Transportation Management Center

Data Capture for Performance and Mobility Measures Guidebook

www.its.dot.gov/index.htm

Final Report — March 27, 2013
FHWA-JPO-13-062

U.S. Department of Transportation

Produced by RITA ITS Joint Program Office

FHWA Office of Operations

U.S. Department of Transportation

Notice

Technical Report Documentation Page

1. Report No. **FHWA-JPO-13-062**	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Transportation Management Center Data Capture for Performance and Mobility Measures Guidebook		**5. Report Date** March 27, 2013 **6. Performing Organization Code**
7. Author(s) Conklin, Clifford A, Bahler, Stephen J, Belmore, Katherine L, Hallenbeck, Mark, Ishimura, John, Schnell, Genevieve M, Clark, James E, Curley, Cathleen E, Kandarpa, Ram, Hill, David, But, Alexander		**8. Performing Organization Report No.**
9. Performing Organization Name And Address Booz Allen Hamilton 20 M St SE, Suite 900 Washington, DC 20003		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-11-D-00019
12. Sponsoring Agency Name and Address U.S. Department of Transportation Intelligent Transportation Systems – Joint Program Office (ITS JPO) 1200 New Jersey Avenue SE, Washington, DC 20590		**13. Type of Report and Period Covered** **14. Sponsoring Agency Code**
15. Supplementary Notes Government Task Manager: Jimmy Chu, Federal Highway Administration, HOTM, E84-405, 1200 New Jersey Ave. S.E., Washington, D.C. 20590. (202) 366-3379		

16. Abstract

The Guide to Transportation Management Center (TMC) Data Capture for Performance and Mobility Measures is a two-volume document consisting of this 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.

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.

17. Key Words Transportation Management Center, TMC, Performance Measures, Performance Data, Performance Analysis, Operations Measures, Incident Response Measures, Mobility Measures	**18. Distribution Statement**		
19. Security Classif. (of this report) Unclassified	**20. Security Class if. (of this page)** Unclassified	**21. No. of Pages** **39**	**22. Price**

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

Acknowledgements

The authors would like to thank the Government Task Manager Jimmy Chu for his direction and guidance throughout this project. Our sincere appreciation is extended to the TMC Pooled Fund Study (TMC PFS) members for their valuable input in developing this Guidebook. A special note of appreciation also goes to the following individuals for their review and input into the development of this document:

- Lisa Schettler, Nevada Department of Transportation
- Robert Koeberlein, Idaho Transportation Department
- Mike Pack, Pennsylvania Department of Transportation
- Suzette Peplinski, Michigan Department of Transportation
- Ming Shiun Lee, URS Corporation

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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 this 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.

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.

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*. This *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 this 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 (SSP) 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 that 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.

Introduction

The Guide to TMC Data Capture for Performance and Mobility Measures consists of two parts: the Guidebook that you are reading now, 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 this Guidebook and provides additional discussion, examples, and guidelines for performance monitoring and associated data collection.

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. The four categories of measures are—

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

For each category of performance measures, this *Guidebook* summarizes key TMC performance metrics. To meet the different needs of TMCs of different sizes, areas of functional specialization, and resource levels, the discussion includes both basic and supplementary or advanced performance monitoring metrics.

TMC Operations Performance Measures

Overview

TMC operations performance measures generally measure the scope of a TMC's activities related to its goals and objectives. Most operations performance measures are "output" measures; that is, they describe and quantify the activities being performed, rather than the effect of those activities on the travel experience of drivers.

Using these and other measures, 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. Performance monitoring and reporting also help to identify and document problems with TMC operations or operational procedures that should be addressed to improve TMC efficiency and optimize performance.

The results of performance monitoring also feed into decision-making processes to determine how selected strategies compare to other investments. Operations performance measures can also be used to determine how effectively the TMC is performing in relation to historical norms. Routine and continued TMC operations performance monitoring helps the agency identify and resolve problems quickly, limiting their impact and exposure to the public, which in turn improves public perception of the agency and strengthens its position in the resource allocation process.

Additionally, the *TMC Data Capture Reference Manual* provides supplemental information about TMC Operations measurement. For more information, see Chapter 2 of the *Reference Manual*.

Basic 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 TMC Performance.

1. ITS Infrastructure and Traveler Information Services Performance Measures

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 how sensor density is being changed. In turn, this information can be used to help demonstrate the effectiveness of potential/new ITS investment in addressing transportation needs and issues.

Infrastructure performance measures, on the other hand, describe the actual performance of the devices and services. These measures are part of a good asset management program and are designed to describe the status of installed equipment, and whether they are operating or being utilized as intended. They also help describe whether the staff performance, given the available maintenance budget, is adequate to support the sensor/device/equipment purchase(s) in support of the TMC's activities.

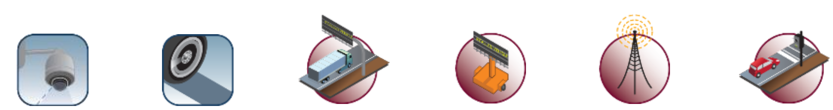
These metrics can be presented in tandem with other performance metrics to demonstrate the return on public investments, and assist upper management and local decision makers in their efforts to justify and advocate for additional resources for continued operations and maintenance.

Combined, the basic measures in this category include—

a. ITS Equipment—Number of Devices
b. ITS Equipment—Coverage
c. ITS Equipment—Usage
d. Traveler Information Services Usage
e. ITS Equipment—Operational Status
f. ITS Equipment—Reliability.

ITS Equipment—Number of Devices. The number of devices metric is an indicator of the size of the inventory of devices used by the TMC. This metric is used to track the status of the system inventory and the pace of system growth or shrinkage over time. In addition, this metric may be compared against other metrics, including historical staffing levels, to help estimate future staff and resource needs. This information may be particularly useful for upper management and local decision makers in their efforts to determine adequate funding levels to safely and effectively operate and maintain systems. 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%

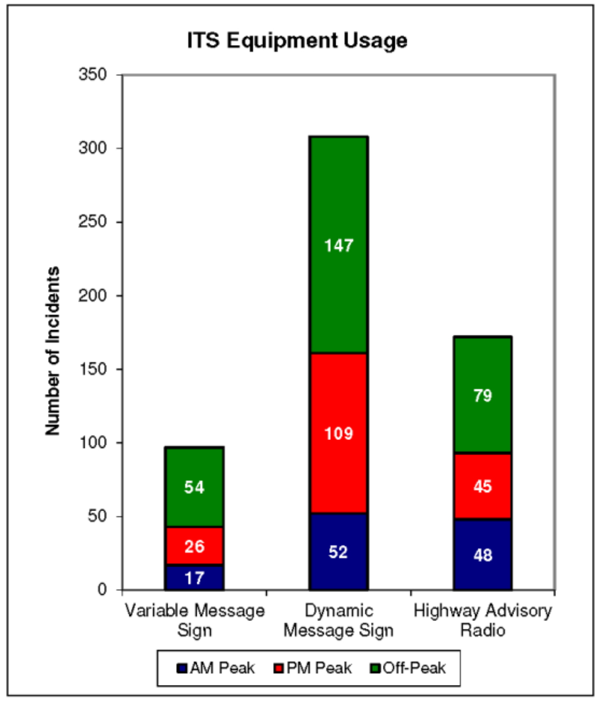
Source: WisDOT STOC 2011 Performance Measures Report

ITS Equipment—Coverage. The coverage metric tracks the geographic scope of deployed field equipment. It allows agencies to internally gauge the extent of their monitoring capabilities. Like the number of devices metric, the coverage metric is an indicator of the scope of a TMC's activities to fight congestion and improve safety.

The coverage metric, combined with the total number of devices, can help determine the density of coverage provided by individual device types. This can help the agency evaluate the quality of service it is providing to the public and to assess its progress toward meeting overall service goals.

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. ITS equipment usage can also be aggregated across a number of secondary characteristics. 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

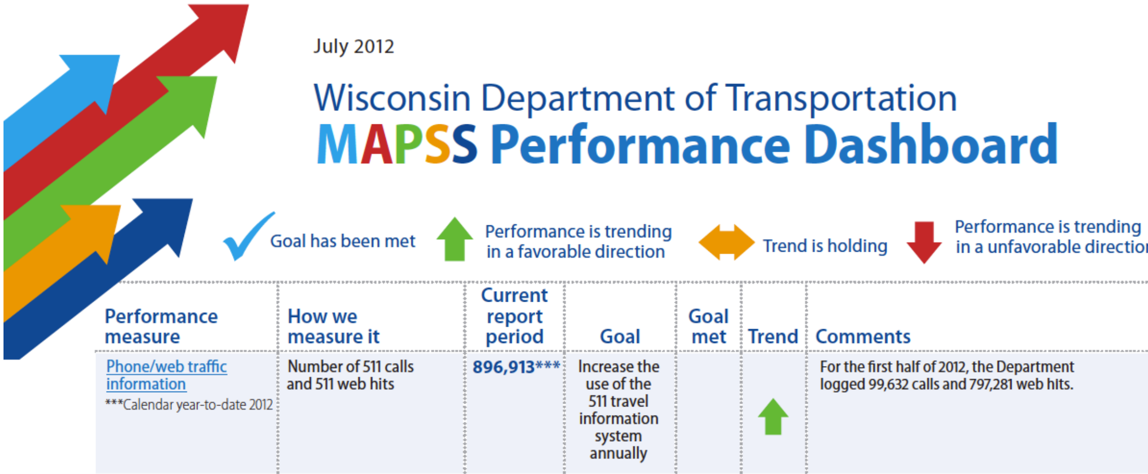


Source: RIDOT TMC Incident Statistics — 4/1/2012 to 6/30/2012

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 depicted in Figure 2-3.

Tracking usage levels over time helps the transportation agency determine how successfully it is providing the public with traveler information, how the public perceives the value of the service, and how best to allocate public funding. Tracking variations in usage over time also allows the agency to effectively plan for the spikes in information use during specific incidents, such as during major weather events.

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

ITS Equipment—Operational Status. This metric monitors the operating status of individual devices, providing agencies with feedback on how well and how reliably individual system components are operating. Knowledge of the devices' operational status provides the agency with information it needs to determine when additional maintenance is needed, anticipate when preventative maintenance should occur and what additional resources might be necessary, and update maintenance and replacement priorities. High equipment failure rates can result in the erosion of public confidence in the system.

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 illustrated in Figure 2-4. These numbers are then summarized in its annual report.

Figure 2-4: Current Field Device Operational Availability

Component	Total	Not Working	Working	System Availability
Closed-Circuit Television (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 it might be cost-effective to replace a system, potentially gaining new functionality rather than allocating time and expense to an old, outdated, and/or underperforming device/system.

2. TMC Operational Responsibilities Performance Measures

Unlike infrastructure performance measures, operational responsibilities metrics describe the activities of the TMC staff, rather than the TMC equipment. These metrics measure the number of times staff actions were taken in response to specific events in the transportation network, and in some situations record details about those actions. As such, these metrics are an indirect reflection of the level of demand for TMC staff responses to traffic issues.

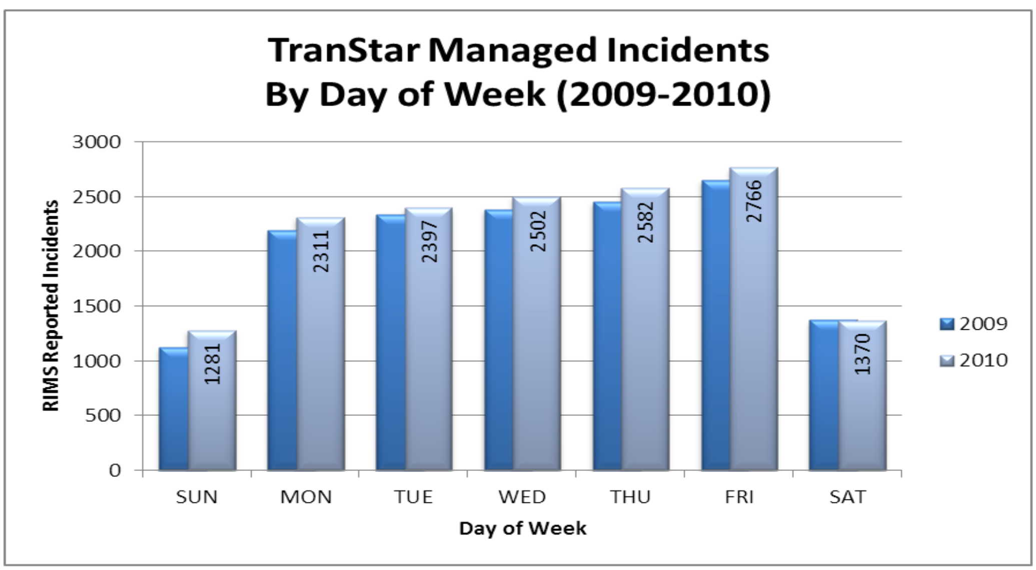
This set of measures can also help decision makers manage the workload of the TMC staff by comparing the level of staff activities (and the significance of those activities) with available resources. When evaluated in combination with other performance metrics, these measures can then be used to assist decision makers in evaluating staff performance and workload, adjusting staff size and schedules to strike an appropriate balance between workload and staff resources, and determining the level of resources necessary to provide a desired level of responsive service.

Measures in this category include—

a. Number of Incidents Managed
b. Number of Planned Events, Weather Events, Etc.

Number of Incidents Managed. This metric measures how many traffic incidents are managed in some way by TMC staff for a given time period. Tracking numbers of incidents over time provides an indicator of the importance of the TMC's role in managing area roadways. This metric can also be combined with other metrics to help summarize the effect of the TMC on incident management. 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: Houston TranStar Managed Incidents by Day of Week



Source: Houston TranStar 2010 Annual Report

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.

3. TMC Staff Performance Measures

Staff performance metrics focus on monitoring the ability of staff to achieve desired levels of performance in specific quantifiable areas of service, as well as monitoring the staff's skill set and knowledge relative to TMC needs now and in the future. Monitoring staff performance allows the agency to determine the nature and extent of any problems that might be impacting agency operations. It also enables the agency to anticipate future staff needs and to take appropriate actions to meet them.

Basic measures in this category include—

a. Staff Performance Targets

b. Staff Retention and Turnover Rates.

Staff Performance Targets. In order to assess 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)

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. Therefore, it is critical that the agency monitor staff turnover so that required knowledge, skills, and abilities do not leave the organization and place the TMC in a position where it is trying to "catch up" to previous levels of system proficiency and understanding. 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.

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 members learn their duties. The staff retention metric provides upper management with an indication of how well the center is doing in its efforts to retain staff.

4. Specialized TMC Performance Measures

Technology Evaluation and Testing. There may be special requests from within the organization or from local elected officials to assess the performance of a specific type of technology or system because of concerns about its use. Such requests may require collection of data and performance measurement by the TMC, outside of the normal performance monitoring process. The Twin Cities (Minnesota) ramp meter evaluation is probably the best-known example. In 2000, the Minnesota legislature required the state Department of Transportation to evaluate the effectiveness of its existing ramp meter program before granting approval to continue operating ramp meters 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.

TMC Operations Measurement: Data Collection Considerations

Typical types of data sets required to compute the TMC operations performance measures described above include 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)
- Dynamic Message Sign (DMS) Operating Status and Message Log
- ITS Maintenance Logs
- Asset Management Systems
- 511/Web Site Travel Information System Usage Reports.

The majority of data required for TMC operations performance measures is typically recorded in some type of database. Data should be stored by the TMC in a format that can be archived and recalled and automatically summarized for trends analysis whenever necessary. In some cases, such as 511 systems, a third party maintains the database. Access to such data should be defined in memorandums of understanding or in contract documents so that the TMC has reliable and timely access to the information it needs, in the format required.

TMC Operations Measurement: Trends

A developing trend in TMC operations management monitoring 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, OneBusAway, and SFPark bring data and the ability to trip plan in real time to the individual; these features 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 available and tracking the number of companies requesting these data feeds when this occurs would be a key “TMC usage” statistic.

TMC Incident Response Performance Measures

Overview

Traffic incidents occur daily on the nation's roadways and it is important to recognize and record how these occurrences are affecting the motoring public. 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. Tracking these measures should be done over time to understand trends in roadway disruptions.

Additionally, the *TMC Data Capture Reference Manual* provides supplemental information about TMC Incident Response measurement. For more information, see Chapter 3 of the *Reference Manual*.

Basic Measures

The performance measures that describe TMC incident response activities are divided into three sub-categories:

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

1. Traffic Incident Statistics

The most common examples of traffic incident statistics are the number of incidents, categorized by classification, time of day, or geographic area, and the number of secondary crashes. In order to report on these measures, the TMC must be collecting incident data. The data can come from a variety of sources and disciplines including, but not limited to TMC staff, law enforcement, fire, Emergency Medical Services (EMS), emergency management, towing and recovery providers, media, and the traveling public; therefore, the accuracy of incident response data can vary.

Basic measures in this category include—

a. Number of Incidents
b. Number of Secondary Crashes.

Number of Incidents. Similar to the discussion in Section 2, 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.

Number of Secondary Crashes. In 2005, the Federal Highway Administration (FHWA) launched a focused state initiative to develop and test consensus-based, multi-agency Traffic Incident Management (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.

Reductions in secondary crashes are an expected outcome and an important safety benefit of an efficient incident management system.

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 be the TMC, law enforcement or both, and how these crashes will be tracked. In addition to tracking incidents by severity level, RIDOT's TMC is currently tracking the number of secondary crashes 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%

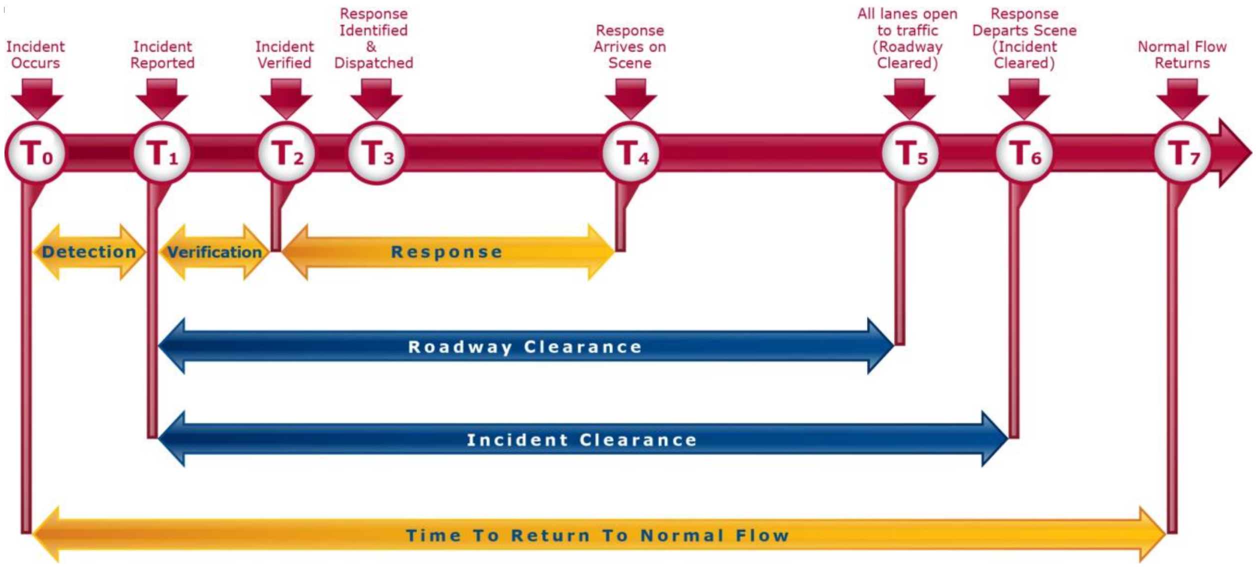
Note: A "secondary" crash is one that is the result of an earlier incident.

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

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

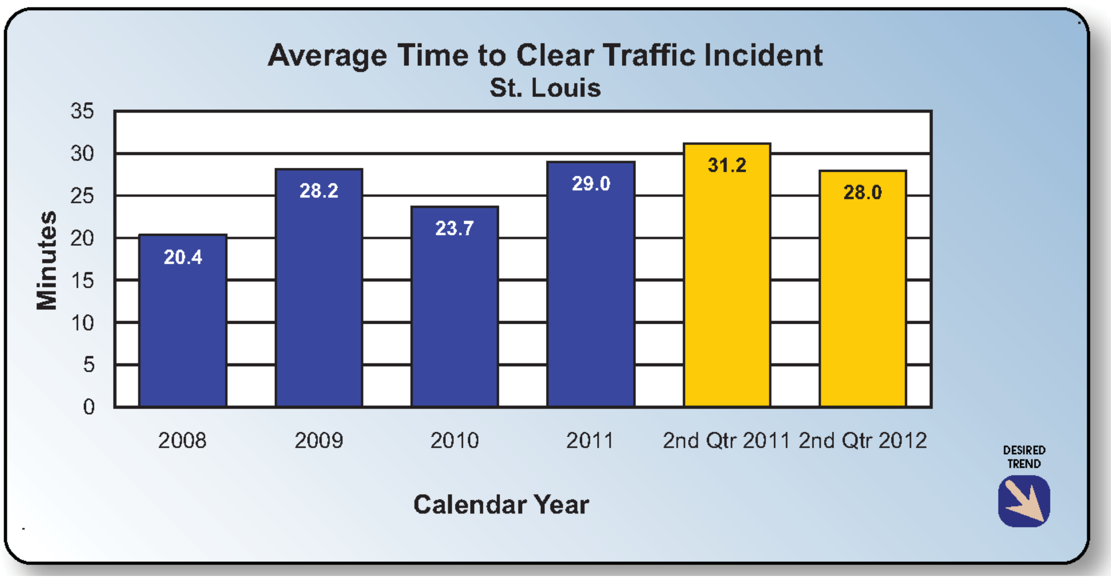
Incident Timeline		Definition
Detection Time	$T_1 – T_0$	The detection time is the time between the incident occurring and the incident being reported. Detection time is not typically reported due the fact that the actual time the incident occurred is often unknown.
Verification Time	$T_2 – T_1$	The 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.
Roadway Clearance Time	$T_5 – T_1$	Roadway clearance time is 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 Timeline		Definition
Incident Clearance Time	$T_6 - T_1$	Incident clearance time is 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 advanced transportation management system. Figure 3-3 illustrates the average time to clear incidents in St. Louis.

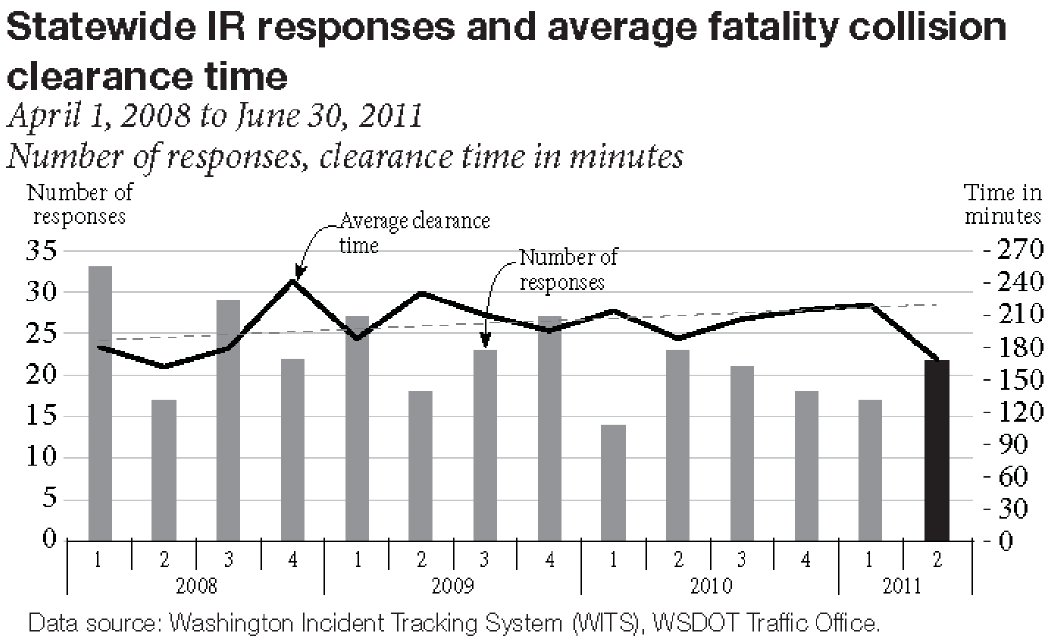
Figure 3-3: Average Time to Clear Traffic Incidents in St. Louis



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

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.

If safety service patrols are operated as part of the TMC, the following basic measures should be reported, as they describe the services being provided:

a. Safety Service Patrol Operations Summary

b. Number of Assists and Number of Services Provided

c. Safety Service Patrol Timeline

d. Safety Service Patrol Motorist Feedback

e. Number of Safety Service Patrol Vehicles

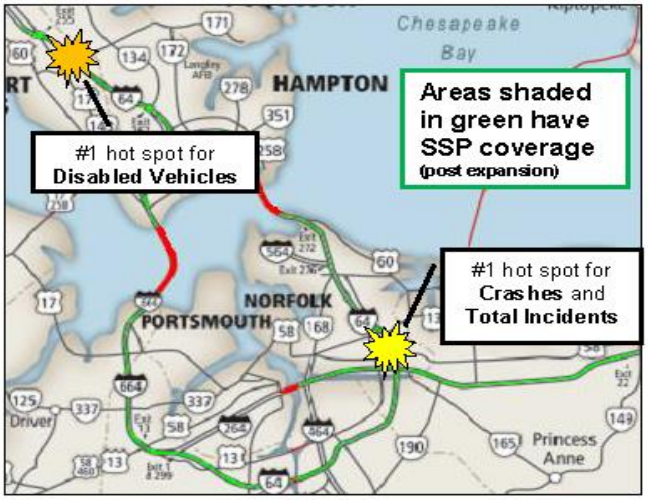
Many agencies find it beneficial to maintain some type of operations summary that documents the basic characteristics of a safety service patrol program. Items typically provided in an operations summary include—

- 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 program, as illustrated in Figure 3-5.

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

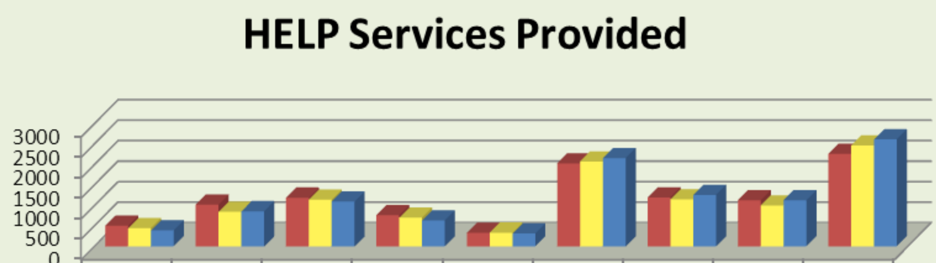


Source: VDOT Hampton Roads TOC 2011 Annual Report

In addition to just reporting, the Hampton Roads TOC is using its performance measures to actively manage operations. For example, quarterly incident data is 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

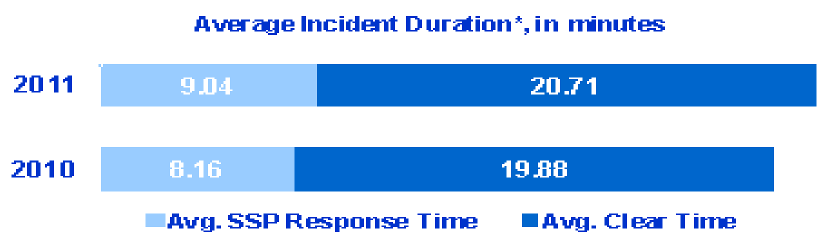
Note: Other includes Extinguish Fire, First Aid, Absorbent, Relocate Vehicle, Fluids, Called Wrecker, Secure Load, Phone Call, Directions, Transported, Unable to Locate, Wrecker Towed, Notified TDOT, Notified Law Enforcement, & Miscellaneous.

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

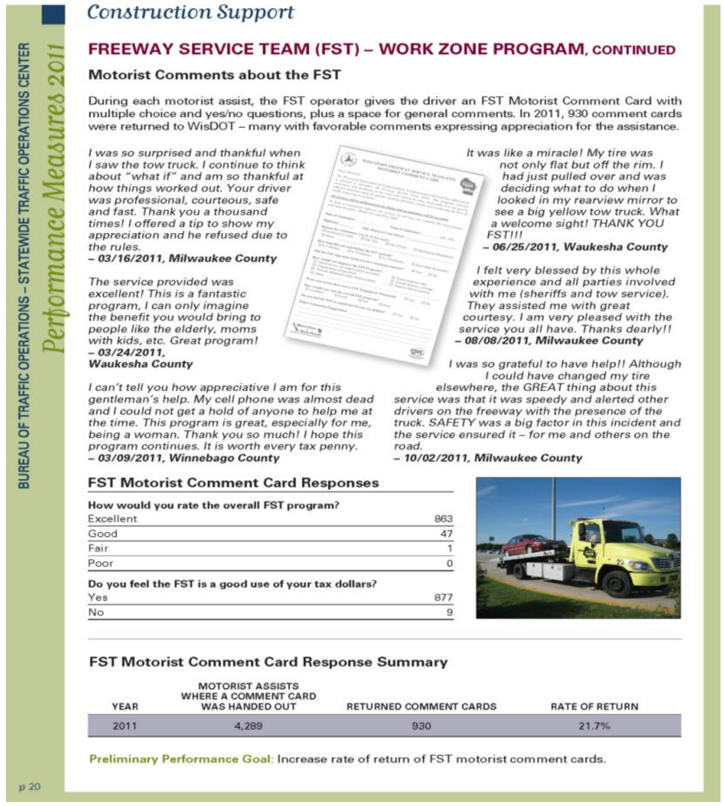


Source: VDOT Hampton Roads TOC 2011 Annual Report

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 State-wide Traffic Operations Center 2011 Performance Measures Report* and depicts 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

Incident Response Measurement: 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, and clarify who will identify an incident as being a secondary crash, as well as 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.

Incident Response Measurement: Data Collection Considerations

Data to support incident response performance measures are typically captured by the TMC using the input of response partners at an incident scene. Incident response data can come 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. Other sources of information can include TMC operators viewing an incident/response on CCTV cameras or computer-aided dispatch (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. In the best circumstances, these data are automatically entered into these databases as part of that reporting process, for example as part of a CAD system or as part of an incident management system being used by responders.

System Mobility Performance Measures

Overview

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 measurement. 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.

Additionally, the *TMC Data Capture Reference Manual* provides supplemental information about TMC Mobility measurement. For more information, see Chapter 4 of the *Reference Manual*.

Basic Measures

Two key basic measures of performance are necessary to describe the level of mobility the transportation system provides:

1. Speeds at Which the System (Traffic) Is Operating
2. Traffic Volumes.

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.

While the spatial and temporal granularity at which these data are collected affect the analytical precision with which the resulting performance measures can be reported, collecting data at even fairly modest levels of geographic and temporal detail can result in very useful performance reporting.

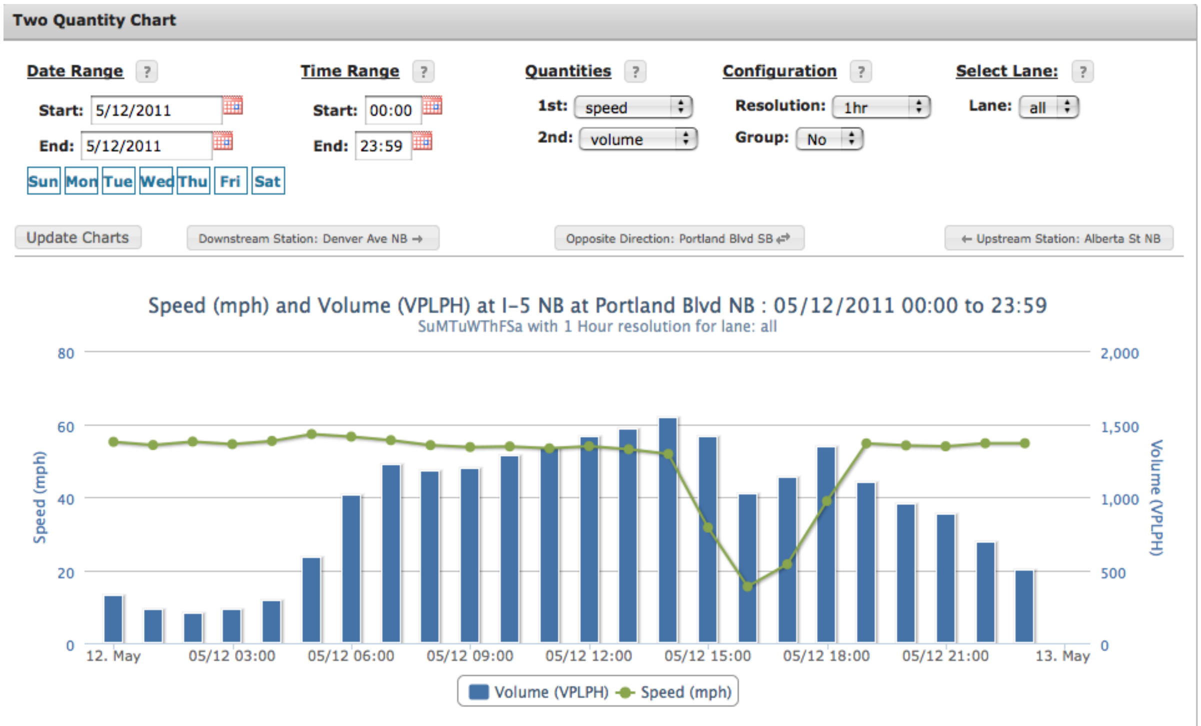
Table 4-1 shows a simple tabular summary of spot location volumes. Volumes are summarized by different time periods (peak period, peak hour, daily); other useful subsets of the data that can be used include weekday vs. weekend, month or season of the year, and days with special events. Figure 4-1 illustrates how basic speed and volume data can be graphically summarized, at a specific location on a given day.

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. Ishimaru and M. Hallenbeck, 1999

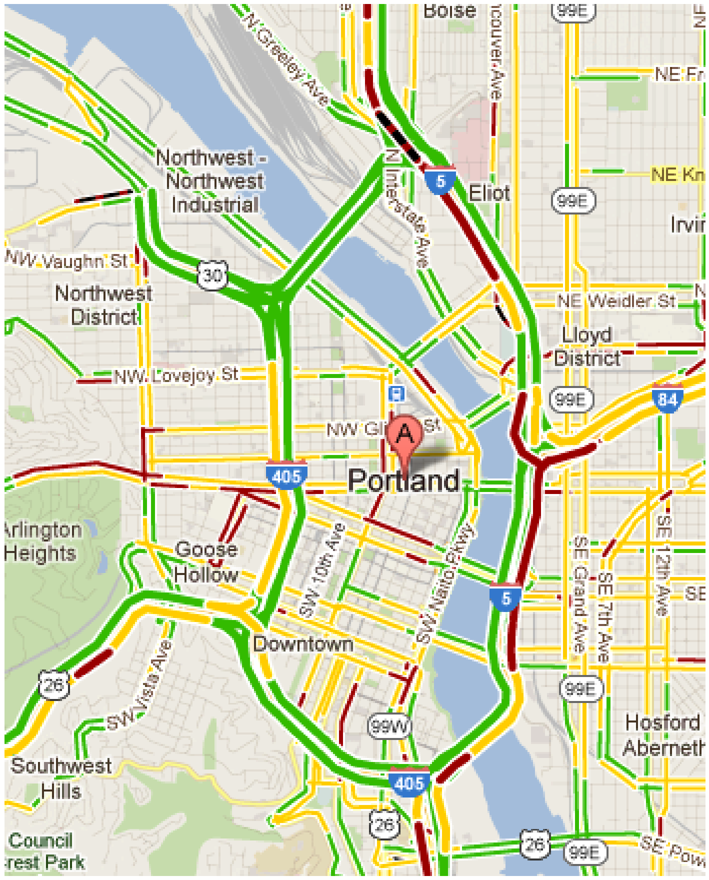
Figure 4-1: Speed and Volume by Time of Day at a Specific Location



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

Basic mobility metrics like speed and volume are attributes of spot locations on a transportation network. Therefore, one of the most intuitive ways that roadway mobility indicators can be succinctly summarized is in map form, such as the congestion display illustrated in Figure 4-2.

Figure 4-2: Map of Portland, Oregon, Freeway Congestion Available on the Internet



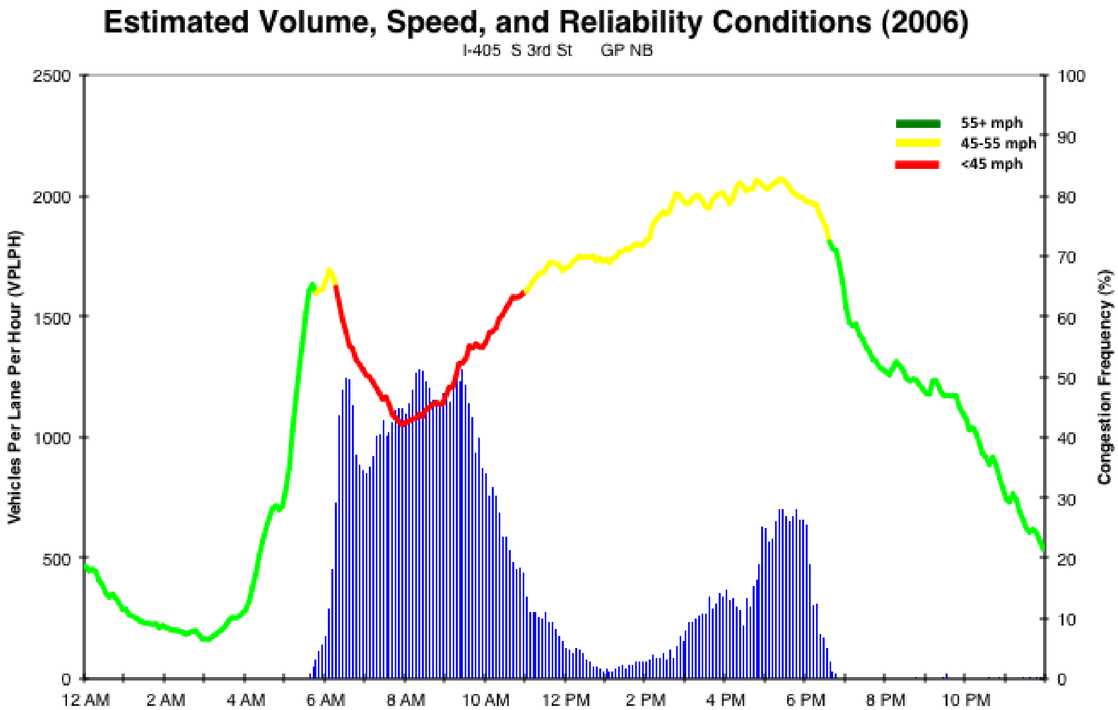
Source: Google Maps

Derived Basic Measures

While volume, speed, and lane occupancy are valuable metrics by themselves, a wealth of additional measures can be readily derived from them with no additional data required, and relatively modest computations. These derived measures can be aggregated at location, corridor, or trip route levels. Examples of key derived basic measures include the following:

- **Aggregate Volume, Speed, and Reliability (by Location).** Volume and speed data at a spot location can be aggregated over a desired time period (e.g., yearly) to produce an overall summary of performance at a spot location. Figure 4-3 illustrates how volume, speed, and reliability metrics can be summarized in a single graph. In the example, volume (line graph) and speed (color coding) are averaged across all weekdays of the year by time of day, while a reliability indicator (column graph) is derived from speed (i.e., reliability = percentage of days in the year when speed is below a threshold value). This provides a succinct site-specific performance summary.

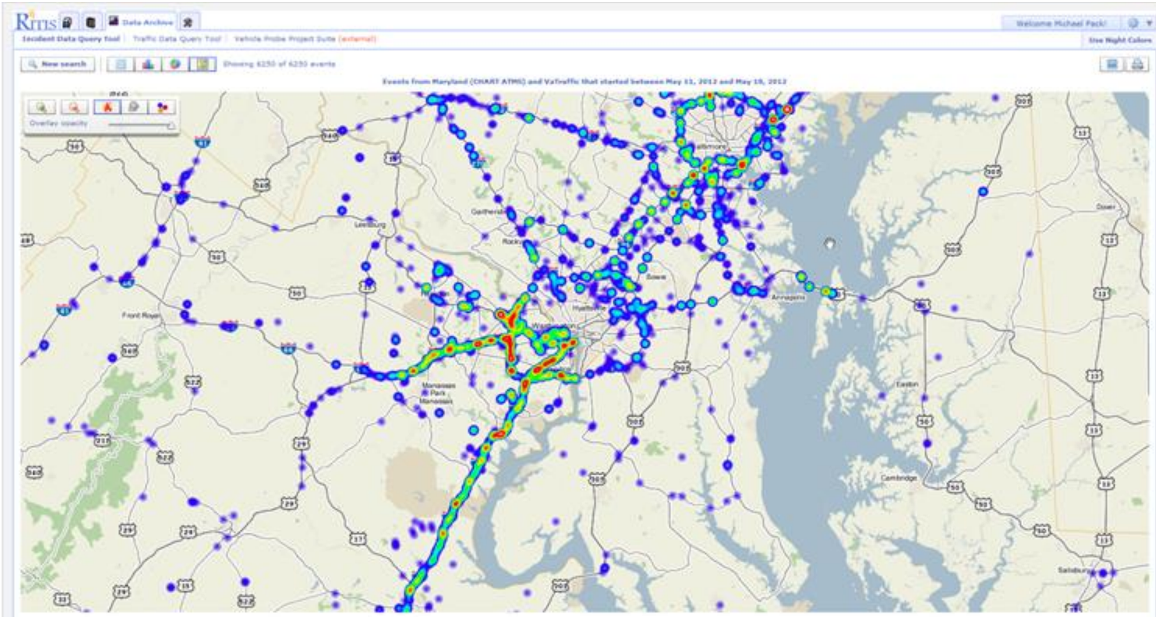
Figure 4-3: Spot Location Volume, Speed, and Reliability by Time of Day



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

- **Aggregate Volume, Speed, or Reliability (by Corridor or Region).** If volume or speed data are available at a series of spot locations along one or more corridors, corridor or regional performance can be described. Figure 4-4 illustrates how reliability data (frequency of congestion/slow speeds) at a series of locations along several corridors in an urban region can be summarized in a single graph showing frequency of congestion as a function of location.

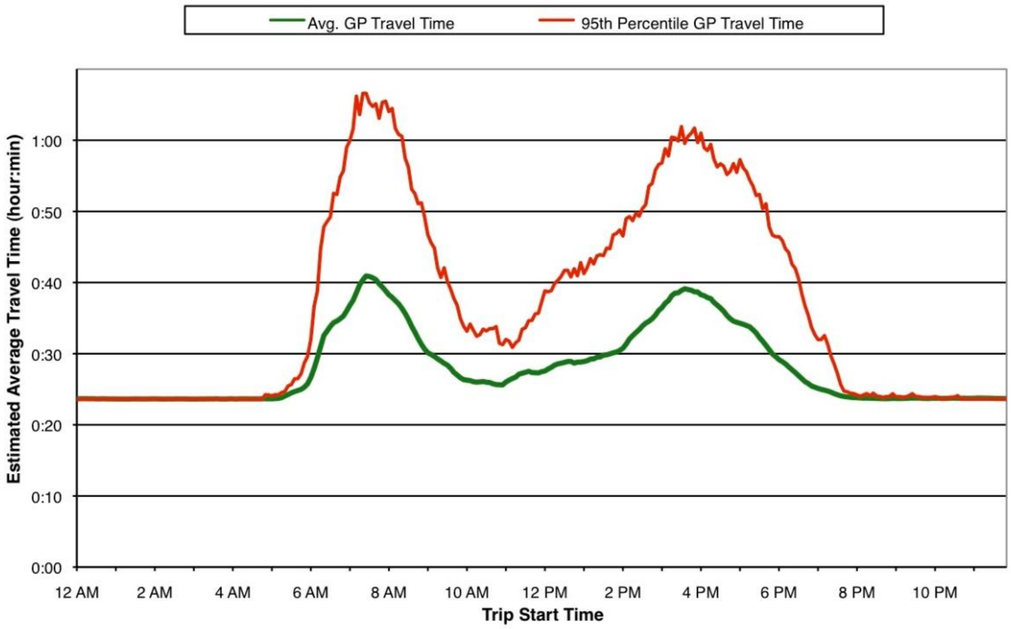
Figure 4-4: Graphical, Region-Wide Congestion Summary from the National Capital Region Regional Integrated Transportation Information System (NCR RITIS) Database



Source: RITIS Web site, CATT Lab at the University of Maryland, http://www.cattlab.umd.edu

- **Travel Times (by Trip Route).** Speed data have a variety of useful "spin-off" metrics that are both descriptive of roadway performance and easily understood by decision makers and the public. Travel times between key locations are an important example of a derived statistic that is intuitive and useful for a variety of audiences. Results can be depicted graphically or in tabular form. Figure 4-5 illustrates how travel time on a given route (averaged for all weekdays of a year) varies by time of day. It also shows the variability (unreliability) of travel times, in the form of 95th percentile travel times. Table 4-2 lists travel times, index values, and trends in a tabular form. While a table does not provide the visual insight into time-of-day travel patterns provided by Figure 4-5, it does 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.

Figure 4-5: 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

Table 4-2: Alternative Travel Time Data Summary Example

				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)		
									MT³ Index					
Route	Direction of travel	Length of route	Peak time of commuter AM rush	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

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.

Source: Washington State Department of Transportation, The Gray Notebook

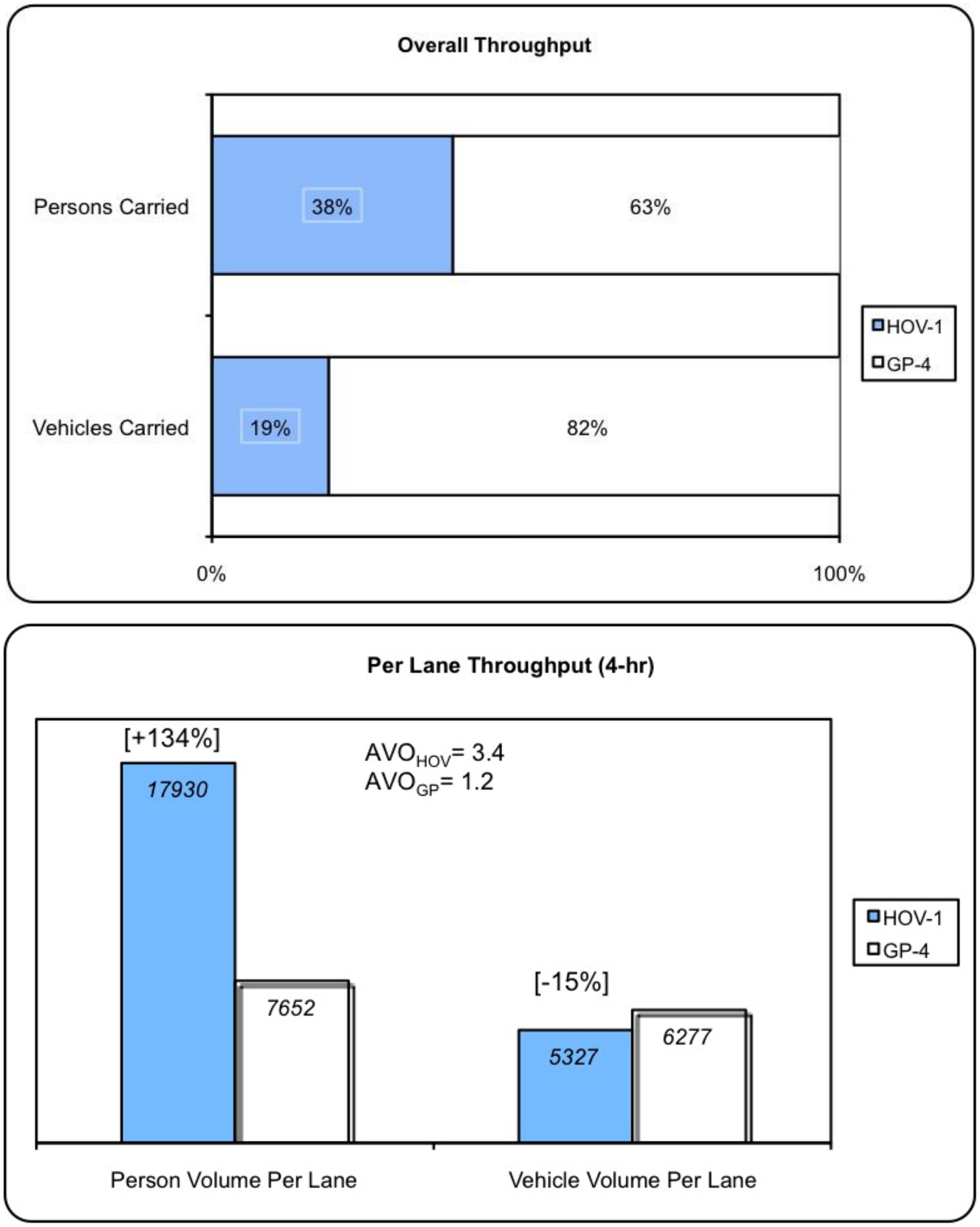
- **Location, Corridor, and Trip Reliability Metrics.** While aggregated average values such as mean volume, mean speed, or average travel time are useful metrics, reliability metrics are necessary to more fully understand the nature of traffic conditions, particularly from a traveler perspective. For example, travel time reliability is an important issue for travelers and freight shippers, and is a useful performance measure for decision makers and the general public. Each of the three derived basic measures listed above (location, corridor, and trip performance) can include reliability metrics derived from existing data.

Advanced or Specialized Measures

Once a TMC starts producing and reporting basic performance measures, the demand for the publication of those measures often increases, especially if those measures shed new 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. (Being able to provide these descriptive pieces of information also provides the TMC with considerable credibility in the public, making it easier to retain public support for the TMC's activities.) Examples of advanced performance measures include—

- **Normalized Performance Metrics.** If cross-corridor comparisons are necessary, it is best to use index-based metrics that adjust for differences in segment length. Examples include travel time-based variations such as the travel rate (minutes per mile), travel time index (TTI), planning time index (PTI), or buffer time index (BTI). Each of these measures is unitless, which allows direct comparisons of the levels of delay on trips of different lengths.
- **Derived Usage and Performance Metrics.** When speed and volume data are available on a road segment, additional metrics can be readily derived such as vehicle-miles traveled (VMT), vehicle-hours of travel (VHT), delay per capita or per vehicle, lost productivity, or bottleneck ranking lists.
- **Person Throughput Metrics.** 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. Reporting person throughput is particularly important for TMCs that operate high occupancy vehicle (HOV) or high occupancy/toll (HOT) lanes, as person throughput describes the relative effectiveness of these facilities in moving people, rather than just vehicles. Figure 4-6 illustrated one way in which person throughput is used to compare the personal mobility provided by HOV lanes vs. general purpose lanes. The upper graphic in Figure 4-6 illustrates person and vehicle throughput for the entire general purpose (GP) or HOV facility while the lower graphic illustrates statistics by lane, which allows the "fair" comparison of a single HOV lane vs. a single GP lane.

Figure 4-6: 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

Mobility Measurement: Data Collection Considerations

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 (some 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 first two of these data sources are commonly used to monitor the performance of their roadway network in real time, while the third source is usually only utilized when there is interest in demand management activities. 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 vehicle probe data may often supply data archive systems complete with analytical capabilities. 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.

1. Fixed Sensor Data

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 every monitored roadway segment.

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 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. Some considerations when using fixed sensor data include—

- **Choosing Sensor Technology.** The selection of the most appropriate technology is a function of a number of factors, including desired types of data, cost of sensors and associated infrastructure, and sensor placement limitations.
- **Owning and Operating Sensors vs. Outsourcing.** Depending on the availability and expertise of TMC staff, available resources, and level of control required, TMCs can place, operate, and maintain their own fixed sensors, or they can contract with private companies for some or all of those services.

2. Vehicle Probe Data

A second major source of mobility information is privately collected vehicle probe data. Private vendors' aggregate Global Positioning System (GPS) data from equipment carried onboard vehicles, review data quality, and produce estimates of average vehicle speed by roadway segment by time period. Some considerations when using vehicle probe data include—

- **Benefit: No sensors to install or operate.** 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. TMCs purchasing private sector data can also obtain data for very large geographic areas of roadways without extensive upfront costs for equipment and installation.
- **Limitation: Limited spatial and temporal data coverage on lower volume roadways.** 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. On lower volume (arterial) roads, speed estimates might not be available for some time periods. Therefore, TMCs should carefully examine the availability and reliability of a vendor's arterial speed estimates before purchasing those data sets.
- **Limitation: Lack of volume data.** Private sector vehicle speed data do not provide facility volumes. A second source of data is necessary to accurately "size" congestion (e.g., to produce estimates of vehicle delay or person delay) on specific segments. Therefore, some fixed sensors are still necessary to provide vehicle volume data for those roadways.
- **Limitation: Segregating data on closely spaced roadways.** It can be difficult to segregate probe data for closely spaced roadways. For example, probe data may not allow sufficient differentiation between vehicle speeds in HOV lanes and those in adjacent general purpose lanes. This can be problematic for a TMC that needs to operate such facilities and needs to compare its operations (e.g., HOV vs. GP performance) as part of its general mobility reporting.

Data Availability and Quality Considerations

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. The data used to support mobility performance measurement activities should be reviewed from the standpoint of data quality and availability and the impacts of lack of data (or lack of reliable data) on measurement and reporting.

- **Maintenance, Quality, and Availability.** 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.
- **Sensor Network Gaps.** In addition, fixed sensors provide data at only the point observed by the fixed sensor. Spot location data from widely spaced sensors might not adequately represent the varying conditions of the entire roadway. A similar type of problem can occur with probe data in rural areas, where the defined road segments can be more than 10 miles long. Probe data can also be sparse when volumes of GPS-equipped vehicles are low.

Future Data Sources

Changing technology continues to affect the availability and cost of data collected by both fixed sensors and vehicle probes. 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) Connected Vehicle Initiative (CVI). While the data collection functions of the CVI had not been finalized when this *Guidebook* was written, CVI vehicles are expected to result in a further increase in amounts of mobility data and to produce a rich source of data about many of the disruptions that limit mobility.

Mobility Measurement: Trends

There are three emerging trends in mobility performance measurement:

1. **The Increasing Use of Vehicle Probe Data Collected by the Private Sector.** Such data sets expand the types and scope of mobility monitoring that can be performed. Their use nevertheless requires continued monitoring and independent testing by the TMC.
2. **The Increased Use of Mobility Performance Measures to Report on the Benefits of Operational Improvement Programs.** These measures are particularly useful when evaluating the benefits of operational strategies compared to capacity expansion projects, and to support continued funding or growth of TMC programs.
3. **The Increasingly Varied Ways in Which These Data Are Being Reported.** This includes alternative formats and reporting frequency, and especially online delivery systems.

As the TMC's performance monitoring system evolves, these trends should be monitored to determine if or when they should be tested or introduced.

Cross-Cutting Performance Measures

Overview

Cross-cutting measures are metrics that combine data from two or more of the other three performance measurement categories described previously in this *Guidebook*, 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. Effective cross-cutting analyses can 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 vulnerable when resources are being allocated.

Considerable research is currently being conducted in the area of cross-cutting measures. Most cross-cutting measures are considered advanced measures, and the computational procedures to derive many of the desired measures are still being developed. Relatively few TMCs have reporting systems that are actively utilizing and reporting cross-cutting performance measures. Reasons for TMCs to do so include—

- 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 a new metering algorithm is working as intended)
- Trying to answer questions concerning the value of their activities in anticipation of future questions by decision makers and the public.

Without strong defensible analyses that describe the benefits of TMC operations and maintenance programs, it can sometimes be difficult for such efforts to compete with traditional capacity enhancement projects in the budget prioritization process. Consequently, developing and reporting performance measures that describe the mobility benefits of these programs—and not simply the effective delivery of services—can directly affect the TMC's ability to maintain and enhance such programs.

Additionally, the *TMC Data Capture Reference Manual* provides supplemental information about TMC cross-cutting measurement. For more information, see Chapter 5 of the *Reference Manual*.

Basic Measures

Cross-cutting performance measures analyze both actual and perceived estimates of value. The one cross-cutting measure recommended for all TMCs is to collect and report on public opinion toward their activities and the perceived quality of their services. Basic customer satisfaction metrics help TMCs describe to decision makers the level of public support for TMC activities, and help TMCs understand what their customers do or do not value. Unlike most cross-cutting measures, public satisfaction measures are not really a combination of previously collected performance measures, though they can reflect the public's perception of several TMC activities in aggregate.

In an era when it is difficult to raise taxes, it is important that the public feels that it is benefiting from its 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—

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

Advanced or Specialized Measures

Advanced or specialized cross-cutting analyses typically require the development of analytical measures that estimate the mobility benefits obtained from specific programs. The TMC should develop measures for those programs that it believes provide the most public benefit or that consume the greatest amount of TMC resources. For example, if the TMC is responsible for significant Incident Response functions, then the mobility benefits from those IR activities should be measured.

The following are examples of specialized cross-cutting analyses that a TMC might use to meet analytical and planning objectives:

- **Incident Delay.** Most TMCs involved with incident response activities are eventually asked to justify their incident response programs in terms of their 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 previous discussion of incident management metrics) with those that describe the performance of the roadway system on which incidents and the agency's response occur (see previous discussion of mobility metrics); combining data from these two sets of measures allows estimation of incident delay. The basic concept is to report on both the amount of incident delay occurring and the changes in that delay that result from the incident response program. This metric can involve some analytical complexity as well as significant data requirements.
- **Recovery Time from Disruptions.** One of the commonly desired reporting statistics is the time required for a roadway to "recover" from an event. For example, a TMC might want 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 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 a newly deployed proactive snow management program. As with incident delay, this metric can involve some analytical complexity.
- **Other Examples of Cross-Cutting Measures.** Because of the variety of TMC activities, a number of other cross-cutting measures are being developed across the country. Many have yet to be published, and those under development tend to be designed for 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.

Cross-cutting Measurement: Data Collection Considerations

Data Availability and Quality Considerations

The majority of data used for cross-cutting measures will be collected for the mobility, incident response, or TMC operations performance measures. 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. 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.

Future Data Sources

The future of cross-cutting data is directly affected by the future data sources for other performance measures. For example, USDOT's CVI promises 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 CVI 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.

Cross-cutting Measurement: Issues and Trends

Because of the inability of many 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 CVI.

The following are some of the issues and trends in cross-cutting metrics development:

- **Evolving Cross-Cutting Algorithms.** Many TMCs are looking for metrics that help them judge the performance or effectiveness of specific programs (e.g., benefits of weather-dependent ramp metering). However, a general difficulty with such cross-cutting measures is that direct measurement of mobility only describes what did happen, not what would have happened without the new program being studied. Therefore, developing performance measures such as throughput volume and speeds is not the real cross-cutting activity. Instead, what is required is (in the case of weather-dependent ramp metering, for example) the ability to extract weather data from one data archive, combine those data with mobility measures, extract data from the ramp metering algorithm, and analyze the three data sets together to judge the performance of the new ramp metering algorithm. The cross-cutting measures should combine different independent variables to allow comparison of the relative performance of the roadway system under 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.

- **The Increasing Availability of Data.** One important trend that TMCs need to track is the change in data availability that is likely to occur when USDOT's CVI is deployed. The CVI is 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 the CVI data has yet to be determined, so this *Guidebook* cannot provide more definitive guidance on the use of those data.

Lessons Learned, Guidelines, and General Considerations

The following are overall lessons learned, guidelines, and issues to consider as you develop or enhance a TMC performance monitoring system and the associated data collection, archiving, and retrieval systems:

- **Take Stock of Your Existing Data.** Understand the scope of your existing data sets, including data types (spot speeds, spot volumes, construction event data, etc.), spatial scope (selected locations, all freeways in the region, etc.), temporal scope (5-minute data for the past five years, etc.), and accessibility (easily query-able, electronically stored, available database tools, etc.). Review the gaps in your data, and determine if it is necessary to address those gaps in the future to meet specific needs (e.g., expand monitoring capabilities to provide better coverage of frequent bottleneck locations).
- **Identify Your Near-Term Monitoring Needs**. Prioritize the desired functions of your performance monitoring system, based on the specific needs of your TMC. Do you have scheduled performance reporting needs that must be met? Do you routinely receive requests from management or legislators asking for specific types of data at specific locations?
- **Start with What You Can Report.** Use the data and measurement processes you already have as a starting point for performance monitoring efforts. Typically, the data you are collecting today, and the performance measures you already use, are a good indicator of what is most important to your agency now, so start there. Then, grow the program over time to include larger geographic areas and additional data items as your needs and capabilities expand.
- **Don't Let the Perfect Be the Enemy of the Good.** You do not have to have a comprehensive, perfect data collection and monitoring system from the start in order to produce useful results. Do not let a long-term focus on achieving the ideal process inhibit you from producing beneficial results along the way, using the data you have now.
- **Collect and Archive Data that Describe Your TMC's Activities.** Data that describe the activities you perform should be collected and stored automatically for later summarization and analysis. This data is necessary to manage your personnel and resources; it also happens to be the same data needed for performance reporting. Do not make the collection of such data a secondary function. It should be part of how personnel do their jobs, through automated steps whenever possible. For example: Every time a DMS sign is changed, that event should be automatically logged so that you know when the sign was activated/deactivated, what it said, and who changed its status. During an incident response event, the dispatch system and/or the personnel themselves should be recording when incident response team (IRT) members are notified, when they arrive, and timestamps of major events (lanes closed/opened, incidents cleared, etc.).
- **Increase Reporting as More Data Become Available.** Increase the reporting on roadway conditions as mobility data become available. Adding descriptive data like the number of people, vehicles, and trucks using your facilities; where, when, and how frequently delays are occurring; and a description of why congestion is occurring in those locations, adds depth and

validity to the performance measurements. Refine your data collection process to capture data items not already available but needed to answer important policy questions (e.g., define and collect “recovery time” data over time).

- **Track and Report Trends in the Metrics.** Once you have good data about your activities, how well you are performing those activities, and the performance of the roadway system itself, start reporting the trends in those measures.
- **Use Reporting Language that Meets Audience Needs.** Clearly communicate your findings to TMC stakeholders (decision makers, TMC staff, the general public, a television audience) in a language that focuses on your audience’s needs. Realize that each audience may need slightly different information, or at least a different presentation of your information. This does not necessarily mean using different metrics; in many cases, the information presented is based on the same data, performance measurement, and/or statistical analysis. It may simply mean using different words or formats to describe your outcome. For example, you may measure congestion on a roadway as the number of days when Level of Service (LOS) falls below LOS F, but when talking to the public, you might describe these results as the average number of days per week when the roadway is congested. When talking to the public, focus on generally understood terms, and use tools like annotated graphics to focus the discussion on the key idea(s).
- **Collect Data to Understand Cause-and-Effect Relationships Associated with Your Activities.** Once you have established a data collection system that monitors TMC activities and roadway performance, perform analyses to understand how they are related. Conduct before and after studies and incident after-action reports to gather facts and data. Use the data to feed into the development of performance measurements such as incident clearance time. In some cases, depending on the data, a statistical analysis can be conducted to show the relationship between TMC actions and performance. Use these studies and computations to better understand and describe the effect of your TMC’s activities on the performance of the roadway system.
- **Set Goals and Monitor Results.** The most successful TMCs have set internal goals and then worked to achieve them. Refine your goals along the way as appropriate, making your goals higher if they are too easy, or setting preliminary, more achievable targets if the initial goals are impractical.
- **Use Your Monitoring and Reporting Outcomes to Actively Manage Your Staff and Resources.** Look for ways to highlight your successes, and work to overcome any shortcomings. Take action to change your activities if you are not being successful. This shows that you are actively managing your TMC and always looking to get better.

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[FHWA-JPO-13-062]

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