	For the first half of 2012, the Department logged 99,632 calls and 797,281 web hits.

Source: WisDOT MAPSS Performance Dashboard – July 2012

Tracking usage over time allows the transportation agency to determine how successful it is in providing the public with traveler information and how much value the public places on these services. Variable usage may allow the agency to associate usage with specific incidents such as use of a statewide 511 system during major weather events. An upward trend would indicate that use in the system is growing and the assumption could be made that the system is gaining public value. Conversely, a downward trend in usage may indicate that the public no longer values the transportation services as much as previously reported. This may be a result of either poor operation of the service or as a result of the public shifting away from the transportation service in favor of new, more advanced traveler information services (ATIS). In either event, tracking usage levels over time will provide direction to the transportation agency on how to allocate public funding for traveler information services.

ITS Equipment – Operational Status

The ability of a TMC to fulfill its mission depends in part on the availability of the tools and resources that the agency has at its discretion. The TMC cannot use systems effectively if they are not reliable and readily available. Establishing metrics for individual ITS devices provides agencies with continual feedback on how well individual system components are operating. This can be compared to the historical record to determine if additional maintenance is needed or if additional resources need to be allocated to maintenance efforts so as to bring the operational status of devices back in line with historical norms or to predefined goals and objectives.

From the public's perspective, it is critical that ITS devices be readily available and reliable. The public has the expectation that freeway management systems will be available when it needs to use them. If devices breakdown and are not operational, this will work to erode public confidence in the system. This equates into a lack of use and ultimately a lack of public support for freeway management systems and the funding that is used to purchase, install, operate, and maintain them. In this regard, the operational status of devices, if monitored and reported often, will allow the agency to take quick action to repair devices so that the impact to the public is minimal.

To provide a simple snapshot of device operational availability, the Hampton Roads Traffic Operations Center (TOC) Weekly Performance Measures provides a comparison between total number of devices and the total working and not working, as depicted in Figure 2-4. These numbers are then summarized in its annual report. This total number of working devices metric helps to demonstrate how well the agency is doing at maintaining system availability and can assist with identifying and prioritizing maintenance needs.

Figure 2-4: Current Field Device Operational Availability

Component	Total	Not Working	Working	System Availability
CCTV	276	33	243	88.0%
DMS	196	31	165	84.2%
GATES	5	0	5	100%
HAR	6	1	5	83%

Source: Hampton Roads TOC Weekly Performance Measures – Week Ending January 6, 2012

ITS Equipment – Reliability

Some agencies are also monitoring both the type of failure by device and the mean time between device failures. When tracked by manufacturer, these metrics can be used to highlight device reliability. In addition, when compared to maintenance activities, this metric can illustrate how well the agency is keeping up on preventative maintenance and performance against reliability expectation. It can also provide indications to management when the need to replace a system(s) is warranted rather than to allocate time and expense to keep providing responsive maintenance to an old, outdated, and/or underperforming device/system. Simply stated, with this information the agency can better respond to maintenance needs, better predict when preventative maintenance should occur, and better set maintenance and replacement priorities.

In other words, it may be more cost effective for the agency to replace an often malfunctioning device with a new device. In addition, with recent advances in technology, it may not only be more cost effective to replace the existing device, but the agency may gain additional functionality with the new device compared to the existing device.

Houston's TranStar TMC develops an annual deficiency report that identifies individual ITS devices and their operating status. The primary purpose of the report is to guide maintenance activity so it is focused on potentially dangerous situations due to failed devices in a timely manner. For instance, when traffic signals malfunction or become inoperable, they need to be repaired quickly to prevent crashes resulting from the device failure.

2.2.2 TMC Operational Responsibilities Performance Measurement

This set of measures is intended to help report on the activities of the TMC staff. They can be used to review TMC's staffing levels and determine the performance of specific staff. Some, but not all, agencies are using these measures to judge whether staff hired by contractors to run a TMC are performing as desired. However, similar measures can be used for non-outsourced TMCs.

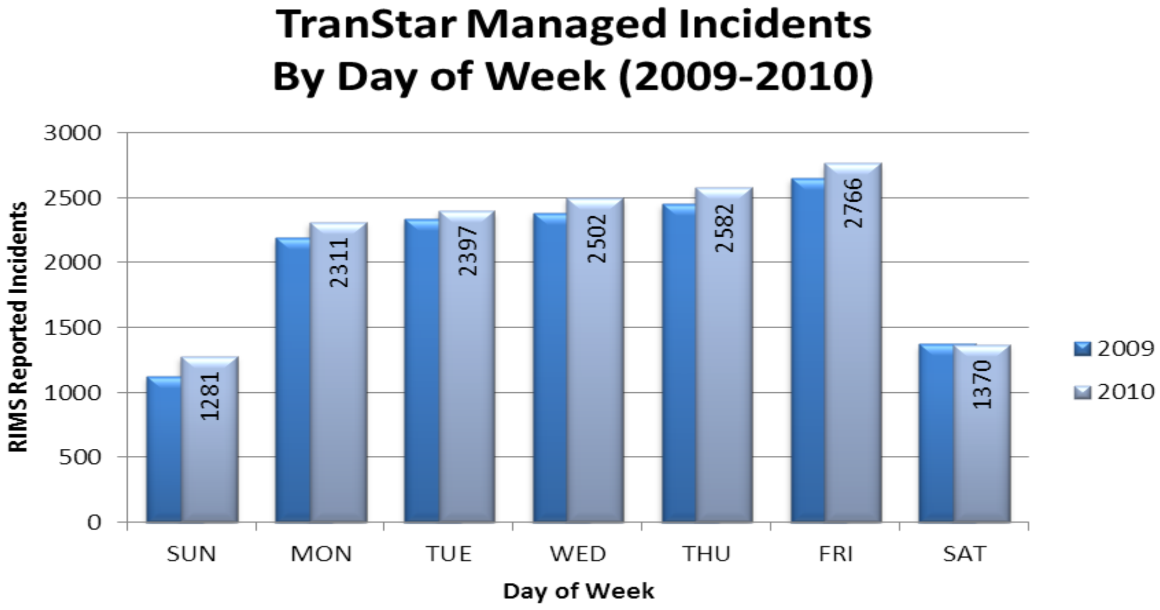
Measures related to TMC operational responsibilities can also be used (within the context of specific events) to report on the circumstances under which the TMC is operating. For example, the fact that a major highway closed for avalanche control 15 times in a year needs context to be informative. It must be reported in the context of snowfall frequency, intensity, and quantity that resulted in the need for avalanche control. Therefore, the fact that 15 closures were necessary (along with the duration of those closures), given the snowfall that occurred, is excellent information in determining the importance of avalanche control activities, the size of the resources allocated to that task, and the effectiveness of those resources.

TMC staff performance and workload are often measured to strike the correct balance of work duties between current staff and to justify staff increases/decreases. Measuring staff performance and workload ensures that staff are not overworked, which may lead to poor response times and decision making, or underworked, which results in inefficient use of public funding. For example, in Hampton Roads, staffing measures are used to measure personnel performance, to adjust staff size and hours, and to better define the operators' shift hours to be the most cost effective.

Number of Incidents

One basic way to quantify the workload of TMC operators is to count the number of incidents the TMC responds to over a defined time period. However, the usefulness of this metric is typically increased by reviewing the number of incidents based on pertinent incident characteristics such as time of day or geographical location. As illustrated in Figure 2-5, the *Houston TranStar 2010 Annual Report* provides a summary of TranStar managed incidents by day of week, with a comparison between 2009 and 2010.

Figure 2-5: TranStar Managed Incidents by Day of Week



Source: Houston TranStar 2010 Annual Report

In addition, many agencies have decided to classify incidents by severity, based on either incident duration or the percentage of the roadway that is closed. The *Manual on Uniform Traffic Control Devices* (MUTCD) provides the following commonly used incident classification system:

- Major—duration greater than 2 hours,

- Intermediate—duration between 30 minutes and 2 hours, and
- Minor—duration less than 30 minutes.

To operate effectively and efficiently, transportation agencies must remain flexible in the manner in which they staff operations. As the number of incidents managed increases or decreases, the agency must be able to actively make adjustments to staffing levels so that freeway operations are not adversely impacted. Although it is likely that existing staff can manage slight increases/decreases in the number of incidents (as compared to historical norms), there will become a tipping point at which the effectiveness of staff in managing incidents will decrease or, conversely, that the agency is expending resources on additional staff when workloads do not justify this expense.

A goal of the TMC should be to determine a range in total number of incidents that a full-time equivalent staff person can effectively handle and then to balance staff levels according to the estimated number of incidents managed by historical levels. By tracking this metric, the TMC will be able to better gauge the average number of incidents that one full-time equivalent staff person would be able to handle. This understanding can then be applied in making staff decisions. This ensures that the staff does not become overworked, that staff retention does not become an issue, and that staff performance does not jeopardize the safety of motorists or the image of the agency.

Number of Planned Events/Weather Events/etc.

In addition to incidents, many TMCs also have response and operational responsibilities related to other events such as planned events (i.e., special events, construction, or maintenance activities) or weather events. These responsibilities must also be considered when reviewing staffing plans, especially how they may be impacted by time of year. For example, regions with severe winter weather may require additional staffing over the winter months.

Some TMCs are charged with the responsibility of monitoring/responding to weather conditions that impact travel. In cold weather climates, this may include assisting maintenance personnel with keeping roads open and safe when snow and ice events occur. Many TMCs track snowfall and compare this against snow and ice removal expenditures. By recording and reporting snow and ice expenditures, TMCs can arrive at a range in expected materials needed to fight snow and ice accumulation for future years.

This type of data recording and support also apply to regions that get annual hurricanes or typhoons, such as Florida and Hawaii, with the resulting flooding and wind effects. In addition, winds, to include tornadoes, also have an impact on travel conditions and may impact TMC operations. In areas where wind can be a problem, the TMC must know when a wind event is occurring and warn travelers or close sections of roadways to all travel.

The occurrence of wildfires/brushfires or fog can significantly reduce visibility and, as a result, can reduce safety and limit mobility locally or regionally and even close interstates and other major roadways. In response, some agencies have implemented warning systems in advance in areas where these conditions are known to recur to alert drivers to their presence and to subsequently reduce speeds. This is just one more responsibility TMC operators may have.

2.2.3 TMC Staff Performance

Monitoring staff performance consists of establishing staff performance targets and tracking the efficiency of staff in meeting these targets. Monitoring staff performance allows the agency to identify inefficiencies or issues that may be impacting agency operations. The results of this analysis allow the agency to reallocate staff resources to align staff knowledge, skills, and abilities to better meet operational responsibilities or to reduce/hire additional staff to improve performance. In some cases, additional staff training may be needed when key staff leave the agency or retire. Depending on the circumstances of the agency, it may be necessary to hire outside contractors to provide staffing.

Staff Performance Targets

In order to assess the TMC staff performance, it is typically required to establish performance targets. Establishing targets can help to reinforce operational priorities and provides TMC operators with clear expectations. In addition, this metric can be used to assess the quality of service being provided to the public. Both the timeliness and the accuracy of information provided can be used to determine how well the agency is doing at providing information to the public.

As an example, in 2007 the Florida Department of Transportation (FDOT) District Six set targets for key operational performance measures that have the greatest impact on the public. As illustrated in Figure 2-6, the *FDOT District Six ITS Annual Report (Fiscal Year 2010-2011)* provided a summary of the TMC's ability to meet these targets.

Figure 2-6: FDOT District Six Key Performance Measures

Performance Measures	FY 09-10 Average	FY 10-11 Average	Target
DMS Efficiency	99.72%	99.82%	>95%
TMC Operator Error Rate	0.43%	0.32%	<0.69%
Time to Dispatch Road Rangers	00:01:05	00:00:56	<00:02:00
Time to Confirm an Event*	00:00:23	00:01:31	<00:02:00
Time to Post DMS	00:03:17	00:02:47	<00:05:00
Time to Notify Other Agencies	00:01:19	00:01:15	<00:07:00

*Does not include events detected by Road Ranger

Source: FDOT District Six ITS Annual Report (Fiscal Year 2010-2011)

Many agencies also collect and maintain a record of comments received from the public. This information may be obtained via the web or from the 511 system's comment line. These comments can be used to assess staff performance. For instance, public comments may indicate that the information posted to traveler information tools is not accurate or that there are errors in the information being posted. An increase in the number of negative comments may indicate that staff are not being trained correctly, that their workloads are preventing them from taking the necessary time to assess the extent or nature of problems being reported, or that they are rushing in posting information and not taking the time needed to check the quality of messages before they are posted.

Staff Retention and Turnover Rates

Successful TMC operations require skilled, well-trained staff in sufficient numbers to operate and maintain ITS devices at pre-determined levels of acceptable availability. The retention of staff knowledge, skills and abilities is critical to TMC performance. Staff are needed to safely and effectively operate the ITS devices under the TMC's control. In addition, maintenance staff must be available to fix problems in a timely manner to reduce the impact on and exposure to the public from device/equipment failures and the resulting loss of public confidence. Delays in fixing problems will result in greater skepticism in the role of TMCs and the funding allocated to these agencies. In addition, senior staff/managers should have the intimate understanding of freeway management systems in use and those available to procure that are critical to advancing the state-of-the-practice and/or performing timely maintenance.

The staff retention metric provides upper management with an indication of how well the center is doing in its efforts to retain staff. Ideally, it is preferable to retain staff so that additional time, budget, and labor effort does not need to be spent on recruiting and hiring new staff. Training new hires takes time away from the existing TMC manager/operator's normal duties and thus leads to decreased return on investment compared to a situation where an existing staff person is retained. As such, the failure to retain staff may lead to intermittent shorthanded operation, increased training cost, decreased operational performance, and the associated downtime while the new staff learns their duties.

Historical agency staff retention rates may provide a baseline the agency can use to assess how well the agency is performing in maintaining desired staff retention rates. Increases in staff turnover may be indicative of problems within the agency that are contributing to staff dissatisfaction. Because of the reasons mentioned previously, it is critical that the agency monitor staff turnover so that required knowledge, skills, and abilities do not leave the organization and place the organization in a position where it is constantly trying to “catch up” to previous levels of system proficiency and understanding.

In some instances, it may take several months to several years for junior/new staff to be trained and gain enough familiarity with the system to operate it as effectively as staff that left the organization. This may result in the agency having to pay to contract out staff or transfer other staff persons into the TMC to fill in gaps in understanding and to provide a base level of coverage.

The loss of staff knowledge may be mitigated to a certain extent through an effective configuration management process where the TMC software is refined and enhanced over time with operator input. Having the operators of the system involved in the process helps to keep them engaged and involved in making the system better.

Nonetheless, staff rotation will always occur. The goal is to establish mechanisms and procedures where staff are trained properly, have access to the resources they need to perform their jobs, and are not overly burdened in their day-to-day work activities when these disruptions occur.

2.2.4 Specialized Operations

Technology Evaluation and Testing

TMCs may receive special requests from within the organization or from local elected officials to assess the performance of a specific type of technology. Whether this request relates to new or unfamiliar technology or concerns that have been raised in other parts of the country, special investigation by local agencies regarding their existing/future device/equipment deployment(s) may require collection of data and performance measurement by the TMC.

The Twin Cities ramp meter evaluation is probably the best known example. In 2000, the Minnesota legislature required the Minnesota Department of Transportation (MnDOT) to evaluate its existing ramp meter program to evaluate the effectiveness of the program before granting approval to continue operating ramp metering in the Twin Cities. During the test, ramp metering operations were terminated and impacts to traffic performance and safety were measured. The result of the study was both a validation of the benefits of ramp metering and development of new ramp metering operational concepts that have since been implemented in the Twin Cities.

2.3 Future TMC Operations Performance Measures Trends

The major trend found by the study team is related to real-time individualized travel information that can be used by the individual to make smart travel choices. The number and sophistication of smartphone apps is constantly growing. For example, apps like INRIX Traffic, BUMP.com, Waze, Muni Tracker, One Bus Away, SF Park, and others bring data and the ability to trip plan in real time to the individual; these apps link road and transit features so users can make the best choice for their individual travel needs.

The development of traveler-specific travel guidance has potential impacts on the features offered by TMCs. For example, many of these systems request direct data feeds describing TMC actions (e.g., notification of accident occurrences and clearances). Making these data feeds available and tracking the number of companies requesting these data feeds when this occurs would be a key “TMC usage” statistic.

2.4 Data Collection and Management – TMC Operations

Data collection is the basis for all performance measurements. Without data there is nothing to measure; but at the same time, the data needs to be valid, accurate, and current to allow for analysis. Data also needs to be stored in a format that can be archived and recalled for trends analysis, or if a longer term study is needed (i.e., mean time between failures [MTBF] of Camera “X” vs. Camera “Z”).

Items to consider regarding data are sources, availability, and quality. These factors are discussed below.

2.4.1 Current Data Sources

The majority of data required for TMC Operations performance measures is typically recorded in some type of database. A few are listed here, but the list could be long and varied due to different naming conventions and software systems. The limited list includes the following:

- Automated Transportation Management System (ATMS) Devices (i.e., detection equipment to include loops or other non-intrusive devices)
- ATMS System (i.e., TMC Operator Event Log)
- DMS Operating Status and Message Log
- ITS Maintenance Logs
- Asset Management Systems
- 511/Website Travel Information System Usage Reports.

2.4.2 Current Data Availability and Quality

The data necessary to support TMC operational performance measures should be readily available in most TMCs. However, the level of effort required to produce performance measures will depend heavily on the format in which the data is stored. Ideally, the data is being stored in a relational database (SQL Server, Oracle, Access, etc.) that allows queries to be developed that can be automated and/or customized to produce reports to measure “production.”

In some cases, such as with 511 systems, the database is maintained by a third party. In those cases, the TMC can typically request specific data sets or summaries, which may actually simplify reporting.

These reports should be included in memorandums of understanding or in contract documents so the TMC is sure to get the information it needs and in the format required.

2.5 Chapter Summary Checklist – Recommended TMC Operations Performance Measures

Table 2-1 shows a simple checklist summarizing the measures identified by the study team as most important for monitoring TMC operations. Tables 2-2 to 2-10 list each of these measures in more detail. Readers should consider these measures for use and reporting in the TMC operation.

Table 2-1: Checklist for TMC Operations Performance Measures

Measure	Level of Measure			Reference Table and Page Number
	Basic	Computed Basic	Advanced	
ITS Equipment – Number of Devices - Percent Expansion (Growth)	x			2-2, page 25
ITS Equipment – Coverage		x		2-3, page 26
ITS Equipment – Usage	x			2-4, page 27
Traveler Information Services Usage	x			2-5, page 28
ITS Equipment – Operational Status	x			2-6, page 29
ITS Equipment – Reliability		x		2-7, page 30
Number of Incidents [Planned Events/Weather Events/etc.]	x			2-8, page 31
Staff Performance Targets			x	2-9, page 32
Staff Retention and Turnover Rates		x		2-10, page 33

Table 2-2: ITS Equipment – Number of Devices

Definition

Number of ITS devices monitored and managed by the TMC.

Purpose/Need

This measure summarizes the efforts that a TMC is taking to fight congestion, improve safety, and provide information to the motoring public. By maintaining historical records, this measure can also provide a clear understanding of the growth of the system over time. From the agency perspective, recording and reporting this metric may be particularly beneficial for advocating for additional funding and resource allocation.

Data Source(s)

- ITS Maintenance Logs
- Asset Management Systems
- TMC Database

Calculations

In addition to summing the number of devices, if historical records are kept, percent of expansion (or growth) can be calculated:

$$\left[\left(\frac{\text{\# of Devices at End of Time Period}}{\text{\# of Devices at Start of Time Period}}\right)-1\right]\text{x }100=\%\text{ Expansion}$$

Data Variations

Number of field devices by device type:

- Cameras
- Detectors
- Dynamic (Variable) Message Signs
- Portable Changeable Message Signs
- Highway Advisory Radio
- Ramp Meters

Desired Outcome/Performance Measure(s)

Track the size and growth of the system.

Limitations/Cautions/Assumptions

Recommend that all information related to field devices, including installation date, be stored in a central database/tracking mechanism to allow for ease of access and to enhance data reliability.

Other Comments

This metric may be compared against other metrics, such as historical staffing levels, to estimate future resource needs.

Level of Measure (Basic, Computed Basic, Advanced)

Basic

Example

WisDOT STOC 2011 Performance Measures Report, page 3 [Reference Figure 2-1, page 14]

FDOT District Six ITS Annual Report (Fiscal Year 2010-2011), page 6: http://www.sunguide.org/sunguide/index.php/tmc_reports/ [Reference Appendix B]

Table 2-3: ITS Equipment – Coverage

Definition

Coverage can be expressed in terms of area (i.e., number of highway miles covered), or in terms of motorists/vehicles receiving a service (i.e., number of motorists that pass by a dynamic message sign).

Purpose/Need

This measure further quantifies the efforts that a TMC is taking to fight congestion, improve safety, and provide information to the motoring public.

Data Source(s)

- ATMS System
- ITS Maintenance Logs
- Asset Management Systems
- TMC Database

Calculations

In addition to providing the amount of coverage, the percentage of coverage can also be calculated:

$$\left(\frac{\text{Miles Covered by Device}}{\text{Total Miles of Roadway Serviced by TMC}}\right) \text{x } 100 = \%\ \text{Miles Covered}$$

$$\text{Total number of people exposed to Variable Message Sign (VMS) messages} \\ = \sum(\text{Directional Average Daily Traffic at VMS Signs}) \text{ summed for all VMS sign locations}$$

Data Variations

Percentage of coverage by device type:

- Cameras
- Detectors
- Dynamic (Variable) Message Signs
- Portable Changeable Message Signs
- Highway Advisory Radio
- Ramp Meters

Desired Outcome/Performance Measure(s)

This metric can help an agency assess the quality of service it is providing to the public. This measure can also be used to identify areas where additional ITS device coverage is needed.

Limitations/Cautions/Assumptions

Consideration should be given to the desired level of coverage when establishing this measure. For example, although a TMC is located in a metro area that includes 100 miles of freeway, ITS deployment may only be planned/needed for a percentage of the system. Therefore, it may be more appropriate to report coverage in terms of identified need rather than for the entire system.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Computed Basic

Example

No example readily available

Table 2-4: ITS Equipment – Usage

Definition

The number of times ITS equipment is used or activated by TMCs. For example, this measure could include the number of messages posted to dynamic (variable) message signs or the number of floodgate messages posted to a 511 system.

Purpose/Need

This measure summarizes the operational activities of the TMC and provides insight into how the transportation network is performing. This metric can also be used to help analyze staff performance and workload. Finally, this metric can be used to review what type of return or value transportation investments are providing.

Data Source(s)

- ATMS System
- TMC Database

Calculations

Basic summation

Data Variations

Device usage by:

- Time of day, day of week or month
- Location
- Type of traveler information provided (i.e., traffic incident, construction, maintenance, adverse weather conditions, travel times, safety messages)

Desired Outcome/Performance Measure(s)

Identify needs, appropriately manage staffing plans, and assist with prioritization of maintenance activities.

Limitations/Cautions/Assumptions

Not all ATMS systems allow TMC operators to track what type of traveler information is being provided without a manual review of posted messages. This type of analysis is typically only cost effective if message type is added as a field to the ATMS system.

It is important to recognize that low usage numbers do not necessarily indicate that the ITS equipment is not needed or not important.

Other Comments

In addition to providing operational insight, reviewing the type of traveler information provided may also be used to support additional or alternative funding sources. For instance, TMCs may be able to present a case for using outside funding to support the installation, operations, or maintenance of ITS equipment that is primarily being used to support construction activities.

Level of Measure (Basic, Computed Basic, Advanced)

Basic

Example

RIDOT TMC Incident Statistics - 4/1/2012 To 6/30/2012, page 2: http://www.tmc.dot.ri.gov/statistics/default.asp [Reference Figure 2-2, page 15]

Table 2-5: Traveler Information Services Usage

Definition

The number of times traveler information services are being used/viewed by the public.

Purpose/Need

Tracking usage over time allows a TMC to determine how successful it is in providing the public with traveler information and how much value the public places on these services.

Data Source(s)

- ATMS System
- Website or phone system tracking records

Calculations

Basic summation

Data Variations

Device usage by:

- Time of day, day of week or month
- Location
- Type of traveler information provided (i.e., traffic incident, construction, maintenance, adverse weather conditions, travel times, safety messages)

Desired Outcome/Performance Measure(s)

Identify whether or not traveler information services are being used by the public.

Limitations/Cautions/Assumptions

A downward trend may be the result of the public shifting away from one traveler information service in favor of new, more advanced services. For example, some agencies have seen a decrease in calls to their 511 systems, while the number of 511 website hits and Twitter subscribers increases.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Basic

Example

WisDOT MAPSS Performance Dashboard, page 2:
http://www.dot.wisconsin.gov/about/performance/index.htm [Reference Figure 2-3, page 16]

Houston TranStar 2010 Annual Report, pages 13-15: http://www.houstontranstar.org/about_transtar/ [Reference Appendix C]

Table 2-6: ITS Equipment – Operational Status

Definition

The amount of time ITS equipment/devices are available for use by a TMC and the public.

Purpose/Need

The ability of a TMC to fulfill its mission depends in part on the availability of the tools and resources that the agency has at its discretion. The TMC cannot use systems effectively if they are not reliable and readily available. Establishing metrics for individual ITS devices provides the TMC with continual feedback on how well individual system components are operating.

Data Source(s)

- ATMS System
- ITS Maintenance Logs
- Asset Management Systems
- TMC Database

Calculations

By tracking the total number of devices, the percent available can be calculated by device type:

$$\left(\frac{\text{Number of Devices Working}}{\text{Total Number of Devices}}\right) \text{x } 100 = \%\ \text{Available}$$

Data Variations

Desired Outcome/Performance Measure(s)

The operational status of devices, if monitored and reported often, will allow the agency to take quick action to repair devices and can assist with identifying and prioritizing maintenance needs.

Limitations/Cautions/Assumptions

The public has the expectation that freeway management systems will be available when they need to use them. If devices break down and are not operational, this will work to erode public confidence in the system.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Basic

Example

Hampton Roads Traffic Operations Center Weekly Performance Measures, page 5:
http://www.virginiadot.org/travel/smart-traffic-center-hro-op-maint.asp [Reference Figure 2-4, page 17]

Table 2-7: ITS Equipment – Reliability

Definition

Device reliability can be reported by monitoring both the type of failure by device and manufacturer, and the mean time between device failures.

Purpose/Need

Reliability information provides indications to management when the need to replace a system(s) is warranted rather than to allocate time and expense to keep providing responsive maintenance to an old, outdated, and/or underperforming device/system. In addition, when compared to maintenance activities, this metric can illustrate how well the agency is keeping up on preventative maintenance and performance against reliability expectation.

Data Source(s)

- ATMS System
- ITS Maintenance Logs
- Asset Management Systems
- TMC Database

Calculations

For a defined time period, the mean time between failures be calculated by device type:

$$\left(\frac{\sum \text{Time Between Failures}}{\text{Total Number of Failures}}\right) = \text{Mean Time Between Failures}$$

Data Variations

Desired Outcome/Performance Measure(s)

With reliability information, an agency can better respond to maintenance needs, better predict when preventative maintenance should occur, and better set maintenance and replacement priorities.

Limitations/Cautions/Assumptions

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Computed Basic

Example

No example readily available

Table 2-8: Number of Incidents (Planned Events/Weather Events/etc.)

Definition

The number of incidents, planned events, weather events, and similar events that occur over a defined time period.

Purpose/Need

Tracking the number and type of incidents or other events that occur quantifies TMC responsibilities and can be used to support resource and funding needs. The TMC will be able to better gauge the average number of incidents that one full-time equivalent staff person would be able to handle. This understanding can then be applied in making staff decisions. This ensures that the staff does not become overworked, that staff retention does not become an issue, and that staff performance does not jeopardize the safety of motorists or the image of the agency. Furthermore, the implementation of successful incident management and traffic operations strategies can be illustrated through a reduction in the number of incidents occurring on the system.

Data Source(s)

- ATMS System
- TMC Database
- Computer-Aided Dispatch (CAD) System
- Crash Reports

Calculations

Basic summation

Data Variations

Number of incidents by:

- Incident classification
- The MUTCD provides a standard time-based incident classification schema:
- Major—duration greater than 2 hours
- Intermediate—duration between 30 minutes and 2 hours
- Minor—duration less than 30 minutes.
- Incident type
- Time of day, day of week or month
- Location

Desired Outcome/Performance Measure(s)

Categorizing incidents or special events by time of day, day of week or month can assist with TMC staffing plans and reviewing incidents by location may identify trouble spots. Furthermore, effective incident management strategies should result in a reduction in the number, and/or severity, of incidents.

Limitations/Cautions/Assumptions

Depending on the sources of information (i.e., access to local law enforcement CAD data or radios, and camera coverage) available to the TMCs, they may only be capturing a percentage of all incidents that occur on the system and this limitation should be documented.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Basic

Example

Houston TranStar 2010 Annual Report, page 17: http://www.houstontranstar.org/about_transtar/ [Reference Figure 2-5, page 18]

Table 2-9: Staff Performance Targets

Definition

Specified targets that are defined and tracked to assess the performance of TMC staff.

Purpose/Need

Establishing targets can help to reinforce operational priorities and provides TMC operators with clear expectations. In addition, this metric can be used to assess the quality of service being provided to the public.

Data Source(s)

- ATMS System
- ITS Maintenance Logs
- Asset Management Systems
- TMC Database
- Public Comments

Calculations

Data Variations

Examples of staff performance targets include:

- Operator error rate
- Timeliness
- Time to answer the phone (number of rings)
- Time to confirm event (verification)
- Time to post messages on DMS
- Time to post messages to 511
- Time to dispatch services (i.e., safety service patrol)
- Time to notify other agencies

Desired Outcome/Performance Measure(s)

The results of this analysis allow the agency to reallocate staff resources to align staff knowledge, skills, and abilities to better meet operational responsibilities or to reduce/hire additional staff to improve performance.

Limitations/Cautions/Assumptions

Each TMC needs to evaluate its responsibilities to determine which tasks are top priority and set its performance targets to match these priorities. Furthermore, these priorities must be clearly relayed to TMC operators.

When possible, historical data should be reviewed in order to identify preliminary targets.

Identifying an automated method to track operator error rate may not be possible; rather, this measure may require manual review of a sample of operator responses.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Advanced

Example

FDOT District Six ITS Annual Report (Fiscal Year 2010-2011), page 10:
http://www.sunguide.org/sunguide/index.php/tmc_reports/ [Reference Figure 2-6, page 20]

Table 2-10: Staff Retention and Turnover Rates

Definition

The retention rate is the percentage of employees who were employed at the beginning of a period and remain employed at the end of the period. The turnover rate is defined as the percentage of employees that exit divided by the total number of employees for a given period.

Purpose/Need

The retention of staff knowledge, skills, and abilities is vital to TMC performance. It is critical that the agency monitor staff turnover so that required knowledge, skills, and abilities do not leave the organization and place the organization in a position where it is constantly trying to “catch up” to previous levels of system proficiency and understanding.

Data Source(s)

- Staffing Records

Calculations

For a defined time period:

$$\left(\frac{\text{Number of Employees Still Employed at End of Time Period}}{\text{Number of Employees at Beginning of Time Period}}\right) \text{ x } 100\% = \text{Retention Rate}$$

$$\left(\frac{\text{Number of Employees that Exited}}{\text{Total Number of Employees}}\right) \text{ x } 100\% = \text{Turnover Rate}$$

Data Variations

May be desirable to track whether staff that left were let go or quit.

Desired Outcome/Performance Measure(s)

Ideally, it is preferable to retain staff so that additional time, budget, and labor effort do not need to be spent on recruiting and hiring new staff.

Limitations/Cautions/Assumptions

Desired retention rates will need to be identified based on the TMCs desired staffing structure. For example, if a TMC utilizes part-time college students as part of its staffing plan, it will likely have lower retention rates than a TMC that hires only full-time personnel.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Computed Basic

Example

No example readily available

Chapter 3. Incident Response Performance Measures

This chapter summarizes basic, computed basic and advanced incident response performance measures. The level of incident response varies greatly from TMC to TMC. Some TMCs are not directly responsible for either incident response activities or the collection of data about those activities. Conversely, some TMCs may be heavily involved in activities and charged with recording data associated with the response of their agencies and possibly tracking the actions of others.

Regardless of the level of responsibility a TMC has toward incident response, having access to performance measures that describe incident response activities is important in understanding the performance of the road network(s). Like the TMC operations measures, the majority of these measures are also “output” measures. That is, they describe the activities being performed, rather than the effect of those activities on the travel experience of drivers.

3.1 Purpose and Need – Incident Response Performance Measures

Traffic incidents occur daily on the nation’s roadways and it is important to recognize and record the impact these incidents have. Incident response performance measures are categorized into traffic incident statistics (e.g., location, number, type, severity), incident timeline (related to milestones from incident occurrence to full roadway clearance), and the presence of a safety service patrol. Basic incident response performance measures are then analyzed with regard to impacts to the roadway network (e.g., incident type, common incident locations), duration of incidents (e.g., detection, response, clearance), and traffic mitigation as a result of an incident (e.g., safety service patrol assists).

3.1.1 General Discussion of Incident Response Performance Measures

Incident response measures describe the number of disruptions occurring on the roadways operated by a TMC, the basic information concerning those incidents, and the resources being used to respond to those occurrences. These measures are intended to identify the need for safe, quick incident response and clearance. Tracking these measures should be done over time to indicate particular trends with roadway disruptions. Basic incident response performance measure categories are incident statistics, incident timeline, and safety service patrol activities.

Advanced performance measures for incident response are used to describe not just the number and kind of incidents, but their duration and the duration of the specific steps taken in response to those incidents. The advanced measures also consider the impact to traffic based on the severity of an incident, and how a safety service patrol can assist with mitigating impacts of traffic incidents. These measures are necessary if the incident response process is to be managed and if the TMC plans to work with the various agencies responding to incidents in order to identify where improvements can and should be made to increase the safety of the responders and the motoring public, decrease the effects of incidents on roadway performance and traveler delay, and identify how best to use the available incident response resources.

3.1.2 Process for Selecting and Prioritizing Incident Response Performance Measures

The intent of the *Guidebook* is to identify performance measures with the broadest applicability across the vast range of TMCs and state demographics. The process of determining the priorities for reporting these measures has been based on input from TMC PFS members through surveys, a review of the literature to identify the performance reports that different agencies routinely produce, a determination of the extent to which these measures are applicable for different TMCs, and a determination of the effects of data availability and other techniques.

3.2 Selected Incident Response Performance Measures

The three main subjects for incident response performance measure reporting are:

1. Traffic Incident Statistics
2. Incident Timeline
3. Safety Service Patrol Activities.

Data within each of these categories can be, and typically is, summarized and reported on in a variety of different methods to portray diverse outcomes and results. Those agencies that have been regularly producing performance measure reports or have a wider base of information should investigate means to produce in-depth performance measure reports and have the ability to support more performance measure outcomes.

3.2.1 Traffic Incident Statistics

The most common examples of traffic incident statistics are number of incidents categorized by classification, time of day, or geographic area and number of secondary incidents. In order to report on any of these measures, the TMC must be collecting incident data from a set area for a particular set of incidents. The accuracy of incident response data is not always perfect and the data is coming from a variety of sources and disciplines including, but not limited to law enforcement, fire, EMS, emergency management, towing and recovery providers, media, and the traveling public.

Number of Incidents

Similar to the discussion in Section 2.2.2.1, the number of incidents that occur over a defined time period can be used as a basic incident response metric. Ideally, the implementation of successful incident management and traffic operations strategies will be reflected through a reduction in the number and/or severity of incidents occurring on the system. The usefulness of this metric is typically increased by reviewing the number of incidents based on pertinent incident characteristics such as time of day, geographical location, type of vehicles involved, or severity of injuries incurred. It may also be useful to track special responses incidents require such as hazardous materials cleanup, heavy-duty recovery operations, or crash investigations.

In addition, many agencies have decided to classify incidents by severity, based on either incident duration or the percentage of the roadway that is closed. The *Manual on Uniform Traffic Control Devices* provides the following commonly used incident classification system:

- Major—duration greater than 2 hours
- Intermediate—duration between 30 minutes and 2 hours
- Minor—duration less than 30 minutes.

Incident data availability and accuracy is dependent on agencies outside the TMC reporting information back to the TMC. Incident statistics are more accurate in situations where the TMC has a direct connection to a public safety agency's CAD system, can view the roadway and incidents on closed-circuit television cameras, or receive incident information from a safety service patrol driver present at the scene. If access to these data sources is limited, the information gathered at a TMC is not representative of all incidents, but is based on a set pool of incident information. This limitation must be acknowledged and stated when producing performance measure reports.

Number of Secondary Crashes

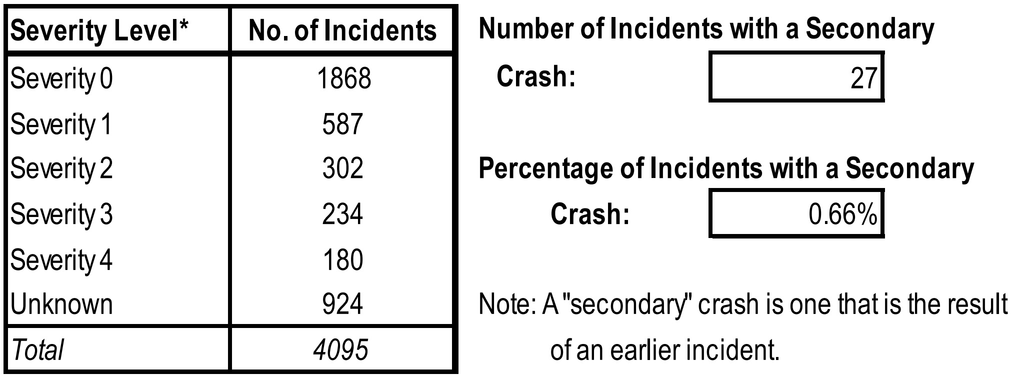
In 2005, FHWA launched a focus state initiative to develop and test consensus-based, multi-agency TIM program objectives and performance measures. One of the three TIM program objectives was to reduce the number of secondary crashes. Secondary crashes are defined as the number of unplanned crashes beginning with the time of detection of the primary incident where a collision occurs either (a) within the incident scene or (b) within the queue, including the opposite direction, resulting from the original incident.

Currently, not many areas report on secondary crashes due to a lack of reporting method, misunderstood or inconsistent definitions, or unfamiliarity with the measure. Before starting to track secondary crashes, it is important to determine and disseminate the standard definition. It is also a good practice to identify which agency will be tracking secondary crashes, whether it is the TMC, law enforcement or both, and how these crashes will be tracked.

When a TMC is able to track secondary crashes, the same basic incident statistics should be gathered such as location, duration, severity, and type. The crash should also be linked back to the initial incident and any information that relates to the cause of the crash should be recorded, such as traffic queue or poor traffic incident management area establishment.

In addition to tracking incidents by severity level, RIDOT's TMC is currently tracking the number of secondary incidents in its quarterly and annual reports, as illustrated in Figure 3-1.

Figure 3-1: Number of Secondary Crashes



Severity Level*	No. of Incidents
Severity 0	1868
Severity 1	587
Severity 2	302
Severity 3	234
Severity 4	180
Unknown	924
Total	*4095*

Number of Incidents with a Secondary Crash: 27

Percentage of Incidents with a Secondary Crash: 0.66%

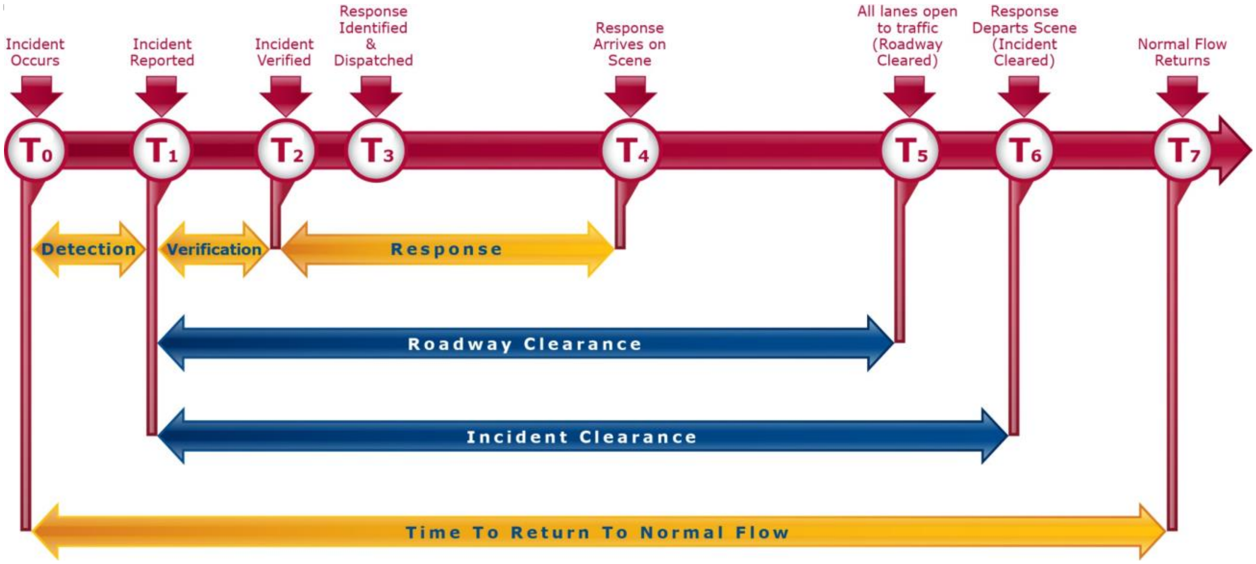
Note: A "secondary" crash is one that is the result of an earlier incident.

Source: RIDOT TMC Incident Statistics Annual Report – 1/1/2011 to 12/31/2011

3.2.2 Incident Timeline

The incident timeline, as depicted in Figure 3-2, starts when an incident occurs, identifies key interim activities, and finishes with traffic returning to normal.

Figure 3-2: Incident Timeline



Source: FHWA

The goal of TIM and related TMC activities is to shorten the distance between T_0 and T_7. The focus should be on making incremental improvements at each phase rather than drastically re-working the way responders perform their duties on scene. Such modifications can help in decreasing the overall duration of the timeline without having negative impacts on safety. Table 3-1 shows a summary of key incident times that should be recorded and tracked.

Table 3-1: Key Incident Times

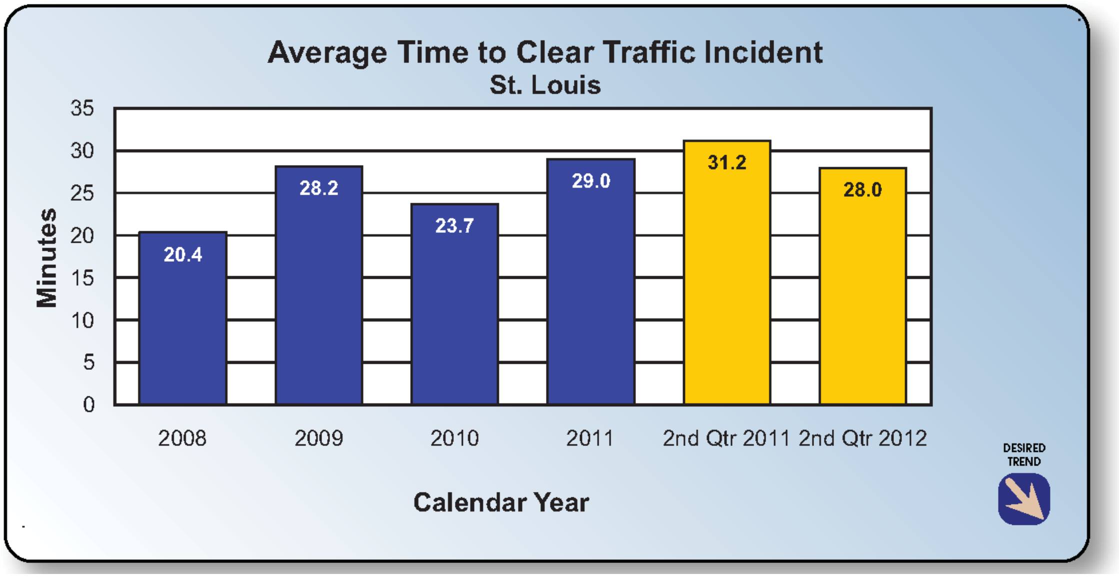
Incident Timeline		Definition
Detection Time	$T_1 – T_0$	The detection time is the time between the incident occurring and the incident being reported. Detection time is not typically reported due the fact that the actual time the incident occurred is often unknown.
Verification Time	$T_2 – T_1$	The verification time is the time between incident being reported and the incident being verified. TMCs can typically assist with verification through use of their CCTV cameras.
Response Time	$T_4 – T_2$	The response time is the time between the incident being verified and the responder arriving on scene. It is important to recognize that law enforcement may not always be the first party to arrive on scene. In some instances, it may be the fire department or a safety service patrol. Response time is dependent on the incident location and each responding party's proximity to the incident.

Incident Timeline		Definition
Roadway Clearance Time	$T_5 – T_1$	Roadway clearance time is defined as the time between the first recordable awareness (incident reported) of the incident by a responsible agency and the first confirmation that all lanes are available for traffic flow. It is one of the three TIM program performance measures identified by FHWA.
Incident Clearance Time	$T_6 – T_1$	Incident clearance time is defined as the time between the first recordable awareness (incident reported) of the incident by a responsible agency and the time at which the last responder has left the scene. It is also one of the three TIM program performance measures identified by FHWA.

Source: FHWA

As part of its *Tracker*, the Missouri Department of Transportation (MoDOT) is reporting on the average time to clear incidents in both Kansas City and St. Louis. The data is collected in the TMC's ATMS. Figure 3-3 illustrates the average time to clear incidents in St. Louis.

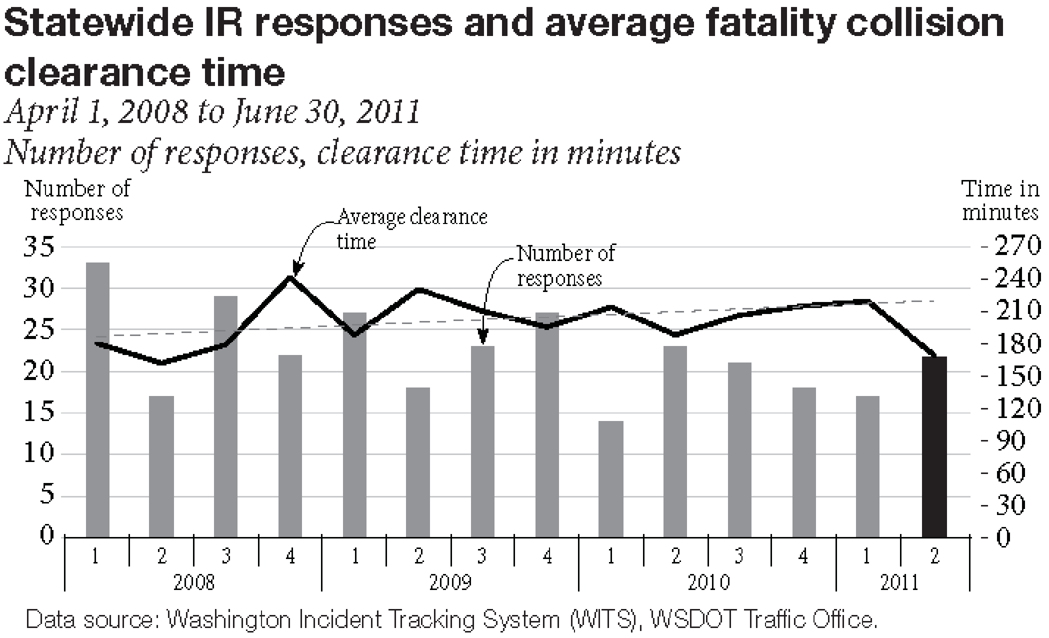
Figure 3-3: Average Time to Clear Traffic Incidents



Source: MoDOT Tracker – Uninterrupted Traffic Flow – 2nd Quarter 2012

Similar to the number of incidents, there is some value in reviewing the times of incidents based on pertinent incident characteristics such as time of day, geographical location, type of vehicles involved, or severity of injuries incurred. As part of its *Gray Notebook*, the Washington State Department of Transportation (WSDOT) provides a summary of average fatality collision clearance times, as illustrated in Figure 3-4. This data is collected by WSDOT's Incident Response (IR) Teams, which are equipped to provide emergency response assistance to motorists and law enforcement at collisions and can also provide minor services to disabled vehicles stopped on the highway.

Figure 3-4: Statewide Average Fatality Collision Clearance Time



Source: WSDOT Gray Notebook Edition 42 – Quarter Ending June 30, 2011

Incident times can be reported on as frequently as deemed appropriate for the agency. Typical reporting periods are monthly, quarterly, semi-annually, or annually. When comparing data it is recommended that information from similar seasonal periods be compared.

Tracking and reporting incident times is complicated by the number of agencies involved in incident response. Complete incident timelines typically require gathering or recording data that is coming from multiple agencies or sources. Based on the goals and objectives of most TMCs, the roadway and incident clearance times are typically the most reported on metrics. However, in order to accurately report this information, it is important that all agencies reporting information are using consistent definitions of these times.

In terms of response times, TMCs typically focus on monitoring and recording response times for services they provide, such as the response time of a safety service patrol. If possible, response times for all response disciplines (law enforcement, fire, towing and recovery, etc.) can be recorded. However, it is understood that tracking response times for responders that are not part of the TMC may be difficult and it may not be possible to obtain accurate and consistent response time information. It is not recommended that TMCs dedicate much time to requesting and tracking this information when developing initial performance measure reports. If this data is collected by the TMC, reporting efforts should acknowledge that the TMC is essentially reporting on the performance of other agencies.

3.2.3 Safety Service Patrol Activities

Safety service patrols are one of the most common tools used by agencies to assist with incident response. Safety service patrol programs generally consist of trained personnel who use specially equipped vehicles to systematically patrol congested or high-volume highway segments searching for and responding to traffic incidents. The types of services provided by safety service patrols vary by program, however, they are typically able to push vehicles off the road, provide gasoline, change a flat tire, and provide minor repairs to help motorists. More robust programs may have additional duties or functions, such as providing clearance and recovery services, assisting with emergency traffic control and scene management, and supporting emergency services activities. Ultimately, safety service patrols are one strategy employed by agencies to help reduce traffic congestion, improve travel time reliability, and improve highway safety.

Safety service patrol operators are typically required to document their activities through some type of patrol log. In addition, many TMCs are responsible for dispatching safety service patrols and maintaining supplemental records. This allows for TMCs to track a number of safety service patrol related performance metrics.

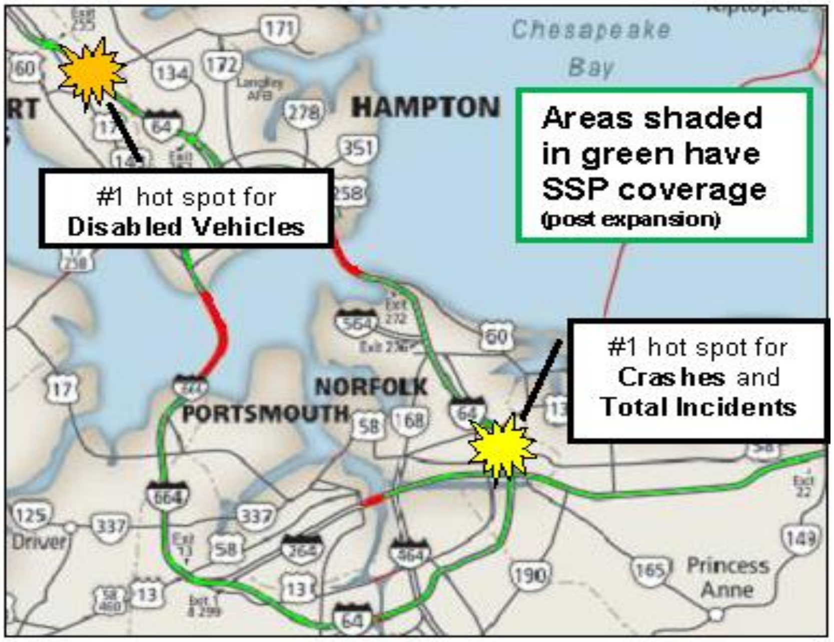
Safety service Patrol Operations Summary

Many agencies find it beneficial to maintain some type of operations summary that documents the basic characteristics of a safety service patrol program. Items typically provided in an operations summary include:

- Number of Safety Service Patrol Vehicles
- Number of Safety Service Patrol Operators
- Patrol Route/Coverage Area and Number of Centerline Miles Covered
- Number of Miles Patrolled
- Service Hours
- Number of Hours Patrolled.

As part of the *Hampton Roads Traffic Operations Center 2011 Annual Report*, the Virginia Department of Transportation (VDOT) includes a coverage map for its Safety Service Patrol (SSP) program, as illustrated in Figure 3-5.

Figure 3-5: Hampton Roads TOC Safety Service Patrol Coverage Map



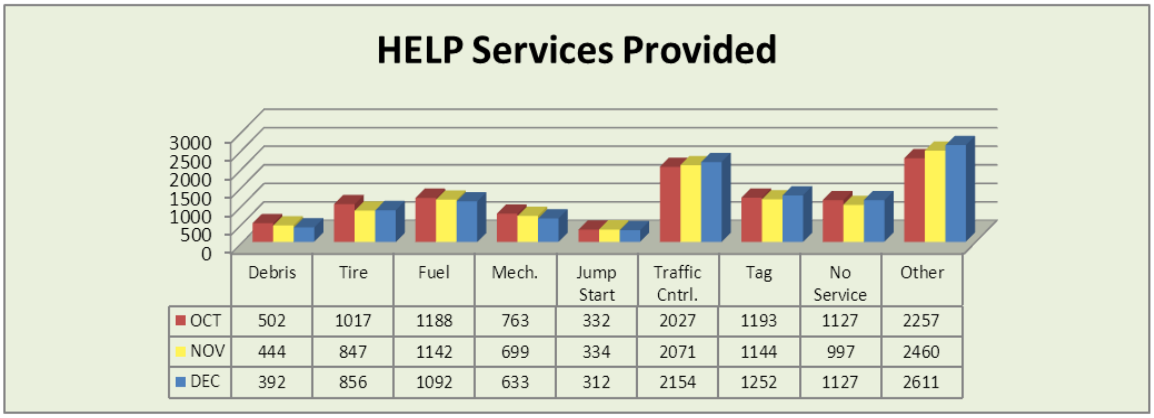
Source: VDOT Hampton Roads TOC 2011 Annual Report

In addition to just reporting, the Hampton Roads TOC is using its performance measures to actively manage operations. For example, quarterly incident data are utilized to reconfigure the Safety Service Patrol routes to promote the most effective use of resources. Maintaining historical operations summary records can also be very valuable in illustrating the benefits of increasing the size of the program or any negative impacts that occurred due to a reduction in the program.

Number of Assists and Number of Services Provided

Two of the most common metrics reported out by safety service patrol programs are the number of assists and the number of services provided. The number of assists refers to how many stops the safety service patrol makes, while the number of services refers to how many services were provided during those assists (i.e., more than one service can be provided during a single assist). As depicted in Figure 3-6, the Tennessee Department of Transportation (TDOT) provides a summary of services provided in its *HELP Program Annual Operations Report*.

Figure 3-6: HELP Services Provided



	Debris	Tire	Fuel	Mech.	Jump Start	Traffic Cntrl.	Tag	No Service	Other
🟥 OCT	502	1017	1188	763	332	2027	1193	1127	2257
🟨 NOV	444	847	1142	699	334	2071	1144	997	2460
🟦 DEC	392	856	1092	633	312	2154	1252	1127	2611

Note: Other includes Extinguish Fire, First Aid, Absorbent, Relocate Vehicle, Fluids, Called Wrecker, Secure Load, Phone Call, Directions, Transported, Unable to Locate, Wrecker Towed, Notified TDOT, Notified Law Enforcement, & Miscellaneous.

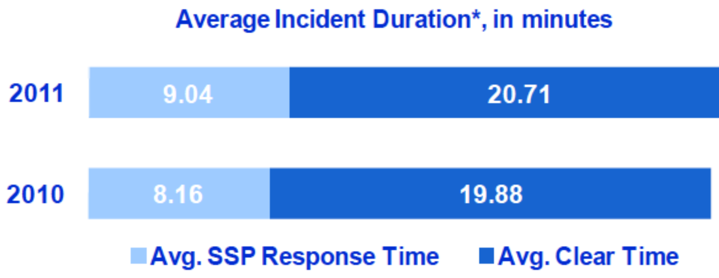
Source: TDOT HELP Program Annual Operations Report – January 1, 2011 to December 30, 2011

Additional metrics can also be reported using the information gathered in the operations summary. For example, the number of assists per mile patrolled or the number of assists made per hour of service can be calculated.

Safety Service Patrol Timeline

The incident timeline was discussed in detail in Section 3.2.2, however, the importance of reporting on these times specifically for safety service patrol programs should be noted. Most safety service patrol programs are tracking response times, roadway clearance times, and incident clearance times. As illustrated in Figure 3-7, the *VDOT Hampton Roads TOC 2011 Annual Report* provides a summary of the average response time and clear time for its Safety Service Patrol.

Figure 3-7: Hampton Roads TOC Safety Service Patrol Average Response and Clear Times



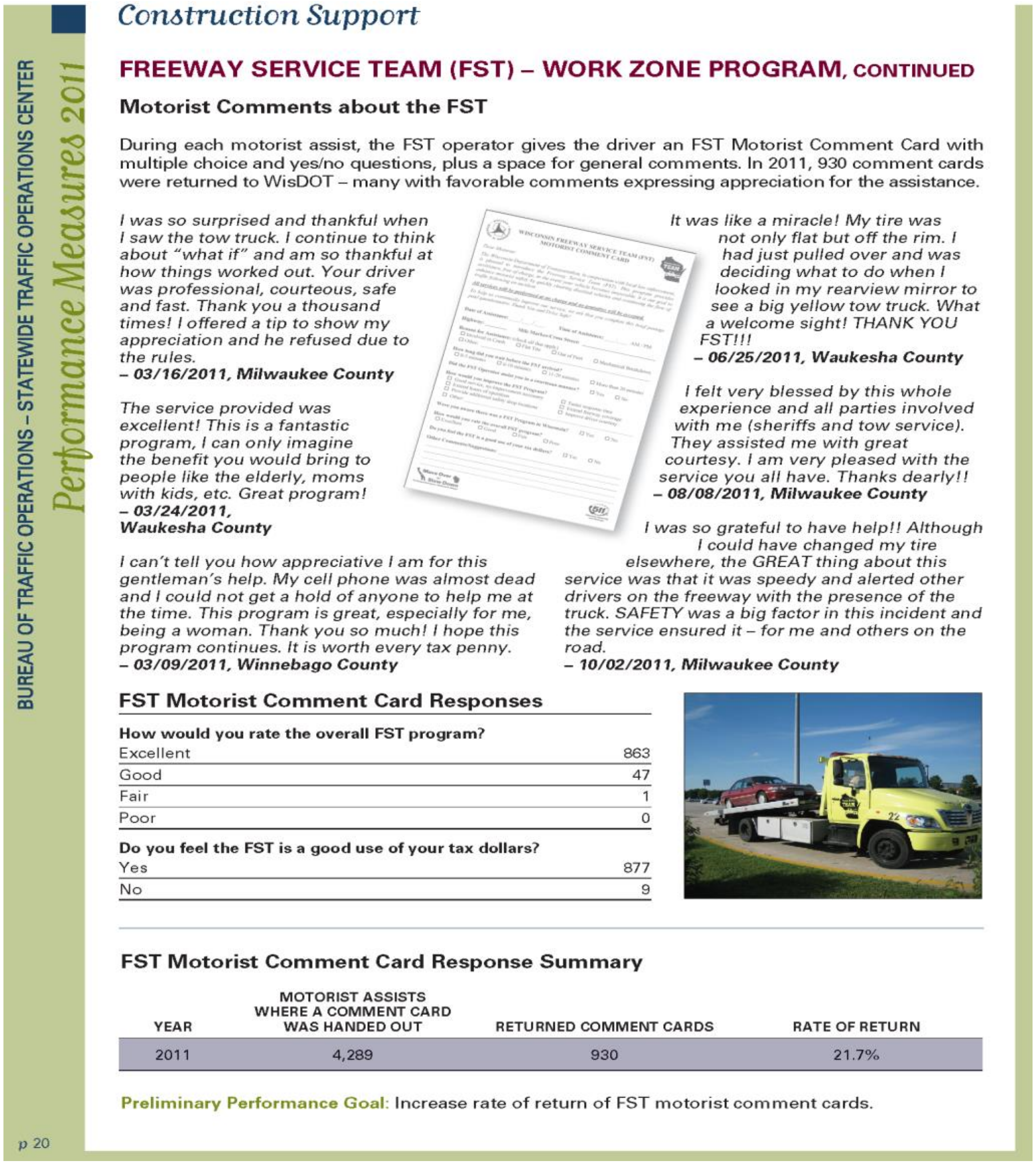
Source: VDOT Hampton Roads TOC 2011 Annual Report

Safety Service Patrol Motorist Feedback

Almost all safety service patrol programs provide the motorists they assist an opportunity to provide comments on the service they received. Some programs do this using a simple survey printed on a postage-paid postcard, while others provide motorists with a link to a website where they can complete the survey. The types of questions asked by each program varies slightly, but the ultimate goal of providing a qualitative method for assessing the value of the program is the same.

Figure 3-8 is from the *Wisconsin Department of Transportation Statewide Traffic Operations Center 2011 Performance Measures Report* and illustrates the data captured by the comment cards returned by motorists assisted by its Freeway Service Team (FST).

Figure 3-8: Freeway Service Team Motorist Comment Card Summary



BUREAU OF TRAFFIC OPERATIONS – STATEWIDE TRAFFIC OPERATIONS CENTER

Performance Measures 2011

Construction Support

FREEWAY SERVICE TEAM (FST) – WORK ZONE PROGRAM, CONTINUED

Motorist Comments about the FST

During each motorist assist, the FST operator gives the driver an FST Motorist Comment Card with multiple choice and yes/no questions, plus a space for general comments. In 2011, 930 comment cards were returned to WisDOT – many with favorable comments expressing appreciation for the assistance.

I was so surprised and thankful when I saw the tow truck. I continue to think about "what if" and am so thankful at how things worked out. Your driver was professional, courteous, safe and fast. Thank you a thousand times! I offered a tip to show my appreciation and he refused due to the rules.
– 03/16/2011, Milwaukee County

The service provided was excellent! This is a fantastic program, I can only imagine the benefit you would bring to people like the elderly, moms with kids, etc. Great program!
– 03/24/2011, Waukesha County

I can't tell you how appreciative I am for this gentleman's help. My cell phone was almost dead and I could not get a hold of anyone to help me at the time. This program is great, especially for me, being a woman. Thank you so much! I hope this program continues. It is worth every tax penny.
– 03/09/2011, Winnebago County

It was like a miracle! My tire was not only flat but off the rim. I had just pulled over and was deciding what to do when I looked in my rearview mirror to see a big yellow tow truck. What a welcome sight! THANK YOU FST!!!
– 06/25/2011, Waukesha County

I felt very blessed by this whole experience and all parties involved with me (sheriffs and tow service). They assisted me with great courtesy. I am very pleased with the service you all have. Thanks dearly!!
– 08/08/2011, Milwaukee County

I was so grateful to have help!! Although I could have changed my tire elsewhere, the GREAT thing about this service was that it was speedy and alerted other drivers on the freeway with the presence of the truck. SAFETY was a big factor in this incident and the service ensured it – for me and others on the road.
– 10/02/2011, Milwaukee County

FST Motorist Comment Card Responses

How would you rate the overall FST program?	
Excellent	863
Good	47
Fair	1
Poor	0

Do you feel the FST is a good use of your tax dollars?	
Yes	877
No	9

FST Motorist Comment Card Response Summary

YEAR	MOTORIST ASSISTS WHERE A COMMENT CARD WAS HANDED OUT	RETURNED COMMENT CARDS	RATE OF RETURN
2011	4,289	930	21.7%

Preliminary Performance Goal: Increase rate of return of FST motorist comment cards.

p 20

Source: WisDOT STOC 2011 Performance Measures Report

3.3 Future Incident Response Performance Measures Trends

One major trend in future incident response performance measurement is reporting on secondary crashes. As mentioned previously, few areas are actively tracking, recording, and reporting on this measure because of a lack of reporting method, misunderstood or inconsistent definitions, or unfamiliarity with the measure. However, actively tracking and reporting on this information is being recognized as imperative from a national level. Identification of methods to clarify the secondary crash definition, reduce confusion on identification, clarify which agency will identify an incident as being secondary, and developing a consistent reporting tool are all steps that should be taken prior to tracking this information.

Another significant trend is the increasing use of performance measures as discussed in this *Guidebook*. Many programs, including TMCs, have not had to report on performance measures in the past and must now defend their budgets in the face of potential reductions. To do this, TMCs are being asked to calculate and report on the benefits produced by their programs and their services. Being able to report on the previously discussed incident response performance measures, as well as changes in those measures over time as a result of changes in the funded operational programs, is significantly useful for describing the reductions in congestion and delay afforded by the TMC.

There have been some efforts to develop benefit/cost (B/C) ratios for incident response related activities, specifically for safety service patrol programs. A study completed by Vanderbilt University in 2008 reviewed B/C ratios developed by safety service patrol programs across the country and found a range from 4.6:1 to 42:1, with an average B/C of 12.4:1. The current difficulty is found in the lack of a standard methodology for reporting B/C ratios. However, as TMCs and programs in more and more states are being forced to compete with traditional capacity expansion projects for limited funding, it is anticipated that additional efforts will be made to produce valid B/C ratios.

3.4 Data Collection and Management – Incident Response Performance Measures

Data to support incident response performance measures is typically captured by the TMC through the input of response partners at an incident scene. Alternate sources of information may be through TMC operators viewing an incident/response on a CCTV camera or through CAD connections with other public safety agencies.

Once information has been reported from the field to the TMC, it is then input into and stored in various databases, allowing queries to be completed and reports compiled with the information categorized and sorted as desired. Common fields for storing information in a database may be incident start/end time, response agencies, number of lanes closed, incident type/severity, incident description, impacts to the roadway, length of traffic queues, and other information that may be pertinent when discussing incident response.

Data archive systems can be purchased to house information at the TMC, including data pertaining to incident response performance measures. Private vendors or in-house technical staff may be able to alter basic data archive/database systems to develop a program that provides more benefit to the TMC and the users in a particular area. Development of a personalized database system is time intensive and can be a complex undertaking.

It is important to note when incident response data is being provided to a TMC from an outside source. It should also be noted when the amount or quality of this information provided to the TMC is out of the control of a TMC operator.

3.4.1 Current Data Sources

Currently, the most common data source are responders assisting at incident scenes in the field. This data is inconsistently provided and may not always be accurate. Unfortunately, this is the main source of data for incident response performance measures as there are no field tools/devices that actively capture this information in use today.

TMC operators may be able to capture limited incident information through viewing incidents and incident response activities through CCTV cameras. In addition, links with public safety agency CAD systems can provide additional incident information to the TMC. If the state crash reporting system has the built-in ability for reports to be run and information compiled, other than by manual means, this is also a potential source of information. If the only way to gather information from the crash report system would be to manually tally the information, this data source may not be feasible or practical to collect, but is still useful.

Information to support safety service patrol performance measures can be captured from manual or patrol service logs. It is recommended that any information captured on logs be entered into a database or a database support tool such as Microsoft Excel or a website. Recording this information electronically allows for an easier reporting process, promotes accuracy of information when it is being reported, and enhances the accountability of operators when they are required to enter the information, particularly if it is regularly checked.

In whatever way information is provided, tracking and reporting out on the information can easily be handled by a basic database. Database tools are most commonly used when reporting on and analyzing incident response performance measures.

3.4.2 Current Availability and Quality

Data to support incident response performance measures should be readily available. If key information is not being provided to the TMC, additional outreach to agencies should be considered. It is important that as much information as possible is provided to the TMC and that this information is being provided as quickly as possible. Because the main source of incident response information is being provided by a person, the quality of the data is unknown.

Because of the potentially limited amount of data or reduced data quality, only information that is complete should be reported out on. If a limited data set needs to be utilized for reporting out on a particular measure to ensure accurate data is being utilized, this should be noted in the report. For example, the roadway clearance time will most likely not be recorded for every incident, however, the incident clearance time should be. When reporting the number of incidents, roadway clearance time and incident clearance time, a sample size for the roadway clearance time should be noted.

Some of the potential limitations to the variety of data sources are identified below.

- TMC Data – information gathered at the TMC based on reports from the field.
    - Data is based on operators viewing a camera or being notified of times by individuals in the field.
    - TMCs may not be regularly notified of all incidents and/or by all agencies in the TMC coverage area.
- CAD System – information can be entered by individuals in the field or at a dispatch center; this data may be linked to or, in some situations, co-located with TMCs.
    - May not include entire incident time if agency recording data leaves scene prior to clearance.
    - May not be accessible by outside agencies.
    - May not be able to be combined with data from other response agencies, which would be necessary for a comprehensive data summary.
- Safety Service Patrol Database (Operator Logs) – entered by safety service patrol operators who assist at incident scenes.

  - Data set is limited to the incidents where the safety service patrol is present.
  - Incident start time may be recorded as the time the safety service patrol arrives on the scene, not the time the incident actually occurred.
- Crash Reports – completed by on-scene responders, typically law enforcement.
  - If the information cannot be queried, it is time consuming to review and pull information.
  - High likelihood for data entry inaccuracies.

3.4.3 Future Data Sources

One future data source for incident response performance measures are law enforcement crash reports. Some states are looking at revising their current crash reports to collect more information on specific incident information including collection of secondary crash statistics. Crash reports can also assist with capturing additional incident response performance information, such as roadway clearance time, response time, detection time, incident location, incident type, and whether the incident was a secondary crash.

3.5 Chapter Summary Checklist – Recommended Incident Response Performance Measures

Table 3-2 shows the above discussed incident response performance measures. Tables 3-3 to 3-9 list each of these measures in more detail. Readers should consider these measures for enhancing and formalizing TMC operations and performance measure reporting.

Table 3-2: Checklist for Incident Response Performance Measures

	Level of Measure			
Measure	**Basic**	**Computed Basic**	**Advanced**	**Reference Table and Page Number**
Number of Secondary Crashes			x	3-3, page 47
Verification Time		x		3-4, page 48
Response Time		x		3-5, page 49
Roadway Clearance Time		x		3-6, page 50
Incident Clearance Time		x		3-7, page 51
Safety Service Patrol Operations Summary	x			3-8, page 52
Number of Assists and Number of Services Provided		x		3-9, page 53

Table 3-3: Number of Secondary Crashes

Definition

Number of unplanned crashes beginning with the time of detection of the primary incident where a collision occurs either (a) within the incident scene or (b) within the queue, including the opposite direction, resulting from the original incident. (Source: FHWA)

Purpose/Need

FHWA has identified reduction of secondary crashes as one of its three program-level performance measures for TIM.

Data Source(s)

- TMC Database
- Crash Reports – some states have added secondary crash as a checkbox on their crash reports.

Calculations

$$\frac{\text{Secondary Crashes}}{\text{Total Crashes}} = \%\ \text{Secondary Crashes}$$

Data Variations

Number of secondary crashes by:

- Incident Classification
- Incident Type/Severity
- Time of Day, Day of Week or Month
- Location

Desired Outcome/Performance Measure(s)

Reduction in the number, and/or severity, of secondary crashes.

Limitations/Cautions/Assumptions

Use of a standard definition by all individuals tracking secondary crashes.

If not recorded, it is very difficult to identify secondary crashes through review of crash data without reviewing each crash report.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Advanced

Example

RIDOT TMC Incident Statistics Annual Report - 1/1/2011 To 12/31/2011, page 5:
http://www.tmc.dot.ri.gov/statistics/default.asp [Reference Figure 3-1, page 36]

Table 3-4: Verification Time

Definition

Time between the incident being reported and the incident being verified.

Purpose/Need

Incident verification is critical to ensuring the appropriate resources are dispatched to respond to an incident.

Data Source(s)

- TMC Database
- CAD System
- Crash Reports

Calculations

$$\text{Time Incident Verified} - \text{Time Incident Reported} = \text{Verification Time}$$

Data Variations

Verification by:

- Notification Type (i.e., phone, CAD, CCTV camera image)
- Time of Day, Day of Week or Month
- Location

Desired Outcome/Performance Measure(s)

Reduction in verification time.

Limitations/Cautions/Assumptions

Not all TMCs are involved in verification efforts.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Computed Basic

Example

No example readily available

Table 3-5: Response Time

Definition

Time between the response being identified and dispatched and the responder arriving on scene.

Purpose/Need

Reductions in response times assist with reducing the overall incident duration.

Data Source(s)

- TMC Database
- CAD System
- Crash Reports

Calculations

$$\text{Time Responder Arrived On Scene} - \text{Time Response Identified and Dispatched} = \text{Response Time}$$

Data Variations

Response time for each agency by:

- Incident Classification
- Incident Type/Severity
- Time of Day, Day of Week or Month
- Location

Desired Outcome/Performance Measure(s)

Reduction in response time.

Limitations/Cautions/Assumptions

In terms of response times, TMCs typically focus on monitoring and recording response times for services they provide, such as the response time of a safety service patrol.

If possible, response times for all response disciplines (law enforcement, fire, towing and recovery, etc.) can be recorded. However, it is understood that tracking response times for responders that are not part of the TMC may be difficult and it may not be possible to obtain accurate and consistent response time information.

It is not recommended that TMCs dedicate much time to requesting and tracking this information when developing initial performance measure reports.

If this data is collected by the TMC, reporting efforts should acknowledge that the TMC is essentially reporting on the performance of other agencies.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Computed Basic

Example

VDOT Hampton Roads TOC 2011 Annual Report, page 9:

http://www.virginiadot.org/travel/smart-traffic-center-hro-op-maint.asp [Reference Appendix D]

Table 3-6: Roadway Clearance Time

Definition

Time between the first recordable awareness (incident reported) of the incident by a responsible agency and the first confirmation that all lanes are available for traffic flow. (Source: FHWA)

Purpose/Need

FHWA has identified reduction of average roadway clearance times as one of its three program-level performance measures for TIM.

Data Source(s)

- TMC Database
- CAD System
- Crash Reports

Calculations

$\text{Time All Lanes Open to Traffic} - \text{Time Incident Reported} = \text{Roadway Clearance Time}$

Data Variations

Roadway clearance time by:

- Incident Classification
- Incident Type/Severity
- Time of Day, Day of Week or Month
- Location

Desired Outcome/Performance Measure(s)

Reduction in roadway clearance times.

Limitations/Cautions/Assumptions

Use of a standard definition by all individuals/agencies tracking roadway clearance time.

As a newer measure, not all agencies are recording or promptly reporting the roadway clearance time.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Computed Basic

Example

RIDOT TMC Incident Statistics - 4/1/2012 To 6/30/2012, page 2: http://www.tmc.dot.ri.gov/statistics/default.asp [Reference Appendix E]

Table 3-7: Incident Clearance Time

Definition

Time between the first recordable awareness (incident reported) of the incident by a responsible agency and the time at which the last responder has left the scene. (Source: FHWA)

Purpose/Need

FHWA has identified reduction of average incident clearance times as one of its three program-level performance measures for TIM.

Data Source(s)

- TMC Database
- CAD System
- Crash Reports

Calculations

$$\text{Time All Responders Have Left the Scene} - \text{Time Incident Reported} = \text{Incident Clearance Time}$$

Data Variations

Incident clearance time by:

- Incident Classification
- Incident Type/Severity
- Time of Day, Day of Week or Month
- Location

Desired Outcome/Performance Measure(s)

Reduction in incident clearance times.

Limitations/Cautions/Assumptions

Use of a standard definition by all individuals/agencies tracking incident clearance time.

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Computed Basic

Examples

MoDOT Tracker - Uninterrupted Traffic Flow - 2nd Quarter 2012, page 1c:
http://www.modot.org/about/Tracker.htm [Reference Figure 3-3, page 38]

WSDOT Gray Notebook Edition 42 - Quarter Ending June 30, 2011, page 25:
http://www.wsdot.wa.gov/accountability/GrayNotebook.pdf [Reference Figure 3-4, page 39]

Table 3-8: Safety Service Patrol Operations Summary

Definition

Summary of the basic operational characteristics of a safety service patrol program.

Purpose/Need

Many agencies find it beneficial to maintain some type of operations summary that documents the basic characteristics of a safety service patrol program.

Data Source(s)

- Safety Service Patrol Database (Operator Logs)

Calculations

Basic summation

Data Variations

Items typically provided in an operations summary include:

- Number of Safety Service Patrol Vehicles
- Number of Safety Service Patrol Operators
- Patrol Route/Coverage Area and Number of Centerline Miles Covered
- Number of Miles Patrolled
- Service Hours
- Number of Hours Patrolled

Desired Outcome/Performance Measure(s)

Maintaining historical operations summary records can also be very valuable in illustrating the benefits of increasing the size of the program or any negative impacts that occurred due to a reduction in the program.

Limitations/Cautions/Assumptions

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Basic

Example

VDOT Hampton Roads TOC 2011 Annual Report, pages 9-10:
http://www.virginiadot.org/travel/smart-traffic-center-hro-op-maint.asp [Reference Appendix F]

Table 3-9: Number of Assists and Number of Services Provided

Definition

Number of assists is the number of stops a safety service patrol makes. Number of services provided refers to how many services were provided during a motorist assist. This accounts for the fact that more than one service can be provided during a single assist.

Purpose/Need

These metrics provide an overview of the activities of the safety service patrol. The applicability of services offered can also be reviewed through these metrics.

Data Source(s)

- Safety Service Patrol Database (Operator Logs)

Calculations

The number of assists can be compared against operational characteristics to provide additional measures for defined time periods:

$$\frac{\text{Total Number of Assists}}{\text{Total Number of Service Hours}} = \text{Number of Assists per Hour}$$

$$\frac{\text{Total Number of Assists}}{\text{Total Number of Miles Patrolled}} = \text{Number of Assists per Mile Patrolled}$$

Data Variations

These measures can be reviewed by safety service patrol route or operator. In addition, the number of services is often reported by type of service.

Desired Outcome/Performance Measure(s)

Provide a quantitative summary of the services provided by a safety service patrol.

Limitations/Cautions/Assumptions

Other Comments

Level of Measure (Basic, Computed Basic, Advanced)

Computed Basic

Example

TDOT HELP Program Annual Operations Report – January 1, 2011 to December 30, 2011, page 4:
http://www.tdot.state.tn.us/incident/help/ [Reference Figure 3-6, page 41]

Chapter 4. System Mobility Performance Measures

This chapter summarizes basic and advanced system mobility performance measures and reporting techniques for TMC performance monitoring activities.

4.1 Purpose and Need – System Mobility Performance Measures

The primary reason that TMCs exist is to help maintain safe, efficient traffic flow on the roadway system. Consequently, performance measures that describe system mobility are critical to TMC performance monitoring. Such measures describe how many people and vehicles are using the system, and the delays—or lack of delay—those users are experiencing.

Mobility is analyzed within the context of **system usage** (background traffic volumes), **disruptions to the roadway network** (crashes, debris, weather, special events, etc.), and **TMC responses to roadway conditions** (traffic control plans, incident response activities, traveler information systems, etc.) to describe the benefits the TMC provides to travelers and the economy in general. These same analyses also inform TMC management, describing where changes in TMC activities bring the greatest benefit to travelers, and where activities can be reduced with the least impact to travel outcomes.

4.1.1 General Discussion of System Mobility Performance Measures

Two basic measures of performance are required to describe the level of mobility the transportation system provides: (1) the speeds at which the system (traffic) is operating and (2) the volume of use. Both types of measures must be collected and reported. Speed data describe whether delays are occurring, but without volume data, speed data alone do not indicate the significance of those delays, nor do they indicate whether the speed reductions are a function of limited roadway capacity relative to demand or are caused exclusively by traffic disruptions. A third useful performance statistic, "lane occupancy," is often collected along with speed and volume data. It is used to describe traffic density—which on freeways is a function of volume and speed—and provides another useful measure of the level of congestion that travelers experience.

These statistics all vary spatially and temporally. The spatial and temporal levels at which these data are collected affect the analytical precision with which the performance measures can be reported, but collecting data at even fairly modest levels of geographic and temporal detail can result in very useful performance reporting.

Speed data in particular can be aggregated over time and space into a variety of performance statistics that are very descriptive of roadway performance, and easily understood by decision makers and the public. In addition, while mean values of these statistics are important, so too are measures that describe the variation in roadway performance over time—that is, the *reliability* of a roadway in the eyes of travelers.

A summary of the basic speed, volume, and lane occupancy reporting metrics is included in Tables 4-7 through 4-9 at the end of this chapter.

Taken by themselves, these mobility measures describe the performance of the roadway system that the traveling public experiences. Correlating these basic measures with data about disruptions on the roadway and the traffic management activities taken in response to those disruptions is necessary to judge the effectiveness of TMC activities on roadway performance. The reporting of the complex interactions among disruptions, traffic operations activities, and actual roadway performance is described in Chapter 5, Cross-Cutting Performance Measures.

4.1.2 Process for Selecting and Prioritizing System Mobility Performance Measures

Prioritizing the development and publication of mobility performance measures is very simple. This *Guidebook* recommends that TMCs start by publishing the mobility performance measures that are based on data in which they have confidence and that describe the performance of key geographic sections of the roads controlled/monitored by the TMC. It is *not* necessary for a TMC to initially report on all roads that they control or monitor when reporting mobility performance measures. Neither is it necessary for a TMC to report all of the measures listed in this *Reference Manual*. However, whenever possible, the TMC should look to provide both summaries of performance over the larger geographic region for which data are available, and more detailed information on specific locations where congestion is most significant.

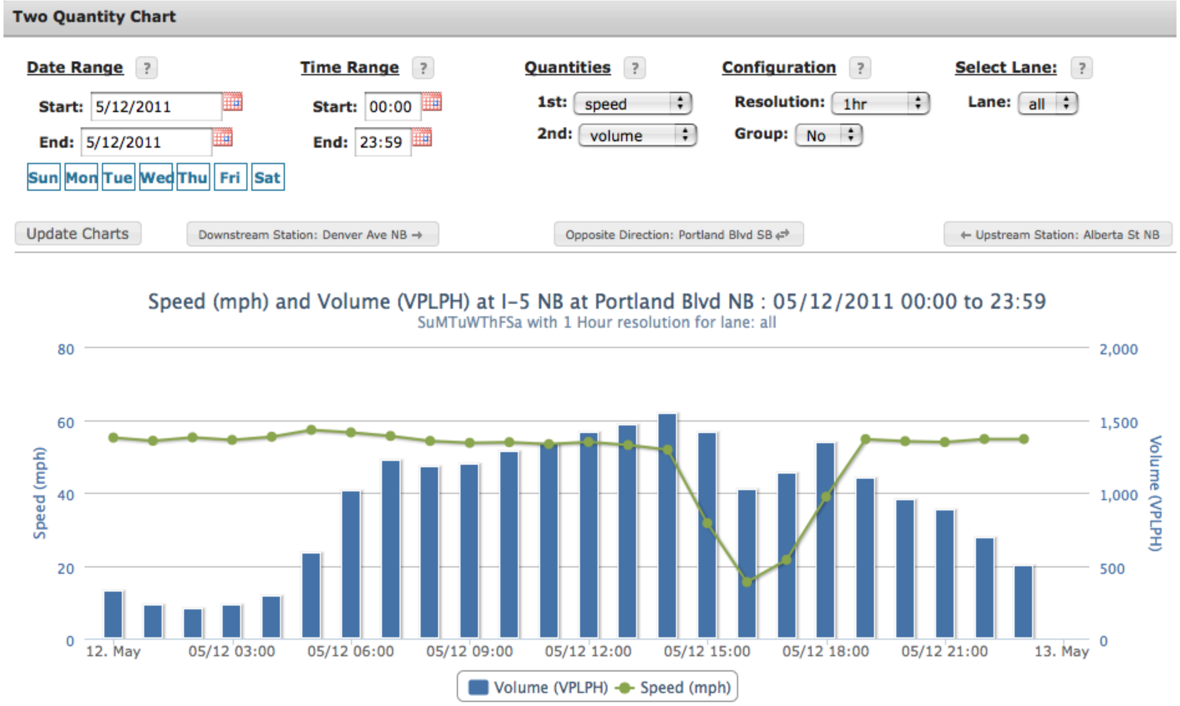
4.1.3 Basic Mobility Performance Measures

Once initial speed and volume data are collected, a limited number of more detailed, site-specific performance reports should be produced. These site-specific measures describe the performance of the key congestion points in the region. That is, these statistics should describe the “worst” locations shown on the map or the key delay points described as slow trips in the travel time statistics.

These site-specific reports also provide an opportunity to describe the traffic volumes on roadways, and to describe the influence that those volumes have on congestion. Figure 4-1 depicts one way to illustrate these relationships. A graphic like this should be used to explain the volume and congestion (decline in speed) patterns occurring at the key congestion points in the TMC-monitored network. Figure 4-1 plots traffic volume and vehicle speed by time of day on the same graph using two different vertical axes, for a specific location, direction of travel, and day. It effectively illustrates that speeds (the green line) drop in the heart of the PM peak period, and that those slow speeds, in turn, cause volume (the blue histogram) to drop as well, not because demand has dropped, but because congestion has lowered the roadway’s functional capacity.

While Figure 4-1 illustrates the effects that congestion has on vehicle throughput on a specific day, illustrations of these same relationships can be shown aggregated over time. Figure 4-2 uses a variation of Figure 4-1 to illustrate these same relationships aggregated over all weekdays in a year. Figure 4-2 color-codes the volume line to illustrate the average speed of vehicles by time of day on this segment of roadway (green is 55 miles per hour [mph]+, yellow is 45 – 55 mph, and red is below 45 mph). The second axis describes the percentage of days this roadway section is operating in Level of Service F conditions. This new statistic, the “frequency of congestion,” is normally calculated by using lane occupancy statistics, but it can also be computed directly from vehicle speed measurements. When lane occupancy exceeds a threshold value[1] set by the TMC (often 35 percent) during a given time period, that period is considered “congested.” Counting the number of days when each time period is “congested” and dividing that by the total number of days used in the analysis computes the fraction of days that each period is congested. This performance statistic describes the reliability of this specific roadway section. That is, it tells motorists how likely they are to experience stop-and-go conditions by time of day at this location. So at the location represented in Figure 4-2, motorists can expect to encounter traffic congestion 40 to 50 percent of the time between 6:30 and 10:00 AM.

Figure 4-1: Speed and Volume by Time of Day at a Specific Location



Two Quantity Chart

Date Range
Start: 5/12/2011
End: 5/12/2011
Sun Mon Tue Wed Thu Fri Sat

Time Range
Start: 00:00
End: 23:59

Quantities
1st: speed
2nd: volume

Configuration
Resolution: 1hr
Group: No

Select Lane:
Lane: all

Source: Portland State University PORTAL database [*http://portal.its.pdx.edu/Portal/index.php/highways*](http://portal.its.pdx.edu/Portal/index.php/highways)

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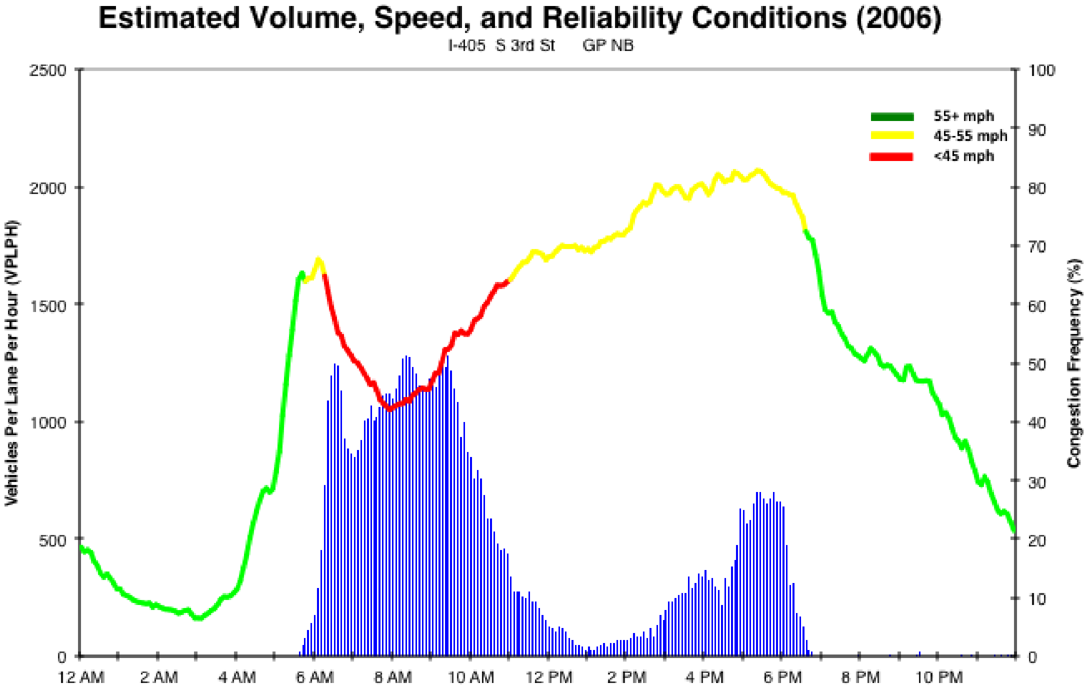
[1] Alternatively, “congestion” can be defined as when speed drops below a specified value such as 35 or 45 mph.

Figure 4-2: Volume, Speed, and Reliability by Time of Day



Source: Central Puget Sound Freeway Network Usage and Performance, by J.M. Ishimaru and M.E. Hallenbeck, 1999

Volumes at these key locations can also be reported in table format, so that trends in volume can be determined and reported. It is recommended that volumes be tracked and reported for at least one location per monitored roadway. More than one location should be reported if different traffic conditions (likely due to different development patterns) are occurring along a corridor.

Tables of volume trends are normally structured to show peak period/peak direction and/or daily traffic volumes, such as shown in Table 4-1. In subsequent years, these volume tables should be modified to show changes in volume over time. Similarly, TMCs can use graphics such as Figure 4-2 to illustrate how those daily volumes change from one year to the next by simply placing a second year's volume by time of day curve on the graph. When trends are reported, it is important to ensure that the data collection equipment at the particular location worked well in both years.

Table 4-1: Example Traffic Volume Summary Table

Northbound (I-5/I-405) or Eastbound (SR 520/I-90) General Purpose Lanes					
	AM Vehicle Volume		PM Vehicle Volume		
Location	Peak Period (6 – 9 AM)	Peak Hour	Peak Period (3 – 7 PM)	Peak Hour	Annual Average Daily Traffic (AADT)
Interstate 5					
S. Pearl St.	20,500	7,500	25,100	6,800	104,600
University St.	18,200	6,600	26,300	6,600	104,400
NE 63rd St.	13,300	5,800	26,200	6,900	98,300
NE 137th	11,600	4,500	28,400	7,400	93,100
Interstate 405					
SE 52nd St	9,300	3,400	12,700	3,400	48,100
NE 14th St	14,500	5,200	26,800	7,100	90,800
NE 85th St	10,200	3,700	21,200	5,700	70,000
SR 520					
76th Ave NE	10,000	3,700	13,300	3,400	54,000
NE 60th St	5,700	2,300	13,800	3,800	44,700
Interstate 90					
Midspan on bridge	13,100	5,400	19,000	5,300	63,900
181st Ave SE	4,700	2,000	13,400	3,900	38,000

Source: Central Puget Sound Freeway Network Usage and Performance, by J.M. Ishimaru and M.E. Hallenbeck, 1999

A summary of the above discussion of spot location metrics based on speed, volume, and likelihood of congestion is included in Tables 4-10 through 4-12 at the end of this chapter. Also, an extension of the spot location-based metrics to summarize performance on an entire corridor is shown in Table 4-13.

Traditionally, once a TMC starts producing basic performance measures, the demand for the publication of those measures increases quickly, especially if those measures shed light on when, where, and why congestion is occurring, how that congestion is changing over time, and why the TMC is pursuing specific actions to improve those conditions. Once the performance data are being routinely reported, the actual measures reported may change slightly to ensure that the performance measures answer the important policy questions decision makers are asking. Data on additional locations or specific time periods may also be reported to respond to specific policy questions (e.g., “How did congestion change as a result of opening the new mall?”).

A successful mobility performance monitoring program may eventually be required to collect data on the performance of other modes of travel. In many urban areas, considerable effort is being placed on shifting travel from single-occupant cars to other modes of transportation including carpools, transit, bikes, and walking. Collecting and reporting data on the performance of these modes is necessary for the region to monitor the success of these programs. While the collection of many of these data items is outside the scope of work for most TMCs, in regions where jurisdictions are actively pursuing shifts in modes of travel to relieve peak period congestion, measures that describe the performance of these modes are frequently part of an advanced traffic management center's performance report. When this is true, the TMC must work with local agencies to obtain, summarize, and report on the use and performance of these alternative modes. Similarly, considerable attention is now being paid to the movement of freight, and in particular trucks. The delays that trucks experience comprise another set of mobility performance measures that many agencies desire but that should only be collected after a more general performance monitoring effort has been well established.

4.2 Selected System Mobility Performance Measures for More Advanced Reporting

Section 4.1 described the primary ways in which speed, volume, and lane occupancy data are initially reported. However, these measures are frequently summarized and reported in a variety of additional ways as part of effectively evaluating and describing the performance of the roadway system. Agencies just getting started with performance monitoring generally produce and use a limited number of these performance measure outputs. Agencies that are actively using performance monitoring to direct the application of their resources tend to use a much larger number of output reports and formats. The following sections describe the more common additional ways in which speed (and congestion), travel time, and volume are routinely reported to meet the management needs of TMCs.

4.2.1 Speed

While volume and speed are fundamental mobility performance measures that should be collected by a TMC, the method by which these measures are reported can vary. One of the best ways that the performance of roadway networks over larger geographic areas can be illustrated is in map form, as in Figure 4-3. Maps are particularly good at illustrating the locations of congestion; they are excellent for describing the geographic locations of congestion without providing too much technical or comparative detail. With GIS versions of these maps, it is also possible to develop and report simple, key, summary statistics, such as the number of centerline miles of roadway that are congested.[2] (When performance data are not universally available, roads for which data are not available can simply not be color-coded. For example, in Figure 4-3, the east-west route I-84 is not currently instrumented for data collection.)

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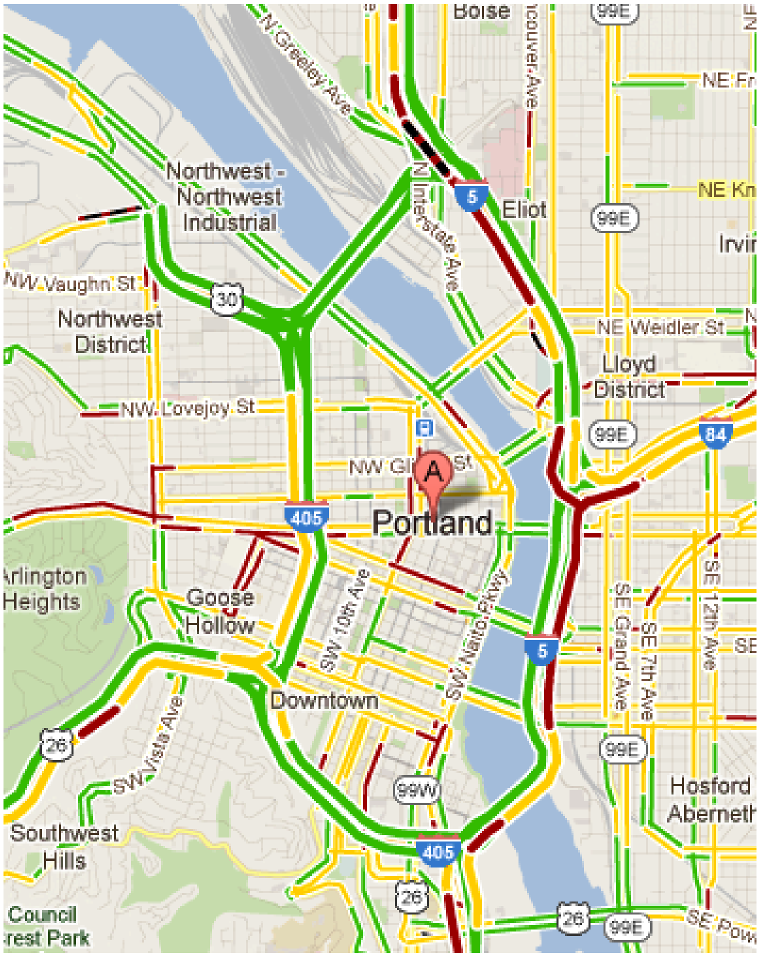
[2] With a good data archive system, a variety of such summary statistics can be prepared by simply writing effective data queries. For example, one summary statistic could describe AM peak period congestion, another PM congestion, and a third could report as congested any road segment on which congestion routinely forms during the week, regardless of the time of day.

Figure 4-3: Map of Portland, Oregon, Freeway Congestion Available from the PORTAL Database

Source: Portland State University PORTAL database *http://portal.its.pdx.edu/Portal/index.php/highways*

The current level of freeway performance of every metropolitan region in the nation is readily available to the public on the Internet. While the accuracy of these data are not always perfect, the major Internet mapping companies (Google, Microsoft, Yahoo, MapQuest, etc.) all provide real-time displays of traffic congestion such as the map depicted in Figure 4-4. These commercially available, Internet-accessible maps are based primarily on vehicle probe data collected by the private sector and typically indicate current average speeds by color coding roadway sections on a map. Many TMCs have access to similar vehicle probe data sets—and the actual summary speed statistics—through contracts with vendors of these data. Other TMCs have access to speed data from agency-owned, fixed sensors that are part of traffic management systems; still other TMCs have access to both kinds of data.

Figure 4-4: Map of Portland, Oregon, Freeway Congestion Available on the Internet



Source: Google Maps

Speed data like these can be stored in a database, and analysts can use them to describe the performance of the covered roadways over different time periods. For example, Figure 4-5 illustrates a similar section of Portland as Figure 4-4, but this image is taken from the PORTAL database. However, instead of current conditions, this map illustrates the average condition observed on these roadway segments over the past five weekdays for a specific 15-minute period early in the PM peak. If this same map was produced for all weekdays in a year, and for the entire PM peak period, it would serve as an excellent description of the location of routine PM peak congestion in the Portland area. The map would not only be easily understood by the public, it would allow analysts to identify congested locations that required more detailed analysis or that might warrant more attention from incident response activities. These same map images can also be produced for consecutive time periods to explore the changing extent and intensity of congestion during specific disruptions (e.g., understanding congestion levels prior to major sporting events or examining congestion that occurred after a major crash). They can also be used to explore the locations and significance of congestion occurring in relation to special events or during specific periods (e.g., how does Friday afternoon traffic differ during the summer when many travelers are leaving for weekend trips, vs. “normal” weeknight travel?). This information can then be used both to design specific traffic management plans and to evaluate the performance of those plans after they have been implemented.

Figure 4-5: Map of Portland, Oregon, Freeway Congestion Available from the PORTAL Database

Source: Portland State University PORTAL database http://portal.its.pdx.edu/Portal/index.php/highways

These same maps can be used to report the frequency with which stop-and-go congestion occurs. As with Figure 4-2, “frequency of congestion” can be computed from either lane occupancy (the mechanism generally used by TMCs that operate their own fixed sensors) or from vehicle speeds. Graphically, the frequency with which congestion forms over some time period (e.g., during peak periods for all weekdays of a year) can be shown in “heat maps” such as depicted in Figure 4-6. Red points in Figure 4-6 indicate the locations where congestion forms most frequently. The volumes, speeds, and frequency of congestion at these locations can then be explored in more detail by using analytical outputs such as those illustrated in Figure 4-2. The geographic information systems (GIS) applications that draw these maps are also capable of computing simple area-wide summary statistics, such as the number of centerline or directional miles of roadway that are congested, and analysts can choose any one of a number of different time periods for that report.

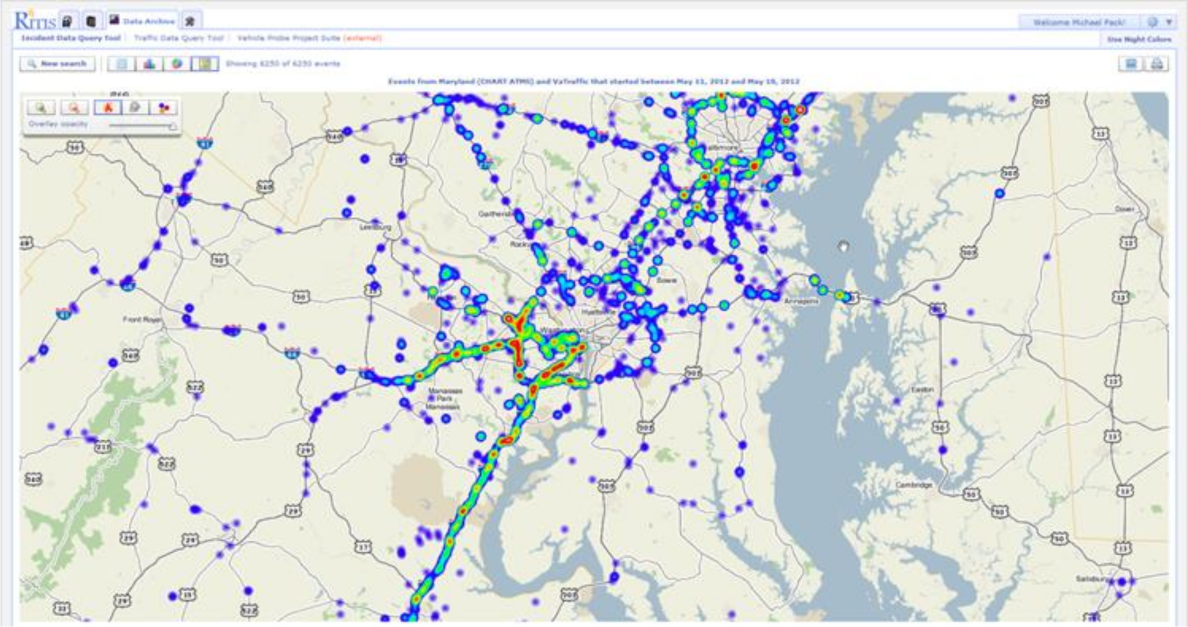
4.2.2 Travel Time

Speed measures are most appropriately used to describe the performance of specific roadway segments. Travel times—the time taken in traveling from one point to another—have the advantage of being easily understood by non-technical audiences, and they are more effective at describing corridor performance to the public and elected officials. Travel times can be computed directly by using a variety of technologies, including automated license plate readers, electronic toll tag readers, and

Bluetooth readers. Travel time can also be estimated or computed from the spot speed data described in subsection 4.2.1.

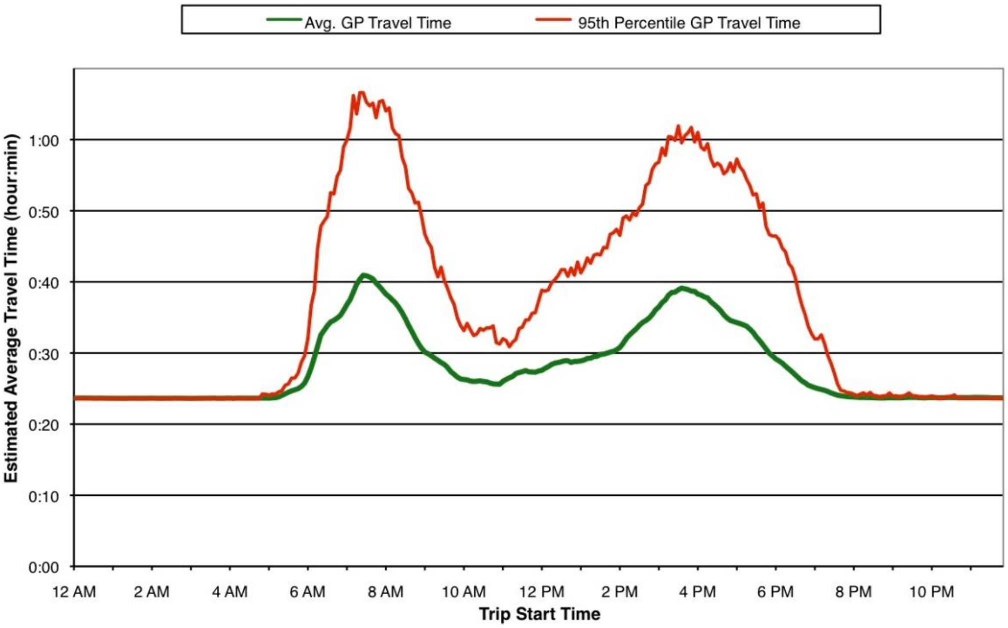
When summarized over multiple time periods, travel times also describe the variability in traffic conditions that travelers experience. This variability affects travelers and freight shippers in that unreliable travel times make them late or require that they build often unnecessary time into their travel plans in case of unexpected delays. Unreliable travel times are a major source of dissatisfaction with roadway performance, and therefore reporting on the reliability of travel times is a common performance measure. Figure 4-7 illustrates the travel times experienced on a corridor for all weekdays in a year.

Figure 4-6: Graphical, Region-Wide Congestion Summary from the National Capital Region (NCR) Regional Integrated Transportation Information System (RITIS) Database



Source: RITIS Web site, Center for Advanced Transportation Technology (CATT) Lab at the University of Maryland, http://www.cattlab.umd.edu

Figure 4-7: Travel Time and Reliability by Time of Day



Source: Freeway Network Usage and Performance, 2001 Update, by R. Avery, J. Ishimaru, J. Nee, and M.E. Hallenbeck, 2003

In the graphic, the green line illustrates the mean (average) travel time for the corridor by time of day. The mean travel time is a good measure of the effects of recurring congestion. The red line illustrates the 95th percentile travel time. The 95th percentile represents a good estimate of the “worst” trip experienced every month and is a good measure of the effects on travel of a bad crash or other incident. Some TMCs also report the 80th or 90th percentile travel time, as these measures are also good descriptors of roadway reliability. The 80th and 90th percentile travel times are also the travel times most likely to improve as a result of improved incident response activities, as these trip times are those most likely to be affected by roadway disruptions. Incident management programs that shrink the size and duration of those disruptions thus shrink the travel times in these upper percentiles. Conversely, the mean and median travel times are primarily driven by routine congestion, which is a function of the volume/capacity ratio commonly found on that road. As a result, the mean or median travel times are unlikely to change greatly as a result of an incident response program. Therefore, reporting on the benefits achieved from the implementation of these programs requires tracking and reporting the upper percentile travel conditions.

Figure 4-7 illustrates that on a routine day, in the peak of the morning commute, commuters can expect this trip to average around 40 minutes, slightly less than twice as long as in late night free flow conditions. However, once a month, they should expect the trip to take over 1 hour. Figure 4-7 also illustrates that this route experiences routine afternoon congestion. That routine congestion is only marginally better than what motorists experience in the morning (the mean travel time at 4:00 PM is about 38 minutes, while the 8:00 AM travel time is just over 40 minutes). However, the “worst” trip that can be expected in the afternoon is slightly better than the morning commute’s 95th percentile trip. This graphic also shows that travelers can expect some level of congestion in this corridor throughout the middle of the day.

The same data used to compute the graphic in Figure 4-7 can be summarized in tabular form. An example of such a table is shown in Table 4-2, which was extracted from material in an early version of WSDOT's *Gray Notebook*. The advantage of a summary such as Table 4-2 is that it reduces a series of complex graphics, such as that shown in Figure 4-7, to a limited number of easy-to-understand statistics and allows the tracking of trends in those statistics over time.

Table 4-2: Example Travel Time Summary Table 2009 AM Peak vs. 2011 AM Peak

Route / Route Description			**Travel time (minutes)**		**Average peak travel time, based on peak time (in minutes)**			**95 % Travel Time (in minutes)**		
To Seattle	**Peak Time**	**Length (Miles)**	**At Peak Efficiency**	**At Posted Speed**	**2009**	**2011**	**%∆**	**2009**	**2011**	**%∆**
I-5 Everett to Seattle	7:30	24	28	24	38	41	3	65	68	3
I-5 Federal Way to Seattle	7:35	22	27	22	33	40	7	53	58	5
I-90/I-5 Issaquah to Seattle	7:45	15	19	15	20	20	0	31	32	1
SR 520 / I-5-Redmond to Seattle	7:45	13	16	13	19	19	0	29	28	-1
I-405/I-90/I-5 Bellevue to Seattle	8:40	10	12	10	12	12	0	21	20	-1
I-405/SR 520/I-5-Bellevue to Seattle	7:50	10	12	10	16	17	1	26	25	-1

Source: Washington State Department of Transportation, The Gray Notebook, June 30, 2011

In the current full *Gray Notebook* report, WSDOT's tabular summaries have expanded beyond just describing travel times and travel time trends, as shown in Table 4-3. WSDOT uses its mobility performance reporting to describe roadway performance in relation to its freeway operations activities. As a result, it includes additional performance statistics that apply to those operational policies. Similar steps should be undertaken by TMCs looking to support their own operational activities.

For example, because of limitations in its ability to expand urban freeway capacity, WSDOT is actively using operational controls (e.g., active traffic management and ramp metering), along with coordinated incident response activities, to maintain maximum freeway throughput during peak periods. This means that during peak periods, the operational goal is to maintain freeway speeds at 45 to 50 mph—not free flow conditions—as maximum throughput occurs near 50 mph. Consequently, travel times are compared to travel times under both free flow conditions and conditions of maximum throughput. To help report on performance relative to this operational goal, WSDOT developed an index called Maximum Throughput Travel Time Index (MT^3I), which is the mean travel time divided by the travel time that occurs under conditions of maximum vehicle throughput. This index is used to compare relative levels of congestion across different travel time routes. As shown in Table 4-3, WSDOT also reports other statistics that are useful in describing roadway performance, including the start time of the slowest trip during a peak period, the average travel time (both in the current year and 2 years earlier[3]), the number of minutes during which congestion occurs on that route (defined as an average trip speed below 45 mph), the MT^{3}I statistic, and the change in vehicle miles traveled on the average weekday during the peak period on that corridor.

Table 4-3: Alternative Travel Time Data Summary Example

Route	Direction of travel	Length of route	Peak time of commuter AM rush	Travel time on the route at		Average travel time at peak of AM rush			Maximum throughput travel time		VMT during peak period	Duration of congestion (how long is average speed below 45mph)		
									MT^3 Index					
				Posted speed	Maximum throughput speed	2008	2010	%Δ	2008	2010	%Δ in VMT	2008	2010	Δ
To Seattle														
I-5 Everett to Seattle	SB	24	7:30	24	28	41	45	8%	1.46	1.58	-2%	2:15	1:50	-0:25
I-5 Federal Way to Seattle	NB	22	7:35	22	27	40	39	-2%	1.48	1.46	-1%	3:25	2:15	-1:10
I-90/I-5 Issaquah to Seattle	WB/NB	15	8:20	15	19	n/a	22	n/a	n/a	1.18	-2%	n/a	0:15	n/a
SR 520/I-5 Redmond to Seattle	WB/SB	13	7:45	13	16	19	20	3%	1.19	1.22	-1%	0:25	0:45	0:20
I-5 SeaTac to Seattle	NB	13	8:35	13	16	25	24	-2%	1.58	1.54	-2%	3:50	2:45	-1:05
I-405/I-90/I-5 Bellevue to Seattle	SB/WB/NB	10	8:35	10	12	n/a	14	n/a	n/a	1.10	0%	n/a	*	n/a
I-405/SR 520/I-5 Bellevue to Seattle	NB/WB/SB	10	7:45	10	12	17	18	7%	1.38	1.48	-2%	1:30	2:20	0:50

Source: Washington State Department of Transportation, The Gray Notebook

A summary such as Table 4-3 does not provide the visual insight into time-of-day travel patterns provided by Figure 4-8, but it provides better summary statistics for tracking changes in roadway performance over time. It also allows publication of a large number of summary statistics in a relatively compact form. This is especially important as the size of the geographic areas covered by performance reporting grows. Therefore, travel time tables should be used in support of maps that illustrate congestion locations, not as alternatives to those maps.

As noted in Section 4.2.1, the big limitation with reporting travel times is that travel time statistics do not describe the locations of the delays slowing travel. Figure 4-8 illustrates one way around this limitation. The Freeway and Arterial System of Transportation (FAST) TMC in Las Vegas displays travel time performance measures online rather than in PDF format like WSDOT's *Gray Notebook*. FAST shows travel times in tabular form on the left of the screen, but when a specific corridor is selected, the map on the right side of the screen highlights the corridor and shows the roadway segments that make up that corridor. The speed of traffic on each roadway segment is color coded, allowing the analyst to determine where slowdowns are located within the corridor.

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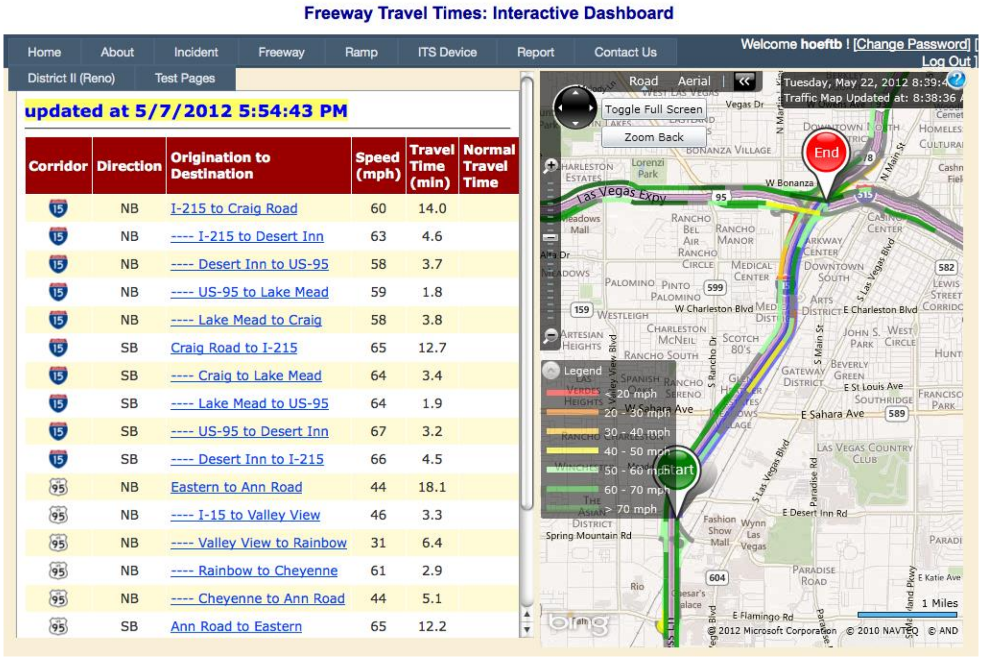
[3] A 2-year reporting period is used to provide more time for changes in travel to occur. WSDOT's experience is that year-to-year changes are often too small to be effectively observed.

Figure 4-8: Illustration of Travel Times along with Delay Locations by Corridor in Las Vegas



Freeway Travel Times: Interactive Dashboard

updated at 5/7/2012 5:54:43 PM

Corridor	Direction	Origination to Destination	Speed (mph)	Travel Time (min)	Normal Travel Time
15	NB	I-215 to Craig Road	60	14.0	
15	NB	---- I-215 to Desert Inn	63	4.6	
15	NB	---- Desert Inn to US-95	58	3.7	
15	NB	---- US-95 to Lake Mead	59	1.8	
15	NB	---- Lake Mead to Craig	58	3.8	
15	SB	Craig Road to I-215	65	12.7	
15	SB	---- Craig to Lake Mead	64	3.4	
15	SB	---- Lake Mead to US-95	64	1.9	
15	SB	---- US-95 to Desert Inn	67	3.2	
15	SB	---- Desert Inn to I-215	66	4.5	
95	NB	Eastern to Ann Road	44	18.1	
95	NB	---- I-15 to Valley View	46	3.3	
95	NB	---- Valley View to Rainbow	31	6.4	
95	NB	---- Rainbow to Cheyenne	61	2.9	
95	NB	---- Cheyenne to Ann Road	44	5.1	
95	SB	Ann Road to Eastern	65	12.2	

Source: FAST Website, operated by the Regional Transportation Commission of Southern Nevada

For performance reporting, most agencies define specific travel time segments in one of several ways. They can represent common trips travelers make (as defined by TMC staff familiar with local commute patterns), key roadway segments on the urban highway network, other roadway segmentation that makes sense to the agency or the public, or the length of the roadway that is instrumented with data collection sensors.

Figure 4-8 illustrates that different “trip lengths” are frequently defined and reported. Travel time segments reported by FAST range in this figure from roughly 2 miles (I-15 from US 95 to Lake Mead) to 14 miles (I-15 from I-215 to Craig Road). The key to selecting travel time segments is to make sure that they will answer questions likely to be asked by the public or by public officials.

Alternatively, travel time statistics derived from basic speed data allow the TMC to produce numerical statistics (travel times between key points) that the public can easily understand. When travel time statistics are used, one can initially report on those corridors for which data are available. For example, the Washington State Department of Transportation started its urban freeway performance reporting system by describing travel times on only 10 “trips” along a limited set of corridors in the greater Seattle metropolitan region. The popularity of this information with decision makers and the general public led to the gradual expansion of the geographic coverage of the TMC sensor network upon which the travel time estimates are based. As a result of that expansion, after 12 years WSDOT now reports in real time on the performance of 64 different trips and is looking to expand its performance reporting to other regions of the state by purchasing private sector-supplied vehicle-probe data.

Travel times lend themselves to simple, easily understood table formats such as the one shown in Table 4-4. These tables describe the effects of congestion along specific, key corridors, allow simple trend analyses, and can be expanded to show 80th or 95th percentile travel times during the peak periods in order to describe the variation that travelers can expect.

A summary of the above discussion of travel time metrics, including average travel time and nth percentile travel time, is included in Tables 4-14 and 4-15 at the end of this chapter. In addition, Table 4-16 lists an approach for estimating an additional trip-based reliability measure, the frequency of slow trips.

Table 4-4: Example Travel Time Reporting Summary Table

Route name (route length in miles) AM peak period trips	Direction of Travel	Average travel time during peak period		
		2009	2010	2011
I-5 Federal Way to Seattle (22)	NB	29	31	33
I-5 Everett to Seattle (24)	SB	31	33	32
I-5/I-405 Everett to Bellevue (24)	SB	32	35	36
I-405 Tukwila to Bellevue (13)	NB	19	20	22
SR 167 Auburn to Renton (10)	NB	13	14	14
I-405/I-90/I-5 Bellevue to Seattle (1 0)	SB/WB/NB	12	12	12
I-405/SR 520/I-5 Bellevue to Seattle (10)	NB/WB/SB	13	14	14
I-5/I-90/I-405 Seattle to Bellevue (11)	SB/EB/NB	12	13	13
I-5/S R 520/I-405 Seattle to Bellevue (10)	NB/EB/SB	14	15	15

Source: Washington State Department of Transportation, Gray Notebook, Congestion Report, 2012

The primary downside of travel times as performance measures is that direct comparisons between corridors are often not possible because length normally varies from one corridor to another. To make comparisons, travel times must be converted either to travel rate (minutes per mile) or to one of several popular indices such as WSDOT's MT^{3}I. The most commonly reported indices are:

- Travel Time Index (TTI)
- Planning Time Index (PTI)
- Buffer Time Index (BTI).

Each of these measures is unitless, which allows direct comparisons of the levels of delay on trips of different lengths. The downside of using these indices is that they are not as easily understood by the public when compared to simple travel times. In addition even when using these indices, care must be taken in selecting a travel time corridor because creating a very long corridor with only a small section of congestion may "undervalue" that congestion, as the large amount of free flow traffic will limit the effect of the small section of congestion. Conversely, limiting the travel time corridor to just a congested segment will "overvalue" the congestion, as that segment is really only a portion of a longer trip. This *Guidebook's* recommendation is to design the corridors so that they cover easily recognized segments of roadway, that is, "common trips" on the monitored roadways. (For example, imagine a "useful trip" a radio reporter would talk about on air.)

TTI is computed as the mean travel time at the peak time of congestion divided by the free flow travel time for that same route segment. It describes the level of routine congestion found on a roadway. TTI is computed as follows:

$$TTI = \text{Mean Travel Time} / \text{Free Flow Travel Time}$$

PTI is the 95th percentile travel time divided by the free flow travel time. It represents the extra time cushion travelers need to incorporate into their travel plans to prevent being late more than once each month. PTI is computed as follows:

$$PTI = \text{95th percentile Travel Time} / \text{Free Flow Travel Time}$$

BTI is a way of describing the 95th percentile trip relative to the normal (mean) condition. In this case, the 95th percentile trip is expressed as a percentage increase in travel time over the mean travel time. It is the “time buffer” that must be included over and above the congestion normally expected by travelers if they hope to be late no more than once a month. BTI is computed as follows:

BTI = (95th percentile Travel Time – Mean Travel Time) / Mean Travel Time

The resulting value is then expressed as a percentage. So a BTI of 20 percent means that travelers must add 20 percent to their normal travel time to avoid being late more than once a month.

The use of these indices allows the production of simple comparison tables. These tables allow different locations to be ranked, such as shown in Table 4-5, even when those ranked corridors have different lengths.

Table 4-5 Ranking of Congestion in Atlanta Using the Travel Time Index

Corridor Atlanta	Travel Time Index			
	2000	2001	2002	2003
I-75A NB (I-285 to I-20 7.72 miles)	1.09	1.13	1.11	1.14
I-75A SB (I-20 to I-285 7.36 miles)	1.05	1.10	1.08	1.15
I-75B NB (I-20 to I-85 Split 3.73 miles)	1.21	1.32	1.30	1.58
I-75B SB (I-85 Split to I-20 4.04 miles)	1.38	1.66	1.56	1.88
I-75C NB (I-85 Split to I-285 8.95 miles)	1.11	1.17	1.09	1.11
I-75C SB (I-285 to I-85 Split 9.63 miles)	1.05	1.09	1.12	1.19
I-85A, NB (Camp Creek Parkway to I-75 4.18 miles)	1.02	1.01	1.01	1.02
I-85A, SB (I-75 to Camp Creek Parkway 4.05 miles)	1.02	1.01	1.01	1.01
I-85B, NB (I-75 to Jimmy Carter Boulevard 14 miles)	1.07	1.16	1.49	1.13
I-85B, SB (Jimmy Carter Boulevard to I-75 13.6 miles)	1.10	1.12	1.09	1.14

Source: NCHRP Web-Only Document 97, Guide to Effective Freeway Performance Measurement: Final Report and Guidebook, August 2006

A summary of the above discussion of TTI metrics is listed in Table 4-17 at the end of this chapter.

TMCs are also likely to perform travel time comparisons when they operate parallel facilities, such as various types of managed lanes (e.g., high occupancy vehicle [HOV], HOT, reversible, or truck-only lanes). These facilities often exist to provide travel time advantages to specific types of vehicles (carpools, transit, or travelers willing to pay a variable toll). When this is true, performance reports should be produced that describe whether these lanes are actually providing travel times advantages. These reports can take the form of both tabular and graphic illustrations of differences in travel time for the parallel facilities. Where specific performance policies have been adopted for facilities, (e.g., “The managed lane should operate at or above 45 mph 90 percent of the time”), these reports may be used to defend or change the control mechanisms or operating policies for those managed lanes. That is, if the adopted policy says that a HOT lane must operate above 45 mph 90 percent of the time and it does not, then the operating agency may need to adopt a different toll pricing algorithm, raise toll rates, or change the carpool definition.

4.2.3 Volume

Volume describes the level of use of the roadway. It describes the number of vehicles (or people or trucks) that use the roadway. Volume is necessary in order to measure the relative importance of delays reported on roadway segments, and thus prioritize when and where TMC resources should be allocated. It is also required to develop most traffic control measures, and understanding its variation in time and space is a requirement for planning and successfully implementing all of the traffic management activities a TMC oversees.

Section 4.1.3 described the basic volume statistics that are used to describe mobility. However, additional statistics are also reported to meet specific analytical needs of TMCs. One key statistic is vehicle miles traveled (VMT), a good measure of total use of a corridor or within a larger group of roads. Calculation of VMT requires data at a number of locations along the corridor. Each traffic volume count then represents travel along a segment of specific length. VMT for that segment is the volume multiplied by the segment length. Values for VMT per segment can then be aggregated to produce VMT estimates for larger corridors or geographic areas.

The primary difficulty in computing accurate VMT estimates occurs when the available data collection devices do not accurately capture changes in traffic volume along the corridor. That is, valid traffic counts may not be available for some road segments, and therefore, the available, sparse counts do not accurately represent volume within a corridor. This occurs either because an insufficient number of traffic volume counters have been deployed or because a significant number of those devices do not operate accurately because of equipment or communications failure. When these problems occur, it is recommended that TMCs use volumes at specific points to track trends in volume (and only at those points, with valid data in both the *before* and *after* time periods) and thus report VMT estimates only as aggregated, “for information only,” statistics rather than as primary performance measures.

When both speed and volume data are available on a road segment, VMT can also be converted to vehicle hours of travel (VHT). This is done by computing the time required to traverse the road segment during each period (usually every 5 minutes) and multiplying that value by the volume of vehicles on that road segment during that period. These values are then summarized to report VHT per peak period, per day, or per year.

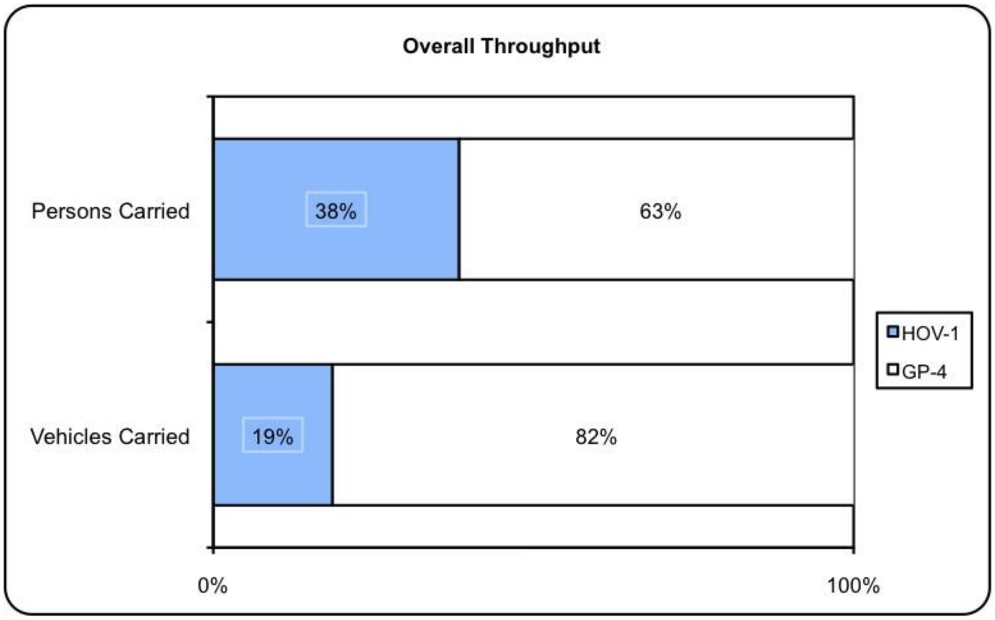
A summary of the above discussion of VMT and VHT metrics is listed in Table 4-18 at the end of this chapter.

Another advanced volume statistic reports road use in terms of the number of people served. In its simplest form, person volume is computed by multiplying the number of vehicles by the average (person) occupancy per vehicle. This requires a data collection effort to obtain average person/vehicle (vehicle occupancy) statistics. Because of the difficulty in determining the number of people in transit vehicles, the programs often count the person occupancy in all vehicles *except* buses. Measured vehicle volume is then adjusted by subtracting transit vehicles. Person volume without transit is then computed by multiplying this adjusted volume by the average number of people per vehicle (not including transit). Finally, transit ridership is obtained directly from the transit agencies (for only those routes operating on that facility) and is then added to that total to obtain total person throughput.

Reporting person throughput is particularly important for TMCs that operate HOV and HOT lanes, as person throughput describes the relative effectiveness of these facilities in moving people, rather than just vehicles. Figures 4-9 and 4-10 illustrate two ways in which person throughput can be used to compare the personal mobility provided by HOV lanes vs. general purpose lanes. Note that Figure 4-9 shows both person and vehicle throughput for the entire facility—separately for HOV and GP lanes—while Figure 4-10 shows statistics by lane, which allows the “fair” comparison of a single HOV lane vs.

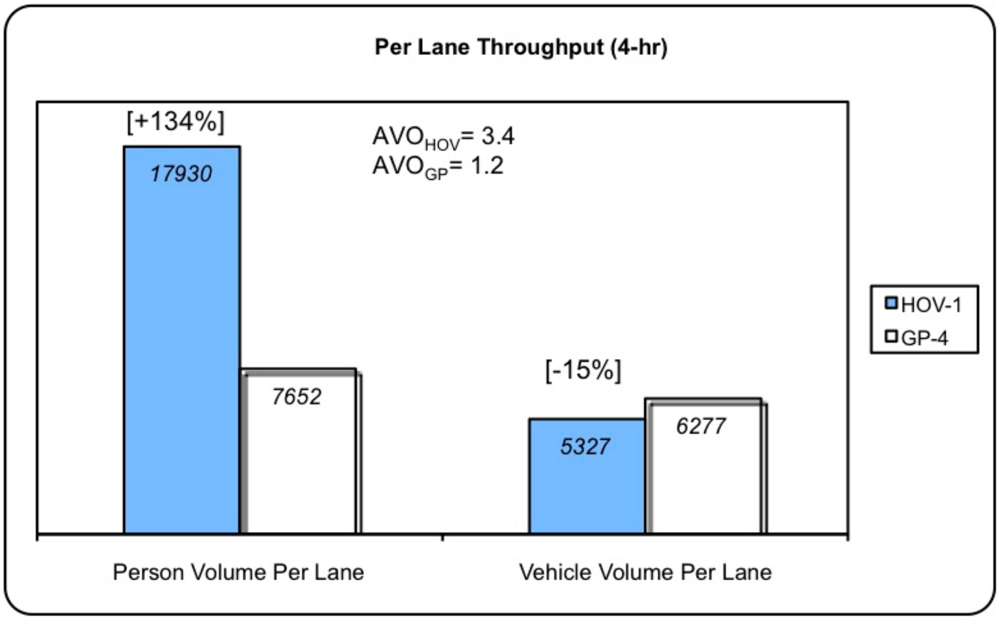
a single GP lane. A summary discussion of person volumes is included in Table 4-19 at the end of this chapter.

Figure 4-9: Person Throughput Statistics Comparing Percent of Throughput In GP and HOV Lanes



Source: HOV Lane Performance Monitoring: 2000 Report, by J. Nee, J. Ishimaru, and M.E. Hallenbeck, 2002

Figure 4-10: Presenting Person Throughput Statistics for HOV and General Purpose Lanes



Source: HOV Lane Performance Monitoring: 2000 Report, by J. Nee, J. Ishimaru, and M.E. Hallenbeck, 2002

Truck volume statistics are also of significant value to public decision makers, if the data collection equipment can accurately collect them. Understanding truck volumes is significantly helpful for valuing the costs of delays, selecting and implementing traffic control plans, and selecting the types of equipment needed by incident response teams (e.g., if large numbers of trucks are present, it may be worth having a heavy-duty tow truck on call, rather than just a conventional tow truck). A summary discussion of truck metrics is included in Tables 4-20 and 4-21 at the end of this chapter.

4.2.4 Other Mobility Measures that Combine Volume and Speed/Delay

Once the basic volume and speed statistics are available and easily manipulated, it is also possible for TMCs to develop and produce a variety of other performance statistics. These may include:

- Vehicle-hours or person-hours of delay
- Lost productivity
- Bottleneck ranking lists.

Person-hours of delay is calculated by first computing VHT for the desired roadway or geographic area. Then, by using VMT for that same area and assuming travel at the speed limit[4], analysts can compute “free flow” VHT. Subtracting that value from actual VHT results in the vehicle delay experienced on the roadway. If this value is multiplied by average vehicle occupancy, the total person delay is computed.

A similar statistic is “lost productivity.” Unlike delay, this statistic assumes that a roadway is productive even when some slowing occurs. “Productivity” only declines once speeds decline to the point at which the functional roadway capacity declines, limiting the number of vehicles that can use the roadway—and creating demand for additional capacity. Tracking the amount of “capacity lost” allows a TMC to determine how effective its traffic control system is at maintaining roadway flow. (For example, one of the key operating concepts behind ramp metering is to either prevent or delay flow breakdown. Tracking lost productivity allows a TMC to track the success of those efforts.)

Lost productivity is computed by aggregating the difference between measured roadway capacity and actual traffic volume, but only when speeds drop below 85 percent of free flow speeds (50 mph for a 60 mph speed limit urban freeway). So, for example, if roadway capacity is 2,000 vehicles per lane per hour, and the roadway actually carries 1,200 vehicles per lane per hour and remains below 50 mph for that hour, the lost productivity is 800 vehicles per lane. On a four-lane freeway, the lost productivity for the full facility would be 2,400 vehicles—more than the capacity of a new lane. Thus a ramp metering system that can keep a freeway flowing at 50 mph is worth one new roadway lane in this example. This illustrates both the reason that TMCs run ramp metering systems and why measuring and reporting lost productivity is a good idea.

Private sector vehicle probe data vendors produce reports that list the “worst” bottlenecks, the “most congested cities,” or the “most congested roadways.” One major problem with these reports is that they do not take into account the volume of vehicles on those roads—since the only data used are vehicle speeds, not volumes. By combining vehicle volume with speed data, it is possible for a TMC to correctly rank the relative importance of its problem locations or corridors. This is good both as input to the project prioritization process and as information for the general public.

A summary of the above discussion of specialized performance measures that are computed from a combination of speed and volume-based statistics is included in Table 4-22 at the end of this chapter.

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[4] Speeds other than the speed limit can be used in the definition of delay.

4.3 Future System Mobility Performance Measurement Trends

There are three major trends in mobility performance measurement. The first trend is the increasing use of vehicle probe data collected by the private sector. The second trend is the increased use of mobility performance measures to report on the benefits of operational improvement programs in order to support continued funding of those programs. A final trend is in the increasingly varied ways in which these data are being reported.

The availability of private sector vehicle probe data allows TMCs to less expensively collect many of the data needed both to identify congestion and produce a variety of travel time and speed statistics for large roadway networks. Consequently, a major task for TMCs is to understand how to obtain, manage, and take advantage of these data. However, access to private sector vehicle probe data does not eliminate the need for placing and operating traditional traffic counting equipment. It only lessens the required number of these agency-supported volume counting devices. As noted above, vehicle probe data by themselves do not describe the volume of vehicles using the roads. Without an understanding of the volume of vehicles on a road, it is impossible to determine whether slow-moving vehicles are a significant problem or a function of the vehicles themselves. Consequently, TMCs must maintain at least a limited number of data collection sites on all of their roads. Procedures must then be developed to combine these limited volume data with the private vehicle probe data to develop a complete set of performance measures.

Reliance on private sector vehicle probe data also requires that the TMC staff understand—and routinely test—the accuracy of those data. This may mean that some roadway detector data are not shared with the private sector and are instead used as controls against which the accuracy of private sector data are compared.

Another significant trend is the increasing use of performance measures. Many operational programs must now defend their budgets in the face of significant state budget reductions. To do this, they are being asked to calculate and report on the benefits produced by those programs. Being able to report the above mobility performance measures—as well as changes in those measures over time as a result of changes in the funded operational programs—is significantly useful for describing the reductions in congestion and delay produced by operational programs. This is particularly important as operational programs in more and more states are being forced to compete with traditional capacity expansion projects for limited funding. Capacity projects have long produced both benefit/cost statistics and estimates of expected congestion benefits, which has given them an advantage over operational programs when competing for funding. Performance measures and benefits reporting for operational programs are therefore necessary for maintaining these programs' improvements.

The final trend discussed in this *Guidebook* is the increasingly varied ways in which mobility performance measures are being delivered. Traditionally, TMCs have produced formal, paper reports that describe the performance of the roadway system and changes in that performance as a result of specific TMC activities (i.e., new traffic control algorithms or new road capacity). An excellent example of this traditional approach to reporting is the WSDOT *Gray Notebook* (GNB) and WSDOT's 6-month supplement to the GNB. However, more and more TMCs are concentrating their mobility performance reporting online. The Las Vegas FAST website, illustrated in Figure 4-8, is an excellent example of this trend. It allows those interested in roadway performance to select specific topic and geographic areas in order to personalize the performance information they request. The same basic interface can also provide TMC analysts with additional data access for analytical purposes.

The downside of these basic Internet sites is that they make it much more difficult to provide text annotations to the numerical summaries. Text summaries that highlight key outcomes are an important aspect of traditional written performance reports. They highlight the key findings of the reports and are particularly useful when communicating these results to non-technical audiences. However, online technology, if designed appropriately, can allow users to create specific queries that address their direct interests. Where resources permit, provision of both kinds of reporting assures that the majority of information needs are met.

4.4 Data Collection and Management—System Mobility Performance Measures

The data needed for mobility performance reporting come from three basic sources:

1. Fixed sensors, which provide some combination of volume, spot speed, and lane occupancy data (they may provide volume by class of vehicles)
2. Vehicle probes, which provide vehicle speed data on segments of roadway
3. Manual collection, which provides information on specific mode choice (e.g., vehicle occupancy counts, transit ridership counts).

The last of these data sources is used only when public interest in the success of travel demand management activities is high enough that resources can be allocated to obtaining and publishing these data. The first two of these data sources generally exist because TMCs use them to monitor the performance of their roadway networks in real time.

Once data are available, the next step is to capture them in an archive so they can be used to create and report performance metrics. A number of data archive systems are currently on the market specifically to provide these services. In addition, private sector vendors of performance data collected from vehicle probe fleets may often supply data archive systems complete with analytical capabilities.

In the past, many agencies have chosen to construct their own archives rather than buying a commercial product. The creation of a data archive is both large and complex and is beyond the scope of this *Guidebook*. However, if a TMC chooses to develop its own archive rather than contract with a vendor of an existing system, the steps needed to create such an archive have been well documented and are available through a number of public sources. The Archived Data User Service website, http://www.fhwa.dot.gov/policy/ohpi/travel/adus.cfm, is a good starting point.

4.4.1 Current Data Sources

Traditional roadway monitoring techniques for volume, speed, and lane occupancy rely on fixed sensors that the TMC deploys and operates. The placement and operation of fixed sensors are still the only means available for collecting traffic volume information, which is a necessary performance measure for all TMC mobility reporting needs. However, traffic volumes are not needed for all monitored roadway segments simply to provide general performance reports. (Depending on the control algorithms being used, traffic management activities *may* need traffic volume data at very detailed geographic intervals or locations. Highway Performance Monitoring System (HPMS) reporting to FHWA also requires volume estimates for each roadway segment, but HPMS requirements do not need to be met by using continuous counting devices.) Performance measurement can almost always use the data collected for traffic management purposes, so long as the data are complete and accurate.

A variety of technologies can be used to collect these data, ranging from (but not limited to) inductive loops cut into the pavement, video image sensors placed above the roadway, and acoustic or radar sensors placed beside the roadway. In all cases, this equipment is placed to support the traffic management functions of the TMC. In many cases, the data collected with the surveillance equipment are used directly by the TMC's traffic control algorithms — usually ramp metering systems or other traffic signal systems. In other cases, the data are collected to provide the TMC staff with information needed to support incident response or to provide the public with useful information about roadway conditions.

The selection of the most appropriate technology for new fixed detectors is a function of a number of factors, including but not limited to the following:

- Specific data needed
- Accuracy of the data required
- Cost of the detectors
- Willingness of the roadway operator to place sensors in the pavement (or conversely, the need to place equipment only beside a roadway)
- Need for volume data by vehicle classification
- Availability and cost of bringing both communications bandwidth and power to the data collection equipment.

An excellent discussion of the relative capabilities of fixed sensors for traffic management purposes can be found in the *Traffic Detector Handbook*, report number FHWA-HRT-06-108[5]. Depending on the availability and expertise of TMC staff, TMCs can place, operate, and maintain their own fixed sensors, or they can contract with private companies for some or all of those services.

The primary advantage of a TMC owning and operating its own fixed sensors is that the TMC controls all aspects of the data collection system. This gives it flexibility in shifting priorities (and funds) from one TMC function to another. The primary disadvantage of owning and operating fixed sensors is that their true costs are often hidden, and as a result, funding for these services can be cut in times of fiscal constraints. Lack of funding for operations and maintenance can result in the loss of considerable data caused by malfunctioning equipment. In addition, operation by a TMC requires full-time employees that may not be available to a TMC.

A growing number of TMCs are outsourcing the traffic monitoring function. A variety of contract mechanisms for this exist, ranging from paying for specific services (e.g., installation and maintenance of equipment) to simply purchasing data while giving the firm supplying data the right to place and service equipment on TMC right-of-way. In addition to reducing the need for public sector full-time employees, outsourcing data collection activities has the advantage of directly identifying the cost of these services and creating an auditable line item for those services, which can then help limit funding losses in tight economic times. Additional information that can help a TMC understand its options for performing traffic data collection will soon be published by the Strategic Highway Research Program's L02 project, *Establishing Monitoring Programs for Mobility and Travel Time Reliability.* The final report for this project was not published when this *Guidebook* was written.

A second major source of mobility information currently available consists of privately collected vehicle probe data. Private vendors aggregate Global Positioning System (GPS) data from equipment carried on board vehicles. They then quality assure and aggregate those data to produce estimates of

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[5] http://www.fhwa.dot.gov/publications/research/operations/its/06108/

average vehicle speed by roadway segment by time period. Data are most commonly provided via a commercially available, standardized series of GIS-based roadway segments called "TMC Codes." For use in mobility reporting, data on these roadway segments must then be converted to the roadway segmentation system the TMC uses.

The primary advantage of using private sector vehicle probe speed estimates is that the TMC does not have to place or operate any data collection equipment. Private sector speed data are also available for most of the "larger" roads[6] in the U.S. This means that TMCs purchasing private sector data can obtain data for very large geographic areas of roadways without extensive upfront costs for equipment and installation. Like contracting for data from fixed equipment, purchasing the rights to use private sector speed data also has the advantage of creating a visible, definable budget item for data. (This can include both real-time data used for TMC operations and archived data used for mobility analysis and reporting.)

One disadvantage of using private sector speed data is that valid speed estimates are only available when the GPS-equipped vehicles that provide data to the vendor are operating. Therefore, on lower volume roads, no speed estimates may be available for some time periods. For higher volume roadways, this will occur only when little or no traffic is present, generally late at night, when free flow speeds can be safely assumed. "Lack of data" on freeways is therefore rarely an issue. However, for lower volume roadways (such as signalized arterials), gaps in the available data can be common during times of the day when congestion occurs, and therefore, TMCs should carefully examine the availability and reliability of a vendor's arterial speed estimates before purchasing those data sets.

A second limitation in using private sector vehicle speed data is that these data do not provide facility volumes. The lack of that information limits the mobility reporting that TMCs can accomplish with just the private sector data. A second source of data is necessary to accurately "size" congestion (e.g., produce estimates of vehicle delay or person delay) on specific segments. Therefore, even though a TMC may rely extensively on private sector speed data to indicate where and when congestion occurs, some fixed sensors are necessary to provide vehicle volume data for those roadways.

A third limitation in using vehicle probe data is that it can be difficult with probe data sets to segregate, and thus report data for, closely spaced roadways. For example, probe data may not allow differentiation between vehicle speeds in HOV lanes and those in bordering general purpose lanes. This can be problematic for a TMC that needs to operate these specialized facilities or that needs to compare its operation as part of its general mobility reporting.

4.4.2 Current Data Availability and Quality

Both fixed sensor and private vehicle probe data can be of good or poor quality. A traditional problem with fixed sensors is that the equipment and its supporting communications systems may not be maintained in appropriate operating condition. The result is that many sensors fail or are poorly calibrated, resulting in inaccurate or completely missing volume and speed data.

In addition, fixed sensors provide data at only the point observed by the fixed sensor. Where sensors are widely spaced (some TMCs rely on fixed sensors spaced more than a mile apart), the volume and speed measurements from those sensors may not accurately represent the conditions on the roadway some distance between those sensors. (For example, with 1-mile spacing, the sensors often

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[6] Actual data availability will change from vendor to vendor. In general, data are commonly available for all freeway segments in the country.

poorly describe roadway conditions midway between detectors, as roadway conditions can change considerably in the length of a half-mile.)

A similar problem can occur in rural areas, where the TMC Code road segments can be more than 10 miles long. This means that the available vehicle probe data points are aggregated throughout that 10-mile segment to determine one value (the “average condition”) that represents travel conditions along that entire 10-mile segment. Not surprisingly, there are times when this single value does not represent conditions throughout the segment. Overly long TMC Code segments are generally not an issue in urban areas, as TMC Code segmentation tends to be much smaller in urban areas.

In addition, as noted above and especially on lower volume roads, private sector probe data sets may not contain any data for specific time periods because no GPS-equipped cars reporting position and speed data to that vendor were present during the desired period. When data are not present, private vendors normally state this in the metadata provided with their data sets. In many cases, the vendor supplies a historical average for use when a data point is needed but no “real/current” data are actually present. The accuracy of that data point is suspect when used for analyses requiring detailed, time-specific data, but that loss of accuracy may be acceptable to the TMC, depending on the specific analysis.

Regardless of the source of the mobility data available to the TMC, it is important for the TMC to be able to identify invalid or missing data so that it can correctly account for them.

4.4.3 Future Data Sources

Changing technology continues to affect the availability and cost of data collected by both fixed sensors and vehicle probes. For example, 10 years ago, it was virtually impossible to collect accurate truck volume data on urban freeways. Now multiple technologies exist that allow such data collection. In addition, the continued improvement in roadside fixed sensor technology, along with lower costs for communications, makes the costs of installation, operation, and maintenance of fixed sensors much lower on most roadways. TMCs in need of new fixed sensors should work with FHWA and peer agencies to obtain the latest information on the costs, benefits, and availability of fixed sensors.

Similarly, dramatic technological improvements in cell phone costs and capabilities are the primary reason that vehicle probe data are more readily available. The increasing availability of vehicle probe data is expected to continue into the foreseeable future. The next possible surge in vehicle probe data is likely to occur when vehicle manufacturers start to deploy vehicles that include the technology associated with the U.S. Department of Transportation’s (USDOT’s) Connected Vehicle research initiatives. While the data collection functions of Connected Vehicle systems had not been finalized when this *Guidebook* was written, connected vehicles are expected to result in a further increase in amounts of mobility data and produce a rich source of data about many of the disruptions that limit mobility.

4.5 Chapter Summary Checklist—Recommended System Mobility Performance Measures

Table 4-6 shows a simple checklist summarizing the measures identified by the study team as most important for monitoring the mobility provided by roads under the control of the TMC. Readers should consider these measures for use and reporting in their TMC operation. The checklist also suggests the approximate level of complexity or sophistication of each measure. *Basic measures* provide a useful starting point when reporting mobility measures. *Computed basic measures* are those measures that can be derived from the basic measures with some additional computation and analyses. *Advanced measures* are appropriate for consideration by TMCs that require more sophisticated reporting capabilities to meet their decision-making or operational needs.

Each measure in the checklist also has an accompanying summary reference table. Each table provides a synopsis of a particular performance measure (or group of related performance measures), and provides an overview of the measure’s usefulness, required data sources, calculation steps or equations, useful variations of the performance measure, and issues or implementation considerations associated with the use of that measure. These summary reference tables for mobility measures, Tables 4-7 through 4-22, immediately follow the checklist.

Table 4-6: Checklist for Mobility Performance Measures

Measure	Level of Measure Basic	 Computed Basic	 Advanced	Reference Table and Page Number
Spot location vehicle speeds and volumes, and lane occupancy percentage • by AM/PM peak • daily weekday • daily weekend	x			4-7, page 81 4-8, page 82 4-9, page 83
Aggregated spot location vehicle speeds, volumes, and frequency of congestion • by AM/PM peak • daily weekday • daily weekend		x		4-10, page 84 4-11, page 85 4-12, page 86
Corridor or regional vehicle (roadway) volumes and speeds • by AM/PM peak • daily weekday • daily weekend		x	x	4-13, page 87 4-18, page 92
Travel time by corridor also computed as TTI or other index		x	x	4-14, page 88 4-17, page 91
90th and 95th percentile travel times by corridor Frequency of slow trips Buffer Time or Planning Time Index		x	x	4-14, page 88 4-15, page 89 4-16, page 90 4-17, page 91
Number of (centerline) miles of congested roadway		x		4-22, page 96
Visual graphics depicting congestion locations and severity along a corridor			x	4-13, page 87
Comparison of HOV, HOT, and general purpose (GP) lane travel time performance			x	4-14, page 88 4-15, page 89 4-16, page 90
MT^3I			x	4-17, page 91
Person throughput			x	4-19, page 93
Truck volumes			x	4-20, page 94
Truck delays and travel times			x	4-21, page 95
Vehicle-hours of delay per corridor			x	4-22, page 96
Person-hours of delay per corridor			x	4-22, page 96

	Level of Measure			
Measure	Basic	Computed Basic	Advanced	Reference Table and Page Number
Number of (centerline) miles of congested general purpose lane roadway			x	4-22, page 96
Lost highway productivity			x	4-22, page 96
“Worst bottleneck” list			x	4-22, page 96

Table 4-7: Spot Location Speed

Definition

Measured or estimated speed of vehicles at a specific location for a specific lane type and direction of travel, by time of day and day of year.

Purpose/Need

Spot speeds provide an indicator of traffic performance at a given location. This basic data is also an essential input to a variety of other performance measures.

Data Source(s)

- Fixed or probe sensors

Calculations

Collect speed data at a specific location, across all lanes of a given type, in a specified direction of travel, at regular intervals throughout the day, for multiple days of the year.

Review data quality and filter unusable data points.

Archive the speed data by location/lane type/direction of travel, by time of day and day of year.

Variations

Speed data can be aggregated and summarized at any level to address analytical needs:

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Calendar year, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly

Desired Outcome

Provide basic performance data at a location; also used to develop other performance measures

Limitations/Cautions/Assumptions

Ideally, data should be collected continuously throughout the year, rather than from limited sampling, so that a complete profile of speed as a function of time of year can be compiled

Other Comments

Speed data can be measured, or estimated via approximate formula based on volume and lane occupancy.

Level of Measure (Basic, Moderate, Advanced)

Basic

Example

Spot speeds can be reported as output from a database query (e.g., Figure 4-1, page 56), or as part of a real-time traffic display (e.g., Figure 4-4, page 61). This metric is also often reported in aggregated form; see Table 4-10: Spot Location Speed (Average), page 84.

Table 4-8: Spot Location Volume

Definition

Measured or estimated vehicle volume at a specific location for a specific lane type and direction of travel, by time of day and day of year.

Purpose/Need

Spot volumes provide a key indicator of traffic usage at a given location. This basic data is also an essential input to a variety of other performance measures.

Data Source(s)

- Fixed sensors

Calculations

Collect volume count data at a specific location, across all lanes of a given type, in a specified direction of travel, at regular intervals throughout the day, for multiple days of the year.

Review data quality and filter unusable data points.

Archive the volume data by location/lane type/direction of travel, by time of day and day of year.

Variations

Volume data can be aggregated and summarized at any level to address analytical needs:

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Calendar year, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly

Desired Outcome

Provide basic usage data at a location; also used to develop other performance measures

Limitations/Cautions/Assumptions

Ideally, data should be collected continuously throughout the year, rather than from limited sampling, so that a complete profile of volume as a function of time of year can be compiled

Other Comments

Level of Measure (Basic, Moderate, Advanced)

Basic

Example

Spot volumes can be reported as output from a database query (e.g., Figure 4-1, page 56). This metric is more generally reported in aggregated form; see Table 4-11: Spot Location Volume (Average), page 85.

Table 4-9: Spot Location Lane Occupancy Percentage

Definition

The percentage of time that a sensor detects the presence of a vehicle, at a specific sensor location for a specific lane type and direction of travel, by time of day and day of year.

Purpose/Need

Spot lane occupancy percentage provides a useful indicator of traffic density, and the level of congestion experienced by travelers. This basic data is also an input to a variety of other performance measures.

Data Source(s)

- Fixed sensors

Calculations

Collect data about the percentage of time when a vehicle is detected at a specific sensor (lane) location, in a specified direction of travel, at regular intervals throughout the day, for multiple days of the year.

Review data quality and filter unusable data points.

Archive the lane occupancy percentage data by location/lane type/direction of travel, by time of day and day of year.

Variations

Lane occupancy data can be used as an independent indicator of traffic congestion (e.g., for the purposes of displaying traffic conditions on a real-time map). Data can summarized at any level to address analytical needs:

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Calendar year, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly

Desired Outcome

Provide basic traffic density data at a location; also used to develop other performance measures

Limitations/Cautions/Assumptions

Ideally, data should be collected continuously throughout the year, rather than from limited sampling, so that a complete profile of lane occupancy percentage as a function of time of year can be compiled

Other Comments

Level of Measure (Basic, Moderate, Advanced)

Basic

Example

While this metric is generally not reported independently, it can be used as a surrogate measure for congestion. For example, aggregated values can be used for a corridor contour graph (e.g., see Table 4-13: Corridor Performance, page 87) while individual values can be used for a real-time online map as an approximate indicator of level of congestion (e.g., Washington State Department of Transportation, Seattle area traffic map: http://www.wsdot.com/traffic/seattle/default.aspx). See Appendix G.

Table 4-10: Spot Location Speed (Average)

Definition

Measured or estimated speed of vehicles at a specific location for a specific lane type and direction of travel, for an average weekday of the year.

Purpose/Need

Spot speeds for the average 24-hour day provide a useful summary indicator of traffic performance at a given location.

Data Source(s)

- Basic spot speed data from fixed or probe sensors, by time of day and day of year

Calculations

Collect speed data at a specific location, across all lanes of a given type, in a specified direction of travel, and aggregate at regular intervals throughout the day (e.g., every 5 minutes), for each weekday of the year.

Review data quality and filter unusable data points.

For each aggregated time increment of a 24-hour day (e.g., every 5 minutes), average speed data across all weekdays of the year, to produce an average 24-hour profile of speed vs. time of day.

(Optional) Categorize speeds based on specified thresholds (e.g., > 55 mph, 45-55 mph, < 45 mph).

Summarize results in graphical form (e.g., average speed vs. time of day, color code by speed category); compare with average volume vs. time of day and likelihood of congestion vs. time of day.

Variations

Speed data can be aggregated and summarized at any level to address analytical needs, e.g.,

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT lane
- Time of year: Calendar year, quarterly, monthly

Desired Outcome

Provide summary view of spot location performance

Limitations/Cautions/Assumptions

Ideally, data should be collected continuously throughout the year, rather than from limited sampling, so that a complete profile of speed as a function of time of year can be compiled

Data should be distributed across all relevant lanes to avoid bias (e.g., “fast” lane vs. “slow” lane)

Other Comments

Speed data can be measured, or estimated via formula based on volume and lane occupancy

Level of Measure (Basic, Moderate, Advanced)

Computed Basic

Example

Washington State Transportation Center (TRAC) – Central Puget Sound Freeway Network Usage and Performance, Volume 1, 1999 Update, for Washington State Department of Transportation, WA.RD 493.1, by J. Ishimaru, M.E. Hallenbeck, and J. Nee, 2001, page 82, Figure 4-19, available at http://depts.washington.edu/trac/bulkdisk/pdf/493.1.pdf. See Appendix H.

Table 4-11: Spot Location Volume (Average)

Definition

Measured or estimated vehicle volume at a specific location for a specific lane type and direction of travel, for an average weekday of the year.

Purpose/Need

Spot volumes for the average 24-hour day provide a useful summary indicator of usage at a given location.

Data Source(s)

- Basic spot volume data from fixed sensors, by time of day and day of year

Calculations

Collect volume count data at a specific location, across all lanes of a given type, in a specified direction of travel, at aggregated regular intervals throughout the day (e.g., every 5 minutes), for each weekday of the year.

Review data quality and filter unusable data points.

For each aggregated time increment of a 24-hour day (e.g., every 5 minutes), average volume data across all weekdays of the year, to produce an average 24-hour profile of volume vs. time of day.

(Optional) Normalize the volumes (e.g., VPLPH = volume per lane per hour) to enable comparisons between locations with different numbers of lanes.

Summarize results in graphical form (e.g., average volume vs. time of day); compare with average speed and likelihood of congestion.

Variations

Volume data can be aggregated and summarized at any level to address analytical needs:

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of year: Calendar year, quarterly, monthly

Desired Outcome

Provide summary view of spot location usage

Limitations/Cautions/Assumptions

Ideally, data should be collected continuously throughout the year, rather than from limited sampling, so that a complete profile of volume as a function of time of year can be compiled

Data should be distributed across all relevant lanes to avoid bias (e.g., “fast” lane vs. “slow” lane)

Other Comments

Level of Measure (Basic, Moderate, Advanced)

Computed Basic

Example

Washington State Transportation Center – Central Puget Sound Freeway Network Usage and Performance, Volume 1, 1999 Update, for Washington State Department of Transportation, WA.RD 493.1, by J. Ishimaru, M.E. Hallenbeck, and J. Nee, 2001, page 82, Figure 4-19, available at http://depts.washington.edu/trac/bulkdisk/pdf/493.1.pdf. See Appendix H.

Table 4-12: Spot Location Likelihood of Congestion

Definition

Likelihood of encountering congestion at a location, for a given lane type and direction of travel.

Purpose/Need

While average volumes and average speeds define the “typical” traffic condition, reliability reflects the variability or uncertainty of travel, which is often of particular importance to a traveler.

Data Source(s)

- Basic spot speed data from fixed or probe sensors, by time of day and day of year

Calculations

Collect speed data at a specific location, in a specified direction of travel, at aggregated regular intervals throughout the day, for each weekday of the year, and review data quality. (See Spot Location Speed metric)

Establish a threshold definition of “congestion” (i.e., what speed constitutes a congested condition).

Determine the frequency of congestion (i.e., what percentage of the total number of sampled days of the year are congested) using the defined threshold speed value, by time of day.

Summarize results in graphical form (e.g., likelihood of congestion vs. time of day); compare with average volume and average speed.

Variations

Reliability data can be aggregated and summarized at any level to address analytical needs:

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of year: Calendar year, quarterly, monthly (see Other Comments below)

Desired Outcome

Provide summary view of spot location travel reliability

Limitations/Cautions/Assumptions

Ideally, speed data should be collected continuously throughout the year, or from a large sample size, so that reliability can be based on a sufficient sampling of conditions throughout the year

Data should be distributed across all relevant lanes to avoid bias (e.g., “fast” lane vs. “slow” lane)

Other Comments

Speed data can be measured, or estimated via formula based on volume and lane occupancy

Congestion can also be defined based on lane occupancy percentage; this enables the likelihood of congestion to be computed directly from a basic sensor data variable if speed data are not available

Level of Measure (Basic, Moderate, Advanced)

Computed Basic

Example

Washington State Transportation Center – Central Puget Sound Freeway Network Usage and Performance, Volume 1, 1999 Update, for Washington State Department of Transportation, WA.RD 493.1, by J. Ishimaru, M.E. Hallenbeck, and J. Nee, 2001, page 82, Figure 4-19, available at http://depts.washington.edu/trac/bulkdisk/pdf/493.1.pdf. See Appendix H.

Table 4-13: Corridor Performance (Volume, Speed, Likelihood of Congestion)

Definition

Measured or estimated average vehicle volume, speed, or likelihood of congestion as a function of both location and time of day, for specific lane type and travel direction, for an average weekday of the year.

Purpose/Need

Corridor or region performance metrics (based on volume, speed, or likelihood of congestion) provide a useful summary indicator of traffic conditions for an entire corridor or region, based on both time of day and location.

Data Source(s)

- Basic spot speed data from fixed or probe sensors, by time of day and day of year, and/or
- Basic spot volume data from fixed sensors, by time of day and day of year, and/or
- Basic reliability (frequency of congestion) data, by time of day and day of year

Calculations

Collect average weekday spot volume, spot speed, and/or spot likelihood of congestion for a series of locations along a corridor or for a series of locations throughout a region (not necessarily one corridor) (see descriptions of Spot Location speed, volume and likelihood of congestion metrics).

Summarize values vs. time of day and location, aggregating as desired.

Graphically display as contour map (if one corridor) or spot location colors on a map (if regional), based on user-specified threshold of “congestion” (e.g., Level of Service [LOS] F).

Variations

Data can be aggregated and summarized at any level to address analytical needs:

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Calendar year, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly
- Corridor-long or area-wide VMT may also be used to measure changes in vehicle usage

Desired Outcome

Provide top-level summary view of corridor or regional usage and/or performance

Limitations/Cautions/Assumptions

Ideally, data should be collected continuously throughout the year, rather than from limited sampling, so that a complete profile of performance as a function of time of year can be compiled

Other Comments

Level of Measure (Basic, Moderate, Advanced)

Computed Basic

Example

Washington State Transportation Center, University of Washington– Central Puget Sound Freeway Network Usage and Performance, Volume 1, 1999 Update, for Washington State Department of Transportation, WA.RD 493.1, by J. Ishimaru, M.E. Hallenbeck, and J. Nee, 2001, page 21, Figure 3-8 (speed-based), and page 31, Figure 3-16 (frequency of congestion-based), available at http://depts.washington.edu/trac/bulkdisk/pdf/493.1.pdf. See Appendix I.

Table 4-14: Travel Time

Definition

Estimated travel time for a specific starting and ending location and trip route, as a function of time of trip start, for an average weekday of the year.

Purpose/Need

Travel times summarize estimated traffic conditions faced by a traveler based on both trip route and time of day, and provide a useful, intuitive metric that can be understood by a broad audience

Data Source(s)

- Spot speeds based on fixed or probe sensors, at locations along a trip route, by day and time
- Trip route distances (between adjacent sensors)

Calculations

Collect weekday spot speed data for a series of locations along a trip route as a function of time of day and day of year. Review data quality and filter unusable data points.

For a given trip route, day of the year, and trip start time, compute segment travel times along the trip route (a segment is defined by adjacent sensor locations). Trip travel time = sum of segment times. Segment travel time is based on (segment length/average segment speed). Average segment speed is based on speeds at segment endpoints at the time the traveler reaches the segment, based on elapsed time up to the segment (i.e., vehicle trajectory method; see Other Comments). Average the travel times for a given start time, across all days, producing a 24-hour average travel time profile.

Variations

Travel time (or equivalent trip speed) can be aggregated to address analytical needs:

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Yearly, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly
- Travel time comparisons (e.g., GP travel time vs. adjacent HOV/HOT lane, HOV/HOT time savings)
- Index values can also be used to compare travel times across corridors

Desired Outcome

Provide summary metric for travel performance and reliability

Limitations/Cautions/Assumptions

Ideally, large sample size is preferred (e.g., data collected continuously throughout the year)

Other Comments

Vehicle trajectory method: See NCHRP web-only document 97, “Guide to Effective Freeway Performance Measurement: Final Report and Guidebook”, section 8.4.2, page 8-17, at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w97.pdf

Travel times based on common routes or corridors are easier for a broad audience to understand

Level of Measure (Basic, Moderate, Advanced)

Computed Basic

Example

See examples in Table 4-16, page 90, and Figure 4-7, page 64.

Table 4-15: n-th Percentile Travel Time

Definition

The n-th percentile travel time for a trip is the travel time T such that n percent of travel times are less than or equal to T. It is defined for a specific trip route and time of trip start, for a given period of time.

Purpose/Need

n-th percentile travel times provide a useful way to summarize the variability (reliability) of traffic conditions and the distribution of travel times. It can be used to evaluate changes in reliability resulting from TMC actions such as incident response.

Data Source(s)

- Travel times for a trip route. (See Travel Time metric description)

Calculations

For a given trip start time or time period (e.g., 7 AM, AM peak period), sort the N travel times in ascending order, where N=number of days, resulting in a series of values Ti, where T1 ≤ T2 ≤ … ≤ TN

Compute x = (n/100) * (N+1). Separate x into (k + d), where k is integer and d is a fraction (0≤d<1)

If 0 < k < N, the n-th percentile value = TK + d * (TK+1 – TK)

If k = 0, the n-th percentile value = T1; If k = N, the n-th percentile value = TN

Example: If N= 261 (e.g., all weekdays of a year) and n=90, x would equal (90/100) x (261+1) = 235.8. Therefore, k = 235 and d = 0.8. So, 90th percentile travel time = T235 + 0.8 x (T236 - T235), where T235 and T235 are the 235th and 236th travel times, respectively, in the sorted ascending sequence of travel times.

Variations

- n=95 is commonly used; however, it can be vulnerable to change from random events. An 80th percentile value can be a better indicator of the effect of TMC activity on trip time variability
- Prior to determining the n-th percentile, daily travel time data can be aggregated or filtered:
- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Yearly, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly

Desired Outcome

Provide summary metric for travel performance and reliability

Limitations/Cautions/Assumptions

Ideally, a large sample size is preferred (e.g., data collected continuously throughout the year)

Other Comments

Source of algorithm: NIST/SEMATECH e-Handbook of Statistical Methods, April 2012, http://www.itl.nist.gov/div898/handbook/prc/section2/prc252.htm (Alternative algorithms exist)

Level of Measure (Basic, Moderate, Advanced)

Computed Basic

Example

Washington State Department of Transportation 2012 Annual Congestion Report, page 37, available at http://www.wsdot.wa.gov/Accountability/Congestion/2012.htm, See Appendix J.

Table 4-16: Frequency of Slow Trips

Definition

Estimated frequency of “slow” trips for a specific starting and ending location and trip route, as a function of time of trip start, for weekdays of a given year.

Purpose/Need

Frequency of slow trips indicates the likelihood of encountering a congested trip on a given route, as a function of the time the trip begins. It also provides a useful metric of travel time variability.

Data Source(s)

- Travel time data (See Travel Time metric description)

Calculations

Compile travel time data as a function of day and time

Establish a threshold definition of “slow” (i.e., what overall trip speed constitutes a slow trip, such as average trip speed < 35 mph).

Determine the likelihood of a slow trip (i.e., what percentage of the weekdays of the year have a speed ≤ the defined threshold “slow” speed value), by time of day.

Summarize results in graphical form (e.g., likelihood of slow trip vs. time of trip start); compare with average travel time and 95th percentile travel time 24-hour profiles.

Variations

Travel time data can be aggregated and summarized at any level to address analytical needs:

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Yearly, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly
- Comparative travel times can also be used to analyze performance (e.g., GP 95th percentile travel time vs. adjacent HOV or HOT lane 95th percentile travel time).

Desired Outcome

Provide summary metric for travel performance and reliability

Limitations/Cautions/Assumptions

Ideally, data should be collected continuously throughout the year, rather than from limited sampling, so that a sufficiently large sample of performance can be compiled

Other Comments

Travel times based on common routes or corridors are easier for a broad audience to understand

Level of Measure (Basic, Moderate, Advanced)

Computed Basic

Example

Washington State Transportation Center, University of Washington– Central Puget Sound Freeway Network Usage and Performance, Volume 1, 1999 Update, for Washington State Department of Transportation, WA.RD 493.1, by J. Ishimaru, M.E. Hallenbeck, and J. Nee, 2001, page 38, Figure 3-19 (chart shows average travel time, 90th percentile travel time, frequency of slow trips), available at http://depts.washington.edu/trac/bulkdisk/pdf/493.1.pdf. See Appendix K.

Table 4-17: Normalized Performance Metrics

Definition

Travel time performance measures that are adjusted to allow corridor-to-corridor comparisons.

Purpose/Need

Performance metrics such as travel times cannot be directly compared between corridors of different lengths. To allow such comparisons, metrics can be adjusted for length (often via unitless index values).

Data Source(s)

- Travel time data derived from fixed or probe sensors and trip route segment lengths (See Travel Time metric description)

Calculations

Use one or more of the following adjusted measures:

Travel time rate: Travel time / Trip length

MT^{3}I: Mean travel time / Travel time at max throughput (see "Other Comments" below)

TTI: Mean travel time / Free flow travel time

PTI: 95th percentile travel time / Free flow travel time

BTI: (95th percentile travel time – Mean travel time) / Mean travel time

Variations

Travel time data can be aggregated and summarized at any level to address analytical needs:

- Day of week: Weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Calendar year, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly

Desired Outcome

Provide summary metric for travel performance and reliability

Limitations/Cautions/Assumptions

Ideally, data should be collected continuously throughout the year, rather than from limited sampling, so that a complete profile of speed as a function of time of year can be compiled

Other Comments

MT3I should only be reported if one is managing freeway operations to optimize capacity rather than achieve free flow conditions. See Washington State Department of Transportation 2012 Congestion Report, page 29, available at http://www.wsdot.wa.gov/Accountability/Congestion/2012.htm.

Level of Measure (Basic, Moderate, Advanced)

Advanced

Example

TTI, PTI, BTI: 2011 Kansas City Scout Congestion Index Report, pages 4-10 (TTI), pages 11-16 (PTI), and pages 17-22 (BTI), available at http://www.kcscout.net/downloads/Announcements/CongestionReport.pdf.

MT3I: See Other Comments above. See Appendix L.

Table 4-18: Cumulative Usage Metrics

Definition

Derived or cumulative metrics of corridor usage.

Purpose/Need

Cumulative measures of corridor-level usage can be derived from volume and speed, including vehicle-miles of travel, vehicle-hours of travel (both aggregate corridor measures)

Data Source(s)

- Basic volume data derived from fixed sensors (See Spot Location Volume metric description)
- Segment lengths
- Segment travel times derived from fixed or probe sensors and segment lengths (See Travel Time metric description)

Calculations

Vehicle-miles of travel (aggregate corridor measure): Sum of (segment vehicle volumes x segment distance)

Vehicle-hours of travel (aggregate corridor measure): Sum of (segment vehicle volumes x segment travel time)

Variations

Travel time data can be aggregated and summarized at any level to address analytical needs:

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Calendar year, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly

Desired Outcome

Provide summary metric for corridor usage

Limitations/Cautions/Assumptions

Ideally, data should be collected continuously throughout the year, rather than from limited sampling, so that a complete profile of speed as a function of time of year can be compiled

Aggregate measures (e.g., for 1 year) should first be computed for each day, then aggregated up to a yearly level. This allows other results to be easily computed by aggregating daily results (e.g., to get monthly or quarterly results, not just yearly), and enables analyses of day-to-day variability.

Other Comments

Level of Measure (Basic, Moderate, Advanced)

Advanced

Example

2011 Kansas City Scout Congestion Index Report, pages 23-24, available at http://www.kcscout.net/downloads/Announcements/CongestionReport.pdf. See Appendix M.

Table 4-19: Person Throughput

Definition

Estimated person volume at a location.

Purpose/Need

Person throughput or person volume is useful as a metric of facility effectiveness in moving people, not just vehicles. A typical example involves analyzing GP vs. HOV (or HOT) lane effectiveness.

Data Source(s)

- Vehicle volumes derived from fixed sensors
- Vehicle occupancy data derived from field observations or other technology
- Transit ridership data from transit agencies

Calculations

Person volume = ([vehicle volume x occupancy per vehicle] for all non-transit vehicles) + transit ridership

Variations

Travel time data can be aggregated and summarized at any level to address analytical needs:

- Day of week: weekday, weekend, Tuesday -Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Calendar year, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly

Desired Outcome

Provide summary view of spot location performance based on moving people, not vehicles

Limitations/Cautions/Assumptions

Ideally, vehicle volume data should be collected continuously throughout the year, rather than from limited sampling, so that a complete profile of volume as a function of time of year can be compiled

Requires collection of sample occupancy data (persons per vehicle), and sample transit ridership data

Occupancy data can be difficult to collect; field observations are labor-intensive and can introduce error, while vehicle occupancy data technology to assist is still unproven in practice

If vehicle counts are disaggregated by vehicle type (e.g., single occupancy vehicle [SOV], 2-person HOV, 3 HOV, 4+ HOV, vanpool). Occupancy data can be disaggregated as well.

Other Comments

Metric used when actively performing demand management

Level of Measure (Basic, Moderate, Advanced)

Advanced

Example

See Figure 4-10, page 71.

Table 4-20: Truck Volumes (spot locations)

Definition

Estimated truck volume at a specific location for a specific lane type and direction of travel, by time of day and day of year.

Purpose/Need

Spot truck volumes provide a key indicator of roadway freight traffic usage at a given location, and are helpful for determining the cost of roadway freight delay, preparing traffic control plans, or configuring incident response equipment (e.g., heavy-duty tow trucks)

Data Source(s)

- Fixed sensors capable of differentiating trucks from passenger vehicles

Calculations

Collect truck volume count data at a specific location, across all lanes of a given type, in a specified direction of travel, at regular intervals throughout the day, for multiple days of the year.

Review data quality and filter unusable data points.

Archive the volume data by location/lane type/direction of travel, by time of day and day of year.

Variations

Volume data can be aggregated and summarized at any level to address analytical needs:

- Day of week: Weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Calendar year, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly

Desired Outcome

Provide summary metric of freight usage on roadways; also used to develop other truck mobility performance measures

Limitations/Cautions/Assumptions

Ideally, data should be collected continuously throughout the year, rather than from limited sampling, so that a complete profile of volume as a function of time of year can be compiled

Other Comments

Truck volumes can be collected using different vehicle classification systems, ranging from simple car/truck systems, to three or four length-based classes, to 13 axle-based classes. HPMS collects truck volume data for two classes, single units and combination units, which is sufficient for most performance analyses concerned with truck mobility.

Level of Measure (Basic, Moderate, Advanced)

Advanced

Example

Washington State Department of Transportation 2010 Gray Notebook: Trucks, Goods, and Freight Annual Report, page 48, available at http://www.wsdot.wa.gov/NR/rdonlyres/BD26D6F0-B554-497C-9D0E-35C546BF179F/0/GrayNotebookMar10.pdf#page=60. See Appendix N.

Table 4-21: Truck Delays and Travel Times

Definition

Estimated truck travel time and delays for a specific starting and ending location and trip route, as a function of time of trip start, for an average weekday of the year. Measures include Truck Hours of Delay (THD), Truck Hours Traveled (THT), Truck Hours Traveled at Free Flow (THTFF).

Purpose/Need

Truck travel times and delays summarize estimated traffic conditions faced by surface roadway freight based on both trip route and time of day

Data Source(s)

- Spot speeds for trucks based on fixed or probe sensors at locations along trip route, by day and time
- Trip route distances (between adjacent sensors)

Calculations

- Collect weekday truck spot speed data for a series of locations along a trip route as a function of time of day and day of year. Review data quality and filter unusable data points.
- For a given trip route, day of the year, and trip start time, compute segment travel times for trucks along the trip route. Trip travel time = sum of segment times. Segment travel time is based on (segment length/average segment speed). Average segment speed is based on speeds at segment endpoints at the time the traveler reaches the segment, based on elapsed time up to the segment (i.e., the vehicle trajectory method; see Example). Average the travel times for a given start time, across all days, producing a 24-hour average travel time profile.
- Truck-hours of delay (per corridor): THT – THTFF; THTFF is computed by assuming free flow speed at all times (THT = vehicle-hours traveled is computed the same as VHT – see "Cumulative Usage Metrics" – but using truck volumes instead of total volume)

Variations

Corridors for which truck travel times are computed usually differ from those computed for passenger vehicles. They should be selected to represent key truck movements in the region.

Desired Outcome

Provide summary metric of freight performance on roadways

Limitations/Cautions/Assumptions

Truck-specific data are often not as widely available as passenger car data. Thus truck performance measures are generally not as precise as similar statistics made using data based on all vehicles.

Other Comments

Level of Measure (Basic, Moderate, Advanced)

Advanced

Example

Vehicle trajectory method: See NCHRP web-only document 97, “Guide to Effective Freeway Performance Measurement: Final Report and Guidebook”, section 8.4.2, page 8-17, at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w97.pdf. See Appendix O.

Table 4-22: Cumulative Performance Metrics

Definition

Derived or cumulative metrics of location or corridor performance.

Purpose/Need

Cumulative measures (derived from volume and speed) provide useful summary performance indicators

Data Source(s)

- Basic volume and speed data derived from fixed or probe sensors
- Segment travel times derived from fixed or probe sensors and segment lengths

Calculations

- Vehicle-hours of delay (corridor): VHT – (freeflow VHT); freeflow VHT is computed by assuming freeflow speed at all times (VHT = vehicle-hours traveled; see "Cumulative Usage Metrics")
- Person-hours of delay (corridor): Vehicle-hours of delay by average vehicle occupancy (the latter will require supplementary data collection; see “Person Throughput” metric description)
- Number of centerline (or directional) miles of congested roadway (corridor): Number of miles of roadway (or percentage of total length) that experience congested conditions at a given time or time period. Definition of “congested” based on user-specified lane occupancy percentage, or speed. Can report by direction of travel.
- Lost productivity (spot location): Difference between highest observed vehicle flow rate and vehicle flow when conditions are less than “maximum throughput” speed (e.g., 85% of free flow speed)
- Bottleneck ranking lists (based on both performance and significance (i.e., both speed and volume): Ranked lists of roadway segments based on vehicle-hours of delay or person-hours of delay

Variations

Travel time data can be aggregated and summarized to address analytical needs:

- Day of week: weekday, weekend, Tuesday-Thursday
- Lane type: GP, HOV, HOT
- Time of day: 24 hours, peak periods only
- Time of year: Yearly, quarterly, monthly
- Time granularity: every 5 minutes, 15 minutes, hourly

Desired Outcome

Provides summary metric for location or corridor-level performance

Limitations/Cautions/Assumptions

Ideally, a large sample size is preferred (e.g., data collected continuously throughout the year)

Aggregate measures (e.g., for 1 year) should first be computed for each day, then aggregated up to a yearly level. This allows other results to be easily computed by aggregating daily results (e.g., to get monthly or quarterly results, not just yearly), and enables analyses of day-to-day variability.

Other Comments

Level of Measure (Basic, Moderate, Advanced)

Advanced

Example

Lost productivity: Washington State Department of Transportation 2012 Annual Congestion Report, pages 24-26, at http://www.wsdot.wa.gov/Accountability/Congestion/2012.htm. See Appendix P.

Chapter 5. Cross-Cutting Performance Measures

This section describes the concept of cross-cutting performance measures and their potential usefulness for TMC performance monitoring activities.

5.1 Purpose and Need—Cross-Cutting Performance Measures

Cross-cutting measures are performance measures that combine data from two or more of the other three performance measurement categories described previously in this *Reference Manual*, sometimes with other non-TMC data sets, to measure the effects of specific TMC programs and strategies on the public's mobility. Cross-cutting measures are designed to illustrate the perceived and actual value of the activities in which the TMC participates. That is, they are designed to analyze the effects on mobility that specific TMC programs are having, as well as track the public's perception of those programs. These analytical results are necessary if decision makers request numerical benefits from TMC activities in order to determine how to best spend limited transportation budgets.

5.1.1 General Discussion of Cross-Cutting Performance Measures

Most cross-cutting measures are considered advanced measures, and the computational procedures to derive many of the desired measures are still being developed. This is an area in which considerable research is currently being conducted, and new developments in performance reporting are being published. Early analyses that demonstrate how to compute and use cross-cutting measures are discussed in reports such as the Strategic Highway Research Program (SHRP)2 L03 report, *Analytic Procedures for Determining Impacts of Reliability Mitigation Strategies,* delivered to SHRP in 2010 and currently awaiting publication. Other reports, such as *Incident Response Evaluation, Phase 3* by Hallenbeck, Watkins, and Pham for WSDOT (report number WA.RD #761.1), discuss additional ways in which mobility data can be combined and analyzed with incident and other data.

Relatively few TMCs have reporting systems that are actively utilizing and reporting cross-cutting performance measures. Those that are doing so are most commonly:

- Responding to legislative questions concerning the benefits the public is obtaining from specific TMC programs
- Looking to understand the performance of, or benefits from, their operations programs for their own management purposes (e.g., determining whether the new metering algorithm is working as intended)
- Trying to answer questions concerning the value of their activities in anticipation of being asked these kinds of questions.

When TMCs lack clear answers to the basic question of “what the public gets from its activities,” they open themselves up to budget cuts from decision makers who lack a clear understanding of the benefits a TMC provides.

Perhaps the most famous case of TMC operations being directly affected by legislative action because of an inability of the TMC to effectively describe the benefits of its operational activities occurred in 2000 in Minnesota. The state legislature required the Minnesota DOT to shut off its ramp metering system in the Minneapolis area for 6 months, and then perform an extensive before/after study of the delays and crashes with and without the metering system. Only after this expensive, live field trial had showed when and where the metering program reduced delays and reduced crashes did the legislature allow MnDOT to reinstall a modified ramp metering control algorithm. The revised metering program was specifically designed to address issues identified by the cross-cutting study that compared the size and location of delays determined by the before/after study of ramp metering plans.

Many other TMCs have experienced significant cutbacks in incident response activities during times of budget constraints. To TMC operators, the benefits of incident response are obvious, but without strong, defensible, numerical analyses that describe the delay reductions that the incident response program is achieving, it is difficult for these programs to compete with traditional capacity enhancement projects in the budget prioritization process. The same can be true for programs such as snow plow operations or development and implementation of special event traffic plans. Consequently, developing and reporting performance measures that describe the benefits to mobility of these programs—not just the effective delivery of services—is directly beneficial to maintaining these programs.

5.1.2 Process for Selecting and Prioritizing Cross-Cutting Performance Measures

Prioritizing the development of cross-cutting performance measures is fairly simple. The first thing that TMCs should measure is public attitude toward their activities and the perceived quality of their services. In an era when it is difficult to raise taxes, it is important that the public feels that it is benefiting from transportation budgets. Where the public is highly supportive of TMC functions, this information can be used to support those programs. Where the public is not supportive of TMC functions, TMCs should use that information to:

- Change their business practices, as appropriate, to provide more obvious direct benefits to the public
- Gain a better understanding of public expectations and why current TMCs activities are not meeting them.

The second priority is to develop defensible analytical measures that describe the mobility benefits obtained from specific programs—as well as which operational activities are *not* providing significant benefits so that those activities can be changed or eliminated. The TMC should develop benefit measures for all of its programs, starting with the activities it believes provide the most public benefit or that consume the greatest amount of TMC resources. These activities will differ from one TMC to another, and therefore, different TMCs will prioritize cross-cutting measures differently. For example, if the TMC is responsible for significant IR functions, then the mobility benefits from those IR activities should be measured. Similarly, if the TMC is involved in snow removal activities, then the mobility outcomes of those snow removal activities need to be measured.

5.2 Selected Cross-Cutting Performance Measures

Cross-cutting measures are designed to describe the combined effects of the previous three categories of performance measures. They are designed to illustrate the value (perceived and actual) of the activities in which the TMC participates and the benefits achieved from specific programs or changes in operational procedures. Most cross-cutting measures are advanced measures, and the computational procedures for many of them are still being developed. The state of the art is still in flux, and many of the leading TMCs are in the process of developing measures and techniques. The following are the recommended cross-cutting measures that TMCs should consider implementing.

5.2.1 Customer (Public) Satisfaction

The only cross-cutting measure recommended for all TMCs is to collect and report on public opinion. The following are the basic customer satisfaction measures that TMCs should collect and report to decision makers so that they (1) understand what their customers do or do not value and (2) can describe to decision makers the level of public support for TMC activities.

Unlike most cross-cutting measures, public satisfaction measures are not really a combination of previously collected performance measures but are instead a summary of how the public views the activities of the TMC and can change frequently based on current events. Understanding and reporting on public satisfaction may best be performed as part of a larger effort to collect traveler satisfaction data. Such information can also be collected as part of routine TMC-related activities. For example, many safety service patrols hand out postage-paid “please comment on this service” postcards to gather data on how customers view their efforts. The resulting data are used both to manage the services being provided and to provide information useful for defending the value of the program. Comment sections on these feedback cards are particularly valuable for obtaining anecdotes that describe the benefits the public gains from safety service patrols. Sending selected comments along with summaries of the survey data to public officials looking to cut these services is a very effective way of demonstrating the direct benefits their constituents receive from the patrols.

A summary of the above discussion of customer satisfaction metrics is included in Table 5-2 at the end of this chapter.

The remaining cross-cutting measures are appropriate for TMCs with more advanced/mature performance monitoring programs. They require more sophisticated data collection and analysis capabilities.

5.2.2 Incident Delay

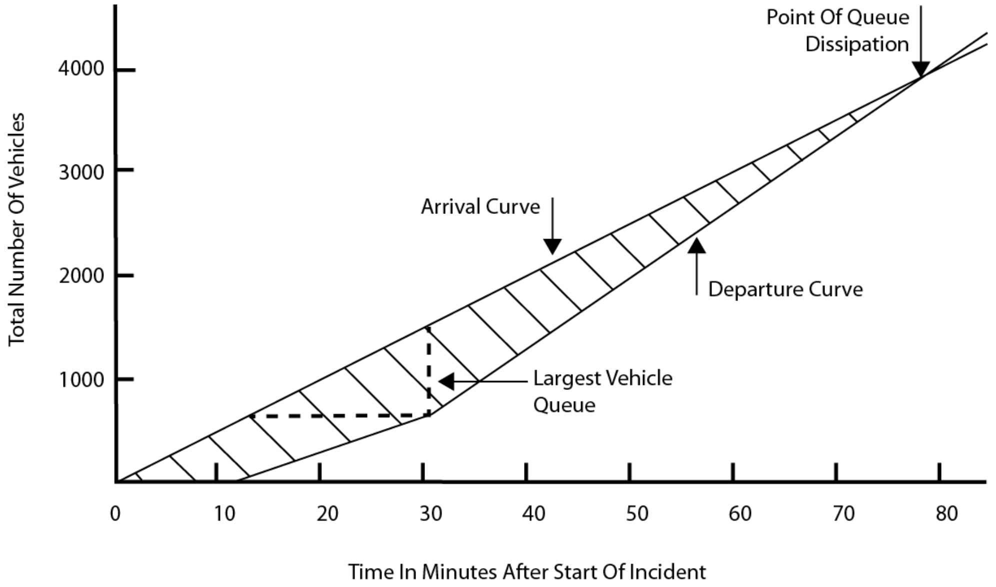
Most TMCs involved with incident response activities are eventually asked to justify their incident response programs in terms of safety and travel time impacts. These safety and travel time benefits are computed by combining the performance measures that describe the TMC’s incident management activities (see Section 3) with those that describe the performance of the roadway system on which incidents and the agency’s response occur (see Section 4). Combining data from these two sets of measures allows calculation of the second recommended cross-cutting performance measure, *Incident Delay*. The basic concept here is to report on both the amount of incident delay occurring and the changes in that delay that result from the incident response program.

Delay is one of the mobility performance measures discussed in Section 4 of this *Guidebook*. It is most commonly computed in terms of vehicle-hours of delay. By combining the geographic and temporally specific measures of where and when delays occur with the geographic and temporally specific measures of where incidents occur, analysts can categorize that delay into “delay caused by incidents” and “other delay.” Simply aggregating the delay “caused by incidents” allows the TMC to report on the total amount of time lost by travelers as a result of incidents. By tracking changes in these statistics resulting from changes in the incident response program, the TMC can track the overall value of those changes in the incident response program.

Unfortunately, the above steps are analytically very complex. Part of this complexity is caused by a lack of a common national definition for “incident delay.” Various TMCs and academic researchers have chosen to define this term differently. The most common definition uses queuing theory to compute the number of vehicles in a queue and the length of time the queue is present as a result of an incident-caused reduction in roadway capacity. By tracking the size and duration of the queue, it is possible to compute vehicle-hours of delay. Figure 5-1 illustrates this approach. It shows a roadway with a base capacity of 4,000 vehicles per hour (vph) and a constant volume of 2,900 vehicles per hour. At the lower left of the graphic, the freeway is blocked by a crash. At 12 minutes, the facility is partially opened to a capacity of 2,000 vph. It is then fully opened to traffic after 31 minutes, at which point the queue starts to decrease in size. The queue has fully dissipated after just over 78 minutes. In Figure 5-1, the cross hatched area between the Vehicle Arrival and Vehicle Departure curves is the incident delay caused by the crash.

Where traffic is free flowing before the incident, as in Figure 5-1, this queuing model serves as a good definition of incident delay. However when incidents occur in saturated (already congested) conditions or when general roadway saturation occurs at some point during the incident queue, the assumption of “roadway capacity” used in basic queuing theory tends to be problematic, leading to inaccurate delay estimates. In addition, when saturated conditions are present during an incident, there is no consensus among practitioners about whether all of the delay measured in the queue at the incident scene should be called “incident delay” or some of that delay should be assigned to “recurring congestion” (i.e., caused by too much base traffic volume), since even without the incident, some delay would have resulted from the saturated roadway conditions. Until national definitions of incident delay are adopted, this *Guidebook* recommends labeling all delay at an incident site as “incident delay” for the purpose of cross-cutting measure development.

Figure 5-1: Calculation of Incident Delay Using Queuing Theory



Source: Principles of Highway Engineering and Traffic Analysis, by Mannering and Kilareski, 1990, page 149.

The first step for computing incident delay is to connect the incident data with the mobility data both spatially and temporally. This means that the TMC's data archive must be able to associate the time and location of the incident with the mobility data that describe when and where delays are occurring and the volumes of vehicles at those locations. Generally, a flag variable must be set to indicate that an incident has occurred (or is occurring) for the relevant directional section of roadway. That flag remains set until (1) the incident has been fully cleared (i.e., the last incident response vehicle has left the scene) *and* (2) conditions on that roadway section are no longer congested.

With flag variables indicating the start and end points of the incident-caused congestion, it is then possible to extract the volume data and use them as inputs to the queuing theory equations that compute delay for individual incidents. Aggregating these values (for the region or by some subset of the region, such as by corridor) for all incidents allows the TMC to produce incident delay statistics that can be tracked over time. It is also possible to compute the percentage of all delay that is caused (or at least partially caused) by incidents. This is done by dividing the total incident delay for the region by the total delay for the region, as computed in Section 4.

Next, the monetary value of incident delay can be readily computed by assigning a dollar value to delay (using units of dollars per vehicle-hour of delay). These dollar estimates are useful in defending the cost of incident response programs, because good IR programs tend to have very high benefit to cost ratios. Where possible, the dollar value of delay should reflect the percentage of traffic that contains commercial vehicles and the different values of time associated with passenger vehicles and commercial vehicles. (That is, the average value of time per vehicle-hour for a road that is 25 percent trucks will be higher than that for a road where only 8 percent of the traffic is trucks.)

The above delay and delay value statistics should also be summarized and reported by type and/or duration of incident, by time of day, and by type of incident response activity, as these summary statistics will help the TMC allocate resources to its IR activities.

Incident delay (or the value of delay) should also be reported within the context of the number and type of incidents, as well as the level of effort of the incident response program. These statistics should be used both internally for management purposes (e.g., determining which activities are effective at improving mobility, how the available TMC resources can be most effectively allocated) and externally to argue for additional resources or defend the current TMC budget. For example, reporting the number of fatal crashes, the delay associated with those crashes, and the value of that delay might support a request to change fatal crash investigation procedures in order to reduce their duration. In the 1990s, WSDOT used this approach to obtain funding for Total Station surveying equipment and training for the Washington Highway Patrol. By using that equipment to collect data at fatal crash scenes, officers dramatically reduced the time spent on scene, thus significantly decreasing the amount of vehicle delay caused by fatal crashes.

The queuing theory approach has two limitations[7] in calculating incident delay. First, it does not account for delay caused by "rubbernecking," as it associates congestion only with delay on the side of the road where the incident occurred. The TMC can set the incident flag for both directions of travel, but work done for the SHRP2 L03 project found that this tends to overstate incident congestion because minor incidents that occur in the "off-peak" direction of travel cause peak direction recurring congestion to be associated with incidents that are not actually affecting travel. Second, with large incidents, queues may back up over a considerable distance on urban freeways. This means that the algorithm that sets the "incident" flag must be able to set that flag on those upstream road segments as the queue grows. These flags (defining the total duration of the congestion for that incident) must remain set until congestion on those upstream road segments dissipates, even if the original incident on the affected road segment clears to free flow. (The actual bottleneck location on the roadway can actually move upstream once the incident scene has been cleared because of the physics of traffic flow on congested urban roadways.)

More sophisticated approaches to computing incident delay can also be implemented to minimize the effects of the limitations discussed above. These more sophisticated approaches are the subject of considerable research being published by TRB and various other research journals. Unfortunately, these more sophisticated approaches are typically subject to a number of very specific data requirements—including the availability of specific variables, very high data quality requirements, very fine levels of detail in volume and speed (for example, some sophisticated approaches require traffic volume data by lane at a maximum 20-second interval), and the ability of the archive to combine data from multiple sources. TMCs with advanced data archives and analytical capabilities are encouraged to explore these more sophisticated techniques, but they are not appropriate for TMCs without both sophisticated data archives and the staff skill sets needed to write, debug, and apply the complex software required to deploy them.

A summary of the above discussion of incident delay metrics is included in Table 5-3 at the end of this chapter.

5.2.3 Recovery Time from Disruptions

One of the commonly desired reporting statistics is the time the roadway takes to "recover" from an event. For example, a TMC might like to be able to state something like, "It used to take the road 50 minutes to recover from lane blocking crashes, but now, thanks to our new incident response program, the road recovers from lane blocking crashes, on average, in less than 30 minutes."

Ideally, these road recovery statistics would be reported both before and after the implementation of any new TMC activity because the difference in recovery times describes the effectiveness of those

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[7] These limitations are in addition to the fact that the queuing theory approach does not separate delay into "recurring" and "non-recurring" portions where incidents occur on roads that would otherwise be congested simply because of high traffic volumes.

new programs and how the public benefits from TMC activities. For example, the TMC might like to report how much more quickly a roadway returns to free flow operation after a major snowstorm as a result of the deployment of a new proactive snow management program.

As with the term “incident delay,” the first problem with reporting on recovery time is that there is no national definition of when “recovery” has occurred. So the first task of the TMC is to develop the most appropriate definition by working with its stakeholders. For example, TMCs that primarily control rural, uncongested roadways would logically select free flow conditions as “recovery.” This is also likely the best alternative for special event traffic occurring on weekends. However, this may not be an appropriate value for urban areas, where high traffic volumes routinely limit travel speeds to 45 or 50 mph on facilities with a 60 mph speed limit. In addition, for winter weather related events, TMCs may not *want* drivers to operate at 60 mph for safety reasons, even after the snow has been removed. In both of these cases, a lower operating speed might be defined as “recovery.”

The definition of “recovery” also needs a geographic component. For incidents, bottlenecks can move up- or downstream from the incident location because of the dynamics of roadway operation. Therefore, the incident-caused “bottleneck” at the actual incident site may have dissipated, but the incident-caused bottleneck at the tail end of the queue may still exist. The road cannot be said to have “recovered” as long as that upstream bottleneck still exists. Therefore, more sophisticated analytical algorithms may be needed to correctly identify delays associated with specific incidents, especially after the incident itself has been cleared.

The same geographic requirement exists for recovery from geographically widespread disruptions, such as those related to weather. In these cases, recovery may best be defined as travel times along specific roadway segments (e.g., “the travel time between points A and B must be below 10 minutes”), or it may be defined as a combination of “point-based” measures (for example, “all road segments between points A and B must have speeds above 45 mph for more than 5 minutes to be defined as recovery”).

All of these definitions are valid. The method the TMC selects should be the one that most directly matches relevant jurisdictions’ policies.

Once “recovery” has been defined, the TMC must automate the identification of “recovery” from the mobility data collected as described in Section 4. Automating this process eliminates the need for TMC staff to manually enter when “recovery” occurred. While some TMCs use manual entry, it is not a recommended practice because staff can be too busy with other activities to remember to stop and enter this information, thus creating either holes in the database or inaccurate data entries.

In addition to understanding when a roadway has “recovered,” it is necessary to have a “start time” for the activities being measured in order to calculate the total time a road operates at reduced efficiency. For incidents, the “start” is easily identified as the first report (notification) of the incident, but for more widespread events, such as weather, the “start time” may need to be more carefully defined. For example, for a snowstorm, should the measurement of the “time to recovery” start when the snow *stops* falling or when the snow *starts* falling? Or should it be the time when plows first start operating? Finally, since the time when snow stops falling will vary geographically as the storm moves through the region, it may be necessary for the TMC to be able to define different “start times” for different parts of the region or for different corridors, which means that more than one “total time until recovery is reached” may need to be computed for different geographic regions within the control of the TMC for a single event.

Once both the beginning and ending times have been identified, the “time to recovery” can then be computed as the time at which recovery occurs minus the start time.

These recovery times can then be aggregated over the course of a reporting period (e.g., a year) for presentation to decision makers. However, because the sizes of disruptions change from event to event (recovery from a disabled vehicle incident should be far quicker than recovery from a fatal crash), it is most appropriate to report recovery time by category or size of event, along with the number of those events. In urban areas, it is generally also beneficial to further segregate reporting by time of day. This is because recovery time after an incident will take longer during the commute periods than late at night simply because traffic volumes are much lower at night and “spare capacity” is available to allow queue dissipation. Therefore, as with general mobility reporting, it is usually[8] appropriate to summarize recovery times during four general periods:

1. Commute periods
2. Midday on weekdays
3. Late night
4. Weekends.

Where little activity occurs during one or more of these periods, that period can be ignored for routine performance reporting purposes.

The need to report time to recovery by category of event emphasizes the need to combine mobility data with other external sources as part of cross-cutting performance measure development. For example, in the case of snow removal, one “size of the event” variable that should be used is the amount of snow that falls. The expectation is that it should take longer to clear snow accumulations of 6 inches than 1 inch. Consequently, tracking snow removal performance by level of snowfall allows a better comparison than a single mean value, which is subject to changes in snowfall from year to year. This also means that the TMC must have a data source that indicates how much snow has fallen, and the TMC must be able to combine that data set with both mobility data and data on actions it takes.

A summary of the above discussion of recovery time metrics is included in Table 5-4 at the end of this chapter.

5.2.4 Other Useful Cross-Cutting Performance Measures

Because of the variety of TMC activities, they are using a number of other cross-cutting measures across the country. It is not possible to describe all of the cross-cutting measures being investigated, as many have yet to be actively published and those under development tend to be intended for both specific TMC tasks and the specific data available to individual TMCs. For example, the Caltrans TMC operating the freeway system in Orange County, California, has developed ways to measure the number of vehicles changing routes as a result of routing messages posted on variable message signs. Tracking these volume changes allows the TMC to judge the effectiveness of specific dynamic message signs. Another cross-cutting measure being investigated by several TMCs is the price sensitivity of HOT lane users combined with tests of the effectiveness of the pricing algorithms used on HOT lanes.

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[8] In some rural areas, different reporting time periods might be used. For example, in recreational areas, the TMC might want to report recovery times for periods when heavy volumes are present vs. when low volumes are present.

5.3 Future Cross-Cutting Performance Measure Trends

Because of the inability of the relatively simple performance measures currently in use to answer key policy questions being asked of TMCs, some TMCs are experimenting with less common performance measures. More sophisticated TMCs are placing considerable effort on developing a better set of analytical tools that describe the changes in congestion that result from specific management activities. The specific topic areas of interest change from TMC to TMC, and are likely to change even more in the future as TMCs begin to deploy new operational strategies such as active traffic management or USDOT's Connected Vehicle initiative.

Many TMCs are looking for information that lets them judge the performance or effectiveness of specific programs. For example, if a TMC were to change its ramp metering program so that metering rates differed between rainy days and dry days, it would want to produce mobility statistics on both rainy and dry days and compare the resulting levels of mobility both against each other and against rainy days before the implementation of the new algorithm. This kind of analysis will help the TMC determine whether the new metering algorithm is working as intended or needs further modification. This is similar to the interest that TMCs have in defining the mobility benefits derived from reducing incident duration.

The difficulty with answering these types of questions—and consequently the difficulty with "cross-cutting measures"—is that direct measurement of mobility only describes what *did happen* and not what *would have happened* without the new program being studied. Therefore, developing the "performance measure" (in this case throughput volume and speeds) is not the real cross-cutting activity. That is the ability to extract weather data from one data archive, combine those data with mobility measures, extract data on the ramp metering algorithm, and analyze the three data sets together to judge the performance of the new ramp metering algorithm. (i.e., Is the algorithm correctly setting the rate, and is that rate resulting in better roadway performance?)

For cross-cutting measures involving incident response, further complications arise from the fact that the effects of incident response depend on time of day. For example, if the incident occurs at 6:30 AM, the expected delay savings from a 5-minute improvement in incident response is very different than if the incident occurs at 8:00 AM, noon, or 11:00 PM. The performance measures described in Sections 3 and 4 can determine overall changes in incident duration, as well as overall changes in travel delay, but because so many exogenous factors affect both incident duration and congestion (weather, the nature of the incident, and traffic volume being just three), the direct relationship between incident response programs and incident delay is difficult to determine. The cross-cutting measures combine these different independent variables to allow comparison of the relative performance of the roadway system under these different operating conditions—given the new TMC activity or a lack of that activity.

Because such comparisons are very difficult to perform analytically, TMCs should expect continued refinement in the tools and procedures available for measuring or estimating the travel benefits from various TMC activities.

Finally, one important trend that TMCs need to track is the change in data availability that is likely to occur when products of USDOT's Connected Vehicle research initiatives are deployed. Such systems are expected to generate enormous amounts of data that describe the environment in which vehicles operate. These data should enable much more robust cross-cutting performance analysis. Unfortunately, the exact nature of that data has yet to be determined, so this *Guidebook* cannot provide more definitive guidance on the use of those data.

5.4 Data Collection and Management—Cross-Cutting Performance Measures

The vast majority of data used for cross cutting measures will be collected for the mobility, incident response, or TMC operations performance measures described in Sections 2 through 4. The majority of the remaining data needed for cross-cutting studies should come from other, automated data sources, such as weather stations or traffic control system logs. Therefore, the primary “new” data collection task to produce cross-cutting performance measures is the acquisition of these external data sets and storage of them in ways that allow them to be easily combined with the other performance measures. Only when these data cannot be obtained from a trusted existing data source should the TMC use operations staff to hand-enter these supporting data.

This means that the archives in which the data are stored must either contain similar geographic references or translation tables that allow the TMC activities to be associated with the actual performance of the roadway system. The more accurate and complete the original mobility, incident response, and TMC operations data sources are, the more accurate will be the cross-cutting measures produced by combining these data.

5.4.1 Current Data Availability

The majority of data needed for cross-cutting studies will come from the data sets discussed in Sections 2 through 4. Thus the primary task in developing cross-cutting measures is to ensure that the data collected and stored for those tasks include the variables needed for desired cross-cutting analyses. If not (e.g., there is no data item indicating that a road segment has “recovered”), then the agency must develop these new variables as expansions of those basic data sources.

5.4.2 Current Data Quality

Similarly, the quality of the cross-cutting analyses is directly affected by the quality of the base data. The better and more reliable the base data sets are, the better and more reliable the analyses that combine those data sets will be.

5.4.3 Future Data Sources

The future of cross-cutting data is directly affected by the future data sources for other performance measures. For example, the products of USDOT Connected Vehicle research initiatives promise to be a rich future source of data once the architecture has been agreed upon and once widespread deployment occurs. Since this data source is not fully defined at this time, it is not possible to give a more definitive description of how the data will affect performance reporting. Another future source may be the data collected as part of collecting highway user fees (e.g., data collected for traditional facility-based or non-traditional VMT-based tolling systems). These data sources are particularly important in that, because these activities generate revenue, the public will have considerable, high-profile interest in knowing what benefits it is receiving in return for those user fees.

5.5 Chapter Summary Checklist—Recommended Cross-Cutting Performance Measures

Table 5-1 shows a simple checklist summarizing the measures identified by the study team as appropriate for initial consideration as cross-cutting measures for TMCs. Readers should consider these measures for use and reporting in their TMC operation. The checklist also suggests the approximate level of complexity or sophistication of each measure. The customer satisfaction measures should be part of basic performance reporting of all TMCs. The remaining measures are appropriate for consideration by TMCs that require more sophisticated reporting capabilities to effectively manage their operations.

Each measure in the checklist also has an accompanying summary reference table. Each table provides a synopsis of a particular performance measure (or group of related performance measures), and provides an overview of the measure's usefulness, required data sources, calculation steps or equations, useful variations of the performance measure, and issues or implementation considerations associated with the use of that measure. These summary reference tables for cross-cutting measures, Tables 5-2 through 5-4, immediately follow the checklist.

Table 5-1: Checklist for Cross-Cutting Performance Measures

	Level of Measure			
Measure	**Basic**	**Computed Basic**	**Advanced**	**Reference Table and Page Number**
Customer satisfaction	x			5-2, page 108
Incident delay			x	5-3, page 109
Value of incident delay			x	5-3, page 109
Incident delay as a percentage of total delay			x	5-3, page 109
Change in response time due to changes in services provided			x	5-3, page 109
Recovery time from incidents, weather (snow, thundershowers, fog, etc.), special events			x	5-4, page 110

Table 5-2: Public Opinion

Definition

Metric that indicates level of public awareness and satisfaction with TMC actions and results.

Purpose/Need

Customer opinion data are useful to (1) understand what travelers do or do not value and (2) describe to decision makers the level of public support for TMC activities.

Data Source(s)

- Survey data

Calculations

Design the survey instrument, including survey format, questions, response options, and distribution method

Distribute and collect survey responses

Analyze results

Variations

Survey questions can address public opinion regarding specific TMC activities (e.g., safety service patrol, HOT lane management) as well as public opinion about broader roadway performance issues

Desired Outcome

Provide summary metric to evaluate public satisfaction with roadway performance and TMC actions

Limitations/Cautions/Assumptions

Care should be exercised when designing the survey instrument, including the specific wording of questions and response options, to avoid bias or incomplete response options that might limit the ability to interpret the survey responses

Other Comments

TMC activity-oriented public opinion surveys can be performed as part of a larger effort to collect traveler satisfaction data. They can also be collected as part of routine TMC-related activities; for example, safety service patrol comment cards that are distributed to customers can be used both to manage the safety service patrol services being provided, and to provide information about traveler perceptions of those services.

Level of Measure (Basic, Moderate, Advanced)

Basic

Example

User perceptions of freeway HOV network: HOV User Survey, Washington State Freeway System, for the Washington State Department of Transportation, by PRR, December 2007. Available at http://www.wsdot.wa.gov/NR/rdonlyres/A04D3925-B39C-4068-BFE3-D19E5CEEEEE8/0/HOVUserSurvey3rdEditionDec07.pdf. See Appendix Q.

Table 5-3: Incident Delay

Definition

Metric that estimates the degree to which incidents introduce congestion into the traffic network.

Purpose/Need

This metric enables measurement and tracking of the effects of incidents on system performance, provides input to help allocate incident response resources, and provides a way to estimate the benefits of incident response efforts.

Data Source(s)

- Incident data (location and time stamps of key incident events) (See Incident-related metrics)
- Mobility data (volume, speed as a function of day, time, and location) (See Mobility-related metrics)
- Estimated value of time for passenger and commercial vehicles

Calculations

Merge incident, mobility data (for each location and time, record volume, speed, incident presence)

Extract volume data when incident is present, and use as inputs to queuing theory equations

Compute incident-related delay (in vehicle-hours)

Monitor amount of delay, number and type of incidents, and type of incident response, over time

Variations

- Incident delay as a percentage of total system delay (recurring plus non-recurring)
- Monetary value of incident delay (based on estimated mix of passenger and commercial vehicles, and average value of time for passenger and commercial vehicles)
- Incident delay as a function of incident type and duration, time of day, incident response type
- Reduction in incident delay (because of a new operational or capacity treatment)

Desired Outcome

Provide summary metric to evaluate the effect of incidents on traffic flow

Limitations/Cautions/Assumptions

Requires agreed-upon definition of when congestion is “incident related” vs. “recurring” (e.g., when incident occurs during congestion)

Queuing theory approach does not account for “rubbernecking” delay in opposite direction of travel

Queuing theory approach should also account for growing upstream queues from large incidents, by updating over time the “incident presence” status of upstream locations affected by the expanding queue, even after the initial incident has cleared

Other Comments

More advanced alternatives to the basic queuing model can be developed; they typically involve more rigorous data requirements, sophisticated data archives, and advanced analytical capabilities

Level of Measure (Basic, Moderate, Advanced)

Advanced

Example

These advanced metrics are subjects of active research, and are not yet commonly reported. Research examples include: Quantifying Incident-Induced Travel Delays on Freeways Using Traffic Sensor Data, Phase 1 by Y. Wang, P. Cheevarunothai, and M. Hallenbeck, 2008, for the Washington State Department of Transportation, WA-RD #700.1; and Phase 2, of that study by Y. Wang, R. Yu, Y. Lao, and T. Thomson, 2010 (WA.RD # 758.1), available at http://depts.washington.edu/trac/bulkdisk/pdf/700.1.pdf and http://depts.washington.edu/trac/bulkdisk/pdf/758.1.pdf; and Incident Response Evaluation Phase 3, by M.E. Hallenbeck, E. Pham, and K. Watkins, also for WSODT, WA.RD #761.1, available at http://depts.washington.edu/trac/bulkdisk/pdf/761.1.pdf. See Appendix R.

Table 5-4: Recovery Time from Disruptions

Definition

Metric that estimates how quickly roadway conditions return to normal following a disruptive event.

Purpose/Need

Recovery time is a useful metric to evaluate effects of TMC activity on a variety of disruptive events that affect traffic such as roadway incidents, weather events, and special events.

Data Source(s)

- Mobility data (volume and speed as a function of day, time, and location)
- Event data (e.g., incident database, weather database, special events calendar)

Calculations

Define definition of event start time and recovery time (see Limitations below)

Monitor and record incident start times (used to determine the point at which recovery begins); also, monitor traffic flow and determine when the recovery definition is or is not being met

Compute recovery time from incident start time, to time when recovery condition is achieved

Record and aggregate recovery time information, by number of events and type or size of events, and time of day (commute periods, midday, night, weekends)

Variations

Desired Outcome

Provide summary metric to monitor effects of TMC activities that address a variety of disruptive events

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Limitations/Cautions/Assumptions

Definition of event start or stop time can vary with event type (e.g., for incidents, start = TMC notification time, while for snow event, start = start or stop time for snowfall)

Data required for defining events must be accessible (e.g., snowfall data)

Requires an agreed-upon definition of “recovery” from event disruption, that is what is considered a “normal” condition (e.g., recovery = free flow speeds for rural uncongested roads or some urban roadways during weekends, recovery = 45 mph for urban roads with 60 mph speed limit)

Definition of recovery should account for associated upstream or downstream bottlenecks

Definition of recovery for geographically widespread disruptions (e.g., weather) can be based on route-based indicators such as travel times, or a series of spot locations (e.g., “travel times between A and B must return to 10 minutes or less”, or “all sensor locations between A and B must have spot speeds > 45 mph for at least 5 minutes”)

Analysis and reporting of “recovery time” should be done within the context of the event (e.g., the amount of snowfall, or the size of a special event)

Other Comments

Level of Measure (Basic, Moderate, Advanced)

Advanced

Example

These advanced metrics are subjects of active research, and are not yet commonly reported.

Chapter 6. Case Studies

Basic Performance Measure Reports

Two good examples the study team found to demonstrate the use of performance measures for basic performance measurements are the Virginia Department of Transportation's Hampton Roads Transportation Operations Center (HRTOC) and the Rhode Island Department of Transportation's TMC.

Virginia Department of Transportation – Hampton Roads Transportation Operations Center

VDOT HRTOC is part of a statewide traffic management network that also consists of travel information centers, the electronic toll collection system, and electronic truck weigh stations. The HRTOC operators are responsible for monitoring interstate traffic, providing information to the motoring public through 511, highway advisory radio (HAR) and message boards, and dispatching the Safety Service Patrol.

HRTOC produces weekly performance measures reports. Each report provides an operations summary and then delves into more detail on specific areas of VDOT, such as control room operations, safety service patrol, maintenance, fleet management, and public information and media relations. A data key is also provided at the end of the report to provide a detailed description of each measure.

In addition to just reporting, the HRTOC is using its performance measures to actively manage operations. For example, quarterly incident data is utilized to reconfigure the SSP routes to promote the most effective use of resources.

Information about the VDOT HRTOC, including weekly performance measure reports, can be found at: http://www.virginiadot.org/travel/smart-traffic-center-hro.asp.

Rhode Island Department of Transportation – Transportation Management Center

RIDOT TMC monitors Rhode Island's interstates and provides information to the motoring public. Data on incidents is gathered through the TMC's intelligent transportation system, RhodeWays, and is stored and utilized to generate performance measures reports.

RIDOT TMC produces quarterly and annual performance measure reports focusing on incident statistics. This report is a good base-level example as to the information that can be displayed for TMCs just starting to collect data. RIDOT TMC is measuring all three of FHWA's identified performance measures, roadway clearance time, incident clearance time, and secondary incidents.

Information about RIDOT TMC, including access to the performance measures reports, can be found at: http://www.tmc.state.ri.us/.

Advanced Performance Measure Reports

The following are two examples for advanced measures that represent a higher standard of reporting. The Washington State Department of Transportation's Gray Notebook, which is considered a "gold standard," and the Las Vegas FAST TMC video reporting system, which shows an emerging trend toward more advanced reporting.

Washington State Department of Transportation's Gray Notebook

WSDOT's *Gray Notebook* is the agency's main performance assessment and reporting tool. The *Gray Notebook* provides quarterly reports on agency and transportation system performance. Initiated in 2001, the *Gray Notebook* has been utilized to provide the latest information on system performance and project delivery.

Quarterly reports include information on work zone safety, incident response, and the Washington State Ferries. Annual reports are expanded to provide information on these topics, as well as bridge preservation, programmatic permits, and construction contracts. For quicker reference and reading, a *Gray Notebook Lite* is developed for each edition. The Lite version provides a summary of the entire edition with a synopsis of some of the topics presented in the edition.

A performance dashboard is also provided in each edition. The dashboard provides an overview of key performance indicators for five policy goals. Information contained in the dashboard represents current and previous performance mark and data for each measure and then indicates which way the program is trending. Assumptions as to what may be leading to the trend are also included.

The *Gray Notebook* is divided into six sections: safety, mobility, preservation, environment, stewardship, and economic vitality, all of which align with WSDOT's transportation policy goals. The *Gray Notebook* website allows users to select which topic they would like to view and brings them to that particular area, instead of having to scroll through the large document.

The *Gray Notebook* is published in February, May, August and November. It is important to recognize that information contained in the document is preliminary and may be adjusted if discrepancies are noted. Any updates are uploaded online and noted in the report. The current and archived editions of the *Gray Notebook* can be obtained from the WSDOT web site. They are currently located online at: http://www.wsdot.wa.gov/Accountability/GrayNotebook/SubjectIndex.htm.

Las Vegas Freeway and Arterial System of Transportation

The Las Vegas Freeway and Arterial System of Transportation is administered by the Regional Transportation Commission (RTC) of Southern Nevada. The Nevada Department of Transportation (NDOT) and the RTC are full-fledged funding partners of FAST. Transportation strategies for FAST are set by the Operations Management Committee, which is comprised of the RTC, Clark County, NDOT, and the cities of Henderson, Las Vegas, and North Las Vegas. The FAST system is comprised of both the arterial and freeway systems.

Like many TMCs, FAST monitors and controls traffic. Traffic is monitored through video images and detector data. If an incident or event occurs, traffic can be managed using various devices, such as ramp meters, DMS, traffic signals, and lane use control signals.

FAST has developed an interactive dashboard that presents near real-time performance measure information. The main feature of the dashboard is a traffic congestion map, which provides an overview of current traffic conditions. The traffic map also displays incidents when FAST is notified and when the incident is cleared.

Additional dashboard information is provided for daily peak speeds (AM and PM peak), time of day speeds (AM and PM peak by hour), freeway average speed (past 30 days and historic) and congestion (AM and PM peak). Individuals visiting the website also have an opportunity to review a historical animation of traffic conditions for a particular date and time period. Previous incident information, camera screen shots, speeds using Bluetooth detection, and current DMS messages can all be viewed through the website.

NDOT utilizes the incident data it collects along with videos recorded at FAST to conduct incident after-action reviews (AARs). AARs are conducted to review the impacts of an incident or traffic event and identify opportunities to improve incident response and traffic management. To enhance the AAR, multiple video feeds are utilized simultaneously, not only showing the incident but the direct impacts to traffic.

For general information on FAST, consult: http://www.nvfast.org/. To access the interactive dashboard, visit the following website: http://bugatti.nvfast.org/Default.aspx.

Appendix A. TMC Data Capture For Performance and Mobility Measures References (Updated: January 20, 2012)

Performance Monitoring Efforts

NCHRP Guide to Effective Freeway Performance Measurement: Final Report and Guidebook, August 2006; NCHRP Web Only Document 97

http://www.trb.org/Main/Blurbs/158642.aspx

Margiotta, R., Lomax, T., Hallenbeck, M., Turner, S., Skabardonis, A., Ferrell, C., and Eisele, B.; *NCHRP Guide to Effective Freeway Performance Measurement: Final Report and Guidebook*; Prepared by Cambridge Systematics, Inc., Texas Transportation Institute, Washington State Transportation Center and Dowling Associates for the National Cooperative Highway Research Program, Transportation Research Board of the National Academies.

This report examines the effective use of freeway performance measures in operating a freeway system and in meeting the information needs of a large spectrum of potential local, regional, and national users. The guidebook is structured to answer four primary questions about freeway performance: (1) what measures should be used; (2) how can the measures be developed with data and models; (3) how should freeway performance be communicated; and (4) how can freeway performance measures be used in decision making. The report includes detailed step-by-step procedures for addressing these four primary issues associated with freeway performance monitoring.

This resource serves as an excellent best practice guide to properly embracing the "what" and "how" of communication and decision making associated with performance measures.

Guide to Benchmarking Operations Performance Measures: Preliminary Draft, Final Report, July 2008; NCHRP (NCHRP 20-7)

http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1218

Tarnoff, P.J., S.E. Young, J. Crunkleton, and N. Nezamuddin, *Guide to Benchmarking Operations Performance Measures: Preliminary Draft, Final Report*. 2008, University of Maryland, Center for Advanced Transportation Technology: College Park, Maryland.

Building upon the National Transportation Operations Coalition initiative from 2004-05 to "define and document a few good measures," this project refines and advances the performance measures by piloting a number of measures through the cooperation of volunteer organizations. The results from the pilot tests are used to determine the usefulness of the measures, to further refine their definition, and to develop implementation guidelines for the measures.

This resource provides useful measurements, refined definitions, and the latest in implementation guidelines regarding performance measures.

Transportation Management System Performance Monitoring, Evaluation, and Reporting—A Technical Handbook, September 2005; FHWA (FHWA-HOP-07-127)
http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/tms_pmer_handbook.pdf

This handbook provides an introduction to TMS performance measurement and explores the specifics of establishing a performance measurement program, including developing individual and detailed performance measures for various functions and sub-functions of a TMS; data collection, screening, archiving and processing efforts; and performance monitoring, evaluation and reporting. This handbook focuses on the equipment, systems, and programs involved in a TMS that can be used to obtain the most efficient and desirable outputs and outcomes.

This resource provides guidance on establishing a performance measurement program, data collection, evaluation, and performance measure reporting.

Primer on Work Zone Safety and Mobility Performance Measurement, September 2011
http://ops.fhwa.dot.gov/wz/resources/publications/fhwahop11033/fhwahop11033.pdf

This primer has been developed to assist agencies in establishing and monitoring a useful set of work zone safety and mobility performance measures. The primer describes possible work zone performance measures, and provides guidance to help agencies select and implement measures that make sense for their own work zone programs. The primer also discusses the use of measures across multiple projects to assess an agency's overall efforts and outcomes against its policies and goals.

This resource outlines the methods and technologies that are available to gather data to monitor the various possible measures and procedures for calculating specific performance measures from different types of work zone traffic monitoring data.

NCHRP Web-Only Document 136. "Performance Measures for Snow and Ice Control Operations."
http://ops.fhwa.dot.gov/wz/resources/publications/fhwahop11033/fhwahop11033.pdf

This research identified and assesses the measures used to evaluate the performance of winter maintenance activities (snow and ice removal from roadways) and to recommend the most promising measures for further development. The researchers issued a survey to snow and ice control agencies throughout North America, Europe, and Asia to obtain data of the performance indicators and measures used, if any, by these agencies. The identified performance indicators and measures were then categorized, defined, and assessed for their usefulness.

This resource provides a process developed to assist snow and ice control operations managers in preparing a customer-focused, environmentally friendly performance measurement program.

Performing Data Integration

Interim Guidance on the Information Sharing Specifications and Data Exchange Formats for the Real-Time System Management Information Program; 2007

http://ops.fhwa.dot.gov/publications/fhwahop08038/04infoshare.htm

Publication of Interim Guidance on the Information Sharing Specifications and Data Exchange Formats for the Real−Time System Management Information Program; Federal Highway Administration, October 2007 Federal Register, p. 58347 − 58379. Washington, D.C.

The publication provides interim guidance and established the Real-Time System Management Information Program to make traffic and travel conditions information available to the traveling public and to ease the information sharing of traffic and travel conditions among public agencies and private enterprise. The publication establishes the standard interface needed to ease the sharing of information/data. The types of information considered for the Real-time Information Program (RTIP) include but are not limited to congestion information, traffic incidents that block the roadway, roadway weather conditions, public transportation service disruptions, construction activities affecting travel conditions, and travel times on roadway links.

This resource establishes the standard interface needed to obtain and share the information when it does exist.

Joint Transportation Management Centers (Presentation) Edelstein, R. "Joint Transportation Management Centers." NCAMPO-NCSITE Annual Meeting, 2009.

http://www.campo-nc.us/2009-conference-slides/Presentations/PDFs/A.1-Joint_TMCs-Edelstein_11-5-09.pdf

This presentation provides a brief overview of select Joint TMCs throughout the nation and shares best practices and future trends. The nine cases that are briefly presented include Los Angeles, CA, Honolulu, HI, Austin and Houston, TX, Fort Lauderdale, FL, Virginia Beach, VA, Atlantic City and Woodbridge, NJ, Pittsburgh, PA, and Chicago, IL. Benefits identified for Joint TMCs include special event, incident, traffic, emergency management, public safety, interagency communication, joint training, and facility and operating cost. No drawbacks to Joint TMCs are presented in the presentation. Trends are presented, along with their benefits, and include co-location, performance measures, outsourcing, partnerships, center-to-center interfaces, and automation.

This resource provides information regarding joint TMC operations including performance measures

Integration of TMCs and Law Enforcement Information

National Cooperative Highway Research Program Report 520; Sharing Information between Public Safety and Transportation Agencies for Traffic Incident Management

http://plan4operations.dot.gov/docs/sharing_nchrp2004.pdf

Brooke, K., K. Dopart, T. Smith, and A. Flannery. "National Cooperative Highway Research Program Report 520; Sharing Information between Public Safety and Transportation Agencies for Traffic Incident Management." Transportation Research Board of the National Academies, 2004.

This report assessed methods, issues, benefits, and costs associated with sharing information between public safety and transportation agencies in support of traffic incident management. It employed a case study approach, including site visits and interviews at 9 major TMC-LE sites in major

US metropolitan areas. This report presents lessons learned from around the country on how public safety and transportation agencies share information for managing traffic incidents.

This resource provides guidance regarding the methods of information sharing between transportation and public safety organizations, the effectiveness of these methods, and the corresponding features of the interagency relationships.

Computer-Aided Dispatch – Traffic Management Center Field Operational Test: Washington State Final Report, May 2006; USDOT- ITS/JPO (Joint Program Office)

http://ntl.bts.gov/lib/jpodocs/repts_te/14325_files/14325.pdf

"Computer-Aided Dispatch – Traffic Management Center Field Operational Test: Washington State Final Report." U.S. Department of Transportation (USDOT), 2006.

This report explores the benefits of integrating computer-aided dispatch, primarily used by public safety and law enforcement, and TMC systems. The CAD-TMC Field Operations Test (FOT) showed substantial improvement in accuracy, but timeliness was recognized as a challenge because of the existing procedures and relationships in place. The FOT proved worthwhile for the agencies to continue their quest to develop a true real-time data exchange system. Several general, technical, and institutional recommendations were made in response to study observations.

This resource provides valuable lessons learned regarding the integration of CAD with TMC operations.

Computer-Aided Dispatch – Traffic Management Center Field Operational Test: State of Utah Final Report, July 2006; USDOT-ITS/JPO

http://ntl.bts.gov/lib/jpodocs/repts_te/14324_files/14324.pdf

"Computer-Aided Dispatch – Traffic Management Center Field Operational Test: State of Utah Final Report." U.S. Department of Transportation, 2006.

This report explores the benefits of integrating CAD, primarily used by public safety and law enforcement, and TMC systems. Due to the existing procedures among the project participants, it is a recognized challenge for the CAD-TMC integration FOT to show substantial improvement in accuracy and timeliness of incident reporting and response. The TMC monitors both the Utah Highway Patrol (UHP) CAD log and the radio frequencies used by UHP troopers and the Incident Management Team specialists.

This resource provides valuable lessons learned regarding the integration of CAD with TMC operations.

Improving Data Quality

Data Quality White Paper; 2008

http://ops.fhwa.dot.gov/publications/fhwahop08038/pdf/dataqual_whitepaper.pdf

K. Ahn, H. Rakha, and D. Hill; *Data Quality White Paper, 2008*; FHWA-HOP-08-038; Prepared by Virginia Tech Transportation Institute and FreeAhead Inc. for FHWA.

This paper investigates data quality measures and how they are applied in existing systems, exploring the relevance of the data quality measures that were defined in a report entitled "*Traffic Data Quality Measures*" and the requirements for the implementation of a real-time information program. The paper examined the quality of traffic data in existing real-time ATIS applications for both public agencies and private sector.

This resource provides recommended data quality measures for three widely used traffic-related parameters—travel time, speed, and weather information. Recommendations are defined for each of the six data quality measures: accuracy, completeness, validity, timeliness, coverage, and accessibility.

Quality Control Procedures for Archived Operations Traffic Data: Synthesis of Practice and Recommendations, March 2007; FHWA
http://www.fhwa.dot.gov/policy/ohpi/travel/qc/qc_procedures.pdf

Turner, S., *Quality Control Procedures for Archived Operations Traffic Data: Synthesis of Practice and Recommendations*, 2007; Prepared by Texas Transportation Institute and Battelle for FHWA.

This report summarizes and provides recommendations for quality control procedures to be used for archived data that have been collected and saved by traffic operations systems; summarizing quality control procedures used in numerous archived data management systems (ADMS) implementations. This report also details the typical steps involved in quality control procedures, including the automation of quality checks, the use of manual visual review, the flagging of failed data records, and the use of metadata to document quality control actions.

This resource provides recommendations for a basic set of quality control procedures that can be adopted, as well as a process to customize quality control procedures for system-specific data quality issues.

Requirements and Feasibility of a System for Archiving and Disseminating Data from SHRP 2 Reliability and Related Studies, 2011; Transportation Research Board (SHRP 2 Report S2-L13-RW-1)
http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-L13-RW-1.pdf

The objective of this project was to determine the feasibility of developing, operating, and maintaining a system to make data from SHRP 2 Reliability projects and other related projects readily available to researchers and practitioners. This included determining the basic requirements and life cycle costs for storing and delivering such data for more than 25 years. The project recommended a solution based around cloud computing data storage and a mixture of open source and commercial, off-the-shelf software; it will ultimately be populated with data from all of the SHRP 2 Reliability research projects and closely related projects from other SHRP 2 research focus areas to assist archiving data for reliability projects.

This resource established several alternative information technology architectures that could be used to develop an online reliability data archive and analyzed the advantages, disadvantages, and costs of each system.

Project/Program Evaluation

Comparative Analysis Report: The Benefits of Using Intelligent Transportation Systems in Work Zones, October 2008; FHWA

http://www.ops.fhwa.dot.gov/wz/its/wz_comp_analysis/comp_anl_rpt_08.pdf

This report describes the use of ITS applications going hand in hand with real-time communication of traveler information. It looks at numerous work zones and how information is communicated within them to travelers.

This resource provides a summary of the findings of a national FHWA study to quantify the benefits of ITS applications for work zone traffic management.

Final Report of the Evaluation of the FORETELL Consortium Operational Test: Weather Information for Surface Transportation, April 2003; FHWA

http://ntl.bts.gov/lib//jpodocs/repts_te//13833.html

Battelle, Final Report of the Evaluation of the FORETELL Consortium Operational Test: Weather Information for Surface Transportation. 2003, Prepared for U.S. Department of Transportation: Washington D.C.

FORETELL™ was developed as a multi-state weather information network designed to reduce winter weather accidents by providing highway managers, trucking professionals, and transit operators with real-time and forecast roadway weather information derived from multiple sources. FORETELL collected weather data from the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), Environment Canada, Road Weather Information System (RWIS) stations, and sensors at airports and agricultural sites.

This resource addresses the need for real-time weather data and advanced forecast information to users via the Internet.

Development of a Real-Time Arterial Performance Monitoring System Using Traffic Data Available from Existing Signal Systems, December 2008; MnDOT

http://www.its.umn.edu/Publications/ResearchReports/pdfdownload.pl?id=1028

This report describes a system for high resolution traffic signal data collection and arterial performance measurement which has been successfully built. The system, named SMART-SIGNAL (Systematic Monitoring of Arterial Road Traffic Signals), is able to collect and archive event-based traffic signal data simultaneously at multiple intersections. This system can generate performance measures for both individual intersections and arterials including intersection queue length and arterial travel time.

This resource provides information regarding the estimation of performance measures, which are highly consistent with the observed data.

Lessons Learned

Intelligent Transportation Systems Benefits, Costs, Deployment, and Lessons Learned Desk Reference: 2011 Update; FHWA (FHWA-JPO-11-140)

http://www.itsknowledgeresources.its.dot.gov/its/benecost.nsf/files/BCLLDepl2011Update/$File/Ben_Cost_Less_Depl_2011%20Update.pdf

Intelligent transportation systems provide a proven set of strategies for addressing the challenges of assuring safety and reducing congestion, while accommodating the growth in transit ridership and freight movement. This report presents information on the performance of deployed ITS under each of these goal areas, as well as information on the costs, deployment levels, and lessons learned regarding ITS deployment and operations since the last such report in 2008. The report, and the collection of four web-based resources upon which it is based, have been developed by the USDOT's ITS Joint Program Office to support informed decision making regarding ITS deployment.

This resource reviews all aspects of traveler information to include deployment examples, performance, lessons learned, benefits, and costs. It is a comprehensive source of real-time traveler information for the US.

The Research and Innovative Technology Administration (RITA) – ITS JPO Lessons Learned Website

http://www.itslessons.its.dot.gov/its/benecost.nsf/DisplayLessonCategory?OpenForm&Management%20&%20Operations)

The USDOT RITA - ITS/JPO website contains a rich data base of relevant ITS projects; see tabs, particularly the tab ”Evaluation & Performance Measurement” as well as the ”System Data & Storage” tab.

This resource provides a rich database of relevant ITS projects addressing lessons learned, data collection, evaluation, and performance measurement.

Project/Program Descriptions

Statewide Incident Reporting Systems – Business and Technology Plan, Final Report, October 2006; NCHRP (NCHRP Project 20-7/Task 215)
http://www.trb.org/NotesDocs/NCHRP%2020-7%20215%20Final%20Report.pdf

The emphasis of NCHRP Project 20-7/215 was to identify current state of the practice relative to real-time incident reporting, and identify strategic directions and actions needed to meet the the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) real-time system management information program objectives. This report serves as a synthesis of the outreach activities, information obtained through surveys and interviews, as well as recommended roles and actions for key stakeholders at the national level. This report indicates that Traveler Information Systems are the primary users of incident data that is collected and includes a section dealing with private sector data sources for incident reporting.

This resource provides trends, key issues, and barriers associated with incident reporting systems, with recommendations to improve the data collection effort needed to support these systems.

The 2011 Urban Mobility Report
http://mobility.tamu.edu/ums/

The *2011 Urban Mobility Report* builds on previous Urban Mobility Reports with an improved methodology and expanded coverage of the nation's urban congestion problem and solutions. The report provides information on long-term congestion trends, the most recent congestion comparisons and a description of many congestion improvement strategies. All of the statistics have been recalculated with a new method to provide a consistent picture of the congestion challenge.

This resource provides useful information/data regarding those major metropolitan areas which experience heightened levels of congestion. The report categorizes each urban area by population size as being very large, large, medium, or small.

RITA ITS Deployment Tracking Database Traveler Information, November 2008; USDOT/RITA
http://www.itsdeployment.its.dot.gov/itspreviousyears/ResultsStateNational.asp?ID=1328&rpt=M&sort=Permdms

The ITS Deployment Statistics website contains a large data gathering on the deployment of ITS technology nationwide. This information is gathered through a series of national surveys to track the level of deployment of ITS technology in metropolitan and rural areas. In the most recent survey, conducted in 2007, transportation agencies in 108 metropolitan areas involved with freeway, arterial, and transit management, public safety, and toll collection as well as state departments of transportation in each state were surveyed; in total, more than 2,300 agencies were surveyed.

This resource's tracking database provides a wealth of relevant information about traveler information services.

Maine Statewide Deployment and Integration of Advanced Traveler Information Systems, July 2008;
http://www.uvm.edu/~transctr/pdf/NBelz_TRB_Jan09.pdf

This study reviewed dynamic message signs, variable speed limit signs (VSLS), and over-height vehicle detection (OHVD) systems, which are key components of ATIS and are the means through which motorists can be provided with en route information pertinent to their travels; data collection and surveys were performed as well. Part of the study consisted of identifying and evaluating the institutional issues and barriers associated with intelligent transportation system deployment. These issues include long-term funding commitments for ATIS, acceptable messaging, integration of information databases, interagency coordination, enforcement, and education of the public.

This resource identified a large barrier to ITS deployments, that is, the challenge of integrating informational databases and the need to be less reliant on the human transfer of information as exists currently. (The technology exists where these systems can be made self-sufficient with optional human overrides if necessary; it was suggested that automation would help reduce the discrepancies that occurred between data-bases.)

Enhancing Road Weather Information through Vehicle Infrastructure Integration (VII), July 2006; National Center for Atmospheric Research – K. Petty and W. Mahoney III

http://ops.fhwa.dot.gov/weather/resources/publications/fhwa/enhrdwxinfothruvii.pdf

This paper summarizes the vehicle data elements that likely would contribute to the development and improvement of road weather products. A synopsis of probable VII product enhancements is provided, along with examples of how vehicle data can be used in the application development process.

This resource discusses the research needs aimed at addressing the technical issues and barriers associated with the use of VII-enabled data.

ITS/Operations Resource Guide 2009 - Clarus Initiative; USDOT/RITA and Clarus System User Guide, June 2011; FHWA

http://www.resourceguide.its.dot.gov/default.asp?SID=3 and http://www.clarus-system.com/

The Clarus (Latin for "clear") Initiative aims to deploy an integrated road weather observational network and data management system that is national in scope. The initiative will build upon the road weather information systems that many state departments of transportation have been deploying for years, primarily in support of winter maintenance activities. Clarus is to provide information to all transportation managers and users to alleviate the effects of adverse weather (e.g., fatalities, injuries, and delays).

This resource website presents the goals, background, approach, milestones, and points-of-contact for the initiative and can be useful to obtain relevant enhancements to database management systems.

Inrix National Traffic Scorecard

http://scorecard.inrix.com/scorecard

The national traffic scorecard is a useful source of information for the country's major metropolitan areas experiencing heightened congestion levels. Included in the scorecard is a list of the 100 most congested regions in the United States along with the number of miles analyzed for that particular region.

This resource website is useful in determining trends and which regions should be focused on with respect to traveler information coverage. In addition, each region includes a population ranking as well.

East Bay SMART Corridors Program, Alameda County Congestion Management Agency

http://www.smartcorridors.net/about.php and http://www.smartcorridors.com/accma/

The East Bay SMART Corridors program consists of three major arterial corridors in the east bay portion of the San Francisco Bay Area—San Pablo Avenue, Telegraph Avenue, and the Hesperian/International/E. 14th Boulevard corridors. The intention of the program is to plan and implement a multi-modal advanced transportation management system along the San Pablo Avenue (I-80) corridor, the I-880 corridor, and the INTEL (International/Telegraph) corridor. The corridors feature an array of Automatic Vehicle Location (AVL) equipped vehicles, detectors, video coverage, optimized and coordinated signals, and transit signal priority.

This resource provides lessons learned on how to successfully bring together a group of local, regional, federal, transit, and emergency service agencies to work cooperatively to solve regional transportation management issues at many levels, including overcoming major infrastructure obstacles.

A Comprehensive Review of Emerging Technologies for Congestion Reduction and Safety, 2009; TRB – Transportation Research Record, Issue # 2129

http://trid.trb.org/view.aspx?id=882359

The New York Metropolitan Transportation Council (NYMTC) funded a project executed by a team from Rensselaer Polytechnic Institute to perform a comprehensive scan of emerging technologies that could affect transportation in the New York City metropolitan region in the next 20 years. A primary goal of the technology scan is to develop a document that serves as a one-stop shop for emerging technology that may be considered for implementation by different transportation agencies in the NYMTC region. This paper briefly presents the different emerging technologies, their characteristics, and important results from the project pertaining to congestion reduction and safety objectives.

This resource reviews new and emerging technologies with a segment dedicated to advanced traveler information systems and could be useful in determining the gap in traveler information from the international and experimental aspects.

Graphical Incident Timeline Generation (Real-time & Archived); CATT Laboratory, University of Maryland

http://www.cattlab.umd.edu/index.php?page=research&a=00015

This research is developing methods for visualizing incident data in an interactive, timeline fashion. This tool generates a graphical timeline of incidents from real-time and archived regional TMC data; the data can include the number and type of vehicles involved, lane status, dynamic message sign postings, queue build-up, and weather data.

This resource tool allows for the dynamic visualization of ongoing incidents and historical incidents; currently, it is being used for incident management, training, performance evaluations, and incident re-creation.

Automated TMC Performance Measurement System; CATT Laboratory, University of Maryland

http://www.cattlab.umd.edu/index.php?page=research&a=00014

Fundamental functions of a TMC include monitoring traffic conditions, responding to incidents, and generally improving the quality of transportation. In their daily operations, most TMCs collect and record data about accidents, including location, responding agencies, lane closures, and weather. The ability to manage and view this data in both real-time and archived is difficult. Furthermore, the ability to derive statistics about the performance of the traffic management system is a daunting task.

This research strives to develop an online performance measurement tool that can automatically calculate many standard TMC performance measures while also allowing for incident re-creation, training, and visualization. This resource would be of great valuable to the TMC Data Capture for Performance and Mobility Measures effort.

Other Guidebooks (For Both Content and Example Layouts)

Model Performance Measures for State Traffic Record Systems, February 2010; National Highway Traffic Safety Administration (NHTSA) (DOT HS 811 411)
http://www-nrd.nhtsa.dot.gov/Pubs/811441.pdf

The U.S. National Highway Traffic Safety Administration has released a white paper that highlights a collection of 61 model measures that are designed to help states monitor and improve the quality of the data in their traffic records systems. The measures, which are voluntary, cover all six traffic records systems—crash, driver, vehicle, roadway, citation/adjudication, and emergency management systems/injury surveillance. The white paper also provides basic definitions for the six performance attributes—timeliness, accuracy, completeness, uniformity, integration, and accessibility.

This resource provides guidance on new collection of 61 performance measures designed to help monitor and improve the quality of data within state traffic records systems.

Report to Congress on Catastrophic Hurricane Evacuation Plan Evaluation, June 2006; USDOT/DHS
http://www.fhwa.dot.gov/reports/hurricanevacuation/rtc_chep_eval.pdf

The USDOT developed a systematic, analytical process to evaluate the readiness and adequacy of state and local jurisdictions evacuation plans. The methodology included identifying the major components of a comprehensive evacuation planning and implementation program, collecting current practices and information on evacuations, developing criteria to assess current plans, conducting onsite discussions with state and local emergency management officials, and identifying lessons learned and best practices from recent evacuations. The assessment criteria were developed from current federal guidelines on evacuations; the issues identified in SAFETEA-LU and the FY 2006 Department of Transportation (DOT) Appropriations Act; government reports on Hurricanes Katrina and Rita; and additional issues identified by USDOT.

This resource is based upon lessons learned and provides best practices to follow regarding evacuation procedures.

Assessment of State of the Practice and State of the Art in Evacuation Transportation Management, June 2006; FHWA (FHWA-HOP-08-014)
http://ops.fhwa.dot.gov/publications/fhwahop08014/task3_case.pdf

FHWA initiated a study to assess the state of the practice and state of the art in evacuation transportation management. The study focused on management of incidents when there is no advance warning or when conditions are changing rapidly. This report documents four case studies regarding no-notice evacuations from a transportation point of view. The intent of the case studies is to identify commonalities and unique distinctions among the cross-section of incidents to identify successes, lessons learned, and best practices to provide guidance to agencies in planning for and managing evacuations, including transportation, public safety, and other public organizations with a role in managing evacuations.

This resource provides best practices to be employed when managing no-notice evacuations.

Next-Generation 9-1-1 Initiative
http://transition.fcc.gov/pshs/services/911-services/nextgen.html

http://www.its.dot.gov/ng911/index.htm

The Next Generation 9-1-1 Initiative is a research and development project to help define the system architecture and develop a transition plan to establish a digital, Internet Protocol (IP)-based foundation for the delivery of multimedia 9-1-1 "calls."

This resource can provide valuable information regarding standard IP protocols used to transfer and share data related to traffic management.

Guide to Sustainable Transportation Performance Measures, August 2011; Environmental Protection Agency (EPA) (EPA 231-K-10-004)
http://www.epa.gov/smartgrowth/pdf/Sustainable_Transpo_Performance.pdf

This report describes opportunities to incorporate environmental, economic, and social sustainability into transportation decision making through the use of performance measures. The document focuses on transportation decision making at the regional or metropolitan level, although many of the performance measures described could be used at the state or local level. For each measure, the guidebook presents possible metrics, summarizes the relevant analytical methods and data sources, and illustrates the use of each measure by one or more transportation agencies.

This resource provides examples of best practices in sustainable transportation performance measurement that are being applied across the country.

Best Practices in Traffic Incident Management, 2010; FHWA (FHWA-HOP-10-050)
http://ops.fhwa.dot.gov/publications/fhwahop10050x/fhwahop10050x.pdf

This report describes task specific and cross-cutting issues or challenges commonly encountered by TIM responders in the performance of their duties, and novel and/or effective strategies for overcoming these issues and challenges (i.e., best practices), including obtaining accurate information from motorists, accessing the scene, and condemning a spilled load. Cross-cutting challenges may include interagency coordination and communication, technology procurement and deployment, and performance measurement. For many of the individual tools and strategies, a wide range of effectiveness was reported by locale, challenging the explicit identification of best practices, and suggesting that local conditions related to the nature and extent of operation, maintenance, and marketing have a significant impact on the perceived or measured success of specific TIM efforts.

This resource offers best practices, tempered to the influence of local conditions when measuring success.

Freeway Management & Operation Handbook, Updated 2011; FHWA (FHWA-OP-04-003)
http://ops.fhwa.dot.gov/freewaymgmt/pubs.htm

This handbook provides an overview of the various institutional and technical issues associated with the planning, design, implementation, operation, and management of a freeway network. The document includes the wide variety of potential strategies, tools, and technologies that may be used to support management and operation of the freeway network. It addresses the major changes in technology (e.g., ITS and architectures) that have occurred and considers a broader view as well, including freeway management in the context of the entire surface transportation network, lane management concepts, roadway improvements (both geometric and operational), performance monitoring and associated measures, established processes for dealing with the risks associated with technology—intensive systems, and the role of freeway management during emergencies and evacuations.

This resource provides helpful guidance regarding effective performance monitoring and measurement.

Highway Evacuations in Selected Metropolitan Regions: Assessment of Impediments, April 2010; FHWA (FHWA HOP-10-059)
http://ops.fhwa.dot.gov/eto_tim_pse/reports/2010_cong_evac_study/fhwahop10059.pdf

This report focuses on two specific areas: (1) assessing mass evacuation plans for the country's high-threat, high-density areas and identifying and prioritizing deficiencies on those routes that could impede evacuations and (2) conducting an analysis of how national highway system (NHS) projects under construction west of the National Capital Region could increase the NCR's evacuation capacity and provide a detailed plan to accelerate such projects. The assessments involved a broad view of what local authorities in 26 metropolitan areas view as the greatest impediments of their NHS routes in supporting a mass evacuation within their region. The study included an assessment of construction and options for accelerating work along NHS routes west of the NCR that would facilitate the movement of NCR evacuees from danger as necessary.

This resource contains data that provides additional insight into the highway impediments that will frustrate area attempts to execute a mass evacuation.

Information Sharing Guidebook for Transportation Management Centers, Emergency Operations Centers, and Fusion Centers, June 2010; FHWA (FHWA-HOP-09-003)
http://ops.fhwa.dot.gov/publications/fhwahop09003/tmc_eoc_guidebook.pdf

This guidebook provides an overview of the mission and functions of TMCs, emergency operations centers, and fusion centers. The guidebook focuses on the types of information these centers produce and manage and how the sharing of such information among the centers can be beneficial to both the day-to-day and emergency operations of all the centers; realizing challenges exist to the ability to share information.

This resource guidebook addresses these challenges and options for handling information sharing. In addition, this resource provides some lessons learned and best practices identified from a literature search and interviews/site visits with center operators.

Field Operations Guide and Visor Cards for Safety/Service Patrols, December 2009; FHWA (FHWA-HOP-10-014)
http://ops.fhwa.dot.gov/publications/fhwahop10014/fhwahop10014.pdf

This guide was developed for Safety/Service Patrol operators and supervisory personnel. It is intended to be carried in their vehicles and used as a quick reference while performing patrol tasks. The guide provides steps and tasks associated with managing incidents—particularly for those situations not encountered every day. This guide is not designed to stand alone, but in conjunction with training and exercises, as well as agency-formal Standard Operating Guidelines or Procedures that will indoctrinate the Safety/Service patrol operators into these good practices.

This resource document is a valuable guide regarding information gathering and sharing of good practices and procedures to follow when dealing with incidents.

Traffic Incident Management Handbook, January 2010; FHWA (FHWA-HOP-10-013)
http://ops.fhwa.dot.gov/eto_tim_pse/publications/timhandbook/tim_handbook.pdf

This handbook includes the latest advances in traffic incident management programs and practices across the country and offers insights into the latest innovations in TIM tools and technologies. The 2010 TIM Handbook also features a parallel, web-based version that may be conveniently bookmarked, browsed, or keyword-searched for quick reference. In addition, a quick resource guide titled, "Want to Know More," follows each chapter and direct readers to supplemental information associated with the specific chapter content.

This resource document is a valuable guide regarding the latest advances in successful TIM programs, practices and procedures to follow.

Surface Transportation Security and Reliability Information System Model Deployment – iFlorida Final Concept of Operations, September 2003; FHWA (DTFH61-03-H-00105)
http://ntl.bts.gov/lib/jpodocs/repts_te/13961/13961.pdf

This report describes model deployment, focusing on enhancing the security and reliability of the surface transportation system through the widespread availability of real-time information; examining how security and reliability can be improved under several situations or scenarios. This document provides an understanding of how the various procurements shall be configured and what elements shall be included as part of the procurements. The iFlorida system model deployment demonstrates best practices and innovative approaches for the collection, processing, use, dissemination, sharing, and archiving of transportation information.

This resource addresses existing surveillance and monitoring systems being augmented to fill gaps, and overall coverage to be enhanced with new sensor types, increased data rates, or increased coverage density.

Real-Time Traveler Information Market Assessment White Paper, February 2010; FHWA (FHWA-JPO-10-055)
http://ntl.bts.gov/lib/32000/32900/32927/rtti_wp.pdf

This report takes a multimodal look at the “lay of the land” of the real-time traveler information market in the United States, including identification and characterization of the gaps in the domestic industry with respect to data coverage, data quality, data procurement methods, and data usage. Ultimately, the focus is to identify the gaps in real-time information across different modes (i.e., traffic, transit, parking, and intermodal/freight). The analysis also documents the institutional, technical, and cost issues associated with collecting real-time data from these modes, opportunities for closing the gaps, and utility of real-time data for uses beyond traveler information.

This resource is helpful in identifying opportunities that best leverage resources and innovative approaches that span multiple modes.

AASHTO Guidelines for Traffic Data Programs, 2nd Edition, Updated 2009; AASHTO
https://bookstore.transportation.org/Item_details.aspx?id=1392

The AAHTO Guidebook is intended for use by state and local transportation agencies, as well as others involved in traffic data programs. The Guidebook focuses is on improving the quality of the traffic information that supports decisions at all levels of the transportation profession. It specifically addresses concerns of state transportation agencies. The Guidelines are organized in eight chapters: (1) Introduction; (2) Traffic Data Collection Needs; (3) Traffic Monitoring Equipment; (4) Editing Traffic Data; (5) Summarizing Traffic Data; (6) Reporting Traffic Data; (7) Retaining Traffic Data; and (8) Quality Control.

This resource recommends professional traffic monitoring practices that reflect current practices, incorporates advancements made in the data collection procedures, and establishes a process for adoption of national traffic monitoring standards.

Service Patrol Handbook, November 2008; FHWA (FHWA-HOP-08-031)
http://www.ops.fhwa.dot.gov/publications/fhwahop08031/ffsp_handbook.pdf

This handbook provides an overview of the Full-Function Service Patrol (FFSP) and describes desired program characteristics from the viewpoint of an agency that is responsible for funding, managing, and operating the services. Presented guidelines and rules of thumb illustrate operational characteristics, sponsorship, level of service, number of vehicles needed, vehicle types and equipment, patrol frequency, operator and manager training, and services provided. The primary audience for the handbook comprises state departments of transportation decision makers, managers, operators, and practitioners who are responsible for, or are considering, implementing an FFSP program as part of a strategy to reduce congestion.

This resource provides program guidance on desired infrastructure needed to operate a successful service patrol.

Federal Highway Administration Intelligent Transportation Systems: Compendium of Field Operational Test Executive Summaries, Updated May 2009

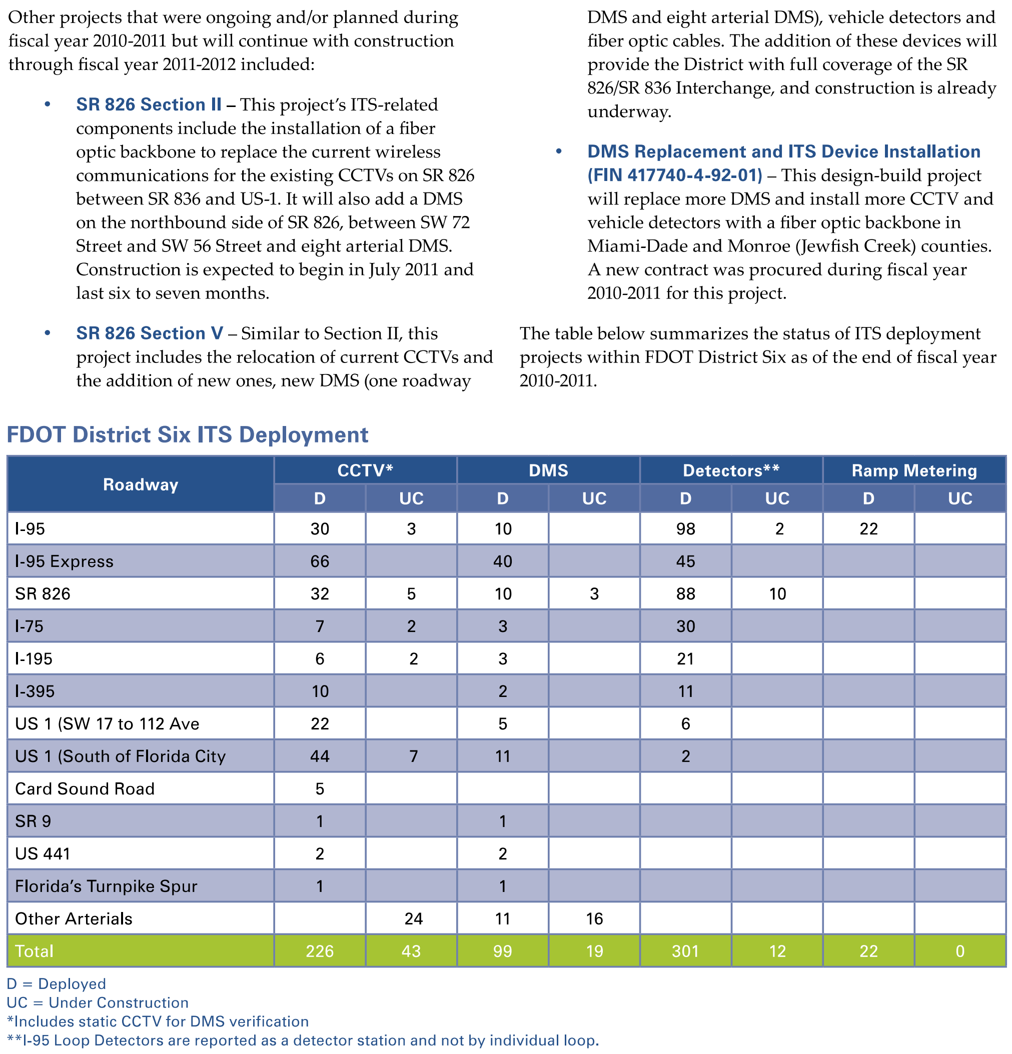
http://trid.trb.org/view.aspx?id=697876

This report contains Intelligent Transportation System Field Operational Test Summaries. Each summary contains the following: FHWA contact (office and phone number); project description; test status or test results; test partners; and references.

This resource provides an assessment and lessons learned regarding field operational tests, from the inception of the FOT program.

Appendix B. FDOT District Six ITS Annual Report (Fiscal Year 2010-2011), page 6

Figure B-1. (http://www.sunguide.org/sunguide/images/uploads/tmc_reports/2011_0921_FDOT_D6_AR_2010-2011(WEB).pdf)



Other projects that were ongoing and/or planned during fiscal year 2010-2011 but will continue with construction through fiscal year 2011-2012 included:

- **SR 826 Section II** – This project's ITS-related components include the installation of a fiber optic backbone to replace the current wireless communications for the existing CCTVs on SR 826 between SR 836 and US-1. It will also add a DMS on the northbound side of SR 826, between SW 72 Street and SW 56 Street and eight arterial DMS. Construction is expected to begin in July 2011 and last six to seven months.
- **SR 826 Section V** – Similar to Section II, this project includes the relocation of current CCTVs and the addition of new ones, new DMS (one roadway DMS and eight arterial DMS), vehicle detectors and fiber optic cables. The addition of these devices will provide the District with full coverage of the SR 826/SR 836 Interchange, and construction is already underway.
- **DMS Replacement and ITS Device Installation (FIN 417740-4-92-01)** – This design-build project will replace more DMS and install more CCTV and vehicle detectors with a fiber optic backbone in Miami-Dade and Monroe (Jewfish Creek) counties. A new contract was procured during fiscal year 2010-2011 for this project.

The table below summarizes the status of ITS deployment projects within FDOT District Six as of the end of fiscal year 2010-2011.

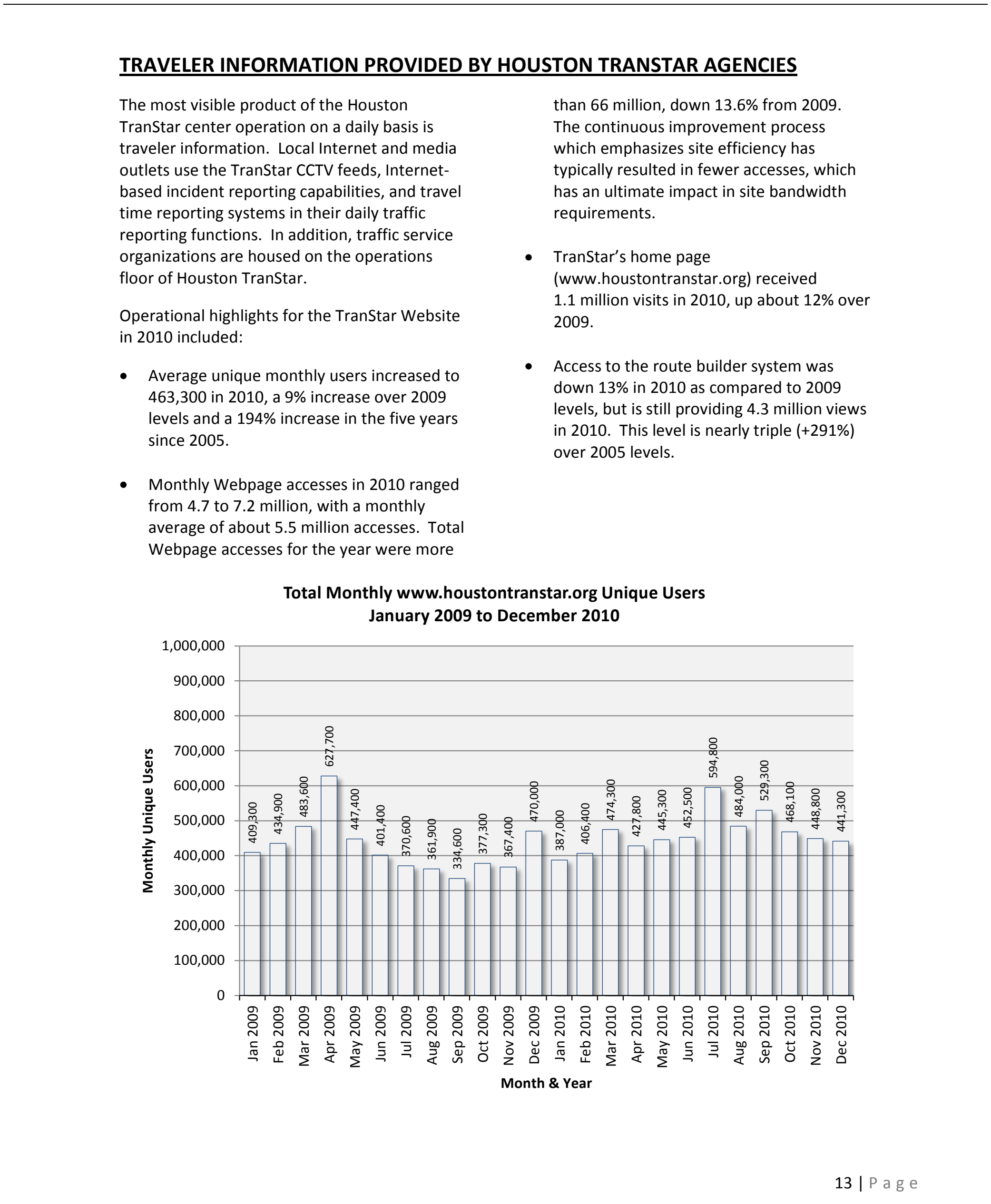
FDOT District Six ITS Deployment

Roadway	CCTV*		DMS		Detectors**		Ramp Metering	
	D	UC	D	UC	D	UC	D	UC
I-95	30	3	10		98	2	22	
I-95 Express	66		40		45			
SR 826	32	5	10	3	88	10		
I-75	7	2	3		30			
I-195	6	2	3		21			
I-395	10		2		11			
US 1 (SW 17 to 112 Ave	22		5		6			
US 1 (South of Florida City	44	7	11		2			
Card Sound Road	5							
SR 9	1		1					
US 441	2		2					
Florida's Turnpike Spur	1		1					
Other Arterials		24	11	16				
Total	226	43	99	19	301	12	22	0

D = Deployed
UC = Under Construction
*Includes static CCTV for DMS verification
**I-95 Loop Detectors are reported as a detector station and not by individual loop.

Appendix C. Houston TranStar 2010 Annual Report, pages 13-15

Figure C-1. (http://www.houstontranstar.org/about_transtar/)



TRAVELER INFORMATION PROVIDED BY HOUSTON TRANSTAR AGENCIES

The most visible product of the Houston TranStar center operation on a daily basis is traveler information. Local Internet and media outlets use the TranStar CCTV feeds, Internet-based incident reporting capabilities, and travel time reporting systems in their daily traffic reporting functions. In addition, traffic service organizations are housed on the operations floor of Houston TranStar.

Operational highlights for the TranStar Website in 2010 included:

- Average unique monthly users increased to 463,300 in 2010, a 9% increase over 2009 levels and a 194% increase in the five years since 2005.
- Monthly Webpage accesses in 2010 ranged from 4.7 to 7.2 million, with a monthly average of about 5.5 million accesses. Total Webpage accesses for the year were more than 66 million, down 13.6% from 2009. The continuous improvement process which emphasizes site efficiency has typically resulted in fewer accesses, which has an ultimate impact in site bandwidth requirements.
- TranStar's home page (www.houstontranstar.org) received 1.1 million visits in 2010, up about 12% over 2009.
- Access to the route builder system was down 13% in 2010 as compared to 2009 levels, but is still providing 4.3 million views in 2010. This level is nearly triple (+291%) over 2005 levels.

Total Monthly www.houstontranstar.org Unique Users
January 2009 to December 2010

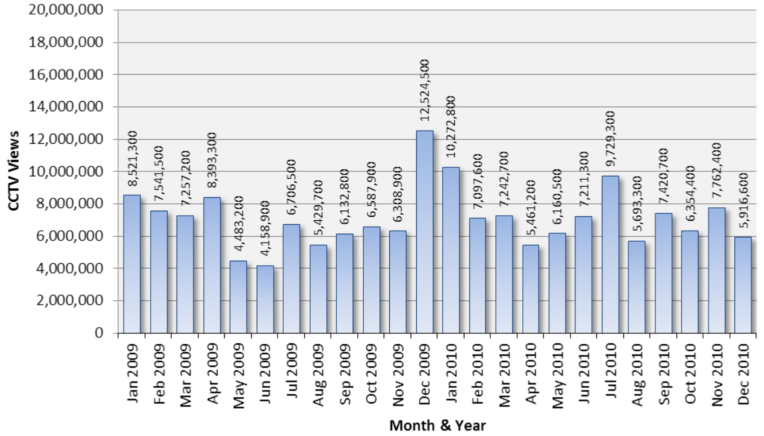
TRAVELER INFORMATION PROVIDED BY HOUSTON TRANSTAR AGENCIES

- CCTV Views:
    - Views of CCTV images increased from 84.0 million in 2009 to 86.3 million in 2010, an increase of 2.7%. However, since 2005, CCTV snapshot views have increased more than 1000%.
    - Views of the regional cameras (primarily used for hurricane evacuation route monitoring) totaled 5.4 million in 2010.

- Traffic data information to third-party providers via the TranStar data feed remained relatively flat in 2010 (5.7 million accesses) over 2009.

- DMS information viewed increased by 55% from 2009 to 2010, with more than 2.3 million views. Since 2008, views of DMS messages have increased nearly 300%.

Houston TranStar CCTV Views, 2009-2010

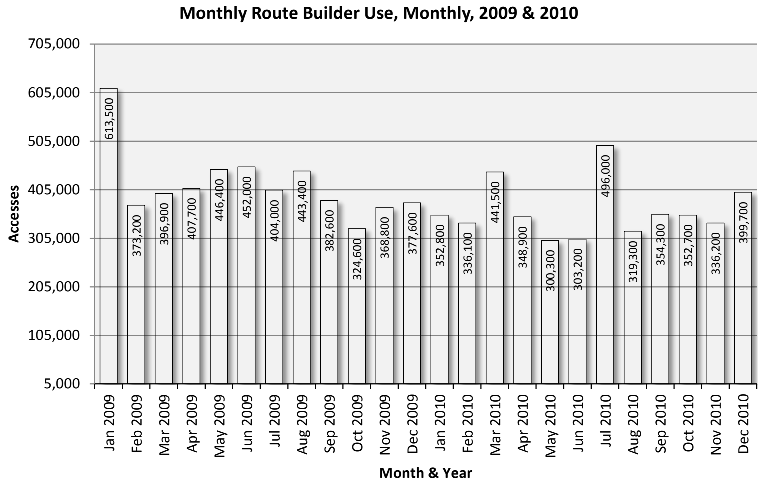


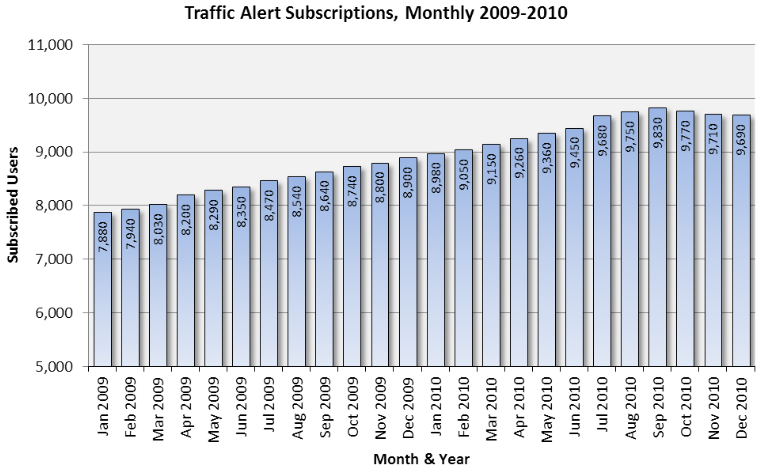
- Traffic alert subscribers increased from an average monthly subscriber base of 8,400 in 2009 to 9,470 in 2010, an increase of 13%. Total monthly users at the end of 2010 were nearly 9,700.

- Mobile traffic data accesses decreased a bit in 2010 to 7.1 million accesses as opposed to 7.4 million in 2009, a 3.5% decrease. However, in the past five years mobile traffic data accesses have increased more than 475%.

- Average monthly accesses to the Virtual Earth version of the speed map was down 50% as users continue to prefer the traditional black background maps for most traveler information.

TRAVELER INFORMATION PROVIDED BY HOUSTON TRANSTAR AGENCIES





Appendix D. VDOT Hampton Roads TOC 2011 Annual Report, page 9

Figure D-1. (http://www.virginiadot.org/travel/resources/2011.pdf)

Safety Service Patrol

Assisting motorists quickly and safely - reducing delays and improving travel in Hampton Roads.

Key Accomplishments in 2011:

- Participated in Quick Clearance Ad Campaign.
- Changed from pneumatic to battery operated impact guns to improve clearance times.
- Started using jump boxes for improved safety and quicker clearance.
- Standardized cones to the 12lb cone which improve safety on scenes.
- Converted arrow boards to LED lighting to increase motorist awareness.

The HRTOC Safety Service Patrol program has evolved from basic motorist assistance into a full incident management and emergency response program. In addition to providing assistance to travelers, the SSP detect events, clear obstructions and debris from the roadway, and provide traffic control for emergency responders.

The majority of events recorded in the HRTOC incident database are detected by the patrollers that are out on the roadway 365 days a year. In 2011 the SSP detected over 30,000 events. The most common type of event detected by the SSP was disabled vehicles. Since the response time for incidents detected by the SSP is usually very low those incidents are not included in the reported average SSP response time.

Quick response time helps lanes be reopened faster and minimizes congestion delays.

Although the average SSP response time increased from 2010 several steps were put in place towards the end of 2011 to help decrease average response time in the coming years.

One cause of the increase in SSP response time in 2011 was an increase in the number of incidents where a SSP was not available to immediately respond to the incident because they were already assisting another motorist.

The most important step in decreasing average SSP response time was the expansion of the SSP routes. In December the patrol area increased from 6 routes, covering 73 centerline miles, to 8 routes covering 89 centerline miles.

To support the route expansion additional SSP personnel were hired and more trucks procured.

Another step taken to reduce average SSP response time was the creation of a “power shift” which was also implemented in December. The power shift allows one SSP on the South Side and one on the Peninsula to continue patrolling the roadways during the shift change of the other SSP. This ensures that there is always a patroller out on the roadways to respond to incidents.

Prior to the implementation of these two steps in December the average SSP response time was 9.2 minutes. Afterwards, the average dropped over a full minute to 7.9 minutes!

*Only includes incidents where a SSP responded, but was not the detection source

Appendix E. RIDOT TMC Incident Statistics – 4/1/2012 to 6/30/2012, page 2

Figure E-1. (http://www.tmc.dot.ri.gov/pdf/2012-2Q.pdf)

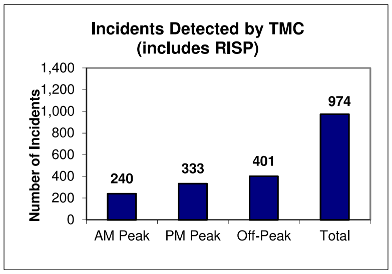
RIDOT TMC Incident Statistics Report

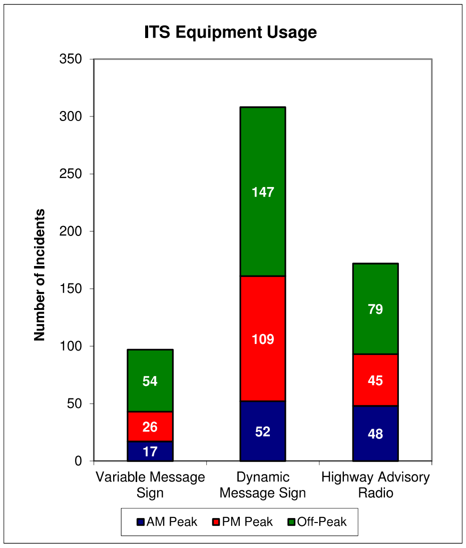
1. Peak Period Incident Statistics*

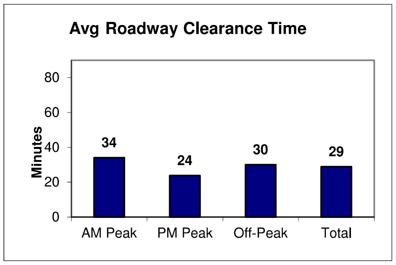
	AM Peak	PM Peak	Off-Peak	Total
Number of Incidents	246	337	411	994
Avg. Incident Clearance Time (min)	48	39	38	41
Avg. Roadway Clearance Time (min)	34	24	30	29
# Detected by TMC Operators	153	74	159	386
# Detected by State Police (RISP)	87	259	242	588
# Notified by RhodeWatchers	0	1	0	1
# Utilizing VMS	17	26	54	97
# Utilizing DMS	52	109	147	308
# Utilizing HAR	48	45	79	172
# Posted to Web	238	335	383	956
Avg. Delay Cost**	$201,939	$164,694	$159,577	$171,796
Total Delay Cost	$49,677,099	$55,501,801	$65,586,114	$170,765,014

* AM Peak: 6:00AM to 10:00 AM, PM Peak: 3:00PM to 7:00PM, Monday - Friday

** Delay Cost is a function of incident duration, volume on the roadway, delay per person, and cost per hour of delay for both commercial and personal vehicles. Average delay cost includes only incidents with a lane blockage and represents average cost per incident.







Note: Statistics in this report are only for incidents that the TMC reported or responded to during the quarter. They do not include all incidents that occurred on Rhode Island roadways.

Incident Clearance Time is the time from the start of an incident (or when it is detected) to the time when responders leave the scene and/or the incident is declared as cleared.

Roadway Clearance Time is the time from the start of an incident (or when it is detected) to the time when all travel lanes are available for traffic.

4/1/2012 To 6/30/2012 Page 2

Appendix F. VDOT Hampton Roads TOC 2011 Annual Report, pages 9-10

Figure F-1. (http://www.virginiadot.org/travel/resources/2011.pdf)

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9

Safety Service Patrol

Assisting motorists quickly and safely - reducing delays and improving travel in Hampton Roads.

The third step taken in 2011 to reduce SSP response time was to continue using quarterly incident data in reconfiguring SSP routes for the most effective use of resources.

A great deal of data about each incident is logged in the HRTOC incident database, including the incident type and if assistance (as well as type of assistance) was needed.

In 2011, the SSP responded to more than 40,000 incidents. The most common types of assistance provided to motorists were helping change tires and dispensing fuel.

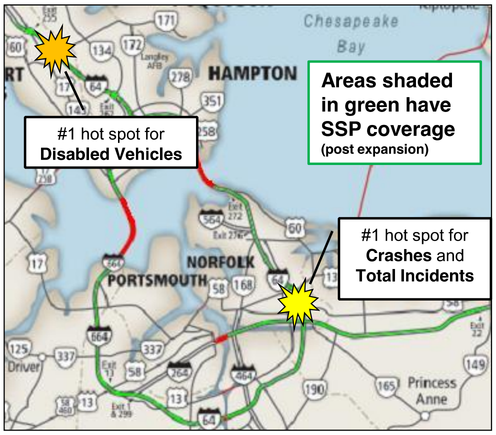
Another important piece of incident data recorded is location.

Roadway areas where the highest number of incidents occur are known as "hot spots". These hot spots receive special attention - increased patrolling and additional data collection - so they can be studied for potential engineering solutions for improved driver safety.

In 2011, the number one incident hot spot for all incident types (crashes, debris, abandoned and disabled vehicles) was on I-64 between the I-64/I-264 Interchange and Northampton Boulevard, where over 2,300 incidents occurred on this area of roadway alone.

This area was also the number one crash hot spot in 2011, with 7% of total crashes occurring at that location.

The number one hot spot for disabled vehicles was on I-64 between Jefferson Avenue and Ft. Eustis Boulevard, with 5% of total disabled vehicles.



Areas shaded in green have SSP coverage
(post expansion)

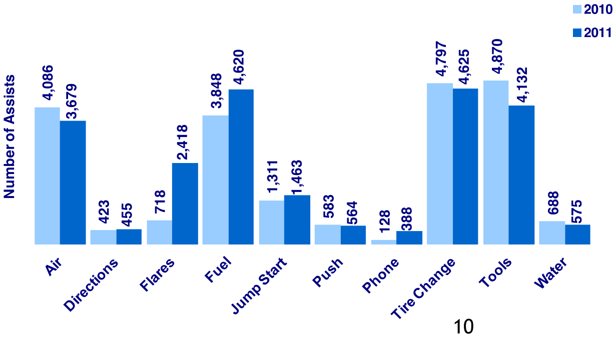
#1 hot spot for **Disabled Vehicles**

#1 hot spot for **Crashes** and **Total Incidents**

The SSP expansion from 6 to 8 routes was executed with the top hot spots in mind. One route was added on the South Side and one on the Peninsula. Some of the existing routes were shortened for better coverage and to reduce the amount of time it takes for a patroller to respond from a nearby route during a major event. As a result, a total of 4 routes now converge at the location of the top incident hot spot.

On the Peninsula, the Pine Chapel facility was reopened so that patrollers do not have to pass through one of the area's tunnels at the start and end of each shift. As another part of the expansion, routes were modified to remove passing through tunnels as part of the route, maximizing the time patrollers can spend on Hampton Roads highways assisting motorists and detecting and clearing events.

Types of SSP Assistance

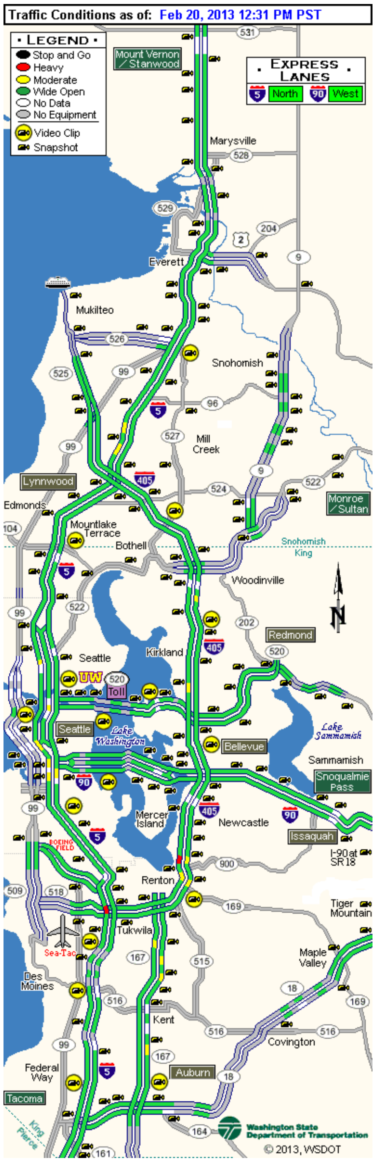


10

VDOT
Hampton Roads TOC

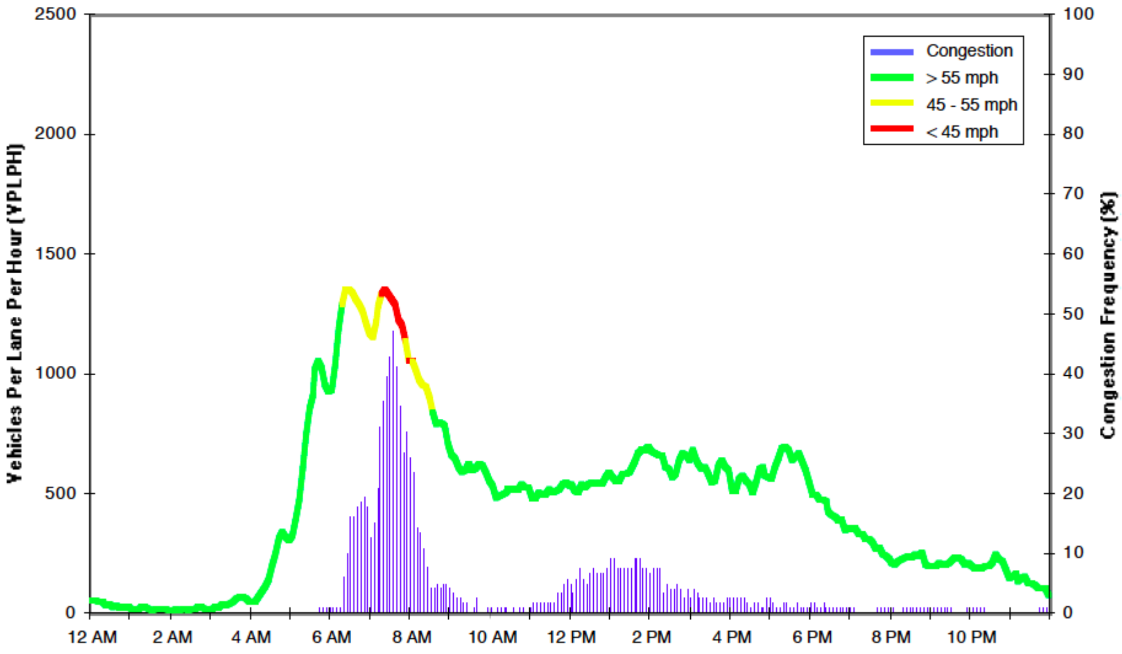
Appendix G. Washington State Department of Transportation, Seattle Area Traffic Map

Figure G-1. (http://www.wsdot.com/traffic/seattle/default.aspx)



Appendix H. Washington State Transportation Center (TRAC) – Central Puget Sound Freeway Network Usage and Performance, Volume 1, 1999 Update, Figure 4-19

Figure H-1. Estimated Weekday Volume, Speed, and Reliability Conditions (1999): Northbound SR 167, South 23rd St, HOV Lane. (http://depts.washington.edu/trac/bulkdisk/pdf/493.1.pdf)



Appendix I. Washington State Transportation Center, University of Washington – Central Puget Sound Freeway Network Usage and Performance, Volume 1, 1999 Update, Figures 3-8 and 3-16

Figure I-1. State Route 167 Traffic Profile: General Purpose Lanes, 1999 Weekday Average. (http://depts.washington.edu/trac/bulkdisk/pdf/493.1.pdf)

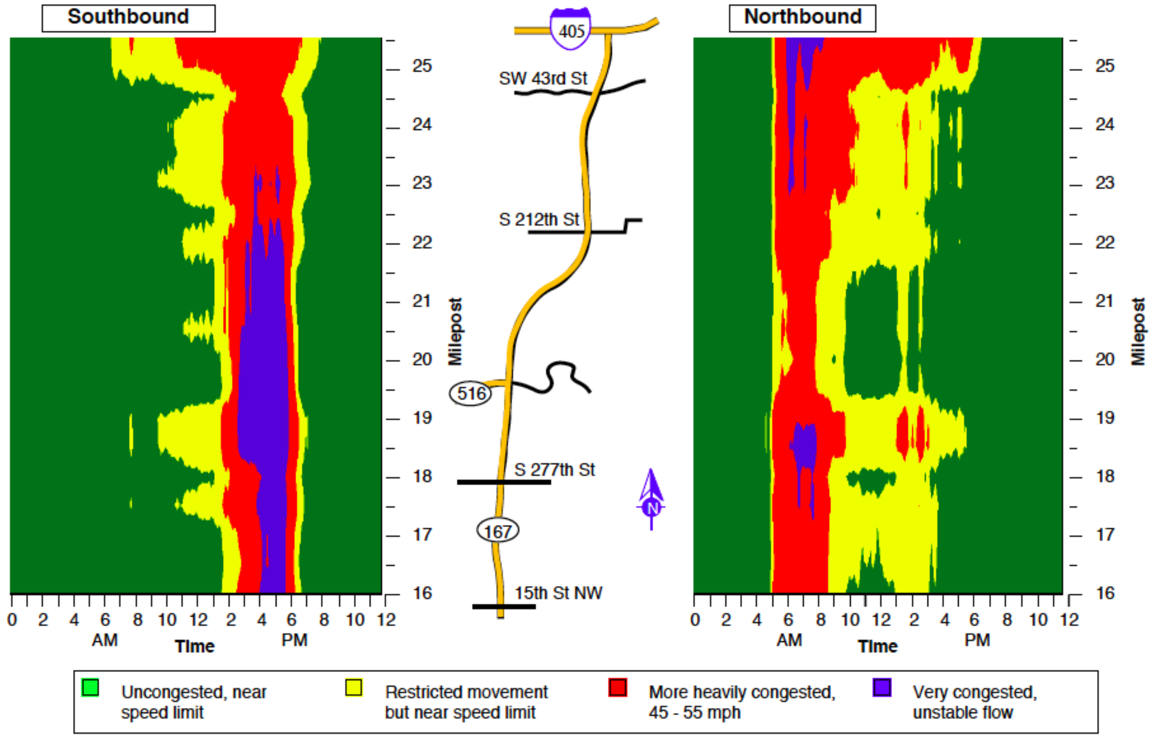
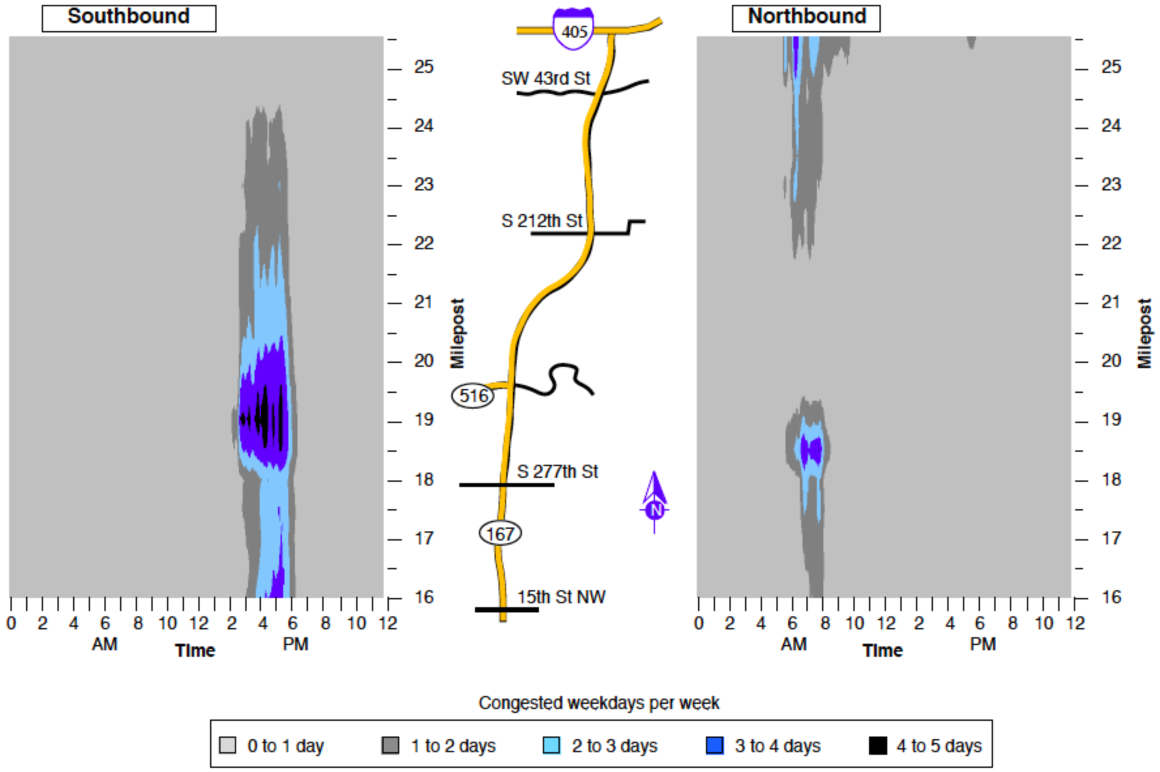
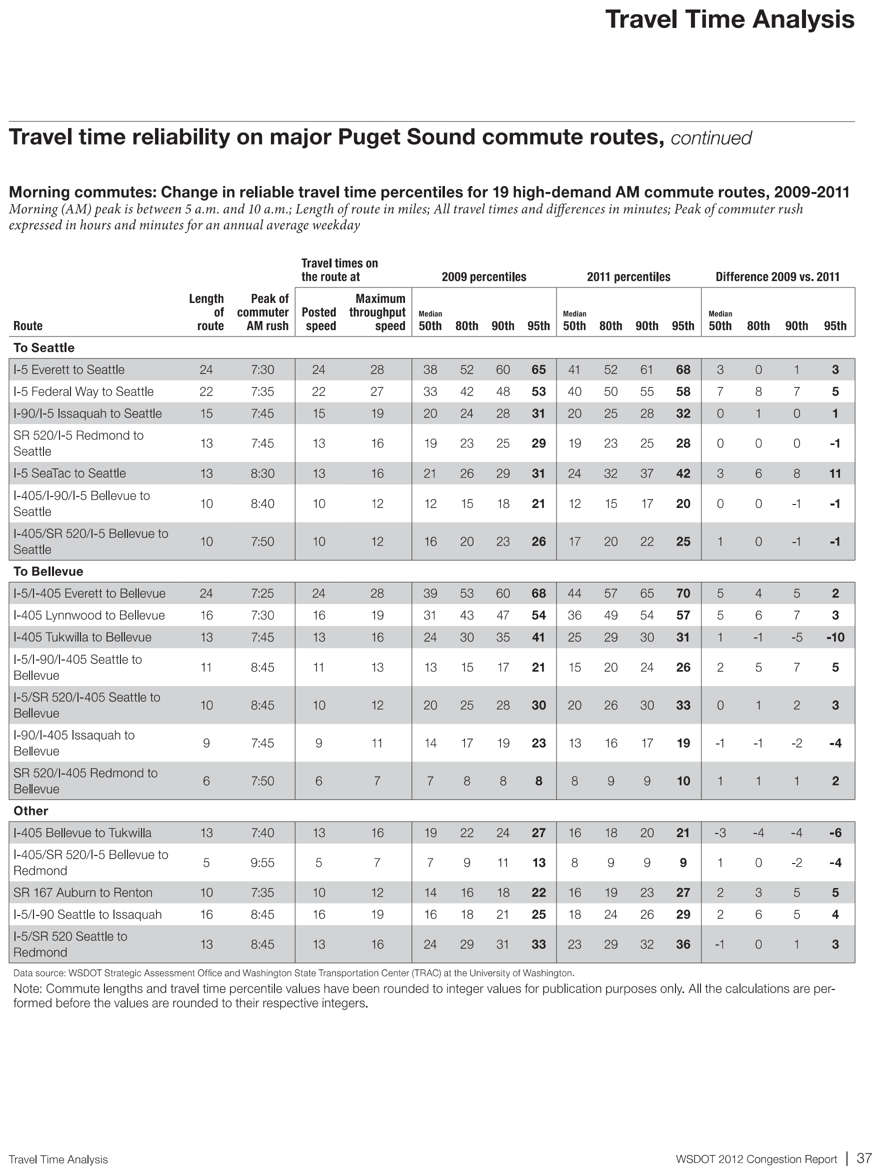


Figure I-2. State Route 167 South Congestion Frequency, General Purpose Lanes, 1999 Weekday Average. (http://depts.washington.edu/trac/bulkdisk/pdf/493.1.pdf)



Appendix J. Washington State Department of Transportation 2012 Annual Congestion Report, page 37

Figure J-1. (http://wsdot.wa.gov/publications/fulltext/graynotebook/CR12.pdf)



Travel Time Analysis

Travel time reliability on major Puget Sound commute routes, *continued*

Morning commutes: Change in reliable travel time percentiles for 19 high-demand AM commute routes, 2009-2011
Morning (AM) peak is between 5 a.m. and 10 a.m.; Length of route in miles; All travel times and differences in minutes; Peak of commuter rush expressed in hours and minutes for an annual average weekday

			Travel times on the route at		2009 percentiles				2011 percentiles				Difference 2009 vs. 2011			
Route	Length of route	Peak of commuter AM rush	Posted speed	Maximum throughput speed	Median 50th	80th	90th	95th	Median 50th	80th	90th	95th	Median 50th	80th	90th	95th
To Seattle																
I-5 Everett to Seattle	24	7:30	24	28	38	52	60	**65**	41	52	61	**68**	3	0	1	**3**
I-5 Federal Way to Seattle	22	7:35	22	27	33	42	48	**53**	40	50	55	**58**	7	8	7	**5**
I-90/I-5 Issaquah to Seattle	15	7:45	15	19	20	24	28	**31**	20	25	28	**32**	0	1	0	**1**
SR 520/I-5 Redmond to Seattle	13	7:45	13	16	19	23	25	**29**	19	23	25	**28**	0	0	0	**-1**
I-5 SeaTac to Seattle	13	8:30	13	16	21	26	29	**31**	24	32	37	**42**	3	6	8	**11**
I-405/I-90/I-5 Bellevue to Seattle	10	8:40	10	12	12	15	18	**21**	12	15	17	**20**	0	0	-1	**-1**
I-405/SR 520/I-5 Bellevue to Seattle	10	7:50	10	12	16	20	23	**26**	17	20	22	**25**	1	0	-1	**-1**
To Bellevue																
I-5/I-405 Everett to Bellevue	24	7:25	24	28	39	53	60	**68**	44	57	65	**70**	5	4	5	**2**
I-405 Lynnwood to Bellevue	16	7:30	16	19	31	43	47	**54**	36	49	54	**57**	5	6	7	**3**
I-405 Tukwilla to Bellevue	13	7:45	13	16	24	30	35	**41**	25	29	30	**31**	1	-1	-5	**-10**
I-5/I-90/I-405 Seattle to Bellevue	11	8:45	11	13	13	15	17	**21**	15	20	24	**26**	2	5	7	**5**
I-5/SR 520/I-405 Seattle to Bellevue	10	8:45	10	12	20	25	28	**30**	20	26	30	**33**	0	1	2	**3**
I-90/I-405 Issaquah to Bellevue	9	7:45	9	11	14	17	19	**23**	13	16	17	**19**	-1	-1	-2	**-4**
SR 520/I-405 Redmond to Bellevue	6	7:50	6	7	7	8	8	**8**	8	9	9	**10**	1	1	1	**2**
Other																
I-405 Bellevue to Tukwilla	13	7:40	13	16	19	22	24	**27**	16	18	20	**21**	-3	-4	-4	**-6**
I-405/SR 520/I-5 Bellevue to Redmond	5	9:55	5	7	7	9	11	**13**	8	9	9	**9**	1	0	-2	**-4**
SR 167 Auburn to Renton	10	7:35	10	12	14	16	18	**22**	16	19	23	**27**	2	3	5	**5**
I-5/I-90 Seattle to Issaquah	16	8:45	16	19	16	18	21	**25**	18	24	26	**29**	2	6	5	**4**
I-5/SR 520 Seattle to Redmond	13	8:45	13	16	24	29	31	**33**	23	29	32	**36**	-1	0	1	**3**

Data source: WSDOT Strategic Assessment Office and Washington State Transportation Center (TRAC) at the University of Washington.

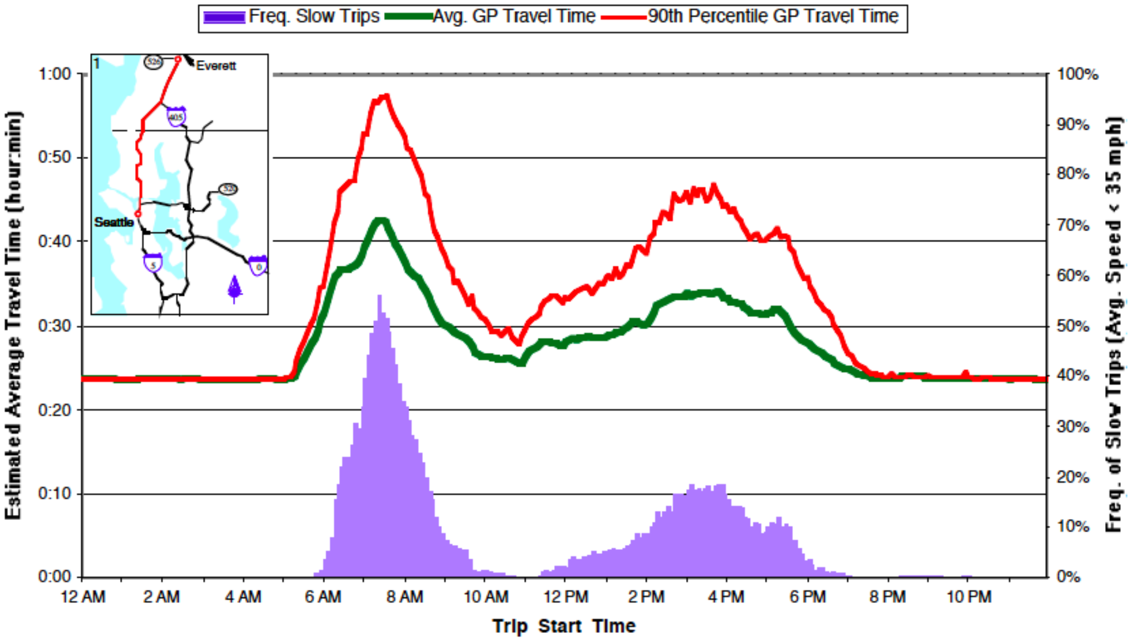
Note: Commute lengths and travel time percentile values have been rounded to integer values for publication purposes only. All the calculations are performed before the values are rounded to their respective integers.

Travel Time Analysis

WSDOT 2012 Congestion Report | 37

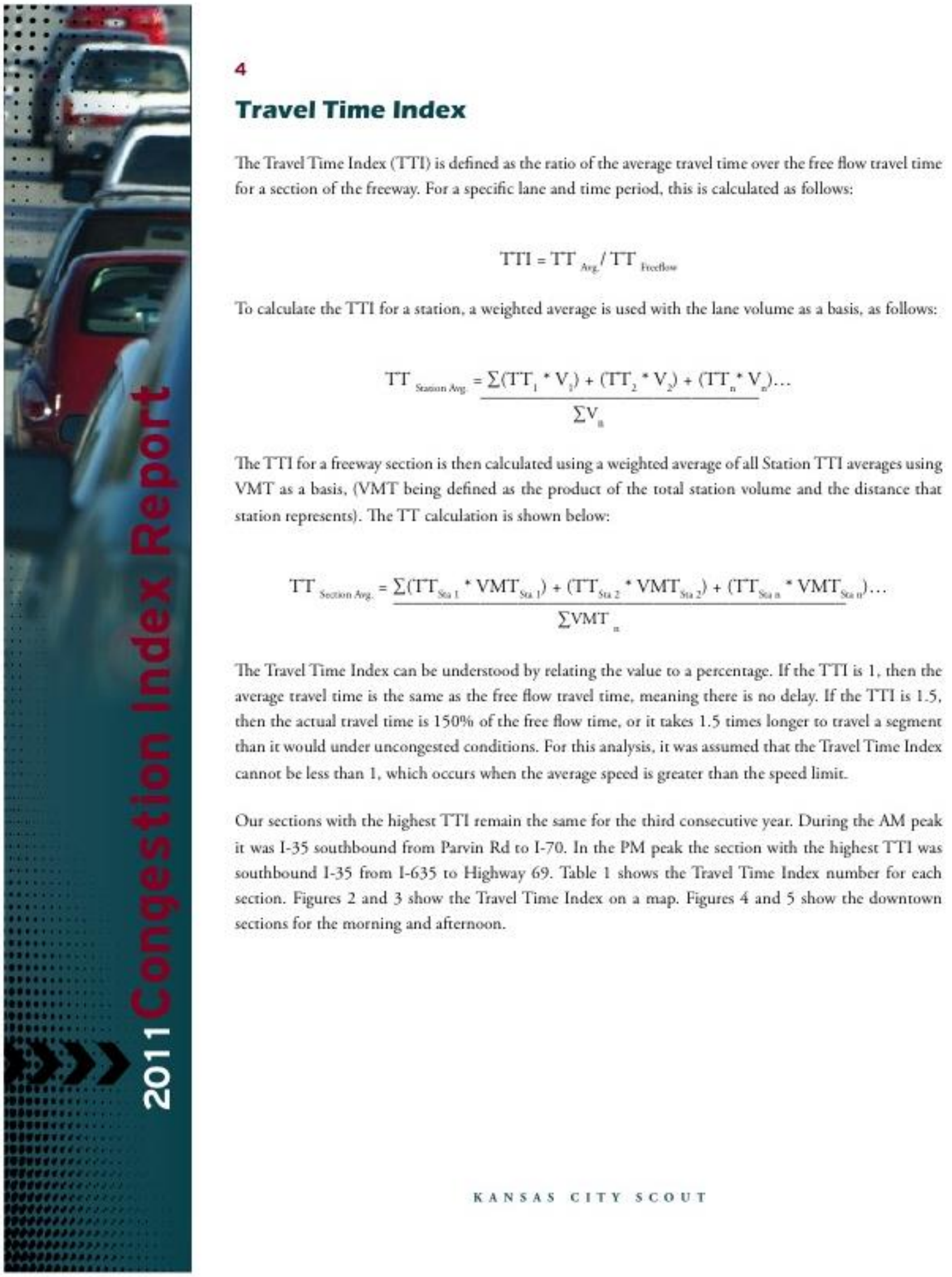
Appendix K. Washington State Transportation Center, University of Washington – Central Puget Sound Freeway Network Usage and Performance, Volume 1, 1999 Update, Figure 3-19

Figure K-1. Estimated Average Weekday Travel Time (1999): SR 526 Interchange to Seattle CBD, General Purpose Lanes (23.7 mi). (http://depts.washington.edu/trac/bulkdisk/pdf/493.1.pdf)



Appendix L. 2011 Kansas City Scout Congestion Index Report, pages 4-10, 11-16, & 17-22

Figure L-1. Pages 4-10 (TTI)
(http://www.kcscout.net/downloads/Announcements/CongestionReport.pdf)



4

Travel Time Index

The Travel Time Index (TTI) is defined as the ratio of the average travel time over the free flow travel time for a section of the freeway. For a specific lane and time period, this is calculated as follows:

$$TTI = TT_{Avg.} / TT_{Freeflow}$$

To calculate the TTI for a station, a weighted average is used with the lane volume as a basis, as follows:

$$TT_{Station\ Avg.} = \frac{\sum(TT_1 * V_1) + (TT_2 * V_2) + (TT_n * V_n)}{\sum V_n}\ldots$$

The TTI for a freeway section is then calculated using a weighted average of all Station TTI averages using VMT as a basis, (VMT being defined as the product of the total station volume and the distance that station represents). The TT calculation is shown below:

$$TT_{Section\ Avg.} = \frac{\sum(TT_{Sta\ 1} * VMT_{Sta\ 1}) + (TT_{Sta\ 2} * VMT_{Sta\ 2}) + (TT_{Sta\ n} * VMT_{Sta\ n})}{\sum VMT_n}\ldots$$

The Travel Time Index can be understood by relating the value to a percentage. If the TTI is 1, then the average travel time is the same as the free flow travel time, meaning there is no delay. If the TTI is 1.5, then the actual travel time is 150% of the free flow time, or it takes 1.5 times longer to travel a segment than it would under uncongested conditions. For this analysis, it was assumed that the Travel Time Index cannot be less than 1, which occurs when the average speed is greater than the speed limit.

Our sections with the highest TTI remain the same for the third consecutive year. During the AM peak it was I-35 southbound from Parvin Rd to I-70. In the PM peak the section with the highest TTI was southbound I-35 from I-635 to Highway 69. Table 1 shows the Travel Time Index number for each section. Figures 2 and 3 show the Travel Time Index on a map. Figures 4 and 5 show the downtown sections for the morning and afternoon.

KANSAS CITY SCOUT

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Table 1: Travel Time Index

Segment and Freeway Description	Segment Length	Morning Peak TTI	Evening Peak TTI
1.I-35 NB (from I-435 to 69 Hwy)	2.92	1.37	1.22
1.I-35 SB (from 69 Hwy to I-435)	2.92	1.07	1.11
2.I-35 NB (from 69 Hwy to I-635)	5.13	1.25	1.22
2.I-35 SB (from I-635 to 69 Hwy)	5.13	1.20	1.78
3.I-35 NB (from I-635 to I-70) Kansas	4.60	1.00	1.00
3.I-35 SB (from I-70 to I-635) Kansas	4.60	1.00	1.44
3.I-35 NB (from I-635 to I-70) Missouri	2.00	1.00	1.11
3.I-35 SB (from I-70 to I-635) Missouri	2.00	1.00	1.01
3.I-35 NB (from I-635 to I-70) Downtown	0.80	1.00	1.46
3.I-35 SB (from I-70 to I-635) Downtown	0.80	1.00	1.01
4.I-35 NB (from I-70 to Parvin Rd)	4.62	1.04	1.09
4.I-35 SB (from Parvin Rd to I-70)	4.62	1.50	1.08
5.I-35 NB (from Parvin Rd to I-435)	4.82	No Detection as of January 2011	
5.I-35 SB (from I-435 to Parvin Rd)	4.82		
6.I-35 NB (from I-435 to 152 Hwy)	3.36	No Detection as of January 2011	
6.I-35 SB (from 152 Hwy to I-435)	3.36		
7.I-70 EB (from I-35 to I-435)	5.80	1.05	1.56
7.I-70 WB (from I-435 to I-35)	5.80	1.07	1.04
7.I-70 EB (from I-35 to I-435) Downtown	1.70	1.04	1.35
7.I-70 WB (from I-435 to I-35) Downtown	1.70	1.00	1.25
8.I-70 EB (from I-435 to I-470)	6.91	1.01	1.21
8.I-70 WB (from I-470 to I-435)	6.91	1.41	1.04
9.I-70 EB (from I-470 to MO 7)	5.34	1.03	1.11
9.I-70 WB (from MO 7 to I-470)	5.34	1.06	1.00
10.I-670 EB (from I-35 to I-70)	0.94	1.11	1.42
10.I-670 WB (from I-70 to I-35)	0.94	1.19	1.17
11.I-435 EB (from I-35 to State Line)	7.32	1.08	1.31
11.I-435 WB (from State Line to I-35)	7.32	1.06	1.30
12.I-435 EB (from State Line to 71 Hwy)	4.22	1.00	1.40
12.I-435 WB (from 71 Hwy to State Line)	4.22	1.15	1.00
13.I-435 NB (from 71 Hwy to 350 Hwy)	5.82	1.00	1.01
13.I-435 SB (from 350 Hwy to 71 Hwy)	5.82	1.01	1.00
14.I-435 NB (from 350 Hwy to I-70)	3.17	1.00	1.12
14.I-435 SB (from I-70 to 350 Hwy)	3.17	1.04	1.05
15.I-435 NB (from I-70 to the Missouri River)	6.36	No Detection as of January 2011	
15.I-435 SB (from the Missouri River to I-70)	6.36		
16.I-435 NB (from the Missouri River to I-35)	4.17	No Detection as of January 2011	
16.I-435 SB (from I-35 to the Missouri River)	4.17		
17.I-635 NB (from I-35 to I-70)	4.09	1.00	1.02
17.I-635 SB (from I-70 to I-35)	4.09	1.01	1.01
18.I-635 NB (from I-70 to the Missouri River)	4.26	1.00	1.04
18.I-635 SB (from the Missouri River to I-70)	4.26	1.06	1.07

CONGESTION INDEX REPORT

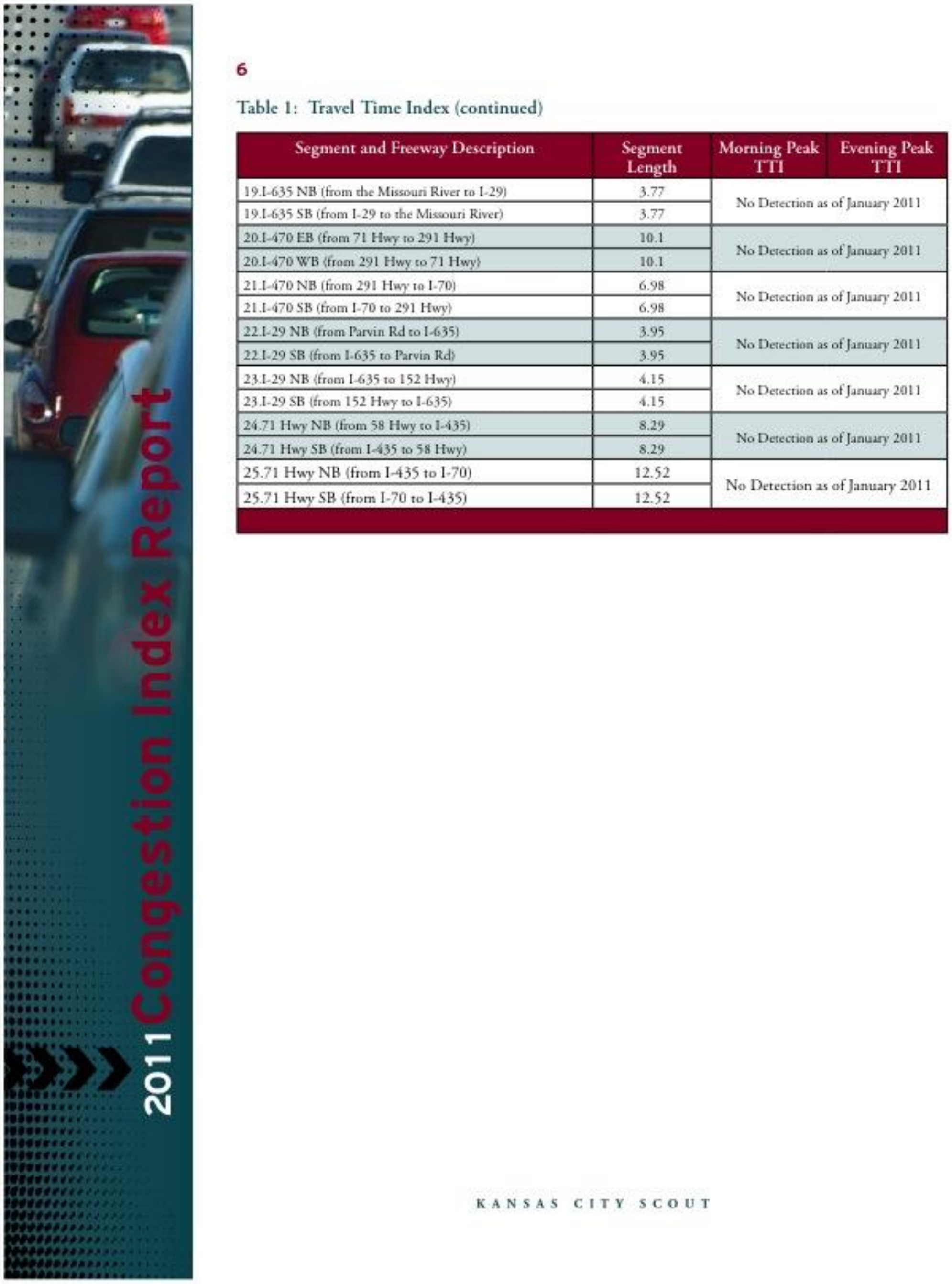

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Table 1: Travel Time Index (continued)

Segment and Freeway Description	Segment Length	Morning Peak TTI	Evening Peak TTI
19.I-635 NB (from the Missouri River to I-29)	3.77	No Detection as of January 2011	
19.I-635 SB (from I-29 to the Missouri River)	3.77		
20.I-470 EB (from 71 Hwy to 291 Hwy)	10.1	No Detection as of January 2011	
20.I-470 WB (from 291 Hwy to 71 Hwy)	10.1		
21.I-470 NB (from 291 Hwy to I-70)	6.98	No Detection as of January 2011	
21.I-470 SB (from I-70 to 291 Hwy)	6.98		
22.I-29 NB (from Parvin Rd to I-635)	3.95	No Detection as of January 2011	
22.I-29 SB (from I-635 to Parvin Rd)	3.95		
23.I-29 NB (from I-635 to 152 Hwy)	4.15	No Detection as of January 2011	
23.I-29 SB (from 152 Hwy to I-635)	4.15		
24.71 Hwy NB (from 58 Hwy to I-435)	8.29	No Detection as of January 2011	
24.71 Hwy SB (from I-435 to 58 Hwy)	8.29		
25.71 Hwy NB (from I-435 to I-70)	12.52	No Detection as of January 2011	
25.71 Hwy SB (from I-70 to I-435)	12.52		

KANSAS CITY SCOUT

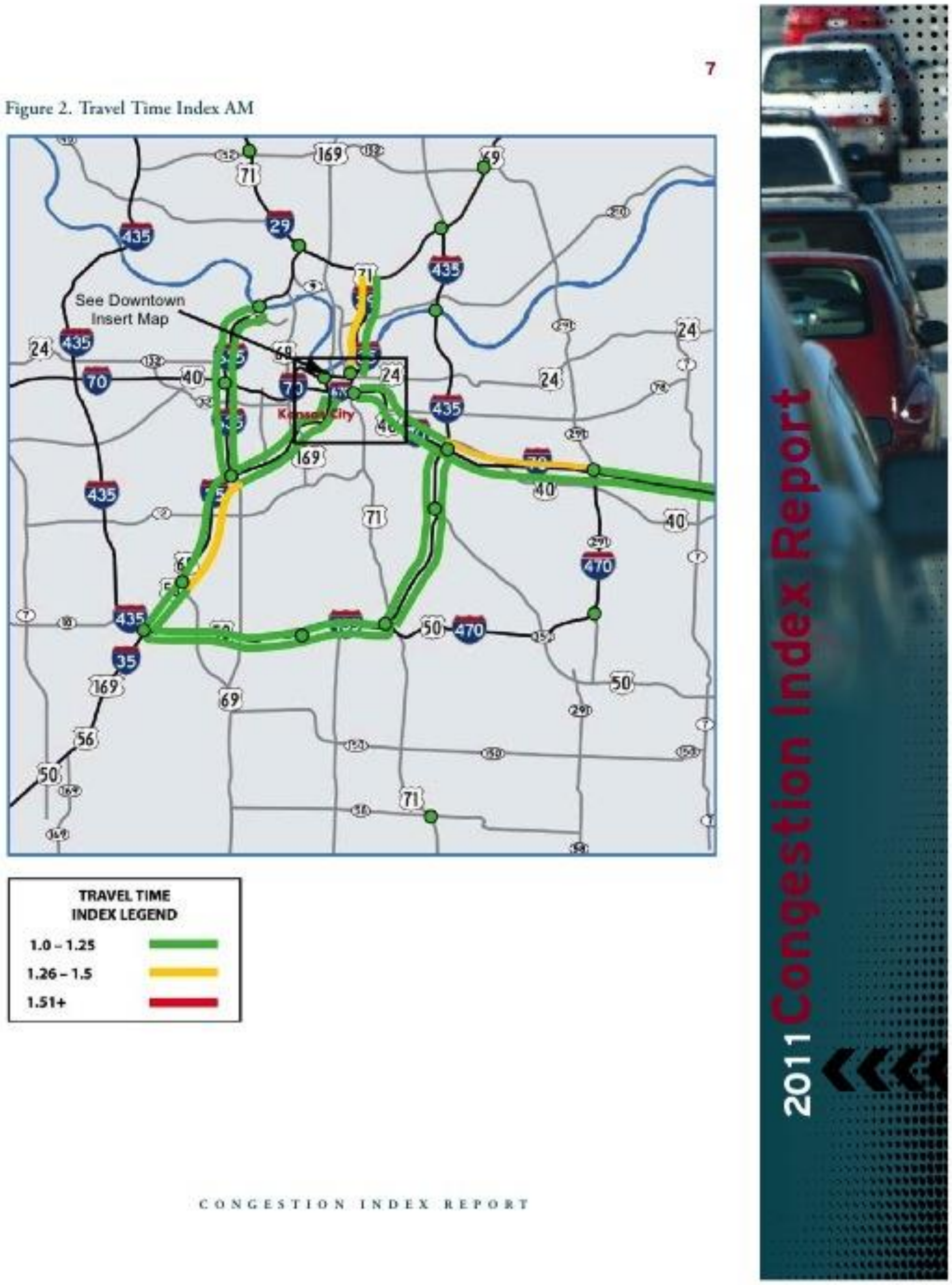

Figure 2. Travel Time Index AM

TRAVEL TIME INDEX LEGEND

1.0 – 1.25	🟩
1.26 – 1.5	🟨
1.51+	🟥

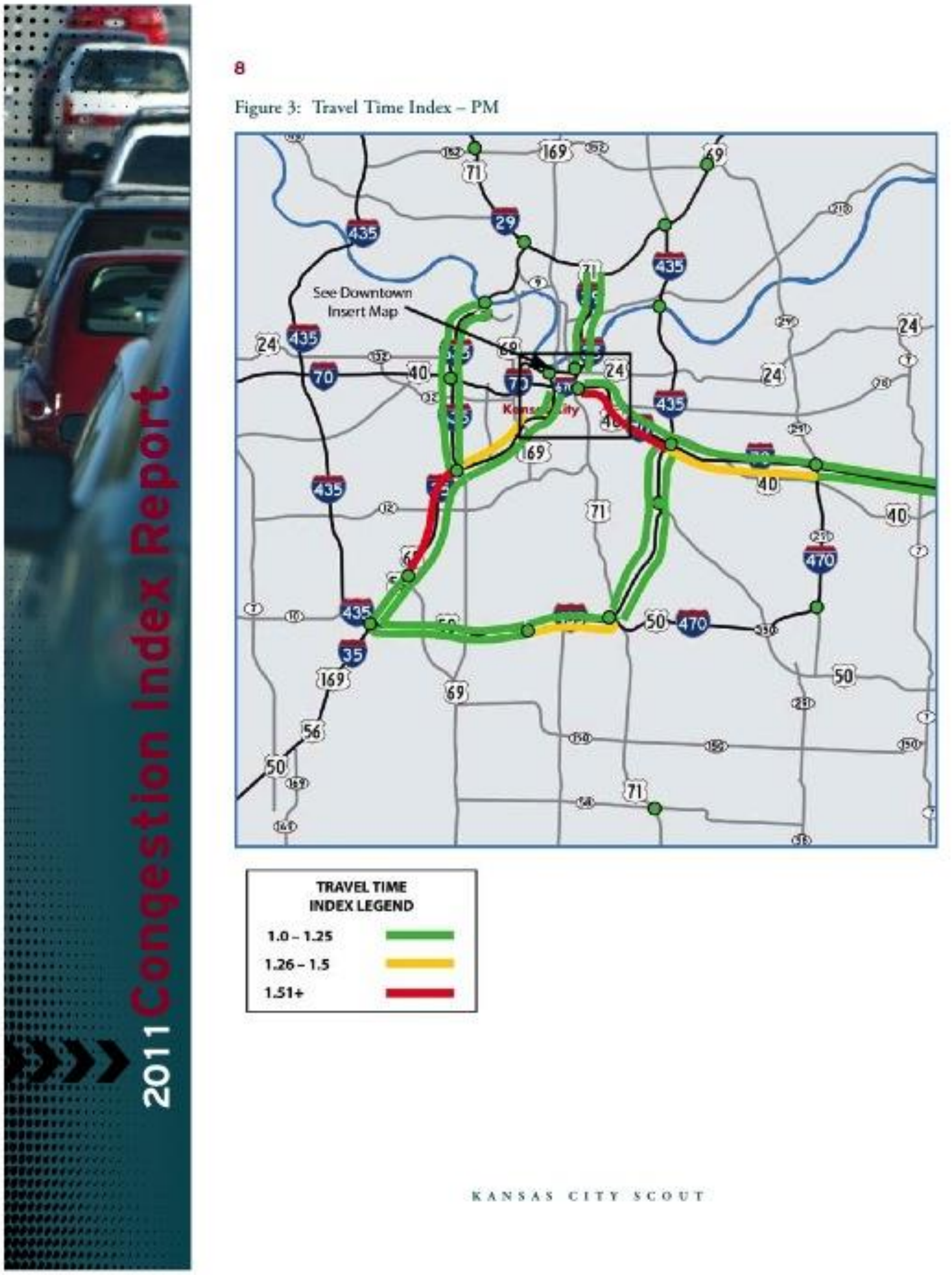

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Figure 3: Travel Time Index – PM

TRAVEL TIME INDEX LEGEND

1.0 – 1.25	🟩
1.26 – 1.5	🟨
1.51+	🟥

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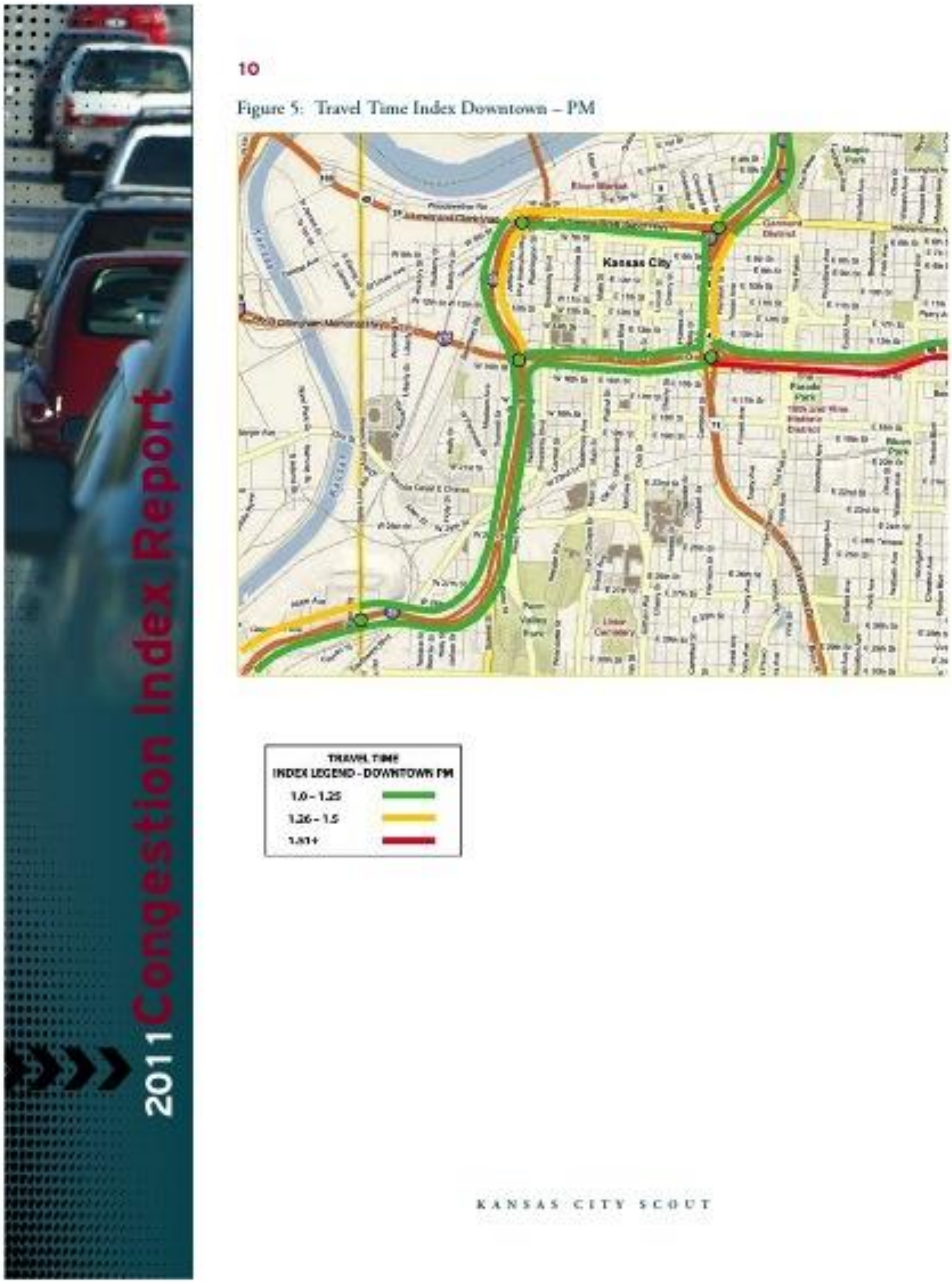
Figure 4: Travel Time Index Downtown – AM

TRAVEL TIME INDEX LEGEND - DOWNTOWN AM	
1.0 – 1.25	🟩
1.26 – 1.5	🟨
1.51+	🟥



10

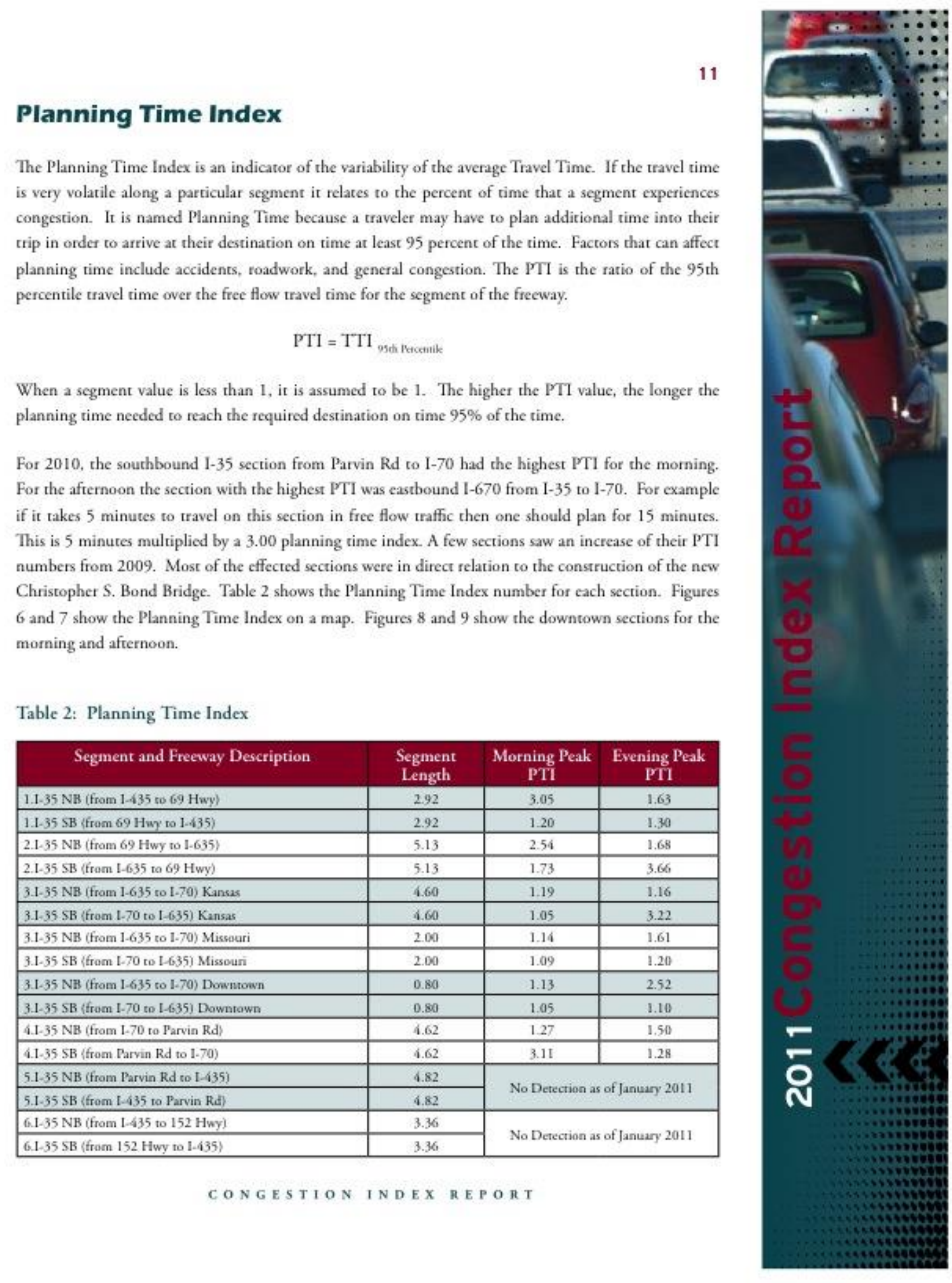
Figure 5: Travel Time Index Downtown – PM

TRAVEL TIME INDEX LEGEND - DOWNTOWN PM

1.0 – 1.25	🟩
1.26 – 1.5	🟨
1.51+	🟥

KANSAS CITY SCOUT

Figure L-2. Pages 11-16 (PTI)
(http://www.kcscout.net/downloads/Announcements/CongestionReport.pdf)



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Planning Time Index

The Planning Time Index is an indicator of the variability of the average Travel Time. If the travel time is very volatile along a particular segment it relates to the percent of time that a segment experiences congestion. It is named Planning Time because a traveler may have to plan additional time into their trip in order to arrive at their destination on time at least 95 percent of the time. Factors that can affect planning time include accidents, roadwork, and general congestion. The PTI is the ratio of the 95th percentile travel time over the free flow travel time for the segment of the freeway.

$$PTI = TTI_{\text{95th Percentile}}$$

When a segment value is less than 1, it is assumed to be 1. The higher the PTI value, the longer the planning time needed to reach the required destination on time 95% of the time.

For 2010, the southbound I-35 section from Parvin Rd to I-70 had the highest PTI for the morning. For the afternoon the section with the highest PTI was eastbound I-670 from I-35 to I-70. For example if it takes 5 minutes to travel on this section in free flow traffic then one should plan for 15 minutes. This is 5 minutes multiplied by a 3.00 planning time index. A few sections saw an increase of their PTI numbers from 2009. Most of the effected sections were in direct relation to the construction of the new Christopher S. Bond Bridge. Table 2 shows the Planning Time Index number for each section. Figures 6 and 7 show the Planning Time Index on a map. Figures 8 and 9 show the downtown sections for the morning and afternoon.

Table 2: Planning Time Index

Segment and Freeway Description	Segment Length	Morning Peak PTI	Evening Peak PTI
1.I-35 NB (from I-435 to 69 Hwy)	2.92	3.05	1.63
1.I-35 SB (from 69 Hwy to I-435)	2.92	1.20	1.30
2.I-35 NB (from 69 Hwy to I-635)	5.13	2.54	1.68
2.I-35 SB (from I-635 to 69 Hwy)	5.13	1.73	3.66
3.I-35 NB (from I-635 to I-70) Kansas	4.60	1.19	1.16
3.I-35 SB (from I-70 to I-635) Kansas	4.60	1.05	3.22
3.I-35 NB (from I-635 to I-70) Missouri	2.00	1.14	1.61
3.I-35 SB (from I-70 to I-635) Missouri	2.00	1.09	1.20
3.I-35 NB (from I-635 to I-70) Downtown	0.80	1.13	2.52
3.I-35 SB (from I-70 to I-635) Downtown	0.80	1.05	1.10
4.I-35 NB (from I-70 to Parvin Rd)	4.62	1.27	1.50
4.I-35 SB (from Parvin Rd to I-70)	4.62	3.11	1.28
5.I-35 NB (from Parvin Rd to I-435)	4.82	No Detection as of January 2011	
5.I-35 SB (from I-435 to Parvin Rd)	4.82		
6.I-35 NB (from I-435 to 152 Hwy)	3.36	No Detection as of January 2011	
6.I-35 SB (from 152 Hwy to I-435)	3.36		

CONGESTION INDEX REPORT

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Table 2: Planning Time Index (continued)

Segment and Freeway Description	Segment Length	Morning Peak PTI	Evening Peak PTI
7.I-70 EB (from I-35 to I-435)	5.80	1.32	3.29
7.I-70 WB (from I-435 to I-35)	5.80	1.43	1.39
7.I-70 EB (from I-35 to I-435) Downtown	1.70	1.64	2.13
7.I-70 WB (from I-435 to I-35) Downtown	1.70	2.14	3.82
8.I-70 EB (from I-435 to I-470)	6.91	1.10	2.19
8.I-70 WB (from I-470 to I-435)	6.91	2.61	1.13
9.I-70 EB (from I-470 to MO 7)	5.34	1.17	1.39
9.I-70 WB (from MO 7 to I-470)	5.34	1.45	1.05
10.I-670 EB (from I-35 to I-70)	0.94	1.42	3.82
10.I-670 WB (from I-70 to I-35)	0.94	1.43	1.40
11.I-435 EB (from I-35 to State Line)	7.32	1.38	2.63
11.I-435 WB (from State Line to I-35)	7.32	1.36	2.82
12.I-435 EB (from State Line to 71 Hwy)	4.22	1.08	2.38
12.I-435 WB (from 71 Hwy to State Line)	4.22	1.82	1.21
13.I-435 NB (from 71 Hwy to 350 Hwy)	5.82	1.10	1.12
13.I-435 SB (from 350 Hwy to 71 Hwy)	5.82	1.16	1.06
14.I-435 NB (from 350 Hwy to I-70)	3.17	1.07	1.84
14.I-435 SB (from I-70 to 350 Hwy)	3.17	1.12	1.13
15.I-435 NB (from I-70 to the Missouri River)	6.36	No Detection as of January 2011	
15.I-435 SB (from the Missouri River to I-70)	6.36		
16.I-435 NB (from the Missouri River to I-35)	4.17	No Detection as of January 2011	
16.I-435 SB (from I-35 to the Missouri River)	4.17		
17.I-635 NB (from I-35 to I-70)	4.09	1.12	1.16
17.I-635 SB (from I-70 to I-35)	4.09	1.19	1.17
18.I-635 NB (from I-70 to the Missouri River)	4.26	1.25	1.34
18.I-635 SB (from the Missouri River to I-70)	4.26	1.32	1.31
19.I-635 NB (from the Missouri River to I-29)	3.77	No Detection as of January 2011	
19.I-635 SB (from I-29 to the Missouri River)	3.77		
20.I-470 EB (from 71 Hwy to 291 Hwy)	10.1	No Detection as of January 2011	
20.I-470 WB (from 291 Hwy to 71 Hwy)	10.1		
21.I-470 NB (from 291 Hwy to I-70)	6.98	No Detection as of January 2011	
21.I-470 SB (from I-70 to 291 Hwy)	6.98		
22.I-29 NB (from Parvin Rd to I-635)	3.95	No Detection as of January 2011	
22.I-29 SB (from I-635 to Parvin Rd)	3.95		
23.I-29 NB (from I-635 to 152 Hwy)	4.15	No Detection as of January 2011	
23.I-29 SB (from 152 Hwy to I-635)	4.15		
24.71 Hwy NB (from 58 Hwy to I-435)	8.29	No Detection as of January 2011	
24.71 Hwy SB (from I-435 to 58 Hwy)	8.29		
25.71 Hwy NB (from I-435 to I-70)	12.52	No Detection as of January 2011	
25.71 Hwy SB (from I-70 to I-435)	12.52		

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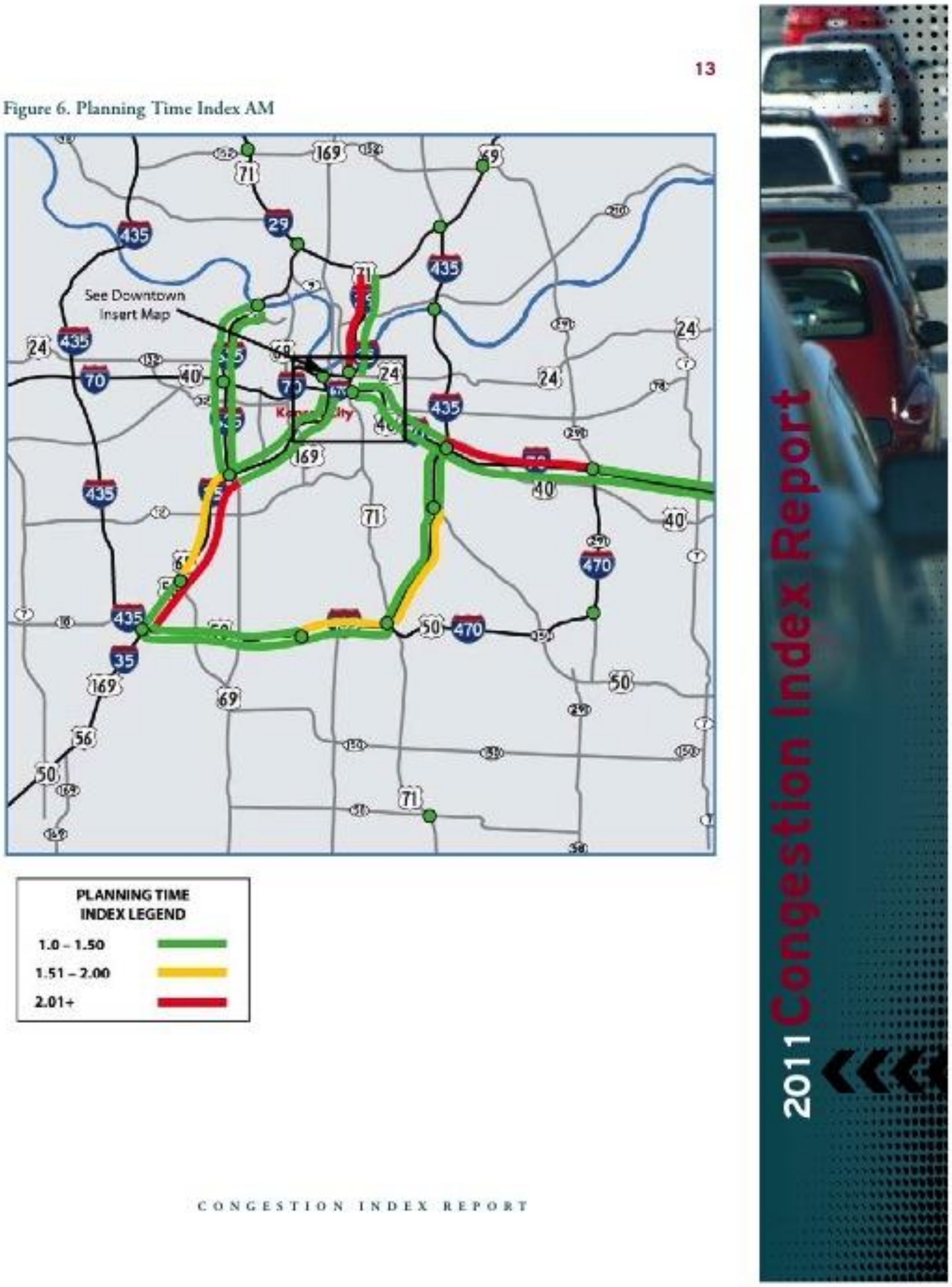

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Figure 6. Planning Time Index AM

PLANNING TIME INDEX LEGEND

1.0 – 1.50	🟩
1.51 – 2.00	🟨
2.01+	🟥

CONGESTION INDEX REPORT

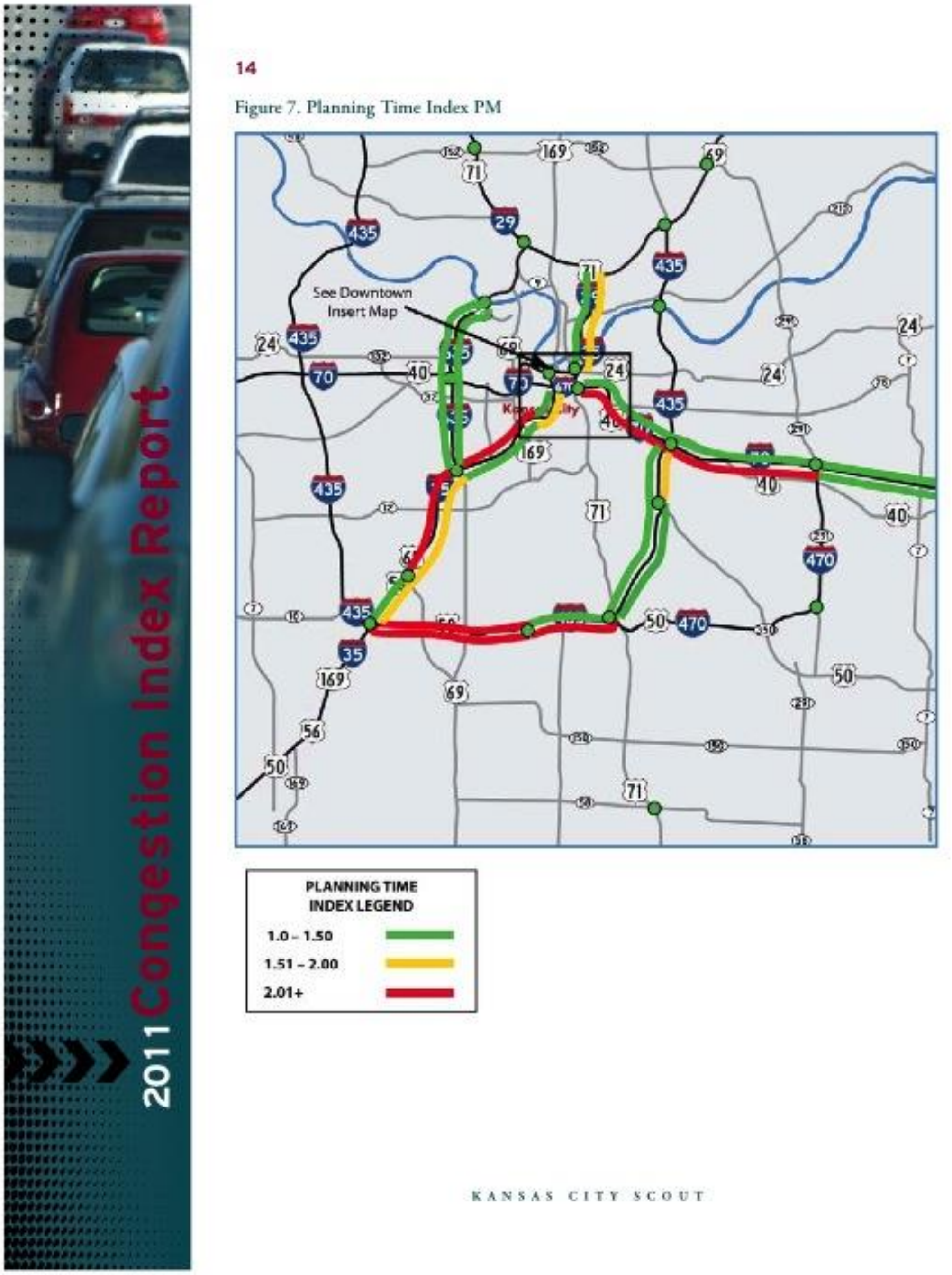

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Figure 7. Planning Time Index PM

PLANNING TIME INDEX LEGEND

1.0 – 1.50	🟩
1.51 – 2.00	🟨
2.01+	🟥

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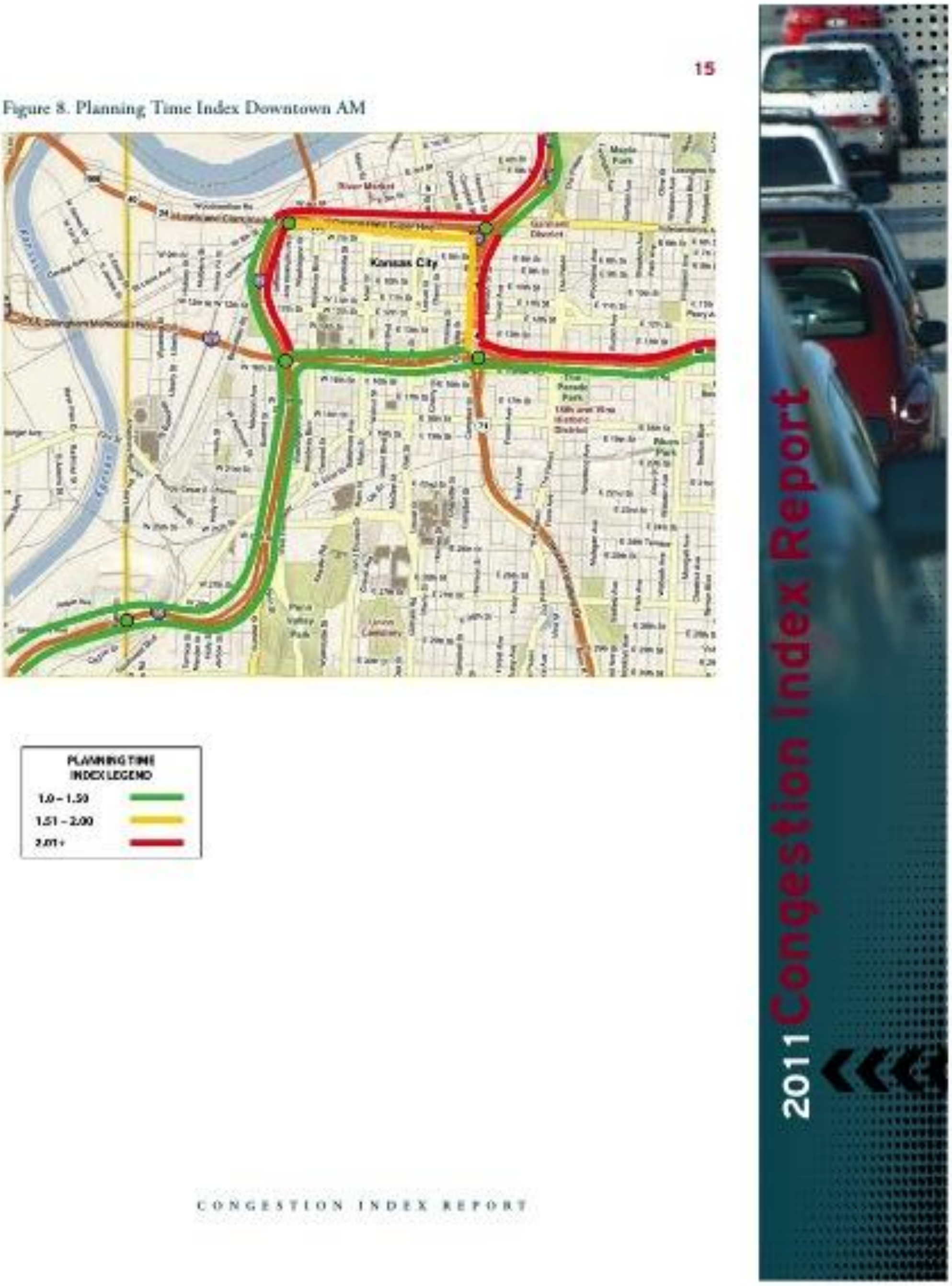

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Figure 8. Planning Time Index Downtown AM

PLANNING TIME INDEX LEGEND

1.0 – 1.50	🟩
1.51 – 2.00	🟨
2.01+	🟥

CONGESTION INDEX REPORT

2011 Congestion Index Report

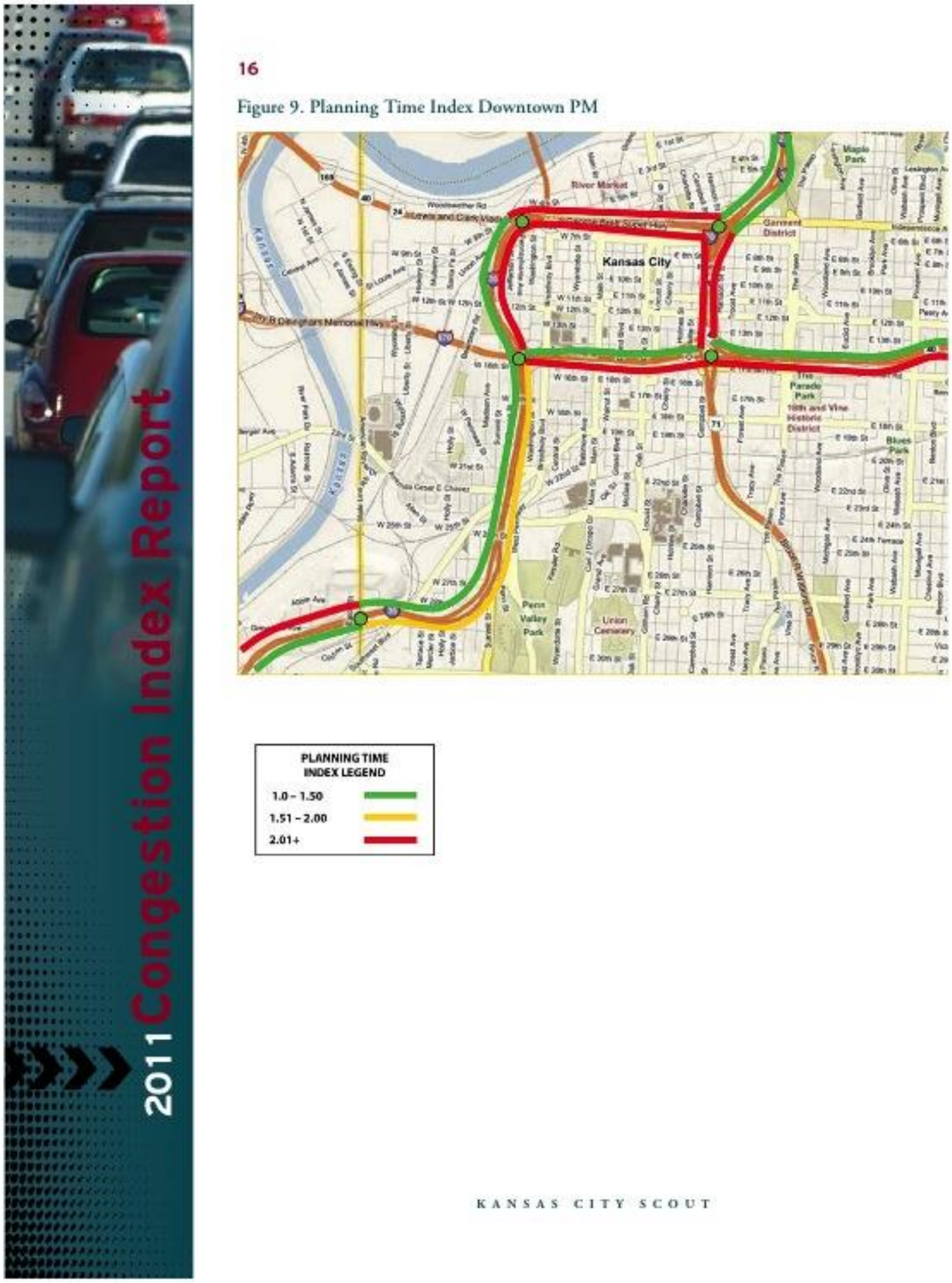

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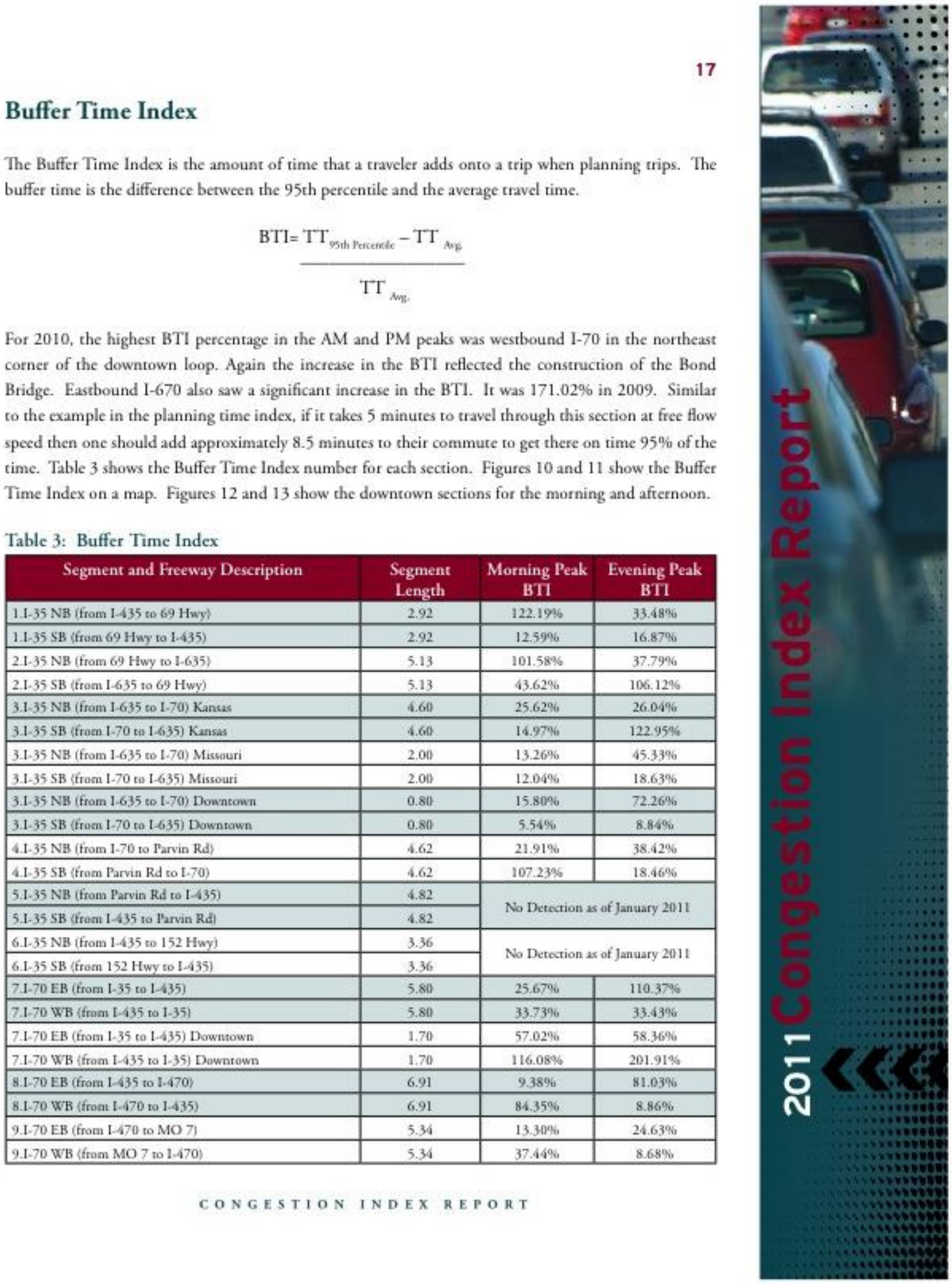
Figure 9. Planning Time Index Downtown PM

PLANNING TIME INDEX LEGEND

1.0 – 1.50	🟩
1.51 – 2.00	🟨
2.01+	🟥

KANSAS CITY SCOUT

Figure L-3. Pages 17-22 (BTI)
(http://www.kcscout.net/downloads/Announcements/CongestionReport.pdf)



Buffer Time Index

The Buffer Time Index is the amount of time that a traveler adds onto a trip when planning trips. The buffer time is the difference between the 95th percentile and the average travel time.

$$BTI = \frac{TT_{95th\ Percentile} - TT_{Avg.}}{TT_{Avg.}}$$

For 2010, the highest BTI percentage in the AM and PM peaks was westbound I-70 in the northeast corner of the downtown loop. Again the increase in the BTI reflected the construction of the Bond Bridge. Eastbound I-670 also saw a significant increase in the BTI. It was 171.02% in 2009. Similar to the example in the planning time index, if it takes 5 minutes to travel through this section at free flow speed then one should add approximately 8.5 minutes to their commute to get there on time 95% of the time. Table 3 shows the Buffer Time Index number for each section. Figures 10 and 11 show the Buffer Time Index on a map. Figures 12 and 13 show the downtown sections for the morning and afternoon.

Table 3: Buffer Time Index

Segment and Freeway Description	Segment Length	Morning Peak BTI	Evening Peak BTI
1.I-35 NB (from I-435 to 69 Hwy)	2.92	122.19%	33.48%
1.I-35 SB (from 69 Hwy to I-435)	2.92	12.59%	16.87%
2.I-35 NB (from 69 Hwy to I-635)	5.13	101.58%	37.79%
2.I-35 SB (from I-635 to 69 Hwy)	5.13	43.62%	106.12%
3.I-35 NB (from I-635 to I-70) Kansas	4.60	25.62%	26.04%
3.I-35 SB (from I-70 to I-635) Kansas	4.60	14.97%	122.95%
3.I-35 NB (from I-635 to I-70) Missouri	2.00	13.26%	45.33%
3.I-35 SB (from I-70 to I-635) Missouri	2.00	12.04%	18.63%
3.I-35 NB (from I-635 to I-70) Downtown	0.80	15.80%	72.26%
3.I-35 SB (from I-70 to I-635) Downtown	0.80	5.54%	8.84%
4.I-35 NB (from I-70 to Parvin Rd)	4.62	21.91%	38.42%
4.I-35 SB (from Parvin Rd to I-70)	4.62	107.23%	18.46%
5.I-35 NB (from Parvin Rd to I-435)	4.82	No Detection as of January 2011	
5.I-35 SB (from I-435 to Parvin Rd)	4.82		
6.I-35 NB (from I-435 to 152 Hwy)	3.36	No Detection as of January 2011	
6.I-35 SB (from 152 Hwy to I-435)	3.36		
7.I-70 EB (from I-35 to I-435)	5.80	25.67%	110.37%
7.I-70 WB (from I-435 to I-35)	5.80	33.73%	33.43%
7.I-70 EB (from I-35 to I-435) Downtown	1.70	57.02%	58.36%
7.I-70 WB (from I-435 to I-35) Downtown	1.70	116.08%	201.91%
8.I-70 EB (from I-435 to I-470)	6.91	9.38%	81.03%
8.I-70 WB (from I-470 to I-435)	6.91	84.35%	8.86%
9.I-70 EB (from I-470 to MO 7)	5.34	13.30%	24.63%
9.I-70 WB (from MO 7 to I-470)	5.34	37.44%	8.68%

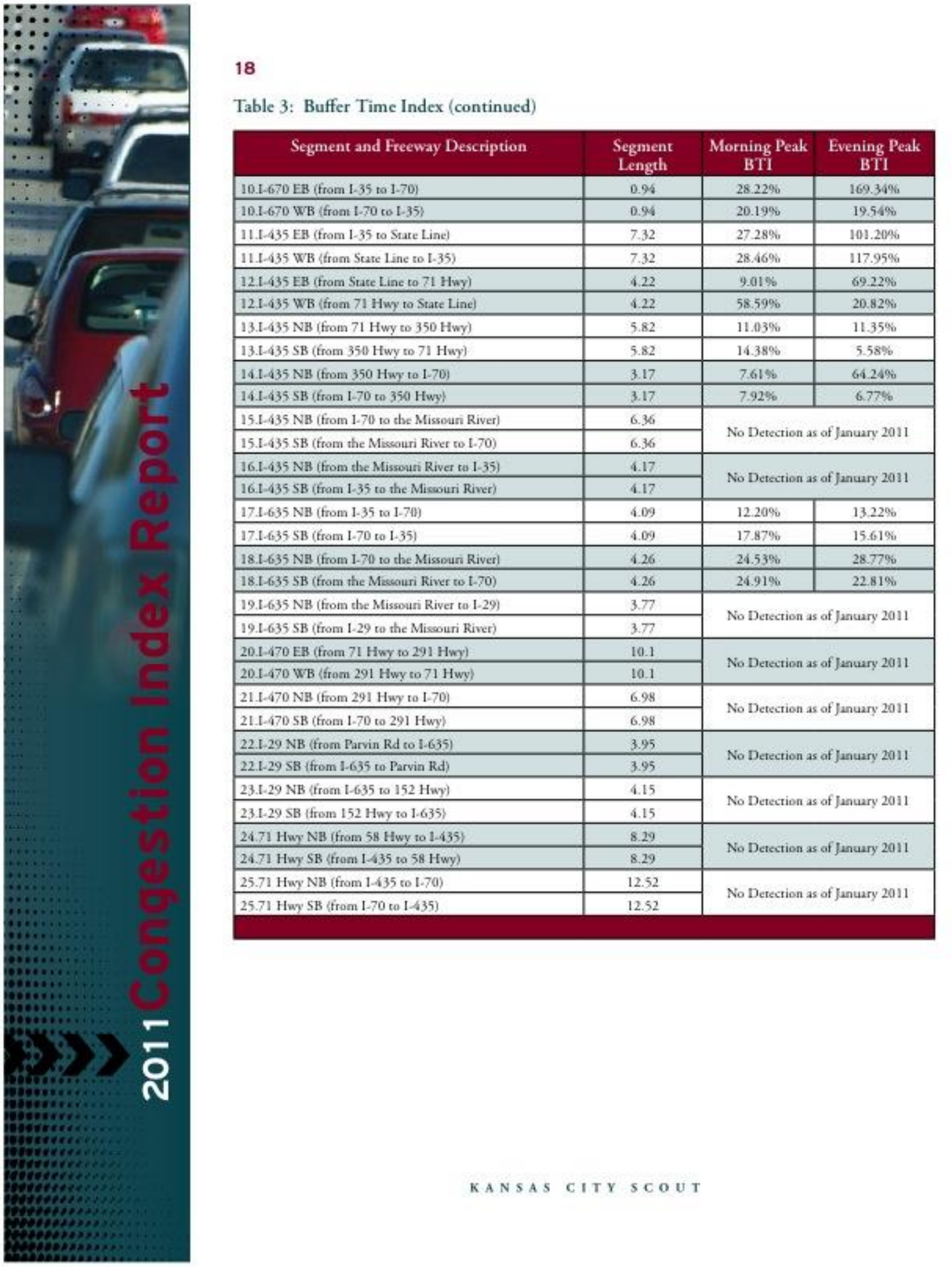


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Table 3: Buffer Time Index (continued)

Segment and Freeway Description	Segment Length	Morning Peak BTI	Evening Peak BTI
10.I-670 EB (from I-35 to I-70)	0.94	28.22%	169.34%
10.I-670 WB (from I-70 to I-35)	0.94	20.19%	19.54%
11.I-435 EB (from I-35 to State Line)	7.32	27.28%	101.20%
11.I-435 WB (from State Line to I-35)	7.32	28.46%	117.95%
12.I-435 EB (from State Line to 71 Hwy)	4.22	9.01%	69.22%
12.I-435 WB (from 71 Hwy to State Line)	4.22	58.59%	20.82%
13.I-435 NB (from 71 Hwy to 350 Hwy)	5.82	11.03%	11.35%
13.I-435 SB (from 350 Hwy to 71 Hwy)	5.82	14.38%	5.58%
14.I-435 NB (from 350 Hwy to I-70)	3.17	7.61%	64.24%
14.I-435 SB (from I-70 to 350 Hwy)	3.17	7.92%	6.77%
15.I-435 NB (from I-70 to the Missouri River)	6.36	No Detection as of January 2011	
15.I-435 SB (from the Missouri River to I-70)	6.36		
16.I-435 NB (from the Missouri River to I-35)	4.17	No Detection as of January 2011	
16.I-435 SB (from I-35 to the Missouri River)	4.17		
17.I-635 NB (from I-35 to I-70)	4.09	12.20%	13.22%
17.I-635 SB (from I-70 to I-35)	4.09	17.87%	15.61%
18.I-635 NB (from I-70 to the Missouri River)	4.26	24.53%	28.77%
18.I-635 SB (from the Missouri River to I-70)	4.26	24.91%	22.81%
19.I-635 NB (from the Missouri River to I-29)	3.77	No Detection as of January 2011	
19.I-635 SB (from I-29 to the Missouri River)	3.77		
20.I-470 EB (from 71 Hwy to 291 Hwy)	10.1	No Detection as of January 2011	
20.I-470 WB (from 291 Hwy to 71 Hwy)	10.1		
21.I-470 NB (from 291 Hwy to I-70)	6.98	No Detection as of January 2011	
21.I-470 SB (from I-70 to 291 Hwy)	6.98		
22.I-29 NB (from Parvin Rd to I-635)	3.95	No Detection as of January 2011	
22.I-29 SB (from I-635 to Parvin Rd)	3.95		
23.I-29 NB (from I-635 to 152 Hwy)	4.15	No Detection as of January 2011	
23.I-29 SB (from 152 Hwy to I-635)	4.15		
24.71 Hwy NB (from 58 Hwy to I-435)	8.29	No Detection as of January 2011	
24.71 Hwy SB (from I-435 to 58 Hwy)	8.29		
25.71 Hwy NB (from I-435 to I-70)	12.52	No Detection as of January 2011	
25.71 Hwy SB (from I-70 to I-435)	12.52		

KANSAS CITY SCOUT

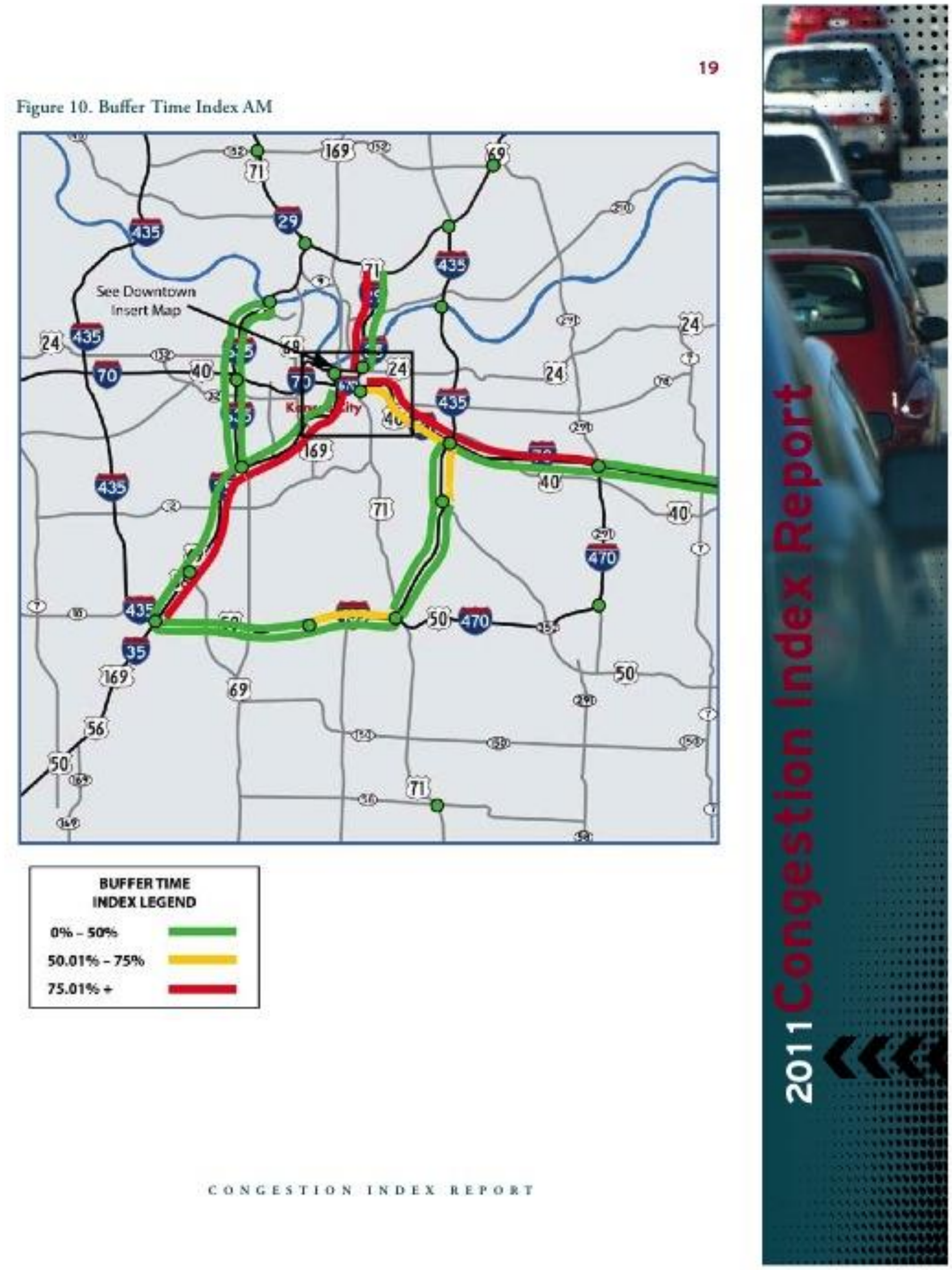

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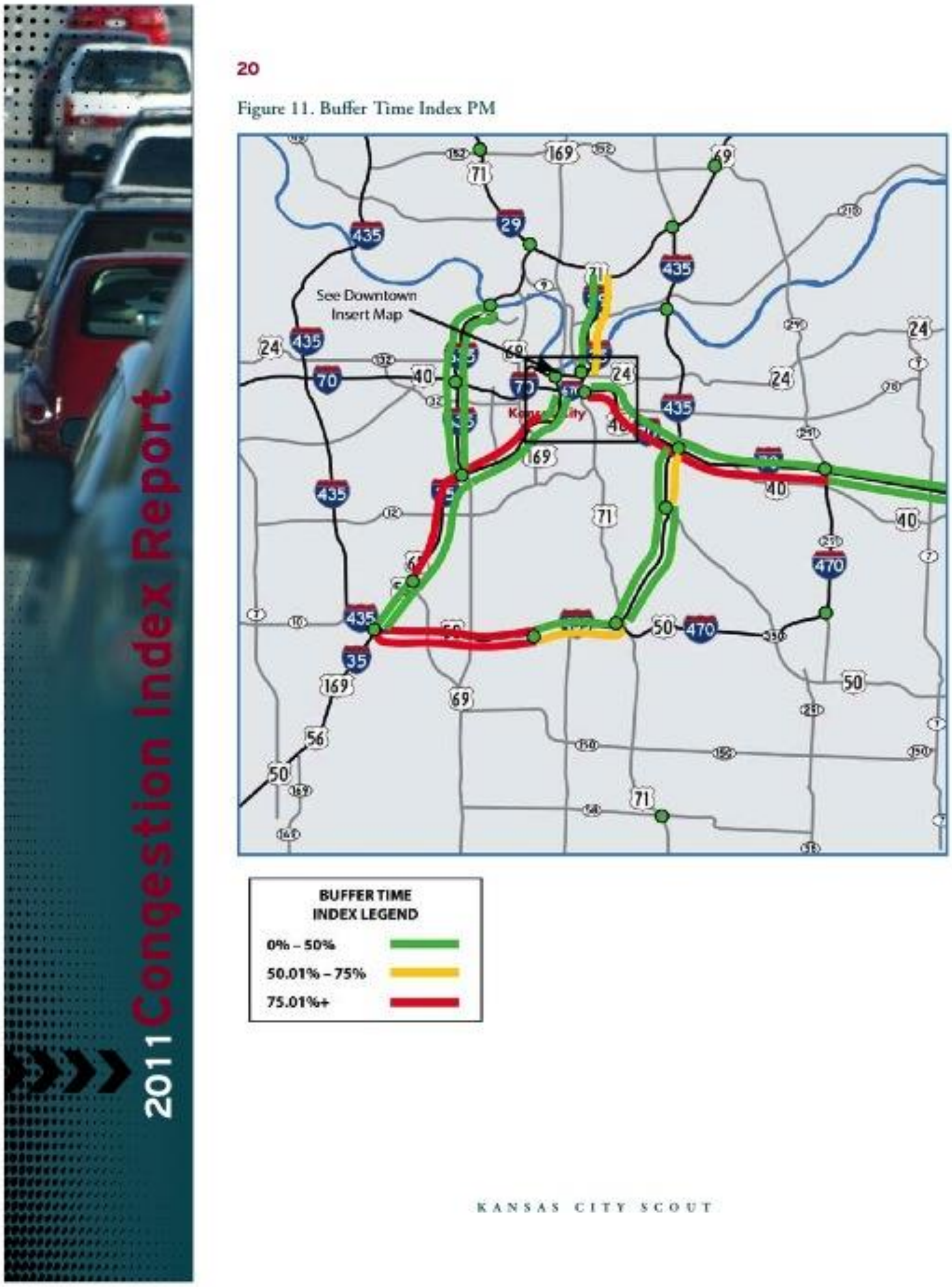
Figure 10. Buffer Time Index AM

BUFFER TIME INDEX LEGEND

0% – 50%	🟩
50.01% – 75%	🟨
75.01% +	🟥

CONGESTION INDEX REPORT



2011 Congestion Index Report

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Figure 11. Buffer Time Index PM

BUFFER TIME INDEX LEGEND

0% – 50%	🟩
50.01% – 75%	🟨
75.01%+	🟥

KANSAS CITY SCOUT

Figure 12. Buffer Time Index Downtown AM

BUFFER TIME INDEX LEGEND

0% – 50%	🟩
50.01% – 75%	🟨
75.01%+	🟥

Figure 13. Buffer Time Index Downtown PM

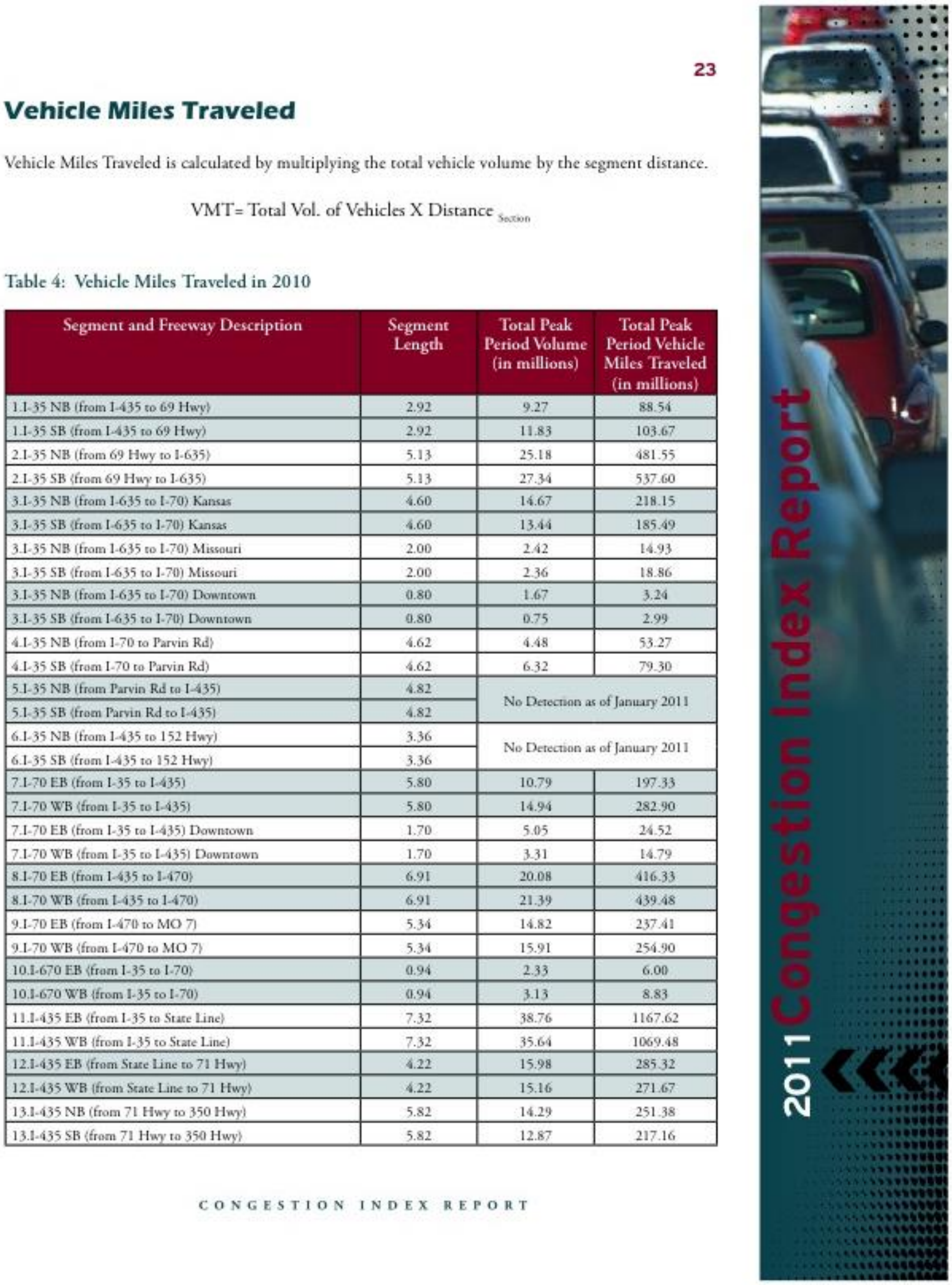
BUFFER TIME INDEX LEGEND

0% – 50%	🟩
50.01% – 75%	🟨
75.01%+	🟥

KANSAS CITY SCOUT

Appendix M. 2011 Kansas City Scout Congestion Index Report, pages 23-24

Figure M-1. Pages 23-24
(http://www.kcscout.net/downloads/Announcements/CongestionReport.pdf)



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Vehicle Miles Traveled

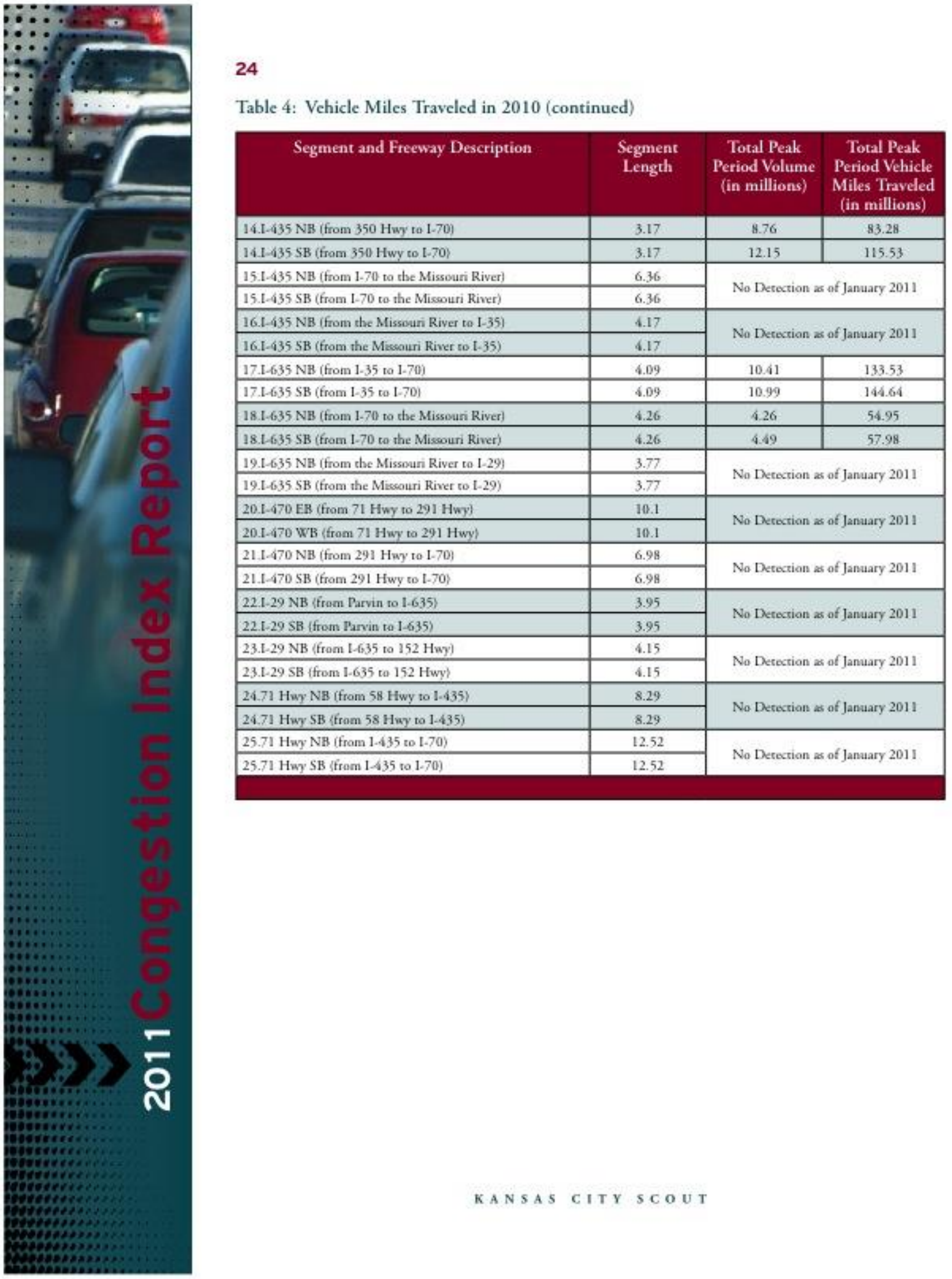
Vehicle Miles Traveled is calculated by multiplying the total vehicle volume by the segment distance.

$$\text{VMT= Total Vol. of Vehicles X Distance}_{\text{Section}}$$

Table 4: Vehicle Miles Traveled in 2010

Segment and Freeway Description	Segment Length	Total Peak Period Volume (in millions)	Total Peak Period Vehicle Miles Traveled (in millions)
1.I-35 NB (from I-435 to 69 Hwy)	2.92	9.27	88.54
1.I-35 SB (from I-435 to 69 Hwy)	2.92	11.83	103.67
2.I-35 NB (from 69 Hwy to I-635)	5.13	25.18	481.55
2.I-35 SB (from 69 Hwy to I-635)	5.13	27.34	537.60
3.I-35 NB (from I-635 to I-70) Kansas	4.60	14.67	218.15
3.I-35 SB (from I-635 to I-70) Kansas	4.60	13.44	185.49
3.I-35 NB (from I-635 to I-70) Missouri	2.00	2.42	14.93
3.I-35 SB (from I-635 to I-70) Missouri	2.00	2.36	18.86
3.I-35 NB (from I-635 to I-70) Downtown	0.80	1.67	3.24
3.I-35 SB (from I-635 to I-70) Downtown	0.80	0.75	2.99
4.I-35 NB (from I-70 to Parvin Rd)	4.62	4.48	53.27
4.I-35 SB (from I-70 to Parvin Rd)	4.62	6.32	79.30
5.I-35 NB (from Parvin Rd to I-435)	4.82	No Detection as of January 2011	
5.I-35 SB (from Parvin Rd to I-435)	4.82		
6.I-35 NB (from I-435 to 152 Hwy)	3.36	No Detection as of January 2011	
6.I-35 SB (from I-435 to 152 Hwy)	3.36		
7.I-70 EB (from I-35 to I-435)	5.80	10.79	197.33
7.I-70 WB (from I-35 to I-435)	5.80	14.94	282.90
7.I-70 EB (from I-35 to I-435) Downtown	1.70	5.05	24.52
7.I-70 WB (from I-35 to I-435) Downtown	1.70	3.31	14.79
8.I-70 EB (from I-435 to I-470)	6.91	20.08	416.33
8.I-70 WB (from I-435 to I-470)	6.91	21.39	439.48
9.I-70 EB (from I-470 to MO 7)	5.34	14.82	237.41
9.I-70 WB (from I-470 to MO 7)	5.34	15.91	254.90
10.I-670 EB (from I-35 to I-70)	0.94	2.33	6.00
10.I-670 WB (from I-35 to I-70)	0.94	3.13	8.83
11.I-435 EB (from I-35 to State Line)	7.32	38.76	1167.62
11.I-435 WB (from I-35 to State Line)	7.32	35.64	1069.48
12.I-435 EB (from State Line to 71 Hwy)	4.22	15.98	285.32
12.I-435 WB (from State Line to 71 Hwy)	4.22	15.16	271.67
13.I-435 NB (from 71 Hwy to 350 Hwy)	5.82	14.29	251.38
13.I-435 SB (from 71 Hwy to 350 Hwy)	5.82	12.87	217.16

CONGESTION INDEX REPORT



2011 Congestion Index Report

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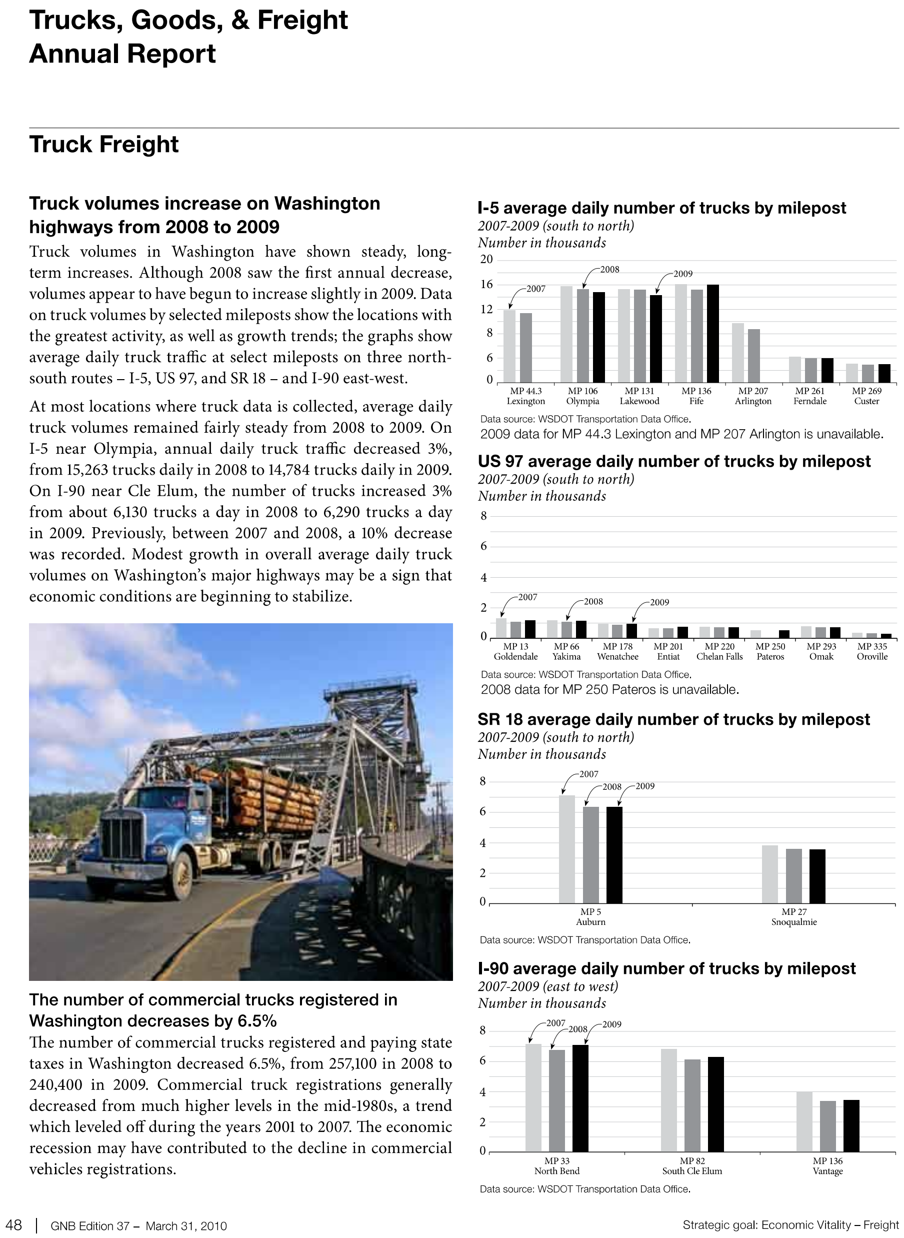
Table 4: Vehicle Miles Traveled in 2010 (continued)

Segment and Freeway Description	Segment Length	Total Peak Period Volume (in millions)	Total Peak Period Vehicle Miles Traveled (in millions)
14.I-435 NB (from 350 Hwy to I-70)	3.17	8.76	83.28
14.I-435 SB (from 350 Hwy to I-70)	3.17	12.15	115.53
15.I-435 NB (from I-70 to the Missouri River)	6.36	No Detection as of January 2011	
15.I-435 SB (from I-70 to the Missouri River)	6.36		
16.I-435 NB (from the Missouri River to I-35)	4.17	No Detection as of January 2011	
16.I-435 SB (from the Missouri River to I-35)	4.17		
17.I-635 NB (from I-35 to I-70)	4.09	10.41	133.53
17.I-635 SB (from I-35 to I-70)	4.09	10.99	144.64
18.I-635 NB (from I-70 to the Missouri River)	4.26	4.26	54.95
18.I-635 SB (from I-70 to the Missouri River)	4.26	4.49	57.98
19.I-635 NB (from the Missouri River to I-29)	3.77	No Detection as of January 2011	
19.I-635 SB (from the Missouri River to I-29)	3.77		
20.I-470 EB (from 71 Hwy to 291 Hwy)	10.1	No Detection as of January 2011	
20.I-470 WB (from 71 Hwy to 291 Hwy)	10.1		
21.I-470 NB (from 291 Hwy to I-70)	6.98	No Detection as of January 2011	
21.I-470 SB (from 291 Hwy to I-70)	6.98		
22.I-29 NB (from Parvin to I-635)	3.95	No Detection as of January 2011	
22.I-29 SB (from Parvin to I-635)	3.95		
23.I-29 NB (from I-635 to 152 Hwy)	4.15	No Detection as of January 2011	
23.I-29 SB (from I-635 to 152 Hwy)	4.15		
24.71 Hwy NB (from 58 Hwy to I-435)	8.29	No Detection as of January 2011	
24.71 Hwy SB (from 58 Hwy to I-435)	8.29		
25.71 Hwy NB (from I-435 to I-70)	12.52	No Detection as of January 2011	
25.71 Hwy SB (from I-435 to I-70)	12.52		

KANSAS CITY SCOUT

Appendix N. Washington State Department of Transportation 2010 Gray Notebook: Trucks, Goods, and Freight Annual Report, page 48

Figure N-1. (http://www.wsdot.wa.gov/NR/rdonlyres/BD26D6F0-B554-497C-9D0E-35C546BF179F/0/GrayNotebookMar10.pdf)



Trucks, Goods, & Freight Annual Report

Truck Freight

Truck volumes increase on Washington highways from 2008 to 2009

Truck volumes in Washington have shown steady, long-term increases. Although 2008 saw the first annual decrease, volumes appear to have begun to increase slightly in 2009. Data on truck volumes by selected mileposts show the locations with the greatest activity, as well as growth trends; the graphs show average daily truck traffic at select mileposts on three north-south routes – I-5, US 97, and SR 18 – and I-90 east-west.

At most locations where truck data is collected, average daily truck volumes remained fairly steady from 2008 to 2009. On I-5 near Olympia, annual daily truck traffic decreased 3%, from 15,263 trucks daily in 2008 to 14,784 trucks daily in 2009. On I-90 near Cle Elum, the number of trucks increased 3% from about 6,130 trucks a day in 2008 to 6,290 trucks a day in 2009. Previously, between 2007 and 2008, a 10% decrease was recorded. Modest growth in overall average daily truck volumes on Washington's major highways may be a sign that economic conditions are beginning to stabilize.

The number of commercial trucks registered in Washington decreases by 6.5%

The number of commercial trucks registered and paying state taxes in Washington decreased 6.5%, from 257,100 in 2008 to 240,400 in 2009. Commercial truck registrations generally decreased from much higher levels in the mid-1980s, a trend which leveled off during the years 2001 to 2007. The economic recession may have contributed to the decline in commercial vehicles registrations.

I-5 average daily number of trucks by milepost
2007-2009 (south to north)
Number in thousands

Data source: WSDOT Transportation Data Office.
2009 data for MP 44.3 Lexington and MP 207 Arlington is unavailable.

US 97 average daily number of trucks by milepost
2007-2009 (south to north)
Number in thousands

Data source: WSDOT Transportation Data Office.
2008 data for MP 250 Pateros is unavailable.

SR 18 average daily number of trucks by milepost
2007-2009 (south to north)
Number in thousands

Data source: WSDOT Transportation Data Office.

I-90 average daily number of trucks by milepost
2007-2009 (east to west)
Number in thousands

Data source: WSDOT Transportation Data Office.

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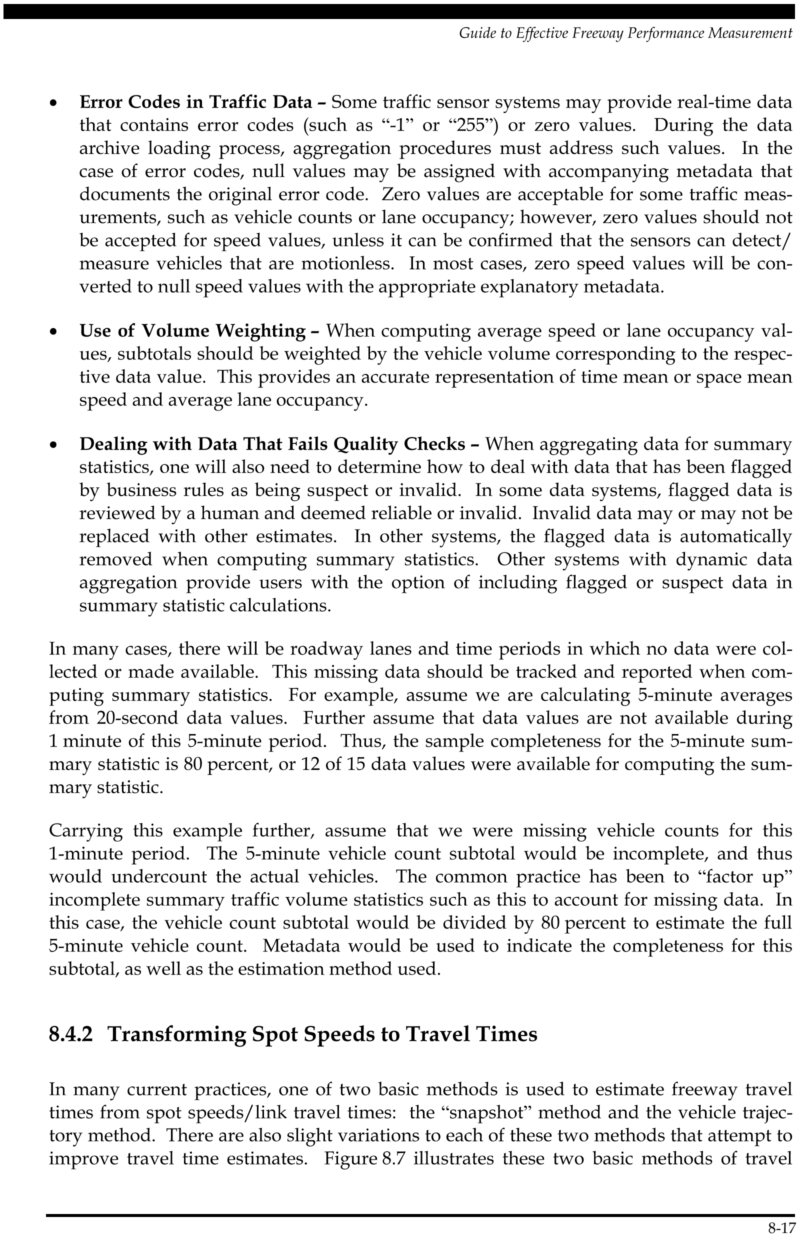
Strategic goal: Economic Vitality – Freight

Appendix O. Guide to Effective Freeway Performance Measurement: Final Report and Guidebook, section 8.4.2

Figure O-1. Section 8.4.2 (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w97.pdf)



Guide to Effective Freeway Performance Measurement

- **Error Codes in Traffic Data –** Some traffic sensor systems may provide real-time data that contains error codes (such as “-1” or “255”) or zero values. During the data archive loading process, aggregation procedures must address such values. In the case of error codes, null values may be assigned with accompanying metadata that documents the original error code. Zero values are acceptable for some traffic measurements, such as vehicle counts or lane occupancy; however, zero values should not be accepted for speed values, unless it can be confirmed that the sensors can detect/ measure vehicles that are motionless. In most cases, zero speed values will be converted to null speed values with the appropriate explanatory metadata.

- **Use of Volume Weighting –** When computing average speed or lane occupancy values, subtotals should be weighted by the vehicle volume corresponding to the respective data value. This provides an accurate representation of time mean or space mean speed and average lane occupancy.

- **Dealing with Data That Fails Quality Checks –** When aggregating data for summary statistics, one will also need to determine how to deal with data that has been flagged by business rules as being suspect or invalid. In some data systems, flagged data is reviewed by a human and deemed reliable or invalid. Invalid data may or may not be replaced with other estimates. In other systems, the flagged data is automatically removed when computing summary statistics. Other systems with dynamic data aggregation provide users with the option of including flagged or suspect data in summary statistic calculations.

In many cases, there will be roadway lanes and time periods in which no data were collected or made available. This missing data should be tracked and reported when computing summary statistics. For example, assume we are calculating 5-minute averages from 20-second data values. Further assume that data values are not available during 1 minute of this 5-minute period. Thus, the sample completeness for the 5-minute summary statistic is 80 percent, or 12 of 15 data values were available for computing the summary statistic.

Carrying this example further, assume that we were missing vehicle counts for this 1-minute period. The 5-minute vehicle count subtotal would be incomplete, and thus would undercount the actual vehicles. The common practice has been to “factor up” incomplete summary traffic volume statistics such as this to account for missing data. In this case, the vehicle count subtotal would be divided by 80 percent to estimate the full 5-minute vehicle count. Metadata would be used to indicate the completeness for this subtotal, as well as the estimation method used.

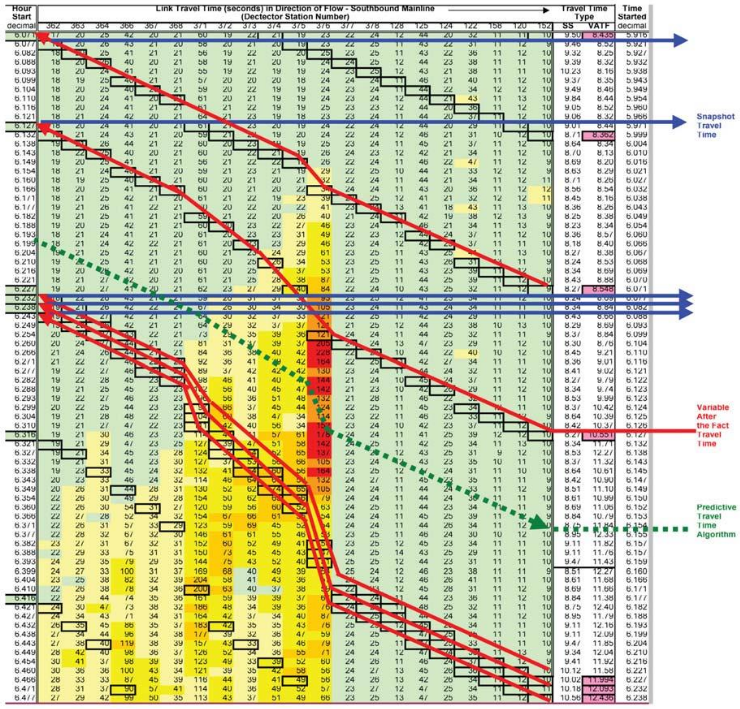
8.4.2 Transforming Spot Speeds to Travel Times

In many current practices, one of two basic methods is used to estimate freeway travel times from spot speeds/link travel times: the “snapshot” method and the vehicle trajectory method. There are also slight variations to each of these two methods that attempt to improve travel time estimates. Figure 8.7 illustrates these two basic methods of travel

8-17

time estimation: the blue arrows represent a snapshot travel time; whereas, the red arrows represent a travel time based on vehicle trajectory.

Figure 8.7 The Snapshot and Vehicle Trajectory Methods of Estimating Travel Times from Spot Speeds



Source: Travel Time Estimates, Displays, and Forecasts: Final Report.[11]

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[11] Oz Engineering and Motion Maps, *Travel Time Estimates, Displays, and Forecasts: Final Report*, Technical Report No. 2, prepared for Maricopa County DOT and Arizona DOT, December 2004.

The snapshot method sums all link travel times for the same time period, regardless of whether vehicles traversing the freeway section will actually be in that link during the snapshot time period. This method (or a derivation of this method) is often used in real-time systems, in which the computer system simply adds all link travel times between a defined origin and destination. In real-time, one cannot directly measure what the link travel time will be when vehicles reach the destination link. Therefore, the snapshot method assumes that the link travel times are constant for the entire duration of the vehicle trip. For example, simply sum all travel times for the time period from 7:00 to 7:05 a.m. and that provides a section travel time for that time period. Because of this assumption, the snapshot method underestimates section travel time when traffic is building (travel times get longer as the vehicle traverses the section) and overestimates section travel time when traffic is clearing (travel times get shorter as the vehicle traverses the section). Some real-time systems apply correction factors or use estimation techniques that account for this error when traffic conditions are changing.

The vehicle trajectory method can only be used after the fact, which is acceptable for performance monitoring purposes. The vehicle trajectory method "traces" the vehicle trip in time and applies the link travel time corresponding to the precise time in which a vehicle is expected to traverse the link. For example, a section travel time that begins at 7:00 a.m. will use a link travel time for 7:00 to 7:05 at the trip origin, but could use a link travel time from 7:05 to 7:10, or 7:10 to 7:15 at the trip destination. The vehicle trajectory method attempts to more closely model the actual link travel times experienced by motorists as they traverse the freeway system.

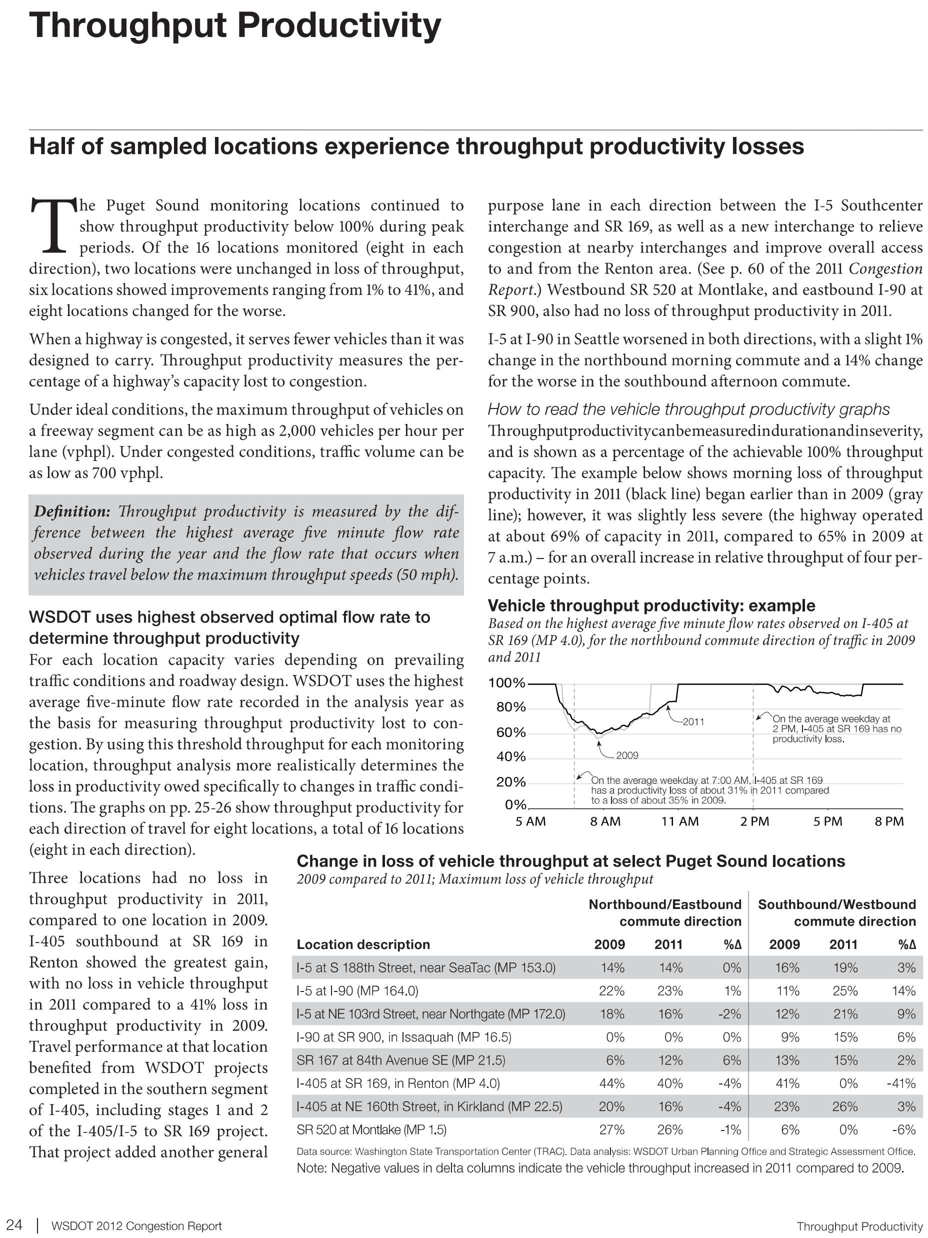
8.4.3 Accuracy of Spot Speed Transformations

Error in freeway travel time estimates can be introduced by several factors. Sensor location affects the travel time error, in that sensors may be installed in areas of free-flow (downstream of a bottleneck) and, thus, speeds measured at a single point may not be representative of speeds along the full length of the link. Sensor spacing also affects travel time error for a similar reason. With widely distributed sensor spacing, a single location may not adequately represent the full length of the link. Long section lengths could also introduce greater error with the snapshot method than with the vehicle trajectory method. As mentioned, the timing will affect the snapshot method (is traffic building or clearing?). As always, missing data due to hardware failures or communications problems will also introduce error into the travel time estimates.

In several areas, field tests using actual probe vehicles have been used to determine whether this travel time error falls within acceptable limits for the given sensor system and travel time estimation algorithm. In Phoenix, AZTech partners did some testing to develop a travel time algorithm that has been deployed recently by the Maricopa County DOT (see Figure 8.7). In Virginia, however, simulation runs and field tests indicated that the travel time error was significant and that additional post-processing, and calibration

Appendix P. Washington State Department of Transportation 2012 Annual Congestion Report, pages 24-26

Figure P-1. (http://wsdot.wa.gov/publications/fulltext/graynotebook/CR12.pdf)



Throughput Productivity

Half of sampled locations experience throughput productivity losses

The Puget Sound monitoring locations continued to show throughput productivity below 100% during peak periods. Of the 16 locations monitored (eight in each direction), two locations were unchanged in loss of throughput, six locations showed improvements ranging from 1% to 41%, and eight locations changed for the worse.

When a highway is congested, it serves fewer vehicles than it was designed to carry. Throughput productivity measures the percentage of a highway's capacity lost to congestion.

Under ideal conditions, the maximum throughput of vehicles on a freeway segment can be as high as 2,000 vehicles per hour per lane (vphpl). Under congested conditions, traffic volume can be as low as 700 vphpl.

Definition: *Throughput productivity is measured by the difference between the highest average five minute flow rate observed during the year and the flow rate that occurs when vehicles travel below the maximum throughput speeds (50 mph).*

WSDOT uses highest observed optimal flow rate to determine throughput productivity

For each location capacity varies depending on prevailing traffic conditions and roadway design. WSDOT uses the highest average five-minute flow rate recorded in the analysis year as the basis for measuring throughput productivity lost to congestion. By using this threshold throughput for each monitoring location, throughput analysis more realistically determines the loss in productivity owed specifically to changes in traffic conditions. The graphs on pp. 25-26 show throughput productivity for each direction of travel for eight locations, a total of 16 locations (eight in each direction).

Three locations had no loss in throughput productivity in 2011, compared to one location in 2009. I-405 southbound at SR 169 in Renton showed the greatest gain, with no loss in vehicle throughput in 2011 compared to a 41% loss in throughput productivity in 2009. Travel performance at that location benefited from WSDOT projects completed in the southern segment of I-405, including stages 1 and 2 of the I-405/I-5 to SR 169 project. That project added another general purpose lane in each direction between the I-5 Southcenter interchange and SR 169, as well as a new interchange to relieve congestion at nearby interchanges and improve overall access to and from the Renton area. (See p. 60 of the 2011 *Congestion Report*.) Westbound SR 520 at Montlake, and eastbound I-90 at SR 900, also had no loss of throughput productivity in 2011.

I-5 at I-90 in Seattle worsened in both directions, with a slight 1% change in the northbound morning commute and a 14% change for the worse in the southbound afternoon commute.

How to read the vehicle throughput productivity graphs

Throughput productivity can be measured in duration and in severity, and is shown as a percentage of the achievable 100% throughput capacity. The example below shows morning loss of throughput productivity in 2011 (black line) began earlier than in 2009 (gray line); however, it was slightly less severe (the highway operated at about 69% of capacity in 2011, compared to 65% in 2009 at 7 a.m.) – for an overall increase in relative throughput of four percentage points.

Vehicle throughput productivity: example

Based on the highest average five minute flow rates observed on I-405 at SR 169 (MP 4.0), for the northbound commute direction of traffic in 2009 and 2011

Change in loss of vehicle throughput at select Puget Sound locations

2009 compared to 2011; Maximum loss of vehicle throughput

	Northbound/Eastbound commute direction			Southbound/Westbound commute direction		
Location description	**2009**	**2011**	**%Δ**	**2009**	**2011**	**%Δ**
I-5 at S 188th Street, near SeaTac (MP 153.0)	14%	14%	0%	16%	19%	3%
I-5 at I-90 (MP 164.0)	22%	23%	1%	11%	25%	14%
I-5 at NE 103rd Street, near Northgate (MP 172.0)	18%	16%	-2%	12%	21%	9%
I-90 at SR 900, in Issaquah (MP 16.5)	0%	0%	0%	9%	15%	6%
SR 167 at 84th Avenue SE (MP 21.5)	6%	12%	6%	13%	15%	2%
I-405 at SR 169, in Renton (MP 4.0)	44%	40%	-4%	41%	0%	-41%
I-405 at NE 160th Street, in Kirkland (MP 22.5)	20%	16%	-4%	23%	26%	3%
SR 520 at Montlake (MP 1.5)	27%	26%	-1%	6%	0%	-6%

Data source: Washington State Transportation Center (TRAC). Data analysis: WSDOT Urban Planning Office and Strategic Assessment Office.

Note: Negative values in delta columns indicate the vehicle throughput increased in 2011 compared to 2009.

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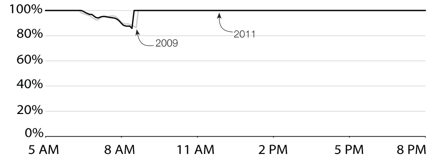
Throughput Productivity

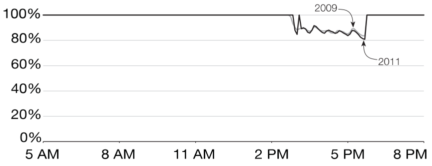
Measuring vehicle throughput productivity on Puget Sound area freeways

Throughput productivity at selected Puget Sound freeway locations by commute direction
Based on the highest observed five minute flow rates; 2009 and 2011; Vehicles per hour per lane (vphpl)

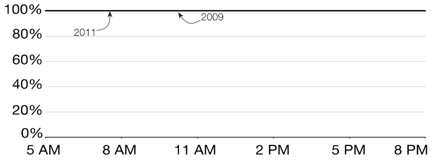
NB I-5 at S 188th Street (MP 153.0)
Based on highest observed five min. flow rate, northbound = 1,945 vphpl



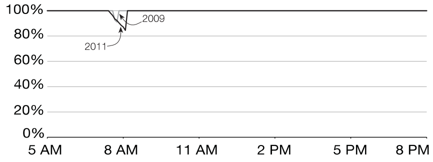
SB I-5 at S 188th Street (MP 153.0)
Based on highest observed five min. flow rate, southbound = 1,690 vphpl



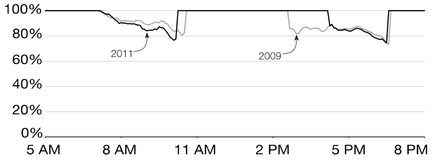
EB I-90 at SR 900 (MP 16.5)
Based on highest observed five min. flow rate, eastbound = 1,675 vphpl



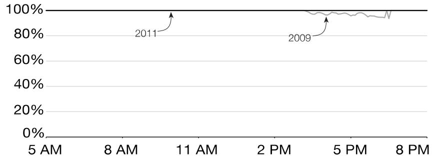
WB I-90 at SR 900 (MP 16.5)
Based on highest observed five min. flow rate, westbound = 1,630 vphpl



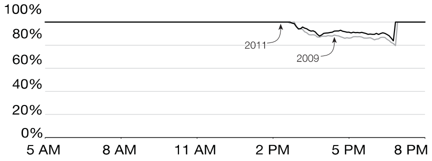
EB SR 520 at Montlake (MP 1.5)
Based on highest observed five min. flow rate, eastbound = 1,750 vphpl



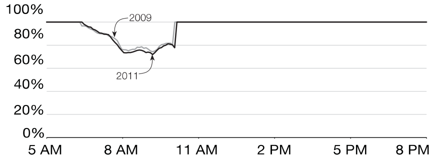
WB SR 520 at Montlake (MP 1.5)
Based on highest observed five min. flow rate, westbound = 1,705 vphpl



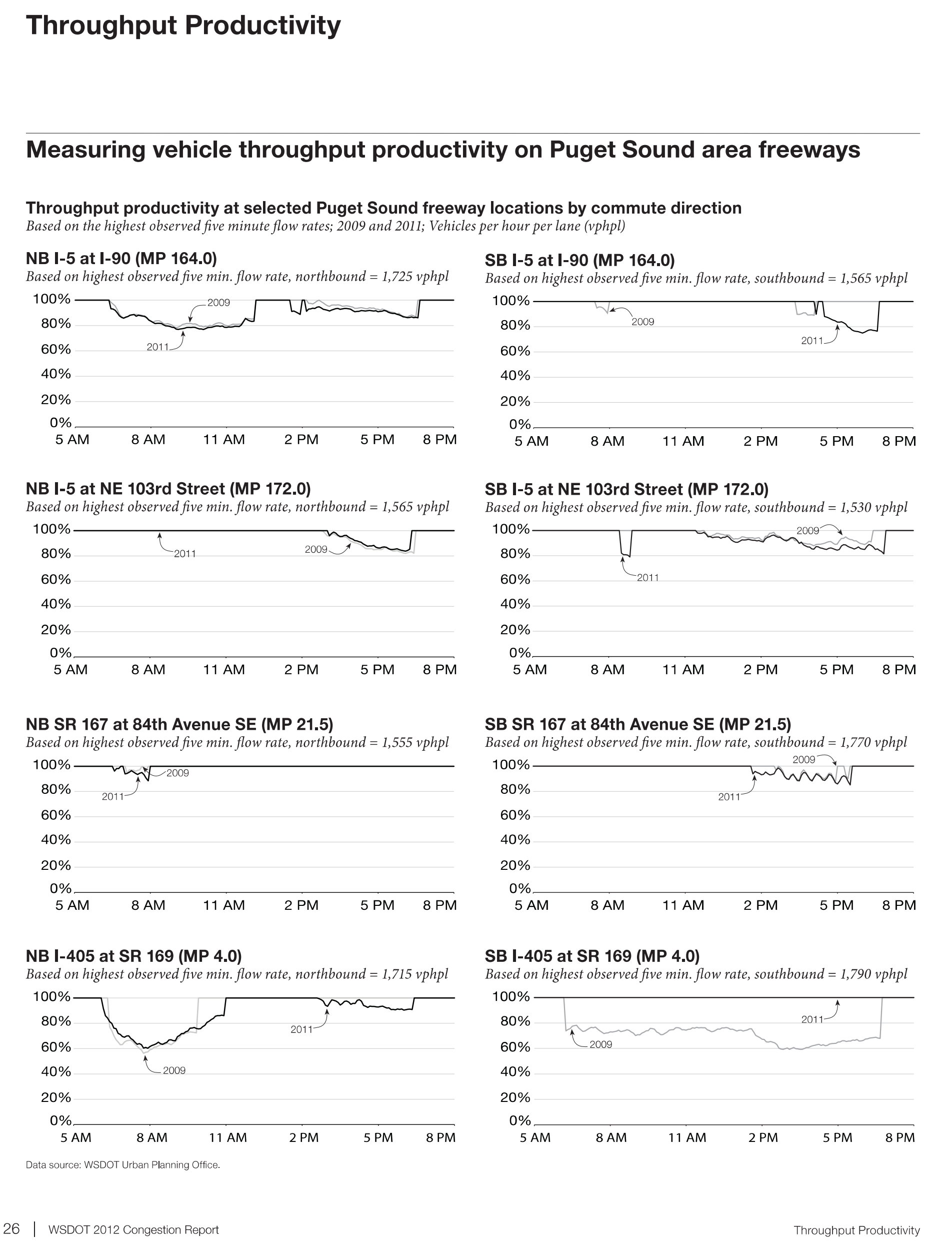
NB I-405 at NE 160th Street (MP 22.5)
Based on highest observed five min. flow rate, northbound = 1,725 vphpl



SB I-405 at NE 160th Street (MP 22.5)
Based on highest observed five min. flow rate, southbound = 1,750 vphpl



Data source: WSDOT Urban Planning Office.



Throughput Productivity

Measuring vehicle throughput productivity on Puget Sound area freeways

Throughput productivity at selected Puget Sound freeway locations by commute direction
Based on the highest observed five minute flow rates; 2009 and 2011; Vehicles per hour per lane (vphpl)

NB I-5 at I-90 (MP 164.0)
Based on highest observed five min. flow rate, northbound = 1,725 vphpl

SB I-5 at I-90 (MP 164.0)
Based on highest observed five min. flow rate, southbound = 1,565 vphpl

NB I-5 at NE 103rd Street (MP 172.0)
Based on highest observed five min. flow rate, northbound = 1,565 vphpl

SB I-5 at NE 103rd Street (MP 172.0)
Based on highest observed five min. flow rate, southbound = 1,530 vphpl

NB SR 167 at 84th Avenue SE (MP 21.5)
Based on highest observed five min. flow rate, northbound = 1,555 vphpl

SB SR 167 at 84th Avenue SE (MP 21.5)
Based on highest observed five min. flow rate, southbound = 1,770 vphpl

NB I-405 at SR 169 (MP 4.0)
Based on highest observed five min. flow rate, northbound = 1,715 vphpl

SB I-405 at SR 169 (MP 4.0)
Based on highest observed five min. flow rate, southbound = 1,790 vphpl

Data source: WSDOT Urban Planning Office.

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Throughput Productivity

Appendix Q. HOV User Survey: Washington State Freeway System, Title Page Only

Figure Q-1. (http://www.wsdot.wa.gov/NR/rdonlyres/A04D3925-B39C-4068-BFE3-D19E5CEEEEE8/0/HOVUserSurvey3rdEditionDec07.pdf)

HOV USER SURVEY

WASHINGTON STATE FREEWAY SYSTEM

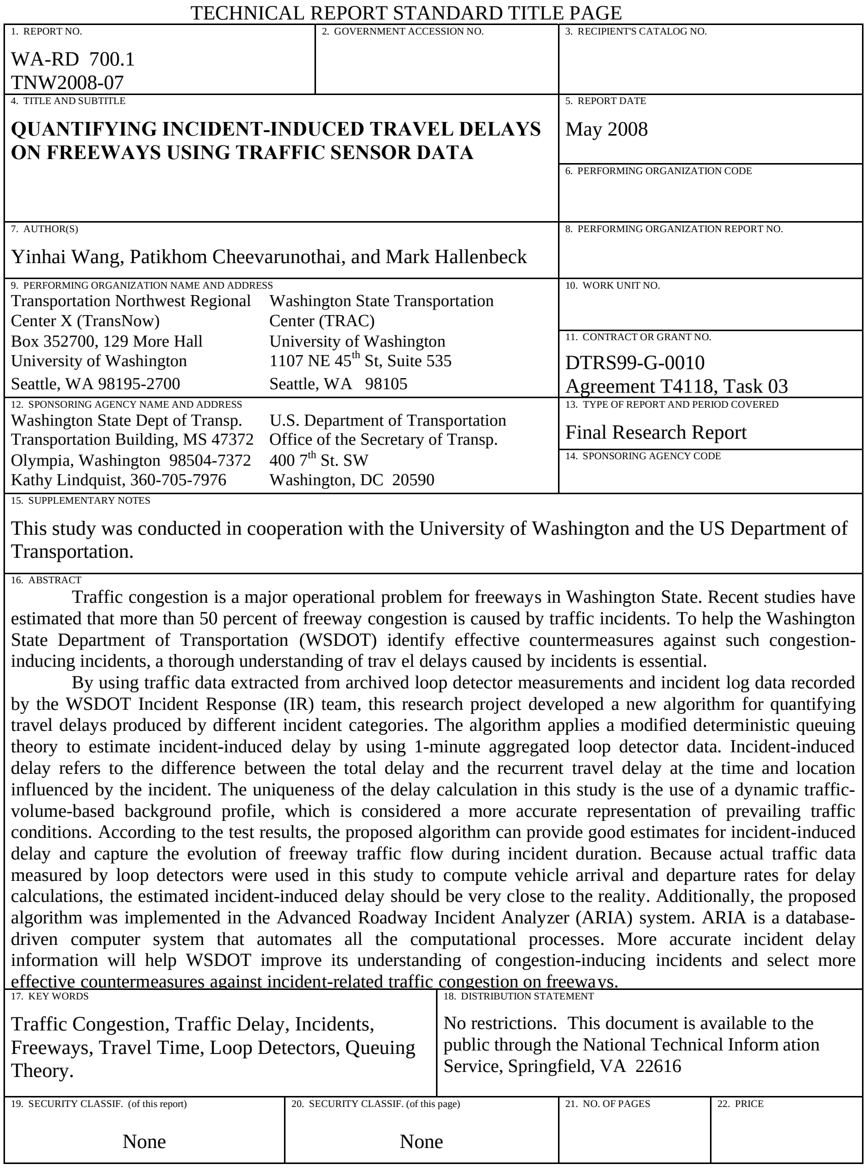
UPDATED: December 2007

Washington State
Department of Transportation

PRR
VISION + VOICE

Appendix R. Quantifying Incident-Included Travel Delays on Freeways Using Traffic Sensor Data, Phases 1 and 2, and Incident Response Evaluation, Phase 3 Technical Report Standard Title Pages Only

Figure R-1. Phase 1 Title Page (http://depts.washington.edu/trac/bulkdisk/pdf/700.1.pdf)



TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. WA-RD 700.1 TNW2008-07	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE **QUANTIFYING INCIDENT-INDUCED TRAVEL DELAYS ON FREEWAYS USING TRAFFIC SENSOR DATA**		5. REPORT DATE May 2008 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Yinhai Wang, Patikhom Cheevarunothai, and Mark Hallenbeck		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Transportation Northwest Regional Center X (TransNow) Box 352700, 129 More Hall University of Washington Seattle, WA 98195-2700	Washington State Transportation Center (TRAC) University of Washington 1107 NE 45th St, Suite 535 Seattle, WA 98105	10. WORK UNIT NO. 11. CONTRACT OR GRANT NO. DTRS99-G-0010 Agreement T4118, Task 03
12. SPONSORING AGENCY NAME AND ADDRESS Washington State Dept of Transp. Transportation Building, MS 47372 Olympia, Washington 98504-7372 Kathy Lindquist, 360-705-7976	U.S. Department of Transportation Office of the Secretary of Transp. 400 7th St. SW Washington, DC 20590	13. TYPE OF REPORT AND PERIOD COVERED Final Research Report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the University of Washington and the US Department of Transportation.

16. ABSTRACT

Traffic congestion is a major operational problem for freeways in Washington State. Recent studies have estimated that more than 50 percent of freeway congestion is caused by traffic incidents. To help the Washington State Department of Transportation (WSDOT) identify effective countermeasures against such congestion-inducing incidents, a thorough understanding of travel delays caused by incidents is essential.

By using traffic data extracted from archived loop detector measurements and incident log data recorded by the WSDOT Incident Response (IR) team, this research project developed a new algorithm for quantifying travel delays produced by different incident categories. The algorithm applies a modified deterministic queuing theory to estimate incident-induced delay by using 1-minute aggregated loop detector data. Incident-induced delay refers to the difference between the total delay and the recurrent travel delay at the time and location influenced by the incident. The uniqueness of the delay calculation in this study is the use of a dynamic traffic-volume-based background profile, which is considered a more accurate representation of prevailing traffic conditions. According to the test results, the proposed algorithm can provide good estimates for incident-induced delay and capture the evolution of freeway traffic flow during incident duration. Because actual traffic data measured by loop detectors were used in this study to compute vehicle arrival and departure rates for delay calculations, the estimated incident-induced delay should be very close to the reality. Additionally, the proposed algorithm was implemented in the Advanced Roadway Incident Analyzer (ARIA) system. ARIA is a database-driven computer system that automates all the computational processes. More accurate incident delay information will help WSDOT improve its understanding of congestion-inducing incidents and select more effective countermeasures against incident-related traffic congestion on freeways.

17. KEY WORDS Traffic Congestion, Traffic Delay, Incidents, Freeways, Travel Time, Loop Detectors, Queuing Theory.	18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

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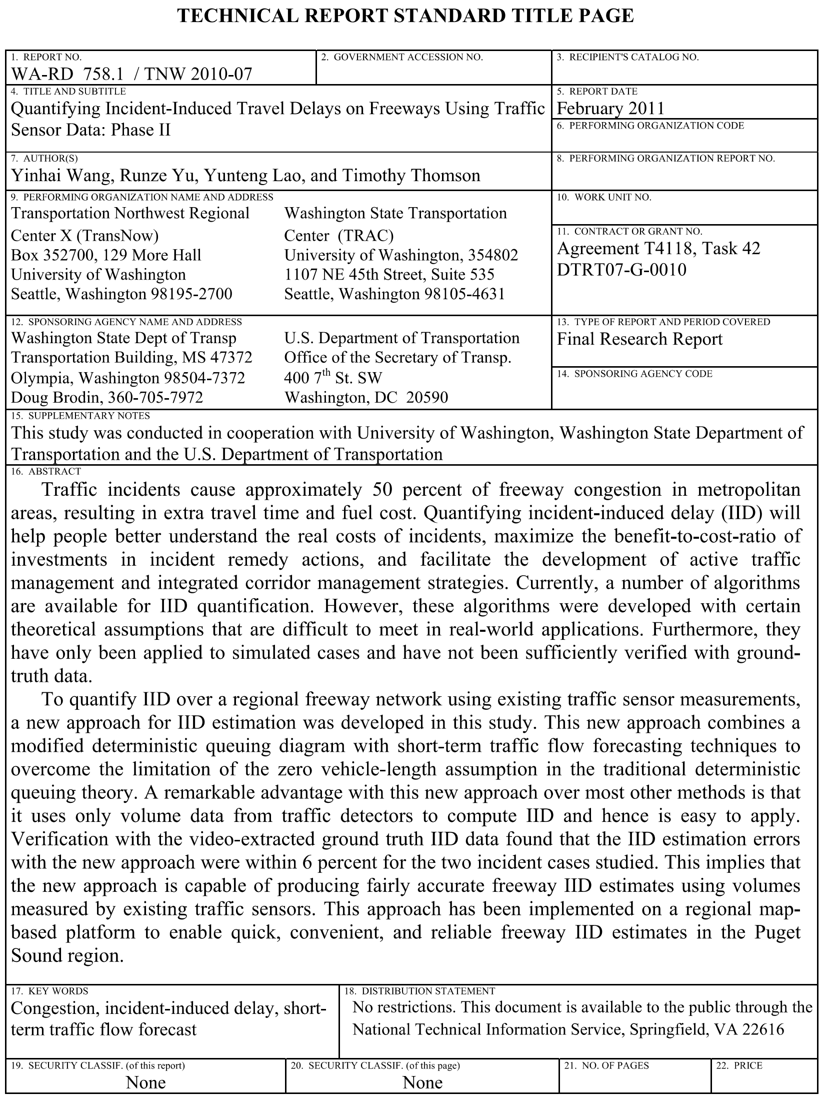
Figure R-2. Phase 2 Title Page (http://depts.washington.edu/trac/bulkdisk/pdf/758.1.pdf)



TECHNICAL REPORT STANDARD TITLE PAGE

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7. AUTHOR(S) Yinhai Wang, Runze Yu, Yunteng Lao, and Timothy Thomson		8. PERFORMING ORGANIZATION REPORT NO.
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12. SPONSORING AGENCY NAME AND ADDRESS Washington State Dept of Transp Transportation Building, MS 47372 Olympia, Washington 98504-7372 Doug Brodin, 360-705-7972	U.S. Department of Transportation Office of the Secretary of Transp. 400 7th St. SW Washington, DC 20590	13. TYPE OF REPORT AND PERIOD COVERED Final Research Report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with University of Washington, Washington State Department of Transportation and the U.S. Department of Transportation

16. ABSTRACT

Traffic incidents cause approximately 50 percent of freeway congestion in metropolitan areas, resulting in extra travel time and fuel cost. Quantifying incident-induced delay (IID) will help people better understand the real costs of incidents, maximize the benefit-to-cost-ratio of investments in incident remedy actions, and facilitate the development of active traffic management and integrated corridor management strategies. Currently, a number of algorithms are available for IID quantification. However, these algorithms were developed with certain theoretical assumptions that are difficult to meet in real-world applications. Furthermore, they have only been applied to simulated cases and have not been sufficiently verified with ground-truth data.

To quantify IID over a regional freeway network using existing traffic sensor measurements, a new approach for IID estimation was developed in this study. This new approach combines a modified deterministic queuing diagram with short-term traffic flow forecasting techniques to overcome the limitation of the zero vehicle-length assumption in the traditional deterministic queuing theory. A remarkable advantage with this new approach over most other methods is that it uses only volume data from traffic detectors to compute IID and hence is easy to apply. Verification with the video-extracted ground truth IID data found that the IID estimation errors with the new approach were within 6 percent for the two incident cases studied. This implies that the new approach is capable of producing fairly accurate freeway IID estimates using volumes measured by existing traffic sensors. This approach has been implemented on a regional map-based platform to enable quick, convenient, and reliable freeway IID estimates in the Puget Sound region.

17. KEY WORDS Congestion, incident-induced delay, short-term traffic flow forecast	18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616		
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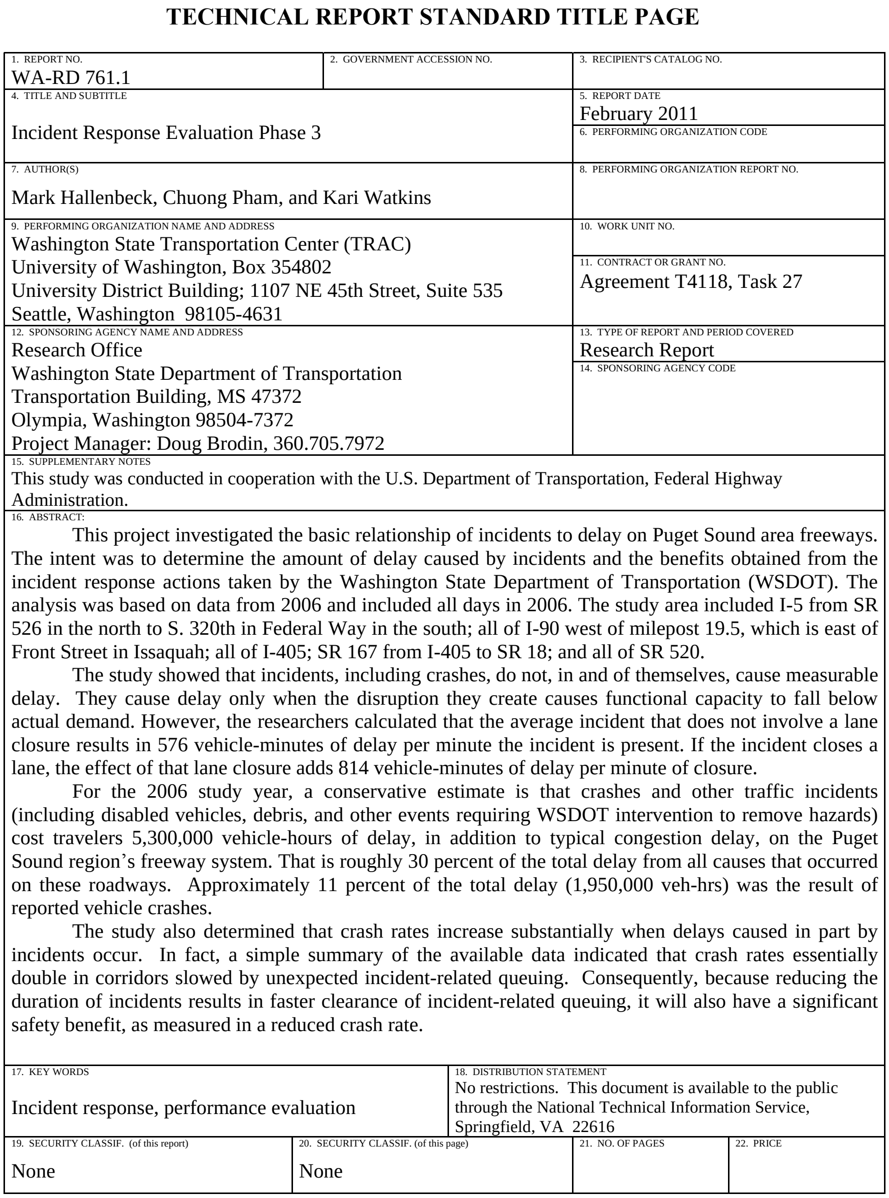
Figure R-3. Phase 3 Title Page (http://depts.washington.edu/trac/bulkdisk/pdf/761.1.pdf)



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4. TITLE AND SUBTITLE
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15. SUPPLEMENTARY NOTES
This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT:

This project investigated the basic relationship of incidents to delay on Puget Sound area freeways. The intent was to determine the amount of delay caused by incidents and the benefits obtained from the incident response actions taken by the Washington State Department of Transportation (WSDOT). The analysis was based on data from 2006 and included all days in 2006. The study area included I-5 from SR 526 in the north to S. 320th in Federal Way in the south; all of I-90 west of milepost 19.5, which is east of Front Street in Issaquah; all of I-405; SR 167 from I-405 to SR 18; and all of SR 520.

The study showed that incidents, including crashes, do not, in and of themselves, cause measurable delay. They cause delay only when the disruption they create causes functional capacity to fall below actual demand. However, the researchers calculated that the average incident that does not involve a lane closure results in 576 vehicle-minutes of delay per minute the incident is present. If the incident closes a lane, the effect of that lane closure adds 814 vehicle-minutes of delay per minute of closure.

For the 2006 study year, a conservative estimate is that crashes and other traffic incidents (including disabled vehicles, debris, and other events requiring WSDOT intervention to remove hazards) cost travelers 5,300,000 vehicle-hours of delay, in addition to typical congestion delay, on the Puget Sound region’s freeway system. That is roughly 30 percent of the total delay from all causes that occurred on these roadways. Approximately 11 percent of the total delay (1,950,000 veh-hrs) was the result of reported vehicle crashes.

The study also determined that crash rates increase substantially when delays caused in part by incidents occur. In fact, a simple summary of the available data indicated that crash rates essentially double in corridors slowed by unexpected incident-related queuing. Consequently, because reducing the duration of incidents results in faster clearance of incident-related queuing, it will also have a significant safety benefit, as measured in a reduced crash rate.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
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