# Planning for Transportation Systems Management and Operations

## PRACTITIONER REFERENCE

U.S. Department of Transportation
Federal Highway Administration

## NOTICE



## NON-BINDING CONTENTS



## QUALITY ASSURANCE STATEMENT

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| **16. Abstract** This document is a resource designed to enable transportation planners, operators, and others to plan for transportation systems management and operations (TSMO) by identifying operations objectives, performance measures, strategies, implementation, and management considerations. It offers practitioners a menu of options for incorporating operations into plans (formal and informal) through an organized collection of sample operations objectives and performance measures. It also features excerpts from an example transportation plan and other key documents, illustrating the results of an objectives-driven, performance- based approach to planning for operations. The collection of operations objectives, performance measures, and plan excerpts can be used to inspire discussion among operations-planning partners as they work to develop their own plans that reflect this approach. The Reference also includes brief discussions of important topics in planning for TSMO such as project prioritization and sustaining TSMO over the long term. | | | |
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## SI* (Modern Metric) Conversion

| FACTORS APPROXIMATE CONVERSIONS TO SI UNITS | | | | |
|---|---|---|---|---|
| **SYMBOL** | **WHEN YOU KNOW** | **MULTIPLY BY** | **TO FIND** | **SYMBOL** |
| **LENGTH** | | | | |
| In. | inches | 25.4 | millimeters | mm |
| ft | feet | 0.305 | meters | m |
| yd | yards | 0.914 | meters | m |
| mi | miles | 1.61 | kilometers | km |
| **AREA** | | | | |
| $in.^2$ | square inches | 645.2 | square millimeters | $mm^2$ |
| $ft^2$ | square feet | 0.093 | square meters | $m^2$ |
| $yd^2$ | square yard | 0.836 | square meters | $m^2$ |
| ac | acres | 0.405 | hectares | ha |
| $mi^2$ | square miles | 2.59 | square kilometers | $km^2$ |
| **VOLUME** | | | | |
| fl oz | fluid ounces | 29.57 | milliliters | mL |
| gal | gallons | 3.785 | liters | L |
| $ft^3$ | cubic feet | 0.028 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.765 | cubic meters | $m^3$ |
| NOTE: volumes greater than 1,000 L shall be shown in $m^3$ | | | | |
| **MASS** | | | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams (or "metric ton") | Mg (or "t") |
| **TEMPERATURE (exact degrees)** | | | | |
| °F | Fahrenheit | 5 (F-32)/9 or (F-32)/1.8 | Celsius | °C |
| **ILLUMINATION** | | | | |
| fc | foot-candles | 10.76 | lux | lx |
| fl | foot-Lamberts | 3.426 | candela/$m^2$ | cd/$m^2$ |
| **FORCE and PRESSURE or STRESS** | | | | |
| lbf | poundforce | 4.45 | newtons | N |
| lbf/$in.^2$ | poundforce per square inch | 6.89 | kilopascals | kPa |

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

## SI* (Modern Metric) Conversion *(continued)*

| APPROXIMATE CONVERSIONS TO SI UNITS | | | | |
|---|---|---|---|---|
| **SYMBOL** | **WHEN YOU KNOW** | **MULTIPLY BY** | **TO FIND** | **SYMBOL** |
| **LENGTH** | | | | |
| mm | millimeters | 0.039 | inches | in. |
| m | meters | 3.28 | feet | ft |
| m | meters | 1.09 | yards | yd |
| km | kilometers | 0.621 | miles | mi |
| **AREA** | | | | |
| $mm^2$ | square millimeters | 0.0016 | square inches | $in.^2$ |
| $m^2$ | square meters | 10.764 | square feet | $ft^2$ |
| $m^2$ | square meters | 1.195 | square yards | $yd^2$ |
| ha | hectares | 2.47 | acres | ac |
| $km^2$ | square kilometers | 0.386 | square miles | $mi^2$ |
| **VOLUME** | | | | |
| mL | milliliters | 0.034 | fluid ounces | fl oz |
| L | liters | 0.264 | gallons | gal |
| $m^3$ | cubic meters | 35.314 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.307 | cubic yards | $yd^3$ |
| **MASS** | | | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.202 | pounds | lb |
| Mg (or "t") | megagrams (or "metric ton") | 1.103 | short tons (2000 lb) | T |
| **TEMPERATURE (exact degrees)** | | | | |
| °C | Celsius | 1.8C+32 | Fahrenheit | °F |
| **ILLUMINATION** | | | | |
| lx | lux | 0.0929 | foot-candles | fc |
| $cd/m^2$ | candela/$m^2$ | 0.2919 | foot-lamberts | fl |
| **FORCE and PRESSURE or STRESS** | | | | |
| N | newtons | 0.225 | poundforce | lbf |
| kPa | kilopascals | 0.145 | poundforce per square inch | $lbf/in^2$ |

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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# LIST OF ACRONYMS

| | |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| ADA | Americans with Disabilities Act |
| ADOT | Arizona Department of Transportation |
| ATDM | active transportation and demand management |
| ATSPM | automated traffic signal performance measure |
| CATT | Center for Advanced Transportation Technology |
| CAV | connected and autonomous vehicle |
| CCTV | closed-circuit television |
| CMM | capability maturity model |
| CMP | congestion management process |
| CMS | changeable message sign |
| CVO | commercial vehicle operator |
| DMS | dynamic message sign |
| DOT | department of transportation |
| EMS | emergency medical service |
| EOC | emergency operations center |
| ETC | electronic toll collection |
| EV | electric vehicle |
| FAST | Freeway and Arterial System of Transportation |
| FHWA | Federal Highway Administration |
| HOT | high-occupancy toll |
| HOV | high-occupancy vehicle |
| ICM | integrated corridor management |
| ICS | incident command structure |
| IPT | investment prioritization tool |
| IT | information technology |
| ITS | intelligent transportation system |
| ITSFM | ITS facility management |
| LOS | level of service |
| LOTTR | level of travel time reliability |
| MaaS | mobility as a service |
| MCDOT | Maricopa County Department of Transportation |
| MC-85 | Maricopa County Route 85 |
| MOD | mobility on demand |
| MOU | memorandum of understanding |
| MPH | miles per hour |
| MPO | metropolitan planning organization |

# LIST OF ACRONYMS *(continued)*

| | |
|---|---|
| MTP | metropolitan transportation plan |
| NHS | National Highway System |
| NHTS | A National Highway Traffic Safety Administration |
| NIMS | National Incident Management System |
| PTI | planning time index |
| QR | quick reference |
| RACI | responsible, accountable, consulted, and informed |
| RADS | Regional Archived Data System |
| RITIS | Regional Integrated Transportation Information System |
| RSU | roadside unit |
| RWIS | road weather information system |
| SHRP2 | second Strategic Highway Research Program |
| SHSMP | State Highway System Management Plan |
| SOV | single-occupancy vehicle |
| SWZ | smart work zone |
| TAMP | transportation asset management plan |
| TDM | transportation (or traffic or travel) demand management |
| TIM | traffic incident management |
| TIP | transportation improvement program |
| TIRC | traffic information for road closure |
| TMC | transportation (or traffic) management center |
| TMS | transportation management system |
| TOAST | Traffic Operations Assessment Systems Tool |
| TPM | transportation performance management |
| TSMO | transportation systems management and operations |
| TTR | travel time reliability |
| TTTR | truck travel time reliability |
| UPWP | unified planning work program |
| V/C | volume to capacity |
| VMT | vehicle-miles traveled |

# FOREWARD

The Federal Highway Administration (FHWA) first published Planning for Transportation Systems Management and Operations: A Practitioner's Reference in 2010 (the Reference – FHWA-HOP-10-027), and the publication was on the leading edge of a national shift to performance-based planning and transportation performance management. The Reference has been a popular guide for transportation agencies looking to incorporate operations into planning and to better plan for operations. It has helped FHWA provide leadership and education for metropolitan planning organizations (MPOs), State departments of transportation (DOTs), and other agencies in planning for operations across the country.

The past decade has seen tremendous changes to the transportation operations landscape. This update replaces the prior version of the Reference that was published in 2010 to reflect these changes and better prepare transportation organizations for the broader responsibilities associated with planning for transportation systems management and operations (TSMO) to support effective system operations and sustain programs and services. The Reference retains those elements that provide support for practitioners in identifying operations objectives, developing performance measures, collecting supporting data, and establishing TSMO strategies to meet operations objectives. The target audience for the Reference is anyone involved in planning for operations, including transportation planners and operations staff at MPOs, State and local DOTs, and transit agencies. The Reference is also applicable to other system operators such as toll authorities and private-sector-managed lane operators. Key updates to the Reference include:

- A revised TSMO lifecycle planning model to reflect additional activities such as program and project development and ongoing operations, monitoring, and evaluation
- Broadening the geographic scope of TSMO planning to include statewide, regional, corridor, and local contexts
- A new section (Section 2) focused on emerging issues in TSMO
- An expansion of the menu of operations objectives, including safety, resiliency, sustainability, and emerging mobility services (Section 4)
- Adding excerpts of various planning and programming documents to illustrate real-world examples of incorporating TSMO by using a performance-based approach (Section 5)

**Changes to the Transportation Operations Landscape**

Much has changed since the *Reference* was released in 2010, including the following:

***The audience has changed.*** Since 2010, TSMO has become a mainstream practice for many agencies. The Reference has a broader audience of practitioners who are more sophisticated in their own approaches. Planning for operations is now practiced at multiple geographic scales, and practitioners can find TSMO programs at State, metropolitan, and local levels. Some programs are even corridor based.

***TSMO programs are in place.*** Many States and regions have well-established TSMO and intelligent transportation system (ITS) programs, infrastructures, and procedures. However, TSMO is a holistic approach to operations, and agencies should consider it not just during implementation or major upgrades to an entire system or on a project-by-project basis. Agencies should consider TSMO from early in the planning process until well after implementation when it comes to ongoing system management and the long-term operation, maintenance, and asset management of devices and facilities.

***Transportation agencies are placing greater focus on holistic system management.*** Transportation agencies are increasingly looking to get the most from their existing facilities, evolving from primarily deploying projects to viewing day-to-day operations and TSMO programs, strategies, and services as increasingly vital parts of delivering their missions.

***Agencies are more actively managing the system.*** Agencies are increasingly using dynamic management strategies—such as active transportation and demand management and integrated corridor management—to more proactively address current or impending performance issues about the transportation system.

***Technology and data have matured.*** Smartphones and in-vehicle information and entertainment systems are replacing dedicated Global Positioning System navigation units and changeable message signs (CMS) as trip-planning, route guidance, and traveler information tools. Several new data collection methods such as Bluetooth, Wireless Display, side-fire radar, mobile devices, drones, crowdsourcing, and commercial subscription services have emerged that can support TSMO performance measures and strategies. The private sector offers a range of new high-resolution data types such as vehicle trajectories. New data management and analytical tools help convert or translate data into information that is valuable to planning for TSMO.

***Travel options, mobility service providers, and vehicle capabilities have advanced.*** The advent of connected and autonomous vehicles (CAVs) means that operational strategies are impacted by the capabilities built into vehicles. CAVs have the potential to smooth traffic flow, reduce crashes, and improve system efficiency, serving as extensions of TSMO strategies. At the same time, new transportation modes have emerged under the umbrella of mobility on demand (MOD) and mobility as a service (MaaS), including electric scooters and bicycles, transportation network companies, trip planning and scheduling apps, and supportive communication infrastructure. In some cases, transit providers have been developing partnerships with the private sector to fill in gaps in their networks, serve special populations, or provide last-mile service.

***Industry knowledge has progressed.*** Researchers and practitioners are now linking safety more closely to operations strategies. The Highway Safety Manual[1] provides a new tool for predicting the impact of safety-focused strategies. Likewise, some researchers have studied the effectiveness of TSMO strategies on safety measures. The second Strategic Highway Research Program (SHRP2) was in progress when the original Reference was written. SHRP2 has since released several products and tools related to TSMO, such as the Organizing for Reliability projects and the reliability data and analysis tools available through SHRP2 Solutions.[2] The compilation of TSMO knowledge and the formalization of TSMO as a core program within transportation agencies are also reflected in the development of the AASHTO [American Association of State Highway and Transportation Officials] Transportation Operations Manual.[3] This first-of-its-kind resource for operations provides an approach agencies can consider to incorporate TSMO into their agencies' strategic, programmatic, and tactical plans and processes.

***Access to data has changed.*** Growth in mobility on demand (MOD), P3, and other initiatives increases the amount and types of available transportation-related data. Public agencies may have difficulty accessing the data due to more restrictive data-sharing practices. Some private companies do not share data with public agencies because they maintain it as proprietary and use it for revenue generation purposes. Others are willing to share data with public agencies in exchange for data collected by the public agencies, such as construction schedules.

1 https://www.highwaysafetymanual.org/Pages/default.aspx

2 For additional information on SHRP2 Reliability solutions, see https://ops.fhwa.dot.gov/shrp2/index.htm.

3 https://store.transportation.org/Item/CollectionDetail?ID=246

***TSMO-related program goals have expanded.*** Prior emphasis for TSMO was on congestion management. Increasingly, TSMO is being seen as a valuable tool to support broader transportation and societal objectives. The need to address such factors as climate change, infrastructure resilience, reliability, and travel time and to consider the equity impacts of transportation is proliferating as regional goals and motivations among State and local agencies. In addition, safety is a key goal for many TSMO programs. These increasingly important program goals will influence operations objectives and planning for TSMO.

***TSMO program plans are proliferating.*** State and local DOTs and MPOs are developing TSMO program plans to guide program activities and the strategic direction of TSMO for States, regions, and localities. The Reference can readily support TSMO program planning through Quick Reference (QR) sheets, and making this connection will significantly broaden the impact of the Reference.

***Transportation performance management is becoming more prominent.*** State DOTs and MPOs use transportation performance management (TPM) as an overarching framework to manage the performance of their transportation systems in coordination with Federal performance management requirements.[4] Agencies use TPM to inform investment and policy decisions toward national performance goals.[5] The Reference helps integrate the performance measures established by FHWA in the areas of safety and system performance, since these are a focus of State DOTs and MPOs, and this document, Planning for Transportation Systems Management and Operations Within Corridors: A Desk Reference, offers examples of supplementary performance measures that State and local agencies can use to initiate, manage, and refine TSMO programs.

***Integration is becoming more widespread.*** Integration is occurring across institutions, modes, public/private areas, technology implementation, and systems management and operations. Integrated corridor management is an example of the growing emphasis on integration that has occurred over the past decade. Regional coalitions continue to enable the integration of TSMO across jurisdictional boundaries and transportation modes, and agencies are giving greater consideration to and placing more emphasis on complete trips as being more reflective of how people travel. A need has arisen for integration between TSMO and related initiatives such as Complete Streets[6] and Vision Zero.[7]

**Overview of the *Reference***

*Planning for Transportation Systems Management and Operations: A Practitioner's Reference* is a resource designed to enable transportation planners, operators, and others involved in TSMO to more effectively plan by identifying operations objectives, performance measures, strategies, implementation, and management considerations. It offers practitioners a menu of options for incorporating operations into plans (formal and informal) through an organized collection of sample operations objectives and performance measures. It also features excerpts from an example transportation plan, illustrating the results of an objectives-driven, performance-based approach to planning for operations at the program, system, and project levels. In addition, it offers excerpts of performance-based elements of transportation improvement programs, an MPO work program, and an asset management plan to illustrate a broader approach to planning for TSMO. The collection of operations objectives and the plan excerpts can be used to inspire discussion among operations-planning partners as they work to develop their own operations objectives and plans that reflect this approach. The *Reference* also provides brief discussions of important topics in planning for TSMO such as system management, project prioritization. and sustaining TSMO programs and services over the long term.

Most readers will find that this document is most useful as a reference whereby they identify the topic or topics of interest and refer to that section or sections of the document rather than read the

4 For more details, see 23 U.S.C. 150(a), 23 CFR 450.206(c), and 23 CFR 450.306(d).

5 For more details, see 23 U.S.C. 150(b).

6 https://highways.dot.gov/public-roads/winter-2023/complete-streets-prioritizing-safety-all-road-users

7 https://highways.dot.gov/safety/zero-deaths

document in its entirety. The reader is encouraged to use the table of contents to locate information of interest.

Section 1: Introduction and Section 3: Developing Operations Objectives offer background to the *Reference* and the objectives-driven, performance-based approach. These sections are helpful in orienting the reader to the information found in the remainder of the document.

Section 2: Key Topics in TSMO describes new issues that have emerged since the first edition of the *Reference* and is for the reader interested in understanding emerging issues in planning for and sustaining TSMO and some potential solutions. It describes such topics as the use of new TSMO data sources, developing the capabilities to support planning for TSMO, sustaining TSMO after initial implementation, and TSMO project prioritization.

Section 4: Menu of Operations Objectives is for the reader interested in creating operations objectives and performance measures to be included in planning documents. This section provides an overview of the categories of objectives to be found in the QR sheets of the appendix.

Section 5: Example Transportation Plan provides readers examples when developing or updating a plan. The examples reflect the use of an objectives-driven, performance-based approach to planning for operations and its effects on the content and focus of a transportation plan. Sections of a plan offer an illustration of how a plan incorporates this approach while acknowledging that no single format will fit all regions. Excerpts of this plan have been tailored for three levels of operations planning—basic, advancing, and comprehensive—to allow readers from a range of regions to find useful examples. The section also contains excerpts of other planning-related documents incorporating TSMO such as transportation improvement program (TIP) and the unified planning work program (UPWP).

Section 6: Supplemental Resources gives readers a list of other sources on which to rely for additional information or assistance.

Finally, the appendix contains a collection of QR sheets that hold operations objectives and their associated performance measures, data needs, and TSMO strategies. The information sheets are organized according to desired system performance outcomes (e.g., efficiency and reliability) and operations areas (e.g., arterial management, work zones, incident management, emergency management). Each QR sheet gives one or more operations objectives focused on a specific topic, such as System Efficiency: Extent of Congestion. Performance measures needed to assess progress toward those objectives are given along with a list of anticipated data needs. Potential data resources or necessary partners are listed, as is a short description of TSMO strategies to consider in achieving the objectives.

## *Reference* User's Guide

This *Reference* is meant to assist you, the reader, in cultivating an objectives-driven, performance-based approach to planning for operations in your area. This quick user's guide will help you in accomplishing your goals as you turn to this *Reference*.

The *Reference* is organized into six sections and an appendix.

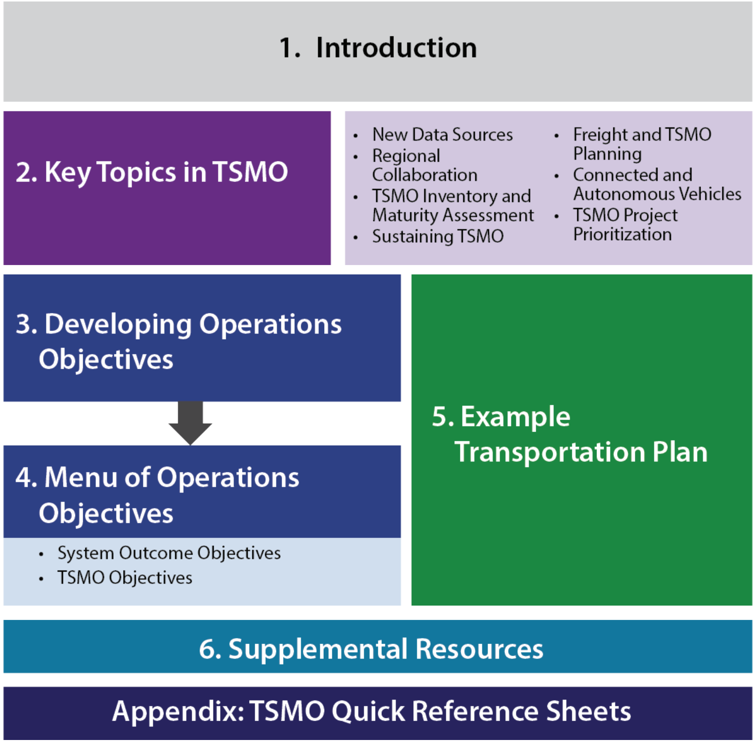


Figure 1. Outline. Reference sections.

Source: FHWA.

**Section 1**

Introduction: Provides a general introduction with an overview of the *Reference*, its contents, and the intended audience. This section is applicable to all readers.

**Section 2**

Key Topics in TSMO: Discusses emerging issues that were not part of the previous *Reference*. This section will be applicable to different audiences depending on the topic area. For example, planners may be interested in new data sources, regional collaboration, freight planning, and connected and autonomous vehicles, while engineers may be more interested in new data sources, regional collaboration, and sustaining TSMO. Managers and executives are most likely to be interested in TSMO maturity assessments and sustaining TSMO.

**Section 3**

Developing Operations Objectives: Gives the fundamentals of developing operations objectives, a cornerstone of the objectives-driven, performance-based approach to planning for TSMO.

**Section 4**

Menu of Operations Objectives: Provides an overview of the QR sheets, which are in the appendix. The objectives in the QR sheets generally fall into two groups: system-outcome oriented and TSMO-strategy focused. The objectives within the TSMO strategy areas are primarily activity based. Within those groups, the objectives are organized into specific outcome and TSMO strategy categories.

System Outcome Objectives

- Efficiency
- Reliability
- Mobility Options and Equity
- Sustainability
- Resiliency
- Safety

TSMO Strategy Objectives

- Arterial Management
- Emergency Management
- Emerging Mobility Services
- Freeway Management
- Freight Management
- Managing Technology Deployment
- Special-Event Management
- Traffic Incident Management
- Transit Operations and Management
- Transportation Demand Management

Managers and planners are more likely interested in system objectives, while TSMO objectives help engineers and planners with TSMO implementation.

**Section 5**

Example Transportation Plan: Provides samples from an illustrative transportation plan to show what operations-related elements of a plan could look like when developed with an objectives-driven, performance-based approach. This plan covers a range of potential planning activities—including long-range planning—and may address some of the emerging issues described in Section 2. This section contains illustrative examples of how organizations have included TSMO in their plans, transportation improvement programs, and unified planning work programs. Section 5 will be of interest to planners or anyone tasked with preparing a plan that involves TSMO.

**Section 6**

Supplemental Resources: This section lists other sources on which to rely for additional information or assistance.

**Appendix**

Offers the reader numerous examples of operations objectives and their associated performance measures, data needs, and other related information. The information is organized in QR sheets.

The remainder of the user's guide will lead you to specific sections of the *Reference* based on your purpose for going to this tool. On the next page are a list of reasons for going to the *Reference* and descriptions of how to use the tool based on those reasons (table 1).

Table 1. Guide for using the ***Reference*** based on reader's purpose.

| Purpose for Going to the *Reference* | Recommended Actions |
|---|---|
| Answer the question, What is an objectives-driven, performance-based approach? | Read Section 1.2. |
| Get ideas for operations objectives to be included in a transportation plan (or supporting operations-planning documents). | Go to the QR sheets in the appendix. This section contains a wide range of operations objectives, which are organized by outcome and TSMO area. |
| Find an operations objective for a specific TSMO area such as traveler information. | Go to Section 4. Look for an objectives category matching TSMO areas of interest. Use the QR sheet numbers to look up the sheets corresponding to that TSMO area in the appendix. |
| Learn what performance measures and data would be needed to track an operations objective. | Go to Section 4. Look for an objectives category matching the operations objectives and then go to the QR sheet containing the operations objective for the performance measure and data information. |
| Find potential TSMO strategies to help improve transportation system efficiency, reliability, sustainability, safety, resiliency, or mobility options and equity. | Examine the TSMO strategies listed in the QR sheets in the category of system efficiency, reliability, or options.<br>Refer to Section 4: Menu of Operations Objectives and look for operations objective sheets that correspond to the system outcome category of interest. |
| See an example of how to shape the operations-related portions of the transportation plan to incorporate selected operations objectives and performance measures. | Read Section 5 to see excerpts of an example plan incorporating operations objectives. |
| Learn more about how to sustain TSMO after initial implementation. | Read Section 2.4 to learn about topics related to sustaining TSMO such as funding, workforce needs, and technology lifecycle management. |

Source: FHWA.

# 1 SECTION 1: Introduction

## 1.1 Purpose of the Reference

This *Reference* is designed as a practical resource for transportation organizations and their partners—including MPOs, State departments of transportation (DOTs), transit agencies, and local governments—to advance TSMO in the transportation planning process as well as in programming, project development, implementation, and TSMO plan development. It recognizes the wide diversity of geographic contexts in terms of size, growth, and transportation needs. Consequently, it is designed with flexibility in mind. The information contained in this document should help support efforts by agencies to incorporate operations objectives, performance measures, and TSMO strategies suitable to their unique circumstances and needs in their plans and programs. This *Reference* gives practitioners tangible examples of operations objectives and performance measures that can be drawn from, in whole or in part, to develop plans. In addition, the *Reference* contains excerpts from an example plan showing how a transportation plan would incorporate operations by using operations objectives, performance measures, and TSMO strategies.

## 1.2 Planning for TSMO

As concern grows about the overall performance of our transportation system, transportation organizations around the country increasingly see operational improvements as serving an important role in addressing transportation challenges. In most urban areas, traffic congestion now occurs more frequently throughout the day and on more roadways than in the past. Funding for major new highway and transit capacity projects is limited, and the time it takes to plan and construct new infrastructure means that it can be years or decades to realize their effects. At the same time, unreliable travel times in multiple modes are caused by incidents, weather conditions, special events, and other factors that require more-immediate solutions and are not resolved solely through transportation infrastructure. Effective multimodal transportation solutions are needed to remain competitive in a global economy, address climate change, and increase equity. The public is increasingly calling for greater government transparency, travel options, and information to make travel decisions.

TSMO helps agencies maintain and even restore the operational performance of the existing transportation system quickly and cost effectively. TSMO is a diverse set of strategies designed to optimize the performance of the existing transportation system. The strategies allow for a more immediate response to traveler concerns than capacity projects offer while improving the reliability, security, and safety of the multimodal transportation system. While operations strategies focus primarily on improving system efficiency, reliability, and mobility options, these strategies often have important safety, equity, economic, resiliency, and sustainability benefits as well. For instance, improving operations through better work zone management, weather information, and traveler information can help reduce crashes and improve safety. Since incidents are major sources of unreliable travel times, strategies to improve system operations can include safety strategies that reduce crashes.

Traditionally, the transportation planning process has not focused significant attention on transportation operations. Given the challenges facing the transportation system, the availability of new technologies and data, the emergence of connected and automated vehicles, and public expectations for real-time travel information and travel time reliability, planning for TSMO is increasingly being recognized as an important element of the transportation planning process.

Moreover, Federal transportation regulations specifically require that metropolitan transportation plans include "operational and management strategies to improve the performance of existing transportation facilities to relieve vehicular congestion and maximize the safety and mobility of people and goods."[8] Federal regulation also requires the "consideration and implementation of projects, strategies, and services that will address" 10 planning factors, including one to "[p]romote efficient system management and operations" in the metropolitan and statewide and nonmetropolitan planning processes.[9] Addressing these challenges requires a new way of doing business: a strategic and informed approach to planning and funding for TSMO.

The next section will describe how planning for TSMO occurs in each of the overarching phases of transportation decisionmaking.

## 1.3 An Objectives-Driven, Performance-Based Approach

### Approach Overview

The Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) promote the use of an objectives-driven, performance-based approach to planning for operations as an effective way to integrate operations in transportation plans. The approach shifts transportation professionals from a project-based approach focused on addressing isolated problems to an objectives-driven, performance-based approach. It focuses on working toward desired system performance outcomes. This approach recognizes that what is measured matters in decisionmaking, and setting specific, measurable performance objectives will facilitate incorporating operations strategies into plans, programs, and projects. This approach is also known as the *performance-based planning and programming approach*. Planning for operations may be conducted as part of a larger, performance-based planning and programming process or as an individual effort. The FHWA Office of Planning, Environment, and Realty has a suite of informational materials available online to support transportation professionals in using this approach.[10] This approach supports transportation performance management and can be part of an agency's strategic approach to use system information to achieve national performance goals.[11]

A key element of this approach is developing operations objectives that state what the area's stakeholders plan to achieve regarding the operational performance of the transportation system. Operations objectives are included in transportation plans and guide the process for incorporating TSMO strategies and tactics into the plan and the transportation improvement program (TIP). These objectives provide specific, measurable, agreed-upon statements of system performance that can be tracked and inform cyclical investment decisions. Operations objectives specify a target to be reached within a set time period. This combines the objectives and targets that are separate in the typical performance-based planning and programming approach.

A plan developed using an objectives-driven, performance-based approach for operations provides a direct connection between operations objectives and project selection. The congestion management process (CMP) uses an objectives-driven, performance-based approach to plan for congestion management. The CMP and planning for operations are often combined in metropolitan regions.[12]

The objectives may relate to such issues as congestion, unreliable travel times, access to traveler

8 See 23 CFR Part 450.324(f)(5), https://www.ecfr.gov/current/title-23/chapter-I/subchapter-E/part-450.

9 See 23 CFR Part 450.206 (a) and (b); 23 CFR 450.306 (a) and (b).

10 FHWA. n.d. "Performance Based Planning and Programming" (web page). https://www.fhwa.dot.gov/planning/performance_based_planning/, accessed October 7, 2022.

11 FHWA. 2021. "What Is TPM?" (web page). https://www.fhwa.dot.gov/tpm/about/tpm.cfm, last accessed October 6, 2022.

12 For more information about the congestion management process, see https://www.fhwa.dot.gov/planning/congestion_management_process/.

information, emergency response time, incident management coordination, and transit operations.

An objectives-driven, performance-based approach to planning for operations includes the elements in the following list, conducted in collaboration among planners, transportation providers, operators, and other stakeholders. Figure 2. Flow Chart. An objectives-driven, performance-based approach to planning for TSMO. illustrates how one element leads to the next in the objectives-driven performance-based approach. Broadly speaking, planning for operations is part of the entire project lifecycle: transportation planning (first four elements of approach), programming, project development, operations, and monitoring, evaluation, and reporting.

- Goals and motivation. Establish one or more goals that focus on efficiently managing and operating the transportation system. Inventory existing capabilities, assets, resources, and current system performance. This step is the starting point for operations stakeholders in the area to define objectives.
- Operations objectives and performance measures. Develop operations objectives—specific, measurable statements of performance to include in plans—that will lead to accomplishing the goal or goals. Operations objectives include specific targets and time frames. Identify performance measures to track progress toward the objectives.
- Systematic process to develop and select TSMO strategies. Using a systematic approach, identify performance needs, gaps, and opportunities for operational improvement. Based on this information, identify TSMO strategies to address the needs and meet your operations objectives. Systematically evaluate and select TSMO strategies within fiscal constraints for inclusion in statewide, metropolitan, corridor, or local transportation plans or TSMO strategic and program plans. The strategies may be either stand-alone or integrated into other transportation projects.
- Programming. Select TSMO strategies for funding, including program investments, collaborative activities, and projects. Identify funding resources and schedule implementation. TSMO strategies should be included in programming documents such as the transportation improvement program.
- Project development. Develop the scope, preliminary design, and final design for the TSMO strategy, as appropriate. Project development includes incorporating TSMO into project alternatives and design as well as developing TSMO projects. Organizations may develop operations plans during this stage to define how the TSMO strategy will operate, including the roles of institutions and people. An operations plan can be developed collaboratively with operations stakeholders to establish a common vision and framework for operations after initial implementation of the strategy.
- Operations. Following initial implementation, optimize and sustain the TSMO activities. This element may include plans to manage the lifecycle of the TSMO assets or maintain interagency operations agreements.
- Monitoring, evaluation, and reporting. Monitor and evaluate the effectiveness of implemented strategies and report progress toward meeting operations objectives. This element supports optimizing the performance of the transportation system. Including a monitoring activity as part of the project development process ensures that progress toward objectives can be verified and helps link policy-level goals with engineering-level strategies and tactics.

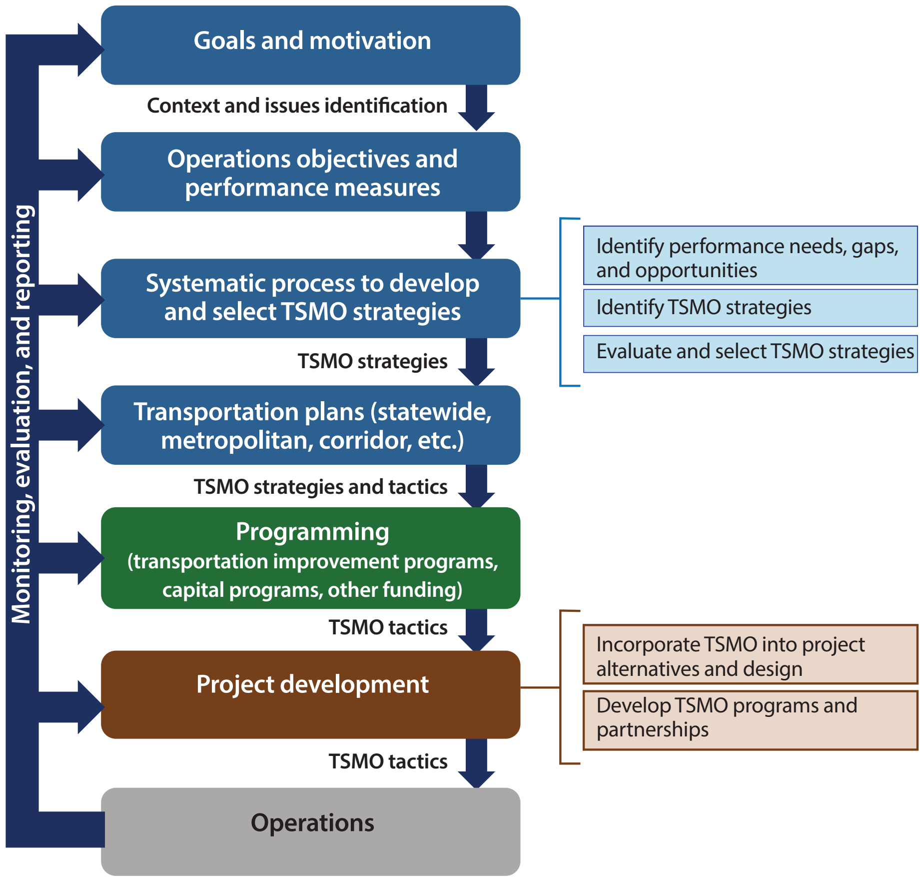


Figure 2. Flow Chart. An objectives-driven, performance-based approach to planning for TSMO.
Source: FHWA.

### Relationship to Systems Engineering Processes and the Intelligent Transportation System Regional Architecture

Overall system management and operations in general—and many TSMO strategies in particular—are supported by ITS. Planning for TSMO considers existing, available ITS elements and ITS elements that may be needed to support effective system management and operations. The ITS architecture defines the physical systems, ownership, functions, and data flows that enable the delivery of strategies and services supported by ITS. The architecture represents the ITS elements and relationships to one another, system operators and other users, and how all elements work together to support TSMO. As needs change and operations planning is updated in an agency or region, TSMO planning can identify the inputs needed for updating the ITS architecture. The systems engineering process then helps refine those needs into specific requirements to support ITS-related project implementation. Planning for TSMO and TSMO program plans identify needs and gaps that, when related to ITS elements, can then be considered in development of the ITS architecture in accordance with 23 CFR Part 940.

The objectives-driven, performance-based approach is integral to the ITS architecture and systems engineering process. The regional ITS architecture is the framework for both institutional and technical integration in a particular region, including statewide. Elements in the architecture tie to what need in the TSMO plan they are addressing or supporting. The overall systems engineering process builds on operations planning conducted through the objectives-driven, performance-based approach. The systems engineering process typically focuses on more-detailed, project-level analyses, including defining the concept of operations and system requirements. The objectives-driven, performance-based approach to planning for TSMO supports the systems engineering process by clarifying user needs and program and project objectives and performance targets.

For many TSMO strategies, both the ITS architecture and the related policies, processes, hardware, and software are likely to need more frequent review as technology improvements in both capabilities and efficiency become available and as system users have increased expectations regarding system performance. Consequently, systems engineering for TSMO strategies must employ a lifecycle approach, anticipating both frequent upgrades or modifications as new functions are added and with eventual obsolescence due to the emergence of more–cost effective and functionally superior alternatives.

In many cases, TSMO strategies not only require maintenance in the sense of caring for and as-needed repairing of hardware or software but also must be operated given that many TSMO strategies are dynamic and require monitoring and managing by either real-time systems or human operators (e.g., adaptive signal controls, dynamic traffic management). Lacking this real-time control, the benefits of TSMO strategies may not be fully realized. These lifecycle requirements are identified and incorporated into TSMO planning, as are policy and practice to result in performance improvements or needed functionality.

Any project seeking to use Federal transportation funds that includes ITS elements or connects with other federally funded ITS projects must be consistent with and included in the ITS architecture.[13]

## 1.4 Getting Started With the Approach

Using an objectives-driven, performance-based approach to plan for operations can seem daunting to transportation organizations that are just beginning to incorporate operations into their planning processes. Taking small steps toward building this approach can help make it accessible.

### Engage Operating Agencies in Your Area

A first step in the approach is simply to bring together operating agency managers to begin a dialogue about improving system performance. Operating agencies are typically already involved in the transportation planning process. However, it is important to engage day-to-day operating agency managers from a system operations perspective. Developing an interagency committee that focuses on improving TSMO that meets regularly has been an effective technique used by several MPOs and State DOTs to engage operators in coordinating TSMO. Transportation organizations can use this forum to determine system performance priorities in the area, operations objectives, data availability, and funding opportunities.

### Raise Visibility and Support of TSMO Among Decisionmakers

In preparing decisionmakers to commit to operations objectives, agencies should first raise their awareness of both system performance issues in the area and the value of operational improvements. In some areas, this has been done through presentations to MPO boards and transportation agency management. Other areas have used flyers and brochures to highlight the benefits that operational improvements bring at a relatively low cost and in a short timeframe. FHWA has several resources aimed at raising the

13 23 CFR 940.11(d). More information on the ITS architecture and systems engineering is available at https://ops.fhwa.dot.gov/int_its_deployment/sys_eng.htm.

awareness of TSMO among decisionmakers. This includes brochures on the benefits of TSMO and leadership forums for regional operations.[14]

### Develop One or More Goals That Focus on the Desired Operational Performance of the Transportation System

Establish one or more goals that focus on areas that can be supported by TSMO such as efficiently managing and operating the transportation system, improving safety, enhancing resilience, improving travel time reliability, or expanding travel choices, and incorporating these goals into planning. The goals provide a basis for developing the operations objectives and should reflect input from operators in the area, such as transit agencies, local DOTs, and micromobility operators. A goal is a broad statement that describes a desired end state. In the transportation planning process, goals stem from the values inherent in the vision for the area. The goals may be created during the development or an update of the transportation plan or in anticipation of the next update cycle.

### Develop a Small Number of Simple Operations Objectives

Work with operators in the area to develop a small number of operations objectives that accurately reflect what area stakeholders would like to achieve and can be achieved within a certain timeframe. The process of defining operations objectives also establishes parameters around the plans, roles, and responsibilities that operators and managers responsible for the day-to-day function and sustainability of operations programs need to consider. Development of operations objectives can begin with the baseline inventory, area or agency goals, and known operational issues. These operations objectives may initially be vague and then grow in specificity as the iterative process to define and refine the operations objectives advances. As the operations objectives become more precise, agencies may select performance measures to provide adequate information for planners, TSMO program managers, operators, and decisionmakers on progress toward achieving the identified objectives.

### Form the Operations Objectives

The following steps may help in developing operations objectives:

- Initially, focus on what to improve or sustain such as travel time reliability or incident clearance time. Develop an objective around an important issue—something that decisionmakers and the public care deeply about—to aid in getting buy-in and commitment to the objective.
- Select the area and time of focus, such as regionally significant arterials during peak hours.
- Identify what data is currently being collected and may be available for tracking the objectives. Based on this information, make the operations objectives more specific and link them to performance measures.
- As fiscal constraints are applied while developing the transportation plan or as resources available from other sources become known, revisit the operations objectives to ensure feasibility.

Collect baseline data for performance measures, and, as appropriate, introduce performance targets into operations objectives or adjust the targets with an understanding of baseline performance. In some cases, sustaining existing good performance may be the goal. Improvements may not always be feasible due to external constraints, travel demand growth, past optimization, etc.

### Use Operations Objectives To Identify and Select TSMO Strategies for Plans and Programs

Once operations objectives have been decided upon, an agency can use them to influence the

14 FHWA. 2022. "Organizing and Planning for Operations" (web page). https://ops.fhwa.dot.gov/plan4ops, last accessed October 7, 2022.

selection of projects and programs. In collaboration with agencies in the area, an agency's TSMO should identify and fully define within the plan the strategies that would help achieve the operations objectives. In selecting projects for funding, the agency should include as a significant prioritization factor the ability to contribute to achieving the operations objectives. The capabilities of the agency to determine the impact of projects on the operations objectives may begin at a rudimentary level and become more comprehensive over time as the organization improves its data resources and analytical tools.[15]

### Collect Data on Selected Performance Measures To Monitor and Report Progress Toward Objectives

Based on resource availability among the collaborating agencies, an agency may establish a regular schedule for collecting data on each performance measure. The difficulty of this element depends on the selection of operations objectives. Monitoring system performance could be sufficient to detect progress toward the selected operations objectives. Both to inform collaborating partners and decisionmakers and to maintain their interest, the agency should regularly report the results of the performance monitoring, whether as a simple memo distributed to the participating agencies and MPO board or as a glossy, full-color publication for the public. The agency can use the information to adjust investments or operations objectives that are no longer appropriate or beneficial.

## 1.5 Reference Structure

This *Reference* contains the following sections:

Section 1: Introduction. An overview of the objectives-driven, performance-based approach is provided in this section. It also features ideas for getting started with implementing the approach for regions that are just beginning to incorporate operations into their planning processes.

Section 2: Key Topics in TSMO. This section describes new issues that have emerged since the first edition of the *Reference*. The section describes topics such as the use of new TSMO data sources, TSMO project prioritization, and sustaining TSMO after initial implementation.

Section 3: Developing Operations Objectives. This section provides a brief background on characteristics of operations objectives and provides a hierarchy for considering and developing operations objectives that a plan might include.

Section 4: Menu of Operations Objectives. This section provides an overview of the categories of objectives found in the QR sheets of the appendix. The structure and definitions of the QR sheets are available in this section to allow readers to find operations objectives based on their particular interests.

Section 5: Example Transportation Plan. This section of the *Reference* provides examples from a transportation plan that illustrate the integration of operations using the objectives-driven, performance-based approach. Examples of applying the approach from basic, advancing, and comprehensive levels are given to provide readers with a stronger understanding of how the approach may affect their transportation plans. This section also contains excerpts from other planning and programming documents to illustrate the integration of TSMO.

15 FHWA. 2017. "Transportation Planning and Analysis Tools: Selecting the Right Tools To Optimize Outcomes." Publication No. FHWA-HOP-17-049. Washington, DC: FHWA. https://ops.fhwa.dot.gov/Publications/fhwahop17049/fhwahop17049.pdf, last accessed October 7, 2022.

Section 6: Supplemental Resources. The document ends with information on additional resources to help in advancing TSMO in the transportation planning process and other parts of the TSMO project and program lifecycle.

Appendix. TSMO Quick Reference Sheets. This section provides a set of one- to two-page QR sheets with sample operations objectives organized by desired system outcomes and TSMO area. In addition to operations objectives, the sheets contain associated performance measures, data sources, and sample TSMO strategies that an agency may consider to meet the objectives.

# 2 SECTION 2: Key Topics in TSMO

This chapter discusses topics that have emerged or that have become more significant since the first edition of the *Reference*. Key topics include technology advances, external markets, and industry best practices. Reviewing these topics at the outset of TSMO planning may benefit planners who seek to identify underrepresented stakeholders, consider data of growing value, and want to shape policy that is resilient to growing challenges. The topics in this chapter include (1) new and emerging data sources, (2) regional collaboration for data sharing and integration, (3) baselining the TSMO inventory and capability maturity assessment, (4) sustaining TSMO after initial implementation, (5) freight and TSMO planning, (6) connected and autonomous vehicle (CAV) considerations, and (7) TSMO project prioritization.

## 2.1 New and Emerging Data Sources

TSMO benefits from numerous advances in data, including location-based services, crowdsourced data, and connected vehicle transmissions. TSMO data sources measure congestion; safety; presence, intensity, and duration of incidents; adverse weather; and special events to support system operator intervention to restore effective transportation service. In general, new public data sources are becoming available that transportation system operators can leverage through data-sharing agreements and software-as-a-service models.

### New and Emerging Data Sources: Opportunities for TSMO Planning

- **Enhanced Performance Measurement in Planning Processes –** Agencies can use emerging data to analyze Federal and non-Federal performance measurement parameters and inform their planning and project selection processes. One example is congestion monitoring, a process that historically involved active sample data collection through the use of such equipment as loop detectors or side-fire radar. Congestion monitoring can now leverage emerging passive data sources—such as cellular phones—to calculate performance measures such as level of travel time reliability in near real time.
- **Expanded Potential Strategies –** Innovation in developing new TSMO strategies benefits from emerging data sources. By being able to monitor road conditions in real time, planners can quantify the benefit and costs of strategies such as traffic incident management and intelligent work zones. These strategies may have previously been challenging for agencies to include in capital funding programs because their benefits to road users could not be quantified.
- **Stakeholder Strategic Coordination –** Emerging data sources allow context of safety and mobility issues to be communicated with greater accuracy to multiple stakeholders. As an example, planners can bring a variety of data on recent past performance of a traffic incident management strategy to meetings to increase the ability to work with stakeholder agencies. As an example, an after-action review between planners and operations stakeholders can assess abnormal safety and mobility issues with time-stamped information, allowing partners to discuss how to improve real-time coordination and providing each agency opportunities for continuous improvement.
- **Public Transparency –** Emerging data sources reduce the burden on agencies to collect data for reporting to the public. This allows

agencies to focus on providing useful traveler information—such as the presence of events, dashboards of reliability, and movement analytics—by mode of travel. Traveler information can influence the public's mobility and travel choices. Planners can tailor the presentation of traveler information to each context so end users have information such as the appropriate times to start trips, receive cautions and updates about nearby crashes, and are alerted about potential impacts to other modes related to their trips.

### New and Emerging Data Sources: Advancing the Practice[16]

The following new data sources can help advance the practice of planning and implementing TSMO solutions:

- **Crowdsourced Incident and Congestion Data –** Crowdsourced data refer to algorithm-generated estimates of speed or public user inputs drawn from sources like fleet telematics, cellular phone locations, user entry into smartphones, and vehicle navigation systems. Data in this category allow transportation management center (TMC) operators, private-sector data providers, and mobility service providers to actively monitor slowdowns in near real time across wide coverage of the transportation system. Providers of these data often archive information, which allows for historical analytics to find predictive patterns in incident and congestion formation.
- **Connected Vehicle and Infrastructure Data –** Industry standards for connected vehicle and infrastructure data stipulate equipped vehicles communicate a basic safety message that includes position, speed, heading, acceleration, and status to other vehicles and roadside equipment.[17] Reporting of connected vehicle messaging can identify near-real-time safety concerns. Such frequent data allow for proactive implementation of traffic management strategies and incident response activity.
- **Signal Data and Automated Traffic Signal Performance Measures –** Traffic signal optimization is a long-standing operational strategy for agencies owning and operating traffic signal equipment. Historically, traffic signal optimization has required manual data collection at individual intersections, modeling, and manual travel time studies for evaluation. The capabilities of traffic signal controllers have advanced to include logging of high-resolution data. Agencies can evaluate this information in standardized formats called *automated traffic signal performance measures (ATSPMs)*. Open-source software and many private-sector products support high-resolution-data processing to provide ATSPMs. ATSPMs reduce the burden on engineers in actively evaluating the effectiveness of traffic signal timing, thereby transforming traditional signal retiming from reactive to proactive processes. Future advances in high-resolution signal data and ATSPMs may further enhance proven TSMO strategies such as traffic signal optimization.
- **Real-Time Trajectory Data –** System management often uses pre-trip and real-time

Figure 3. Image. Traffic signal.
Source: Thinkstock.

16 FHWA. 2019. *Considerations of Current and Emerging Transportation Management Center Data,* "Chapter 2. Emerging Data Sources." Report No. FHWA-HOP-18-084. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop18084/ch2.htm, last accessed October 7, 2022.

17 https://www.its.dot.gov/research_archives/connected_vehicle/pdf/JPO_cv_standards.pdf

traveler information to direct travelers to options that avoid congested conditions. The use of real-time trajectory data is an emerging tactic in support of TSMO because it enables reporting of individualized traveler information and allows transportation managers to confirm that drivers have adopted the recommendations. With revealed traveler preferences for diversion or other behavior decisions, system operators can modify TSMO strategies for future planned and unplanned congestion.

### New and Emerging Data Sources: Potential Issues To Address

- **Data Privacy and Security –** Advanced TSMO data sources may focus on vehicles' broadcasting and receiving high-precision locational and temporal data. An example is real-time trajectory data, which involve locating broadcasting devices at frequent intervals at the individual vehicle signature level. The challenges with this level of situational awareness are safeguarding travelers' personal identifiable information while providing them beneficial safety and operation information. Similarly, greater data precision makes the data sources more valuable to those with malicious intent. One solution is to promote industry data standards that private providers must adhere to when collecting and processing data.
- **Data Quality –** When agencies use TSMO from private partners, agencies relinquish control of data collection, storage, and access. Because private data sources are generally proprietary, agencies may not be able to get enough detail to review data quality. This puts the onus of data quality on the private data providers. Promoting industry data standards that private providers must adhere to may help ensure better data quality.
- **Data Sustainability –** The availability of new data sources has the potential to support ongoing performance monitoring and allow agencies to measure progress on a wide range of objectives. It is important for agencies to select objectives, define performance measures, and use supporting data that allow for year-over-year performance monitoring. Agencies may want to consider the future availability and comparability of data.
- **Operating Costs –** Agencies need to identify potential funding sources for ongoing operating costs. Purchasing field equipment is covered by capital funding streams, but vendor data services may fall into different funding streams in which data purchases may be harder to justify to management against competing priorities. In addition, public agencies need to consider the potential of vendor lock, a concept under which proprietary private data cannot be integrated with data from other companies, making the agency reliant on a single company.
- **Coverage Equity –** Private companies collect TSMO data to market the data to agencies while making a profit. As a result, data coverage decisions may be based solely on cost rather than the usefulness of data for operations decisions or geographic equity. Users with low incomes or limited digital footprints may be underrepresented, and data providers have little incentive to improve representation of these groups.
- **Data Management** – New data sources may generate datasets that are too large and varied for traditional data management techniques (figure 4). Modern data management techniques may provide agencies with more flexibility in handling these new and rapidly evolving data sources. National Cooperative Highway Research Program (NCHRP) Report 952 provides a roadmap for agencies wanting to transition to big-data management.[18]

18 National Academies of Sciences, Engineering, and Medicine. 2020. Guidebook for Managing Data from Emerging Technologies for Transportation. https://doi.org/10.17226/25844, last access October 7, 2022.

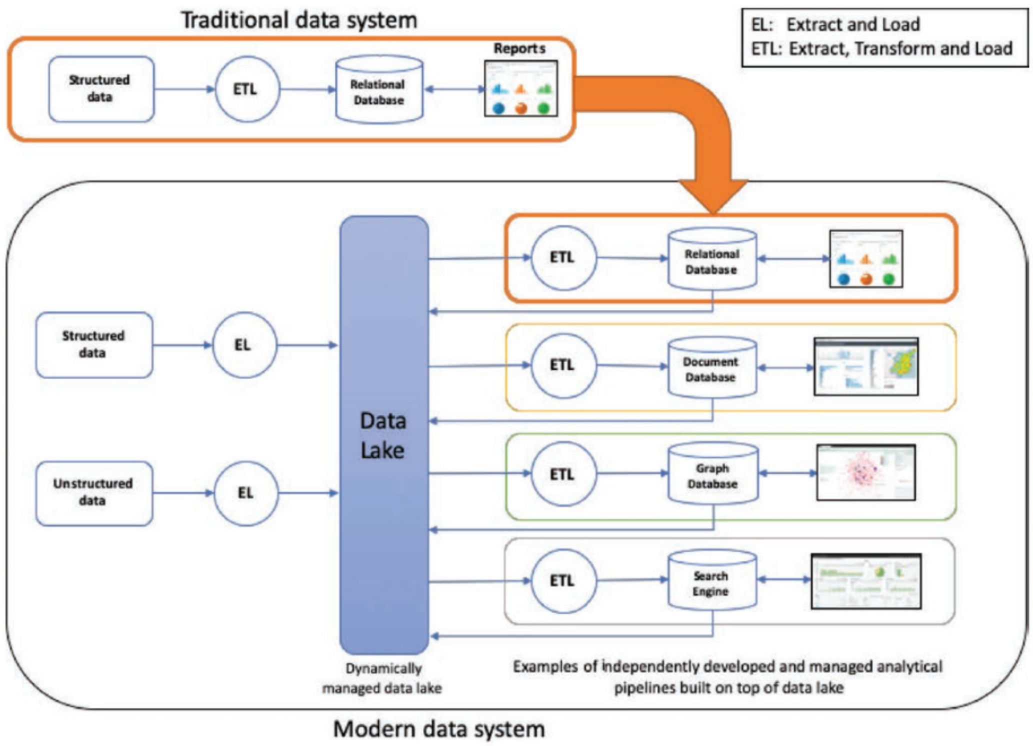


Figure 4. Diagram. Comparison of traditional and modern data systems.
Source: National Academies of Sciences, Engineering, and Medicine Guidebook for Managing Data from Emerging Technologies for Transportation, 2020.

## New and Emerging Data Sources: Examples of Implemented Solutions

- **Nevada DOT Incident Management**[19] – The Freeway and Arterial System of Transportation (FAST) is part of the Regional Transportation Commission of Southern Nevada (the regional MPO). FAST manages and operates the TMC and ITS system in southern Nevada in partnership with local member agencies and Nevada DOT. FAST uses a third-party artificial intelligence provider to integrate crowdsourced congestion data, connected vehicle data, and automatic-vehicle-location information with traditional data, such as from closed-circuit television (CCTV) cameras, to locate incidents. This has increased the efficiency of monitoring and dispatching freeway service patrols to incidents and has enhanced traveler information shared with the public.
- **Maryland DOT Trajectory Data Analysis**[20] – In coordination with the University of Maryland Center for Advanced Transportation Technology laboratory, Maryland DOT developed a standard data viewer for trajectory and trip data from a prominent, location-based services provider. The origin–destination type information is used to develop spatial and temporal coverage of turning movement volume and user delay for specific intersection movements. This use case has focused on recent historical analysis, but the data providers are trending toward releasing data with shortened latency, which may facilitate real-time evaluation in the future.
- **Texas DOT Freeway Service Patrol Analysis –** A Texas DOT district aggregated third-party crowdsourced data with crash data, computer-aided dispatch data, traffic volume data, and vehicle classification data to better understand

19 Nevada Department of Transportation. n.d. "Initiatives and Strategies" (web page). https://nvtsmo.com/initiatives-and-strategies/#imsoftware, last accessed October 7, 2022.

20 FHWA. 2019. "Chapter 2. Figure 19. Emerging Data Sources." *In Considerations of Current and Emerging Transportation Management Center Data*, Report No. FHWA-HOP-18-084. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop18084/ch2.htm, last accessed October 7, 2022.

the impacts of such incidents as secondary crashes and the effectiveness of its freeway service patrol in reducing them by analyzing aggregated data to enhance freeway service patrol programs. Aggregating and analyzing new and traditional data sources are providing better insights into the causes of congestion and opportunities to enhance operations.

### New and Emerging Data Sources: Next Steps

To incorporate new data into TSMO planning, agencies may consider the following steps:

- Inventory current data used.
- Identify data needs and gaps in data.
- Consider new data sources.
- Identify how data would be used.

## 2.2 Regional Collaboration for Data Sharing and Integration

Active system management benefits from regional collaboration in planning and operations as well as real-time or near-real-time data. Such timely data are necessary to determine operator interventions and provide traveler information. Active system management can also leverage archived data to make data-driven decisions to identify patterns and strategies for future management. Data collection is an ongoing responsibility of transportation system operators. The use of those data can benefit the entire ecosystem of transportation operators and stakeholders in a region if shared systematically. As system management matures, regional collaboration becomes more complex and involves merging different types of data (e.g., traffic, safety, weather, geometrics, transit schedules) to support multimodal solutions.

Regional collaboration is key for more than just data sharing. Successful implementation of system management strategies may include establishing regional data standards, agreements on agency roles during daily operations and incidents, resource sharing, and regional standards for operating strategies. This section focuses on accumulation, distribution, sharing, and actionable use of data, as well as the planning, implementation, processes, and regional collaboration that can help ensure use of these data. Further research may be needed for concepts on performance measurement and decision support.

### Regional Data Collaboration: Opportunities for TSMO Planning

- **Enhanced Objectives –** To strategically enhance the transportation system, agencies may want to establish specific and measurable outcomes. Data awareness increases a planner's capability to align these measures to a desired vision. As an example, shared data from on-scene responders allow regional planners to monitor and strategically reduce incident clearance times.
- **Stakeholder and Agency Alignment –** As data are shared among agencies and integration increases, collaborating parties learn how they can use the data and services among one another. If agencies jointly decide to collaborate, they may want to work out how to accomplish shared activity informally at first. Over time, a natural desire may arise to simplify the exchanges by maintaining consistency that can lead to formal data structures, sharing mechanisms, adopted roles and responsibilities, and policies.
- **Enhanced Project Development –** Data sharing and integration generate deeper insights into corridor operations. Regional collaboration early on can cast a vision that those insights are of strategic value and align with a master transportation system plan. As data sharing and integration become operational, regional coordination can foster how the new corridor insights are reapplied to planning studies, regional funding, multimodal projects, and projects that impact the public. Over time, regions can adopt projects that foremost benefit the regional vision for transportation through attainment of near-term objectives rather than traditional project selection that overemphasizes far-future demand.

- **Strategy and Tactic Monitoring and Evaluation –** The transportation industry has evolved from strictly long-term-alternatives analysis to real-time and near-term decisionmaking and projects. Positive, rapid monitoring and evaluation can help agencies identify unproductive transportation spending. Agency staff use regional collaboration for data sharing and integration to set expectations for how investments will be evaluated early.

## Regional Data Collaboration: Advancing the Practice

- **Regional Integrated Data Exchanges[21] –** Data exchanges use large-capacity data storage and complex processes to fuse varied data from multiple agencies. Through regional integrated data exchanges, agencies can better leverage data across partners for integrated and multimodal operations.
- **TMC Colocation –** Transportation system operations conducted from a centralized physical location among multiple agencies improve response because they reduce the time needed to notify and transact with partner agencies. They also break down data silos among agencies and promote regional problem solving. In the past few years, several agencies have practiced colocation as a strategy to facilitate regional collaboration.
- **Virtual TMCs –** The advancement of technology has expanded the capabilities of TMCs through virtual means. It was once necessary to be physically located at adjacent operator stations to quickly communicate responsibilities and to reference all available information. Increases in computing power, cloud storage use, and videoconferencing capabilities have enabled management centers to monitor, control, and manage their systems while including remote operators. Such centers may require regional collaboration in data sharing. Virtual TMCs can also improve regional collaboration in system management because these centers are built to have defined methods and procedures for communicating and assigning responsibilities, so participants are prepared for any role in which they may engage.

## Regional Data Collaboration: Potential Issues To Address[22]

- **Data Availability and Collection–** Transportation agencies range in sophistication—from collecting real-time data and storing these data in robust data systems to collecting relatively minimal data. Practices depend on the type of data collected, the sensitivity of data collected, staff capacity to use and manipulate data, and agency funding strategies. The first step in regional collaboration is securing the data necessary for operations at real-time or near-real-time intervals.
- **Funding –** Maintaining information technology (IT) hardware and investing in software can help ensure that data are available for sharing. Capital funding may be committed by a single agency, committed by a consortium of agencies, or acquired through grant programs. Funding may also involve multiple departments within an agency. For example, IT or information services may be in a separate department with separate funding and priorities. System maintenance can be more challenging to commit because of existing policies that govern agency funding uses—especially if multiple agencies are responsible for committing shares of the funding.
- **Communication –** Regional collaboration includes joint responses to events that need immediate attention. Agencies often have robust methods and policies to internally communicate data and responses. Once communication extends beyond a single agency network, added challenges to

21 Ohio. "Ohio Integrated Data Exchange." Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) application for FY 2017. https://ops.fhwa.dot.gov/fastact/atcmtd/2017/applications/ohiodot/index.htm, last accessed October 7, 2022.

22 Dhanesh Motiani, Neil Spiller, et al. 2014. *Advances in Strategies for Implementing Integrated Corridor Management (ICM)*, NCHRP Project 20-68A, Scan 12-02. Washington, DC: National Cooperative Highway Research Program of the Transportation Research Board. https://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-68A_12-02.pdf, last accessed in October 7, 2022.

developing an agreed-upon method of communication and the information that can be communicated may arise.[23] For example, clear communication among multiple agencies would be beneficial for a specific emergency with multiple responding agencies.

- **Institutional Policies –** State agencies, municipal agencies, transit agencies, and other stakeholders each have their own governing policies around data and network security. Developing a regional collaboration policy for data may include formal and binding agreements, with vested agencies taking on additional roles and responsibilities to operate in shared-data environments, or within defined data exchange policies, to avoid any partner agency from operating outside its institutional practices.
- **Staffing –** Creating and maintaining databases for multiagency operations may fall outside of traditional job descriptions. Staffing is a frequently cited challenge to adopting newer agency practices such as the upkeep of regional data collaboration.

## Regional Data Collaboration: Examples of Implemented Solutions

- **Live-Video-Sharing Agreements[24] –** Most State DOTs participate in video-sharing agreements with other agencies, the media, and the public. Sharing video streams helps first responders decrease incident response times, improves relationships and collaboration with other agencies, and promotes trust from the public. In order to formalize any data sharing, agencies may want agreements to identify partnership roles and usage terms. For example, Tennessee DOT has an access agreement for live-video and information sharing that provides general terms, user responsibilities, and liability clauses for agencies interested in sharing live video.
- **Regional Integrated Transportation Information System[25] –** The University of Maryland developed the Regional Integrated Transportation Information System (RITIS) as a platform for geographic monitoring of roadway conditions and performing advanced analytics of transportation data for four agencies in the Washington, DC, metro area. RITIS has since expanded to other geographies. RITIS is an example of a regional integrated data exchange because it permits data from a variety of sources to be entered into a common platform for review. For example, RITIS can use speed data to detect events, locate events through camera feeds, and store agency-created event records that partner agencies can review to identify the impact of events on their operations. RITIS is accessible through a data visualization interface. The platform uses cloud servers for data storage and fusion. As a result, the system is outside any agency's direct operation. As a third-party regional data integration system, RITIS allows partner agencies to leverage the platform's shared staffing. The tradeoffs are that the software becomes a service cost, and data-sharing agreements may be needed among agencies and the third-party vendor.
- **Metropolitan Area Transportation Operations Coordination[26] –** For road weather management, Maryland, the District of Columbia, and Virginia DOTs formed a partnership to share CCTV coverage and assist communications during winter weather operations. The Metropolitan Area Transportation Operations Coordination partnership helps the DOTs assess the road

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23 FHWA. 2010. *Information Sharing Guidebook for Transportation Management Centers, Emergency Operations Centers, and Fusion Centers. Report* No. FHWA-HOP-09-003. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop09003/index.htm, last accessed October 7, 2022.

24 FHWA. 2019. *Transportation Management Centers: Streaming Video Sharing and Distributio*n. Report No. FHWA-HOP-19-037. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop19037/index.htm, last accessed October 7, 2022.

25 The Eastern Transportation Coalition. 2022. "RITIS & PDA Suite" (web page). https://tetcoalition.org/projects/ritis-pda-suite/, last accessed October 7, 2022

26 FHWA. 2019. *Transportation Management Centers: Streaming Video Sharing and Distribution.* Report No. FHWA-HOP-19-037. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop19037/fhwahop19037.pdf, last accessed October 7, 2022.

network and enables consistent language when describing the transportation system status level to one another and the media. Data sharing allows agencies to effectively communicate to improve standard operating procedures and strengthen multiagency coordination.

- **Regional Archive Data System**[27] – The Regional Archive Data System (RADS) (figure 5) is an example of another solution not driven by a State DOT or university. Instead, RADS is coordinated by AZTech, a regional partnership among Federal, State, regional, county, and city agencies to improve traffic operations. RADS serves as a regional repository of ITS operational data from participating jurisdictions. RADS was started in the mid-1990s and has since evolved to:
  - Serve as a regional data repository that can facilitate the growth of regional ITS.
  - Generate new, shareable traveler information through data processing engines.
  - Provide new services to transportation operators and the traveling public.

Some of the new functions include provision of dynamic travel-time information through multiple platforms, integration of public-safety-related incident data, and distribution of traffic signal timing information.

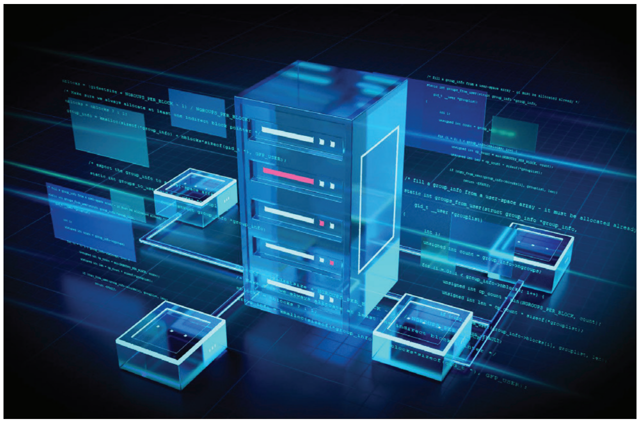

Figure 5. Image. Abstract image of data server.

Source: iStock by Getty Images.

### Regional Data Collaboration: Next Steps

The first steps in regional collaboration for data sharing and integration may include the following:

- Develop or clarify a performance vision and goals.
- Engage stakeholders with roles in the performance vision.
- Specify the key objectives for sharing and integration among stakeholders.
- Communicate existing data under management and capabilities for data sharing and integration.
- Develop and execute baseline strategies and tactics to increase data sharing and integration toward objectives.
- Meet regularly to monitor the statuses of objectives, strategies, and tactics.

## 2.3 Baselining the TSMO Inventory and Capability Maturity Assessment

Agencies often develop TSMO strategies and plans based on analyzing the current transportation system to identify gaps. Inventorying existing ITS infrastructure and current TSMO practices provides a TSMO maturity baseline to help agencies identify coverage and capability gaps in ITS and TSMO services such as service patrols. Likewise, a capability maturity model (CMM) assessment allows agencies to evaluate current institutional capabilities to identify opportunities for capability improvements. TSMO inventory considerations include infrastructure, hardware, software, other assets, data, agreements, policies, practices, standards, personnel, funding, strategies, modal options, mobility services, and formalized processes and groups. A baseline and CMM assessment may lead to the development of a TSMO strategic or programmatic plan.

27 AZTech. n.d. "Regional Archive Data System (RADS)" (web page). https://www.aztech.org/Projects/RADS, last accessed October 7, 2022.

## Baseline and Capability Maturity Assessment: Opportunities for TSMO Planning

- **Stakeholder and Agency Alignment –** Collaborating to understand the current system enables each contributor to focus on realistic components of setting objectives. As partners see that the current system has limitations, they may choose to prioritize addressing those limitations. Reviewing with fresh eyes the inventory data of a partner may generate new insight that all partners adopt because of their shared understanding of joint challenges.
- **Enhanced Planning and Programming –** Early adoption of a baseline enhances the business case for future investment because the gap between the envisioned transportation system and the currently limited TSMO program can be made clearer and more transparent for all to see. The resulting projects can be presented as natural extensions of the current system and strategically built into funding programs over time rather than deriving from a reactive practice of conceptualizing and programming new features with no linkage to a master transportation system plan.
- **Regional Consistency in Transportation Decisionmaking –** Agencies make enhancements to improve the quality of transportation they provide. In the absence of strong integration activities, such as those in a corridor coalition, agency decisions can become independent of a shared regional vision. The transportation decisionmaking process flows through multiple professionals in the same organization, which may weaken consistency with the regional planning process. Effective use of team building to maintain the input of ultimate asset managers and planners into the design process can be enabled by curating an active TSMO inventory.

## Baseline and Capability Maturity Assessment: Advancing the Practice

- **State-of-the-Practice Report –** A state-of-the-practice report documents a baseline for a transportation agency's TSMO inventory. The objective of this report is to analyze existing transportation and operations programs, plans, and processes to understand current and future transportation needs. The state-of-the-practice report can incorporate recommendations to improve data collection found in existing reports and plans.
- **CMM Assessment –** A CMM assessment provides insight into an agency's current capabilities. Stakeholder involvement is a key component of this activity. The American Association of State Highway and Transportation Officials (AASHTO) developed six dimensions of capability to be included in a maturity assessment: business processes, systems and technology, performance measurement, culture, organization and workforce, and collaboration. The CMM assessment evaluates the maturity of the six capability dimensions on a scale from level 1 (ad hoc) to level 4 (optimized). The evaluation results can help agencies benchmark current operations and identify desired levels of future capabilities for each dimension. Through the L01 and L06 projects, the SHRP2 program advanced the use of the CMM for TSMO and incorporated strengths and weaknesses of each dimension.[28]
- **ITS Service Level or Master Plan –** A service level or master plan provides detailed recommendations and actions for an ITS network. The plan, which can be networkwide or for an identified area, describes existing ITS network conditions, system gaps, recommendations, cost estimates, and a business case for ITS investment. The plan should be consistent with the applicable ITS architectures in the area. The plan aims to identify opportunities for and challenges to incorporating an ITS into the business processes of the transportation organization.
- **Corridor Management Teams –** When multiple agencies manage a corridor together, they may consider creating teams or holding

28 FHWA. n.d. "SHRP2 Solutions: Improving Transportation Systems Management and Operations and Fostering More Reliable Travel Times Through Business and Organizational Solutions" (web page). https://www.fhwa.dot.gov/goshrp2/Solutions/Reliability/L06_L01_L31_L34/Organizing_for_Reliability_Tools, last accessed October 6, 2022.

recurring meetings to discuss operational practices, data-sharing policies, and equipment standards. Such forums can be used to draft memorandums of understanding that formalize policies and procedures among agencies.

- **Ownership of Shared Communication Assets –** Transportation agencies often share communications infrastructure through leases, public–public partnerships, and public–private partnerships. The owner of the shared communication system may need to establish responsibilities if connections to partner facilities exist. The owner of the shared communication system is often responsible for maintenance and management costs of the communication system.
- **Data Sharing –** Data sharing is widespread within agencies and among partners. For example, an organization's CCTV camera feed can be shared with local municipalities to expand corridor coverage without incurring additional costs. When sharing data, agencies may consider drafting open agreements or memoranda of understanding to identify the purpose of the data sharing, set standards, and define clear roles for the partnership.

### Baseline and Capability Maturity Assessment: Potential Issues To Address

- **Data Collection –** Agencies may want to collect background information to document existing conditions as part of a capability maturity assessment. Documenting existing conditions for the capability maturity assessment includes reviewing existing databases, studies, reports, and plans to gather information on the current transportation network. Information on the existing ITS infrastructure, such as system engineering documents, as-builts, or design plans, is also helpful to document the existing communications network. The ability of agencies to access archived plans depends on the agencies' archive processes and overall data availability.
- **Working with Private Companies –** Agencies may choose to outsource data collection or purchase proprietary data from private companies. Agencies should consider the long-term consequences of using private-company data and potential downstream restrictions on access to and use of proprietary data provided by private sector entities.
- **Stakeholder Involvement –** The baselining of TSMO inventories can include multiple stakeholders, such as State and local transportation agencies. Stakeholder participation is key because ITS architectures rely on infrastructure provided by multiple partners, and the success of TSMO strategies can depend on stakeholder support and collaboration. Engagement and active participation can help encourage stakeholder involvement.
- **Data-Sharing Agreements** – Agencies may choose to develop data-sharing agreements or memorandums of understanding that document the sharing and use of data among agencies. Agencies may want to revise these documents on a regular basis to make sure they reflect current data needs and data-sharing arrangements.

### Baseline and Capability Maturity Assessment:

### Examples of Implemented Solutions

- **Iowa DOT ITS and Communications System Service Layer Plan[29] –** The Iowa DOT developed a specific ITS and communications system service-layer plan to share recommendations and define actions supporting the overall TSMO program plan goals and objectives. This plan includes an inventory of existing ITS devices and communication systems, proposed strategies and tactics, and a gap analysis of the current and proposed systems. A service level cost estimate helps identify annual funding for maintenance and expansion of the system through proposed strategies and tactics.
- **Caltrans Transportation Management Systems Baseline Inventory[30] –** Caltrans developed a transportation management system (TMS) master plan to make the business case for investing in ITS field equipment and incorporating ITS into its standard business processes for operating the roadway. As part of the TMS master plan, Caltrans developed a baseline inventory that identifies the location of current and proposed ITS assets, the cost of deployment, typical asset lifecycles, and lifecycle maintenance and replacement costs. Many elements of the TMS baseline inventory have been updated and incorporated into the Caltrans transportation asset management plan (TAMP) and the State highway system management plan (SHSMP), which operationalized the TAMP in a performance-driven and integrated management plan.

### Baseline and Capability Maturity Assessment: Next Steps

Initial steps in developing a TSMO inventory or baseline could include the following:

- Develop or clarify a performance vision and goals.
- Engage stakeholders with a role in the performance vision.
- Engage in a capability maturity self-assessment.
- Develop objectives for desired future state of capability maturity.
- Investigate and document existing TSMO assets within the bounds of the vision and dimensions of capability maturity.
- Establish a reporting framework and protocol for TSMO inventory elements.
- Monitor the condition of the TSMO inventory and/or capability maturity assessment regularly.

## 2.4 Sustaining TSMO after Initial Implementation

TSMO system maintenance is the ongoing responsibility of all agency stakeholders. To maximize the mobility and safety benefits of TSMO systems, agencies can focus on ensuring TSMO systems are properly maintained and adjusted for optimal performance. TSMO infrastructure is repaired and replaced when necessary, and hardware and software may be updated to achieve agency performance objectives. The successful use of TSMO may depend on the commitment of resources over the full lifecycle of TSMO infrastructure. Agencies may consider analyzing the benefits and costs of TSMO investments and communicating the business case to decisionmakers. Dividing and defining maintenance responsibilities early in the project lifecycle can help sustain TSMO devices over time. Sustaining TSMO focuses on funding through lifecycle benefit–cost analysis, staffing, technology lifecycle management, and coordination needed to maintain existing and future TSMO implementations.

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29 Iowa Department of Transportation. 2018. *Intelligent Transportation Systems (ITS) and Communications Systems Service Layer Plan*. https://iowadot.gov/TSMO/ServiceLayerPlan3.pdf, last accessed October 7, 2022.

30 California Department of Transportation. 2018. *California Transportation Asset Management Plan—Fiscal Years 2017/18-2026/27*. Sacramento, CA: Caltrans. https://dot.ca.gov/-/media/dot-media/programs/asset-management/documents/20190726-am-finalcaliforniatamp-a11y.pdf, last accessed October 7, 2022.

### Sustaining TSMO: Opportunities for TSMO Planning

- **Modernized Programming –** Traditional capacity expansion projects lead to a onetime change in system conditions. TSMO projects perpetuate a cycle of continual improvement. As a result, the growth of TSMO programs could result in changes to programming decisions and funding levels to keep systems operational. For example, TSMO solutions may reduce the overall cost to be programmed but increase recurring costs for operations support (contracted staff, contracted services, etc.). Sustaining a TSMO system provides an opportunity for an agency to consider and enhance its overall programming process.
- **System Monitoring and Transparency for Real-Time Response –** Proactive TSMO planning to manage system enhancements through their lifecycles can create effective monitoring. Assigning resources to ensure TSMO assets are in working condition at all times enables equipment to capture unexpected events, such as crashes, and alert partnering agencies with minimal delay. Conversely, poor system upkeep can leave gaps in reporting and long system downtimes that could reflect on the quality of agency performance.
- **Improved Regional State of Repair –** Transitioning to a TSMO mindset may provide flexibility to scale back system expansion. Rapid system expansion could draw from funds available for maintaining a state of good system repair. However, choosing TSMO and planning only for the impact to capital funding will leave a region with a new class of technology assets potentially leading to a state of poor repair. Planning TSMO deployment responsibilities through formal maintenance ownership could prepare the region for a future state of good repair.
- **Standard Operating Procedure Documents –** Agencies may consider documenting standard operating procedures, so they can sustain the operating improvements they have made through TSMO.

### Sustaining TSMO: Advancing the Practice

- **Responsibility Matrix or Responsible, Accountable, Consulted, and Informed (RACI) Chart –** A RACI chart outlines roles and responsibilities for maintenance before implementation. A responsibility matrix helps clarify roles, which is especially important for cross-departmental and interagency programs. Those responsible for a task work to complete the task. Those accountable oversee, review, and approve the work that has been completed for a task. Those consulted for a task are typically experts who can provide valuable input. Those informed are kept updated on progress. For example, Arizona DOT developed RACI charts to define transportation management strategies and roles during project development and construction (table 2).[31] Agencies may want to develop institutional agreements for operations while assigning roles and responsibilities.

31 Arizona Department of Transportation. 2020. *2020 Work Zone Safety and Mobility Process Review Report.* Phoenix, AZ: ADOT. https://azdot.gov/sites/default/files/media/2021/04/ADOT-2020-process-review.pdf.

Table 2. Arizona DOT's RACI table for project construction.

| Project Description (or Activity) – as Applicable to Project | Construction Advisory Team Roles* | | | | | |
|---|---|---|---|---|---|---|
| | Law Enforcement** | Contractor | RE | TOC | RTE | ACT |
| **Motorist Information Strategies** | Chapter 5 | | | | | |
| Smart Work Zone | | R | A | I | C | I |
| Changeable Message Board | | R | A | I | C | |
| Existing Fixed Overhead Digital Dynamic Message Sign | | C | A | R | C | I |
| Ground-Mounted Signs | I | R | A | | C | |
| AZ511 Traveler Information System | C | C | A | R | C | I |
| Sequential Flashing Lights | | R | A | I | C | |
| Website | I | C | C | I | C | R |
| Freight Transportation Information | C | C | C | C | C | R |
| Mobile Device Application | C | C | C | I | C | R |
| Public Involvement Plan | C | C | C | I | C | R |
| **Traffic Incident Management & Enforcement Strategies** | Chapter 6 | | | | | |
| Access of Emergency Services | C | R | A | I | C | |
| Traffic Incident Management | R | C | C | A | C | I |
| Law Enforcement | R | C | C | A | C | I |
| Emergency Vehicle Access Management and Planning | C | R | A | C | C | |
| **Construction Traffic Management Plan (TMP) Strategies** | Chapter 7 | | | | | |
| Lane Restrictions | I | R | A | I | C | C |
| Project Coordination | | R | A | I | C | C |
| **Stakeholder Coordination** | Chapter 8 | | | | | |
| Team Meeting | I | A | R | I | C | A |
| Corridor/Network Management Strategies | Chapter 9 | | | | | |
| TMP Effectiveness Monitoring | I | A | R | I | C | C |
| **Alternate Route Strategies** | Chapter 10 | | | | | |
| Detours | C | R | A | C | C | C |
| **Public Information Campaign** | Chapter 11 | | | | | |
| Printed Communications Materials | | A | C | I | I | R |
| Press Releases | | A | C | I | I | R |
| Project Hotline and Public Feedback | | A | C | I | I | R |
| Electronic Media | | A | C | I | I | R |

RE = Resident Engineer; TOC = Traffic Operations Center; RTE = Regional Traffic Engineer; ACT = Arizona DOT Communications Team.
* R = Responsible (does the work); A = Accountable (to review/ensure the work is getting done); C = Consulted (for input as needed); I = Informed (as needed, is kept in the loop on progress).
** Law Enforcement could be department of public safety, enforcement and compliance, or local (city or county) uniformed law enforcement officers.

Table 2. Arizona DOT's RACI table for project construction. (continuation)

| Project Description (or Activity) – as Applicable to Project | Construction Advisory Team Roles* | | | | | |
|---|---|---|---|---|---|---|
| | Law Enforcement** | Contractor | RE | TOC | RTE | ACT |
| Emergency Contingency Plan | Chapter 12 | | | | | |
| Contingency Plans | I | R | A | A | C | C |
| Emergency Communication Plan | I | C | C | A | C | R |
| Traffic Operations Center Response Protocol | I | A | A | R | C | I |

RE = Resident Engineer; TOC = Traffic Operations Center; RTE = Regional Traffic Engineer; ACT = Arizona DOT Communications Team.
* R = Responsible (does the work); A = Accountable (to review/ensure the work is getting done); C = Consulted (for input as needed); I = Informed (as needed, is kept in the loop on progress).
** Law Enforcement could be department of public safety, enforcement and compliance, or local (city or county) uniformed law enforcement officers.
Source: Arizona DOT. 2020. *Arizona Department of Transportation 2020 Work Zone Safety and Mobility Process Review Report*. . https://azdot.gov/sites/default/files/media/2021/04/ADOT-2020-process-review.pdf, accessed February 8, 2023. accessed February 8, 2023.

Source: Arizona DOT *2020 Work Zone Safety and Mobility Process Review Report*, modified by FHWA.

- **Staffing Plan[32] –** Staffing needs include hiring skilled and knowledgeable management, professional, and technical personnel. Some responsibilities, such as software management and monitoring services, may need outsourcing to other organizations in the case of a shortage of skilled staff. A staffing plan can help identify missing positions and how many maintenance workers are needed to oversee and repair TSMO equipment. The plan may outline training and skills needed to deploy TSMO and strategies for training, developing, and hiring qualified workers. New training may be required for existing staff.
- **Schedule of Maintenance –** Agencies can consider developing schedules of regular physical and digital maintenance and checkups on all developed TSMO equipment after the implementation is complete. The frequency of replacement and maintenance checkups can be determined over each asset's lifecycle.
- **Asset Management System –** It may be helpful to keep an inventory of ITS devices and other TSMO-related equipment. Such information as the age, make, and model of a device helps determine the appropriate timing for its replacement or upgrade. Data management is considered another element of asset management. Managing, evaluating, and analyzing data are helpful for sustaining TSMO strategies. Data are becoming more readily available, and TSMO systems collect vast amounts of data, such as speeds and weather conditions, through individual devices. Ensuring the data are transmitted and recorded accurately can support sustainable TSMO strategies.
- **Diagnostics –** Some agencies run frequent diagnostics to determine the operating condition of devices. For example, the Caltrans Performance Measurement System[33] provides near-real-time access to data-reporting diagnostics. Performance measures can be used to track and assess system conditions.

32 FHWA. 2017. *Developing and Sustaining a Transportation Systems Management & Operations Mission for Your Organization: A Primer for Program Planning*. Report No. FHWA-HOP-17-017. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop17017/index.htm, last accessed October 7, 2022.

33 https://dot.ca.gov/programs/traffic-operations/mpr/pems-source

- **Linking ITS Architecture –** Connecting TSMO equipment to an existing ITS-maintained system, such as a fiber-optic communication backbone, may help an agency monitor the health of TSMO equipment and provide input into regular maintenance. System linkages can be implemented and documented in the applicable regional ITS architecture. New TSMO equipment should be compatible and connected to the applicable State or regional ITS architecture.

## Sustaining TSMO: Potential Issues To Address

- **Funding[34] –** Budgeting for systems maintenance is a key part of a TSMO program. Budgets can include funding ongoing device services, replacing devices, and maintaining system hardware and software. Funds can also be allocated to hiring staff, purchasing technology, and upgrading infrastructure. Sustainable funding may be provided through Federal, State, or local funding. If multiple TSMO project needs arise at the same time, it may be important to set criteria or use a decisionmaking tool for prioritizing funds to address higher-priority maintenance concerns. Agencies may want to identify funding sources that support TSMO programs over a 5–10-year period.
- **Technology Life Cycle Management[35] –** TSMO strategies are highly dependent on software that support such functions as managing traffic, interacting with field devices, and sending information. Emerging technologies are rapidly evolving, and they can provide many benefits, but implementation carries challenges. TSMO systems can be designed to quickly adapt to new technologies. With more research being done on autonomous and connected vehicles, the approach to disseminating traveler information and transportation management may change. Although new technologies may automate some responsibilities, they bring an increased need for advanced cybersecurity and data management. Configuration management helps stakeholders determine when and how to adapt existing technologies or adopt new technologies. Because technology is rapidly evolving, agencies may want to consider a system's remaining life and changes in technology when planning maintenance and replacement activities. Agencies may also want to consider the flexibility of new software to accommodate future changes before deciding to deploy. Another item, which is often overlooked, is retraining operators and staff on using new technologies.
- **Division of Responsibilities –** Without a clear division of maintenance responsibilities, conflicts and a lack of accountability on task ownership may occur. Without accountability, many routine system issues may go unaddressed. A last-minute decisionmaking process could delay resolving maintenance issues, and the division of responsibilities may be distributed inequitably among stakeholders. Once responsibilities have been assigned, coordination across agencies and departments can become more streamlined and seamless.
- **Placement of Devices[36] –** Placing ITS devices along roads and highways can provide easy access to maintenance crews, even in temporary work zone environments. Agencies may want designers and contractors to review the placement of and access to equipment during the design phase of TSMO deployment.

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34 Ibid.

35 FHWA. 2017. *Developing and Sustaining a Transportation Systems Management & Operations Mission for Your Organization*. Report No. FHWA-HOP-17-017. https://ops.fhwa.dot.gov/publications/fhwahop17017/index.htm, last accessed October 7, 2022.

36 FHWA. 2018. *Enhancing Transportation: Connecting TSMO and Maintenance*. Report No. FHWA-HOP-18-090. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop18090/fhwahop18090.pdf, last accessed October 7, 2022.

### Sustaining TSMO: Example of Implemented Solution

- **Responsibility Matrix**[37] – Texas DOT developed separate TSMO program plans for every district. Each program plan includes a responsibility matrix. The matrix describes key action items, provides a recommended timeframe and frequency for implementation, assigns responsible task leads, and lists corresponding metrics to evaluate the effectiveness of the action item. These matrices were developed based on discussions, meetings, surveys, and workshops with key stakeholders. The plans are meant to be working documents. As TSMO capabilities and capacities expand, the responsibility matrix can be revised to reflect new TSMO goals.
- **ITS Facility Management System**[38] – Florida DOT uses the ITS Facility Management (ITSFM) system database to manage daily program maintenance and emergency response needs. This database comes with standards for naming conventions and abbreviations to instill data input consistency. ITS operation and maintenance personnel have access to the software and are responsible for managing and maintaining the database with accurate information. The database provides access to asset inventory and real-time camera feeds. The ITSFM system assists with routine maintenance activities, troubleshooting, and pretrip diagnostics.

### Sustaining TSMO: Next Steps

Steps in incorporating TSMO lifecycle sustainment in TSMO planning may include the following:

- Gather lessons on ownership and maintenance level for existing agency assets.
- Set objectives related to needed enhancements for operations and maintenance of existing assets.
- Identify any gaps in knowledge, skills, abilities, or staff levels to attain objectives.
- Engage likely future asset owners, operators, and maintenance staff upon identifying new TSMO system enhancement concepts.
- Apply the system engineering approach for user scenarios, including those of agency operators and maintenance staff.
- Develop programming costs to account for capital, operations, and maintenance costs at the time of capital programming.

37 Texas Department of Transportation. "Transportation Systems Management and Operations," https://www.txdot.gov/safety/tsmo.html.

38 Florida Department of Transportation. n.d. "ITS Facility Management" (web page). https://www.fdot.gov/traffic/itsfm/index, last accessed October 7, 2022.

## 2.5 Freight and TSMO Planning

**Figure 6. Image. Truck on highway.**

Source: Getty Images.

With growth in e-commerce, lean manufacturing processes, and increasingly complex global supply chains that depend on safe, secure, and reliable goods movement, State and local agencies are increasingly seeing the value in incorporating freight into TSMO planning (figure 6). This is often done in partnership with the freight industry, as trucking companies, package delivery services, ports, and rail intermodal facilities seek to incorporate management strategies that optimize their performance. In some cases, TSMO strategies may be perceived as impairing effects on goods movement (e.g., lane restrictions, parking restrictions, prohibited routes); in other cases, TSMO strategies can be identified specifically because they will improve goods movement.

For the purposes of TSMO planning, freight includes multiple modes such as rail, intermodal transfer facilities, seaports, heavy trucks on roadways, local delivery, and, in some cases, nonmotorized and small-scale carriers (e.g., cargo bicycles, e-bikes) and delivery on demand (e.g., transportation network companies) for freight using independent delivery providers. Additionally, TSMO plans may include consideration of the variety of carrier types, ranging from long haul for hire carriers and private fleets that may travel 500 or more miles per trip to urban delivery, other short-haul local carriers and private fleets that operate largely within a single region, to drayage operators that service seaports and nearby warehouse and distribution/consolidation centers. Additionally, depending on State and local regulations, some carriers may operate longer combination vehicles with multiple trailers. Finally, many heavy vehicles may be transporting hazmat and require special routing and driver credentials and thus may benefit from TSMO strategies that provide real-time accurate information regarding routes and restrictions.

### Freight: Opportunities for TSMO Planning

- **Strengthen Regional Community Vitality** – Planning processes are intended to support a community or collection of communities. TSMO planning services a number of communities, one of which is the transportation and logistics industry. This sector of businesses moves critical goods to keep jobs strong in a region. In proactive collaboration with freight TSMO planners can adequately plan for issues of the freight haulers' business operations. Further, this two-way relationship allows planners to advise freight operators on the impact of decision for the general traveling public. Oftentimes, a win-win compromise can be struck, but at least a rapport grows allowing for fruitful collaboration and negotiation. Beyond serving commercial vehicle operators and considering the needs of other travelers, integrating freight planning into the planning process can directly address equity impacts of heavy trucks, including how underrepresented populations are affected by designated truck routes, hazmat exposure, truck parking areas, noise and light pollution, and emissions.
- **Proactively Benefit Safety –** Both Freight haulers and TSMO planners account for the importance of safety, but they may have limited natural interaction on the subject. TSMO planners can augment potential safety goals and objectives to be inclusive of freight movement and reap the benefits of public–private partnership in the accomplished strategies and tactics. Mixing the expertise of the TSMO planner to leverage resources can benefit the public by changes in the name of safety carried out by freight stakeholders.

- **Gain Freight Insights To Improve the Planning Process –** TSMO and general transportation planners connect the needs of the system with the demand likely on the system, which inherently is based on activity centers or land use and zoning. In working with freight haulers, the TSMO planning community can draw from a depth of resources on goods movements to identify how strategic regional redevelopment can remove constraints on goods movement and benefit the public through separation of certain modal conflicts (e.g., freight to pedestrian).
- **Improve Air Quality –** Improvements in freight management can improve air quality through TSMO strategies that limit idling in designated areas and by providing or promoting auxiliary power sources in truck parking areas so that drivers need not idle engines to maintain power in their vehicles.

### Freight and TSMO Planning: Advancing the Practice

Many effective TSMO strategies for freight begin with the planning process within either an individual agency or a regional planning entity (e.g., MPO or multistate coalition). Often, these strategies are advanced in response to growing freight traffic that contribute to regional congestion or the desire to accommodate goods movement to support the regional economy and quality of life.

Transportation planners typically focus on longer-term needs and opportunities, and shippers, carriers, and others involved with goods movement generally focus on shorter-term demands. Planners are increasingly engaging key stakeholders to gain a deep understanding of the latter's issues and concerns. Key freight stakeholders who may need to be engaged in the planning process include shippers, carriers, port authorities, railroads, intermodal operators, drayage operators, local delivery carriers, and retail representatives. Areas where planners can consider TSMO strategies fall into several areas, including, for example:

- **Improving long-haul goods movement** – TSMO planners engaged in topics of long-haul freight may consider topics including freight-specific traveler information, freight-user-focused-event management, freight modal capacity and bottlenecks, and freight system management. In freight-specific traveler information, the planning process often includes considering critical logistics questions such as travel time reliability on the current route, upcoming route decisions and restrictions, and end-of-trip considerations like parking location and availability. A second focus area for long haul is planning for cases in which weather events or incident events occur. Planning and coordination in this second focal area involve discussion of information collection and dissemination, communication protocols, and response teams. Freight users use information similar to that for private vehicles (e.g., travel times, weather, detours, delays, incidents), but their risk profile is different (e.g., size or weight restrictions, hazmat restrictions, and parking limitations). If freight users are involved in an event, the likely the economic impact to all stakeholders is greater, so robust event management of freight users can help avoid and mitigate adverse outcomes. The third long haul consideration involves system capacity and operational bottlenecks. In this focus area, TSMO planners may want to consider whether separation of freight is feasible and preferable. Separation may be infrastructure intensive like dedicated truck lanes or climbing lanes or policy and enforcement intensive as in the use of lane or facility restrictions.

Figure 7. Image. Delivery truck on city street

Source: Getty Images.

- **Improving urban goods movement** – Partnership with freight may also consider urban goods movement (figure 7). Urban areas are likely to have areas that become congested with a mix of general and freight traffic, but understanding freight operations better can mitigate their contribution to transportation disruptions. TSMO strategies may focus on operations, policy, and infrastructure. Operations planning for freight may focus on priority-type treatments to limit delays to goods affecting businesses and downstream consumers. One example of operational improvement may be traffic signal priority for freight traffic. A second focus area in TSMO planning around freight is policy development and regulation. Freight vehicles may have requests for deliveries that bring them into congested areas at inopportune times. Early collaboration on policy may avert the frequency of these freight congestion spikes by regulating and managing curbside space for peak delivery times and implementing off-peak delivery strategies for flexible deliveries. Finally, freight stakeholders and TSMO planners may collaborate on infrastructure to cut down on delays, queues, and emissions. A concentrated area like a port facility may represent a well-defined bottleneck that can be bolstered with infrastructure to process freight vehicles more efficiently and benefit the local community.

**Planning Work Zone Management on the National Highway Freight Network[39]** – Work zones can affect heavy vehicles as well as work zone operations due to narrow lane widths, detour requirements, and other restrictions that may affect the flow of traffic approaching and passing through a work zone. TSMO planners can benefit by working with freight suppliers when developing work zone management strategies. One opportunity is analysis of potential work zone diversion. Freight stakeholders have resources that focus on logistics innovation, including automated route planning, in-transit visibility, dynamic rerouting, time-certain delivery, and onboard real-time information sharing. Early dialogue on planned major projects allows those freight users to assess the impact to their operations and comment on the planned project. The earlier a project is shared transparently, the more likely the freight stakeholders can adapt to the work zone or comment constructively to benefit the work zone. Another opportunity is coordinated work zone planning. When multiple facilities are under construction simultaneously, a compounding effect on congestion can result as demand exceeds capacity. Evaluating work zones together through the use of scenario-planning tools can help uncover when the impacts to freight and other stakeholders will be severe. Agencies may want to consider new strategies and tactics to mitigate the work zone. Finally, freight stakeholders can provide input to the scheduling of major work zones before projects are let to a contractor so that multiple concurrent work zones do not cause excessive delays. TSMO planners can help create opportunities for input and collaboration so that lane widths, structures clearances, tapers, access restrictions, and temporary traffic control devices do not adversely impact freight operations.

Commercial-goods movement is an evolving service with emerging concepts that will likely affect how goods are transporting. Truck platoons and connected vehicles are currently operational and can reduce fuel consumption significantly. Autonomous commercial vehicles are being tested on both long-haul (with a safety driver on board) and predetermined local routes. Innovations in first- and last-mile delivery include cargo bicycle and e-bike local pickup and delivery services, and several transportation network service companies include goods delivery as a service.

39 See the FHWA "National Highway Freight Network" (web page). https://ops.fhwa.dot.gov/Freight/infrastructure/nfn/index.htm for a description of the National Highway Freight Network.

### Freight and TSMO Planning: Potential Issues To Address

- **Adequate Safe and Secure Truck Parking –** Operators of heavy vehicles (more than 26,000 pounds) and other commercial and passenger vehicles are limited by hours of service (HOS) regulations,[40] which restrict the number of consecutive hours of driving and total hours over the course of a designated time period. Commercial vehicle operators often operate on narrow time windows for picking up and delivering goods at origins and destinations. Consequently, drivers need places to take rest breaks and also places to stage before their designated pickup and delivery time windows. Parking is often in short supply—especially during hours when many drivers prefer to rest. Commercial vehicle operators can park legally in designated truck parking areas along State and Federal roadways or in private truck stops that provide both parking and other amenities (e.g., showers, restaurants, vehicle services). TSMO can help by providing accurate and timely information regarding the availability of safe and secure parking and availability of electric vehicle charging so that drivers can take full advantage of their hours-of-service allowance and avoid parking in illegal or unsafe locations.
- **Urban Delivery –** Delivering goods to retail and residential locations often conflicts with peak periods of private vehicle traffic, and due to limited curbside load/unload locations, commercial vehicles often block travel lanes when loading or unloading. Additionally, heavy trucks often make deliveries in residential locations due to the growth in e-commerce, resulting in heavy vehicles operating on neighborhood roads that may not be designed for high volumes of heavy-vehicle traffic. Accommodating urban delivery requires innovations—many of which are TSMO strategies—in how retailers and carriers work together to avoid conflicts with other modes or vehicles. Innovations include, for example, designated delivery zones on city streets that reduce lane blocking, off-peak delivery that reduces the number of heavy vehicles during peak congestion periods, and use of smaller vehicles, cargo bikes, or autonomous vehicles for first- and last-mile deliveries.
- **Information Tailored for Heavy Vehicles –** Both long-haul and local commercial vehicles need information that is presented in ways that are appropriate for goods movement. Long-haul carriers need information well in advance of travel times so they can plan routes and schedules. They need information about weather (current and predicted), work zones, major incidents or special events that could affect their trips, route restrictions (e.g., size or weight), and expected travel times. Local delivery vehicles need information regarding travel time, utilities, weather, commercial vehicle restrictions, incidents, and other information that could affect delivery patterns and schedules.
- **Multijurisdictional Coordination and Data Sharing –** Commercial vehicles often operate in multiple jurisdictions and need to plan routes and schedules that reflect past, current, planned, and predicted conditions. Coordination and data from contiguous jurisdictions are needed to ensure commercial vehicle operators can plan trips appropriately. In some cases, data sharing may involve third parties, but jurisdictions are likely to have collected data that can be used in planning and operating the regional transportation system—especially regarding commercial vehicle operations. Coordination may include, for example, winter maintenance plans, major incident response teams (including hazmat response), and coordinated real-time information collection and distribution.
- **Work Zone Coordination –** Major trade corridors typically cross multiple regions and States where major projects and routine maintenance can result in congestion that interferes with goods movement.

40 See the FMCSA "Summary of Hours of Service Regulations" (web page). https://www.fmcsa.dot.gov/regulations/hours-service/summary-hours-service-regulations for detailed description of hours-of-service limitations.

Multijurisdictional coordination of major work zones and communications with carriers can help carriers plan for delays or adjust routes and schedules, as well as help jurisdictions stage work zones to avoid multiple simultaneous work zones from occurring along high-volume routes.

- **Efficient Size/Weight/Safety Enforcement –** Most commercial vehicles that pass through weigh stations along freeways are released without any violation of size, weight, safety, or credentials. Electronic screening using onboard transponders and weigh-in-motion technology and other fixed- and mobile-enforcement methods can focus efforts on violators without delaying safe and legal carriers and operators.
- **Incident Response and Clearance –** Incidents, especially those involving heavy vehicles, whether at fault or not, often result in major delays for commercial and private vehicles. Incidents involving heavy vehicles may require specialized towing and recovery vehicles and methods, hazmat cleanup services, and, in some cases, recovery or disposal of cargo. Prepositioning or other contractual arrangements with towing and recovery, improved detection of and appropriate response to incidents, interagency coordination, multijurisdictional coordination, and accurate traveler information can help improve incident response and clearance.

### Freight and TSMO Planning: Example of an Implemented Solution

#### Using Work Zone Data in Connected and Smarter Work Zone Applications for Truck Mobility: Maricopa County, Arizona

During the past several years, Maricopa County DOT (MCDOT), in conjunction with other agencies in the AZTech partnership, has led several initiatives to enhance regional work zone data management practices. To supplement the event data system used to track work zone data for Arizona DOT (ADOT), MCDOT built the Traffic Information for Road Closures (TIRC) application to collect and disseminate construction, maintenance, and road and lane closure information. The TIRC application provides a rich arterial information system for use by neighboring agencies.

Beginning in 2016, Maricopa County and ADOT conducted a series of pilots along Maricopa County Route 85 (MC-85), a major freight corridor, to expand the use of data and technology for improved work zone management. They used data from the RADS for in-vehicle messaging for truck drivers along with detection and CMS to encourage all travelers to consider alternative routes.

Recognizing the need for connected and automated vehicles to be supported in work zones, MCDOT and ADOT partnered with the University of Arizona and a trucking company to develop and test a connected vehicle application.

Using RADS data, the connected vehicle application provided work zone information based on location for truck drivers through the drivers' in-vehicle systems. The information enabled truck drivers to navigate smarter work zones more safely and save time, money, and emissions.

The MC-85 project allowed MCDOT to successfully demonstrate smart work zone (SWZ) technologies on an arterial (figure 8). The technologies included an arterial-travel-time system to encourage the use of alternative routes based on current conditions as well as innovative CAV technologies. These experiences can be leveraged to facilitate future SWZ and CAV deployments in work zones. Through a Work Zone Data Initiative pilot effort, MCDOT is currently considering expansion of the RADS Work Zone Data Exchange application-programming-interface feed to incorporate all work zones in the area.[41]

41 FHWA. 2020. *Utilizing Work Zone Event Data in Connected and Smarter Work Zone Applications—Maricopa County, Arizona.* Report No. FHWA-HOP-20-022. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop20022/fhwahop20022.pdf, last accessed October 7, 2022.

RADS is funded by MCDOT with in-kind support from Arizona DOT. To expand and build on RADS, MCDOT expands its partnerships to include the private sector to plan for and obtain grant funding. This is critically important in TSMO planning for freight, which is dominated by the private sector.


Figure 8. Chart. In-Vehicle Messages About Work Zone on MC-85 Corridor.

Source: FHWA, Utilizing Work Zone Event Data in Connected and Smarter Work Zone Applications—Maricopa County, Arizona.

### Freight and TSMO Planning: Next Steps

Next steps in freight and TSMO planning may involve the following activities:

- If not already available, develop a database of goods movement and related commercial vehicle activity in the region of interest (e.g., central business district, urban area, multistate corridor). This may include data about truck stops, truck rest areas, major warehousing and distribution centers, major manufacturers, fleet owners and operators, and data regarding commercial vehicle volumes, sizes, and weights on roadways within the region of interest. Also, it is helpful to have data on planned commercial developments that will generate additional commercial vehicle traffic. Much of the data needed to support TSMO planning for freight may be available in existing plans prepared by a State's motor carrier division or a related agency responsible for motor carrier safety and enforcement, including size and weight enforcement.
- Engage key stakeholders who are affected by goods movement or who generate demand for goods movement and stakeholders directly involved with goods movement in the region of interest. These stakeholders may include neighborhood and community groups as well as major generators of goods movement that contribute to the economic base and supply the goods for the region. Key stakeholders will likely include multiple public agencies responsible for operation and maintenance of roadways (including bridges and tunnels), traffic enforcement, commercial vehicle safety, incident response (including hazmat response), winter maintenance, and environmental protection. Multiple working groups may be formed to address various aspects of goods movement within the region.
- Work with key stakeholders to develop goals and objectives with respect to goods movement in the region of interest, including goals related to environmental impacts (e.g., noise, light, emissions), equity, safety, economic activity, and mobility.
- Develop criteria for determining how well objectives are achieved and the data needed to assess and measure performance against the objectives.

Once these steps have been taken, planners and operators, working with key stakeholders, can begin to identify TSMO strategies that offer opportunities for improving goods movement and take into consideration the needs of communities affected by heavy-vehicle traffic.

## 2.6 Connected and Autonomous Vehicle Considerations

Figure 9. Illustration. Connected and autonomous vehicles provide real-time data between roadway infrastructure and other vehicles.

Source: U.S. DOT ITS Joint Program Office

Connected and autonomous vehicles will affect TSMO planning and operations. Agencies have begun to pursue projects to support connected vehicles while the research on automated capabilities continues. For example, Georgia DOT and the Atlanta Regional Commission are partnering to equip 1,000 intersections with connected vehicle technology in the Atlanta region.[42] Vehicles' ability to exchange real-time data with one another and nearby infrastructures (connected vehicle technology) and scan their environments for potential conflict points (automated vehicle technology) may reduce crashes, improve transportation operations, and lead to higher roadway capacity (figure 9). CAVs remain in the research and development phase of deployment, and mainstreaming could take decades because of the complexity of the current vehicle market and ecosystem. At the conceptual level, CAVs represent the potential to achieve public benefits, including:

- Newfound ease of travel, as time previously spent driving can instead be used more productively—for at least a portion of each trip
- Accessibility and connections for areas not serviced by traditional public transportation
- Potential for lower travel costs per mile, as users shift from personal automobile ownership to shared, on-demand vehicles
- Potential for travelers with disabilities and older adults to access more destinations by using shared, on-demand vehicles

### Connected and Autonomous Vehicles: Opportunities for TSMO Planning

- **Regional Vitality and Equity –** Increased participation by the private sector in deploying and developing infrastructure for CAVs may create inequitable outcomes. TSMO planners may want to define user-oriented objectives for technological advancement and use strategies and tactics to direct outcomes to benefit the public in a manner that enhances communities equitably.
- **Evolution of the Planning Process –** To date, CAVs have been conceptualized to primarily use existing pavement and bridges within the transportation system. New planning opportunities may come from that evolution to focus on stewardship of plans for transportation operational advances, regional advancements in data and analytics, management of publicly owned technology, and enhanced development of transportation policy.
- **Enhanced Strategies and Tactics –** CAVs may create new space for real-time responsive transportation. Communities that currently have marginalized access to transportation may be able to have goods delivered to them affordably on demand and may be able to use a shared vehicle to reach a previously inaccessible destination. CAVs hold promise because the private sector has made investments in a

42 Junior Knox. 2020. "The Region's Connected Vehicle Technology Is Getting Ready to Roll." Commuter Connections (blog), Atlanta Regional Commission. March 6, 2020. https://atlantaregional.org/whats-next-atl/articles/the-regions-connected-vehicle-technology-is-getting-ready-to-roll/, last accessed October 7, 2022.

mobility-as-a-service ecosystem that would supplant the current ownership-dependent model of transportation. However, the TSMO planning community can develop strategies and tactics for CAVs that do not create unintended public impacts.

- **New Data Sources** – Agencies may consider leveraging new data sources, such as crowdsourced data, to support CAVs.

### Connected and Autonomous Vehicles: Advancing the Practice

These potential changes may impact travel forecasting and operations analysis during the planning phase of a project. With respect to forecasting, CAVs may increase travel demand because of the newfound ease of travel, potential for lower travel costs, and potential for greater access by older adults and travelers with disabilities.

Traffic operational analysis may also change, as driver characteristics common to traffic models are altered. Impacted characteristics may include decreased vehicle headways, improved response times, and vehicle-to-vehicle coordination at intersections. Numerous agencies have modeled the potential impacts of CAVs to study their impact on travel demand. Agencies have also studied corridor-level performance relating to the potential for CAVs to improve efficiency. For example, Ohio DOT recently evaluated the potential impacts of CAVs on regional travel demand and transportation operations along three corridors in the State.[43]

Practitioners may also want to consider how connected vehicle communications will specifically interact with and enhance existing TSMO strategies. For example, signal phase and timing messages can be coordinated with red light running and signal countdown applications. Generally, the flow of data will have two potential impacts:

- Infrastructure-to-vehicle communications will provide TMC operators a new mechanism for communicating real-time traveler information to drivers. For example, in addition to posting messaging on CMS or via smartphone applications about an upcoming closed lane, connected vehicle roadside units (RSUs) might broadcast this message directly to individual vehicles as the vehicles come within range of the closure.
- Vehicle-to-infrastructure communications will provide a new data source for real-time traffic conditions. As vehicles pass RSUs, the RSUs will broadcast messages to the vehicles, indicating the vehicles' location, speed, heading, and other information about vehicle telematics. These data can be used to detect traffic density, sudden queuing, or even deteriorating road weather conditions.

This document does not aim to characterize all the potential planning and operational considerations for implementing CAV infrastructure. The emergence of CAV presents new opportunities to enhance many topics described in the QR sheets related to anticipated data needs, data resources and partners, and management and operations strategies. For example, in the implementation of managed lanes, connected vehicle technology could become both a data resource (indicating vehicle class, traffic conditions that warrant dynamic pricing, etc.) and a management strategy (exchanging traveler information messages about HOV lane use, toll transaction data, etc.).

### Connected and Autonomous Vehicles: Potential Issues To Address

- **Security Credential Management System –** Connected vehicles rely on an exchange of security certificates to verify the authenticity of messages coming from infrastructure and vehicles. The U.S. Department of Transportation (USDOT) worked with the automotive industry and industry security experts to design and develop a state-of-the-art security credential management system (SCMS) that enables users to have

43 CDM Smith. 2019. *CAV Traffic Simulation Literature Review*. Columbus, OH: Ohio Department of Transportation. https://transportation.ohio.gov/static/Programs/StatewidePlanning/Modeling-Forecasting/CAVTrafficSimulationLitReview.pdf, last accessed October 7, 2022.

confidence in one another and the system as a whole. The SCMS uses encryption and certificate management to facilitate trusted communication.[44] In 2020, Florida DOT developed a statewide SCMS platform.[45]

- **Replacing Stranded Assets –** Dedicated-short range communications (DSRC) uses short-range communication among vehicles or between vehicles and infrastructure over a dedicated communication spectrum. In 2020, the Federal Communications Commission released this spectrum to Wi-Fi and designated cellular vehicle-to-everything communications. This leaves some DSRC-reliant assets stranded and unable to use the spectrum.
- **Timing CAV Deployments –** Many agencies grapple with when to deploy infrastructure to support CAV developments. Agencies may want to monitor market demand and deploy infrastructure accordingly so that infrastructure is not deployed too early or too late.
- **Standardizing Data –** Connected vehicles may be likely to generate a vast amount of new information. This leaves agencies in the position of having to standardize and manage the potential influx of data from multiple vehicle-based sources and private data providers.

## 2.7 TSMO Project Prioritization

Advances in technology and in the way we operate transportation systems offer alternatives and options for improving the performance of existing and planned capacity. Additionally, changes in traveler expectations and in the travel services they use offer opportunities for changing the way the system operates that can improve system performance. However, realizing these improvements requires careful planning and decisionmaking to ensure that the best available alternatives and options are considered.

This section provides an overview of how TSMO strategies can be identified, evaluated, and prioritized, leading to major improvements in transportation system performance. TSMO strategies can be integrated into existing transportation infrastructure and can also be included in planned new capacity to ensure that new capacity is operated effectively.

### TSMO Project Prioritization: Opportunities for TSMO Planning

TSMO strategies or projects can be considered in multiple situations, including:

1. Identifying areas within the transportation network where TSMO projects could improve system performance
2. Identifying which TSMO projects are most appropriate for improving system performance in a specific location (e.g., roadway segment and corridor)
3. Comparing TSMO projects with major capital investments to identify opportunities where TSMO strategies are more cost effective than major capital investments in capacity expansion projects
4. Integrating TSMO strategies into planned capital improvement projects so that they are embedded in all project design, development, and implementation plans

Each of these situations is considered below, including some practical recommendations on how State and local DOTs and other agencies can address them in ways that improve the performance of the regional transportation system.

44 USDOT, ITS Joint Program Office. n.d. "Security Credential Management System (SCMS)" (web page). https://www.its.dot.gov/resources/scms.htm, last accessed October 7, 2022.

45 FDOT. n.d. "Security Credential Management System (SCMS)" (web page). https://www.fdot.gov/traffic/teo-divisions.shtm/cav-ml-stamp/cv/maplocations/scms, last accessed October 7, 2022.

### TSMO Project Prioritization: Advancing the Practice

1. *Identifying areas within the transportation network where TSMO projects could improve system performance*

In many cases, the questions begin with, "Where is the problem or opportunity for improving mobility? rather than, Which TSMO strategy will work best to address this problem or take advantage of an opportunity?" In this case, the road network is typically already in place, and the questions and concerns arise in the context of looking for ways to improve the regional transportation system either due to existing mobility issues or in anticipation of changes in the volume or patterns of demand. Most often, the problems and opportunities arise through data collected throughout the region and analyzed to determine travel time reliability, including seasonal, daily, and hourly variability within various roadway segments. Mobility data can come from a variety of sources, including roadside sensors, probe vehicles, and publicly available or commercial-travel-time data.

Simulation analyses can be used to project travel time reliability based on changes in demand volume and patterns within the existing network that could occur based on project economic development and regional growth patterns. Heat maps help visualize both the spatial and temporal aspects of delay for various segments of the regional network. Once the areas of concern are identified, this information—along with information regarding traffic incidents, weather patterns, special events, work zones, road closures, and other factors that affect mobility—can be used to identify specific causes for delay and unreliable travel time.

Given the mobility data and subsequent analysis, transportation operators and planners can identify hotspots where TSMO strategies could prove useful in relieving bottlenecks or preventing future congestion problems. The TSMO strategies could include demand reduction strategies (e.g., managed lanes, transit priority), more-efficient use of existing capacity (e.g., adaptive signal control), improved work zone and special-event management (e.g., real-time traveler information), more-effective detection and response to traffic incidents (e.g., TMCs, cameras, prepositioned response resources).

The primary goal of this type of analysis is to identify when and where TSMO strategies might be most effective within the regional transportation network. The specific TSMO strategies to be deployed will depend on further analysis. Additional information on integrating TSMO into the transportation-planning process is available on FHWA's Organizing and Planning for Operations website.[46]

2. *Identifying which TSMO projects are most appropriate for improving system performance in a specific location (e.g., roadway segment and corridor)*

Beyond determining where specific hotspots exist in a regional transportation network, operators and planners may consider identifying which TSMO strategies or combinations of strategies will be most effective in addressing needs related to regional and local mobility objectives. In some cases, these TSMO strategies will focus on specific roadway segments; in others, they will apply to a major corridor within the regional transportation network or to the entire regional network. For example, a regional traffic incident management strategy might well involve multiple jurisdictions and agencies that coordinate detection, response, and clearance activities through a single set of protocols and related technologies (e.g., sensors, communications, emergency medical services (EMS), traveler information, traffic diversion routes). Other strategies may focus on a major corridor in an effort to reduce congestion and improve travel time reliability thorough adaptive signal control, traveler information, and lane management strategies (e.g., HOV, high-occupancy tolls (HOTs), reversible lanes). Other strategies may focus on

46 See the FHWA "Transportation Systems Management and Operations (TSMO) Plans" (web page). https://ops.fhwa.dot.gov/plan4ops/tsmo_plans.htm for additional resources.

specific areas of concern such as a central business district where parking management, pedestrian safety, speed management, transit priority, and other localized strategies may be appropriate for achieving mobility, safety, accessibility, air quality, and other objectives.

Priorities for individual TSMO strategies and combinations of strategies can reflect regional priorities and resources. Approaches for prioritizing TSMO strategies typically involve identifying specific criteria that relate to regional transportation system objectives and then scoring candidate TSMO strategies or combinations of strategies with respect to these criteria. Not all criteria may be equally important, so operators and planners will often need to make judgments with respect to tradeoffs among the criteria to identify TSMO strategies that are most effective at achieving objectives.

3. *Comparing TSMO projects with major capital investments to identify opportunities where TSMO strategies are more cost effective than major capital investments in capacity expansion projects*

Often, operators and planners are faced with needs that could be addressed through major capital investments that expand capacity as a means for improving mobility in the regional transportation network. These major investments typically involve more time and effort to develop (e.g., extinguishable message signs, right-of-way acquisition, environmental reviews, public comment and review) and significantly more resources—primarily funds but also greater involvement by more public- and private=sector entities. TSMO strategies can typically be designed, developed, and deployed more quickly with less disruption to mobility during installation than capacity expansion projects. Additionally, TSMO strategies lend themselves to updating and upgrading as needs change and more-advanced technologies become available.

The tradeoff between TSMO strategies and major capacity expansions is generally driven by regional priorities and objectives. If needs are within the existing roadway network, TSMO strategies can often provide benefits that address needs at much lower costs than would a capacity expansion project. Major capacity or accessibility projects often accompany new development or growth in demand within a region, requiring transportation infrastructure to provide needed accessibility to development areas or to divert traffic to avoid congestion and improve travel time reliability.

Again, the decision regarding TSMO strategies or major capital investments in new capacity is based on the nature of the need, the time available to address the need, the resources available, and the potential effectiveness of TSMO strategies for achieving mobility objectives. The underlying premise is that transportation planners and operators achieve maximum performance of the existing transportation network through effective transportation system management and operations before embarking on investments in additional capacity.

4. *Integrating TSMO strategies into planned capital improvement projects so that they are embedded in all project design, development, and implementation plans*

Frequently, transportation operators and planners are already considering or have decided to invest in major capital improvement projects. Historically, these projects focused almost exclusively on the design and development of the roadway, leaving many of the operational aspects (signs, stripping, controls) to the transportation engineers who will operate and maintain the roadway once it is constructed.

More recently, transportation planners and operators recognize the importance of addressing operations as part of the project development process. TSMO strategies are integrated into the planning process, as has been demonstrated through multiple capacity expansion projects that include HOT or other managed lane features (e.g., dedicated truck lanes, lane restrictions) as part of the project design. Additionally, many projects have TSMO strategies as part of the design, including, for example, roadside technology (e.g., sensors, communications, CMS, hardened shoulders, speed management). Selecting which TSMO strategies to include in the design of the project is similar to selecting TSMO strategies for an existing roadway network and is often based on historical demand patterns and analytical models that can predict demand and travel times based on how the new capacity is managed.

### TSMO Project Prioritization: Potential Issues To Address

The major hurdle for TSMO in many jurisdictions is that TSMO strategies are not considered during the planning process as viable alternatives to capacity expansion or, in some cases, not viewed as effective in addressing congestion issues when compared with capacity expansion. If TSMO strategies are considered, they may be viewed as *alternatives* to capacity expansion rather than as an integral part of any alternative. TSMO strategies are often added on after major investment projects are planned and, in some cases, completed, as a way of managing the facility rather than as an integral part of the design process. Moreover, TSMO projects may be viewed as local projects rather than projects to be considered across multiple jurisdictions and involving multiple agencies (e.g., public works, transportation, law enforcement, EMS, incident response).

In some jurisdictions, funds are set aside for TSMO projects so that they do not compete directly with capacity expansion projects. In these cases, the TSMO projects are prioritized and selected based on where they can be effective in addressing regional goals and objectives (especially operations objectives) and can be implemented with available resources.

TSMO strategies typically have shorter lifecycles than new capacity and require hardware and software upgrades as newer and more-advanced technology becomes available. Consequently, proactive TSMO planning includes plans for these upgrades and eventual obsolescence. As onboard technology becomes more pervasive in both commercial fleets and private vehicles, transportation agencies will need to integrate both data and controls that take advantage of these capabilities through vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-everything solutions. Additionally, TSMO strategies often require extensive collaboration and cooperation among multiple public and private agencies across multiple jurisdictions—thus the need to agree to resource sharing, liability, funding arrangements, and associated protocols for cooperation.

TSMO strategies and projects often call on skills and knowledge that are not available with existing staff. Agencies often outsource design, implementation, and operations because they lack the in-house resources with the needed capacities and competencies. TSMO strategies often involve sensors, networks, communications, data analytics, displays, and decisionmaking as well as protocols and agreements that are unique to these strategies. New technical skills and additional technical training may be needed to develop, design, implement, and operate technologies and processes associated with TSMO strategies.

### TSMO Project Prioritization: Examples of Implemented Solutions

Several State DOTs and other entities have developed and use tools for identifying areas where TSMO strategies could be used to improve regional transportation system performance or to prioritize TSMO strategies for addressing specific needs and objectives.

*Identifying Hotspots for TSMO Strategies*

Ohio DOT developed the Traffic Operations Assessment Systems Tool (TOAST) as recommended in its 2018 TSMO Early Action Implementation Plan. The tool uses an interactive spreadsheet to identify system hotspots and prioritize projects. TOAST data calculations are run on route segments, and a total score is calculated for each route to identify those that can benefit from TSMO strategies. TOAST reports are generated statewide and by district and indicate the top 25 segments or hotspots by using data in the following categories: travel time performance, bottlenecks, TSMO safety, incident clearance, secondary crashes, volume per lane,

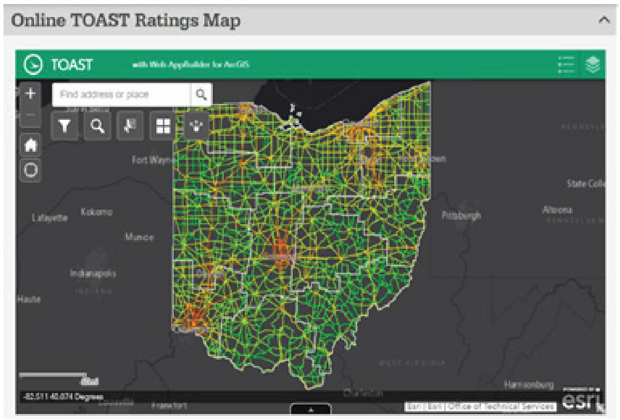


Figure 10. Ohio DOT's online TOAST ratings map.

Source: NDOT TSMO Investment Prioritization Tool.

freight corridors, and safety performance. Ohio DOT created an interactive online TOAST ratings map to allow stakeholders to zoom in and identify ratings on roads of interest.[47] Figure 10 shows the online map identifying hotspots where TSMO strategies could contribute to relieving congestion.

*Prioritizing TSMO Strategies*

Nevada DOT (NDOT) used the TSMO Investment Prioritization Tool (IPT) to prioritize TSMO projects for further consideration.[48] Selection criteria were established for the IPT, and definitions were aligned with the One Nevada Transportation Plan. Long-range plans and documents were reviewed to ensure a unified strategic direction in developing and using this tool.

Following development, the NDOT conducted workshops with districts to incorporate the tool into everyday business. After the 2019 workshops, NDOT began integrating the IPT into the Traffic Operations Division's business processes, and the IPT is now incorporated into the development and selection of projects within NDOT's ITS Strategic Deployment Plan.

NDOT's Traffic Operations Division uses IPT to prioritize projects and share results. After discussions with districts, the Traffic Operations Division prioritizes projects and allocates resources based on a systematic needs assessment. The tool's criteria include enhancing safety, preserving infrastructure, optimizing mobility, fostering sustainability, enhancing reliability, optimizing customer service, and enhancing collaboration. Figure 11 shows how TSMO projects are evaluated, scored, and prioritized. The prioritization criteria in the figure include alignment with strategic goals and objectives, project cost, and implementation timeframe. Additionally, the process assesses relevant risks and limitations and their severities. The return on investment is calculated based on the input values. Note that the points available to each of the criteria relate to strategic goals and all are set to a maximum of one point, suggesting that they are equally important for the purposes of prioritizing TSMO projects.

In some jurisdictions or regions, funds are specifically designated for TSMO projects, and

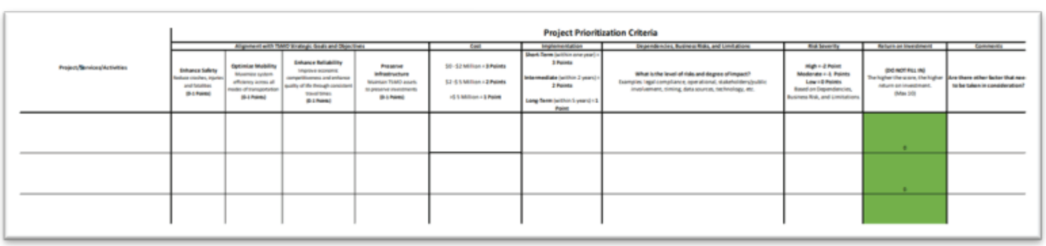


Figure 11. Nevada DOT's framework for prioritizing TSMO projects.

Source: NDOT TSMO Investment Prioritization Tool.

47 Ohio Department of Transportation. n.d. "Traffic Operation Assessment Systems Tool (TOAST)" (web page). https://www.transportation.ohio.gov/wps/portal/gov/odot/working/data-tools/resources/toast, last accessed October 7, 2022.

48 Nevada Department of Transportation. "NDOT TSMO Investment Prioritization Tool (IPT) – Case Study." Washington, DC: National Operations Center of Excellence. https://www.transportationops.org/case-studies/tsmo-investment-prioritization-tool-ipt, last accessed October 7, 2022.

the goal is to prioritize TSMO projects for funding from this designated source. One example of this approach is in the Portland, Oregon Metropolitan Planning Organization, Metro.

Metro developed a 10-year regional TSMO plan to guide operations investments in the region. The TSMO plan identifies two categories of actions: (1) those for regional programs and projects that require interagency cooperation and (2) those for individual travel corridors and single-agency services. After the allocation of funding for the TSMO program in the metropolitan TIP, Metro then works with its regional operations collaborative group, called TransPort, to evaluate and select projects to receive TSMO program funds. Of these funds, one-third goes to regionwide projects and two-thirds go to corridor-specific projects. Corridor projects are organized under mobility corridor concepts , in which 24 unique, multimodal corridors in the Portland region connect major activity centers. Each corridor includes a combination of freeways and highways, parallel networks of arterial streets, regional multiuse paths, high-capacity transit, and frequent bus services that connect major activity centers, as defined by the regional growth concept.

### *Prioritization of Transportation Systems Management and Operations Projects Among All Project Types*[49]

The potential for TSMO projects to be selected in a process that includes open competition with major capital investment projects depends on the selection criteria used for evaluation. Criteria that address mobility, reliability, and cost effectiveness help TSMO initiatives compete effectively for funding.

- As an example, the Delaware Valley Regional Planning Commission, the MPO for the Philadelphia region in New Jersey and Pennsylvania, developed the TIP – LRP Project Benefit Evaluation Criteria to help guide project investment decisions for the TIP and long-range plan by using data.[50] The result of this analysis is one of the considerations in selecting projects for the TIP or long-range plan. DVRPC uses these criteria to evaluate projects of various modes and types by applying existing analytical processes such as the congestion management process. TSMO projects are evaluated alongside other types of projects through this process.
- The criteria, shown in figure 12, include safety, equity, and reliability and congestion. In this figure, the "children" serve as subcategories of the "parent" criteria. The safety criterion receives the largest weight, at 27 percent. Reliability and congestion accounts for 11 percent of the project's score. For reliability and congestion, projects score based on location in a congestion management process (CMP) congested corridor, implementation of a CMP strategy appropriate for that corridor, or location on a road with a high planning time index (PTI); or transit facility with a low on-time performance. The set of common project selection criteria relates to the broader transportation goals and objectives identified in the Connections 2045 Plan for Greater Philadelphia.

### *Integrating TSMO Strategies Into Major Capital Investment Projects*

In 2015, Colorado's DOT developed a TSMO evaluation process to support TSMO considerations in projects using "a holistic approach to project development that encourages stakeholders to consider safety, operations, and technology elements early in the project life-cycle."[51] The

49 FHWA. 2016. *Planning for Transportation Systems Management and Operations Within Corridors: A Reference*. Report No. FHWA-HOP-16-037. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop16037/ch4.htm#ch4.1, last accessed October 7, 2022.

50 Delaware Valley Regional Planning Commission. n.d. "TIP – LRP Project Benefit Evaluation Criteria." Philadelphia, PA: DVRPC. https://dvrpc.org/LongRangePlanAndTIP/pdf/4690_Designed_Final_TIP-LRP_Benefit_Evaluation_Criteria.pdf, last accessed October 7, 2022.

51 Colorado Department of Transportation. n.d. "TSM&O Evaluation Executive Summary." Denver, CO: CDOT. https://www.codot.gov/library/traffic/traffic-manuals-guidelines/traffic_analysis_forecasting_guidelines/TSMO_Evalulation_Summary, last accessed October 7, 2022.

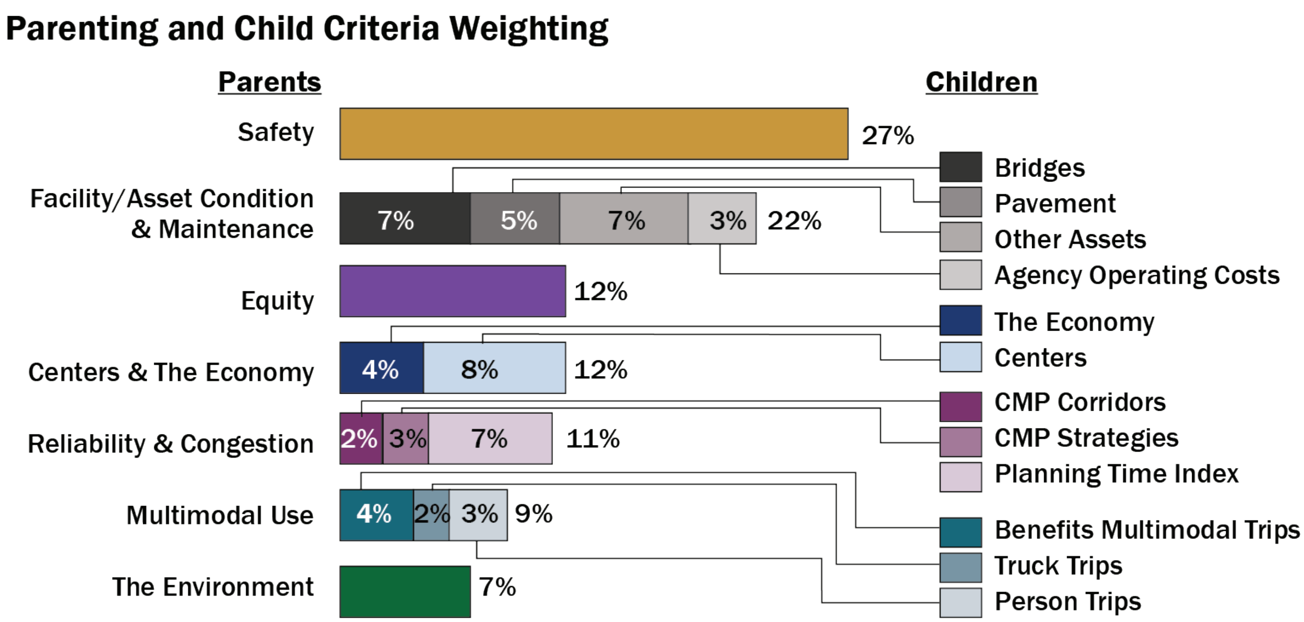


Figure 12. Graph. DVRPC's TIP-LRP criteria weighting chart.

Source: Delaware Valley Regional Planning Commission.

Project Development Manuals and Evaluation Tool provides an evaluation framework to support recommendations for improvement. Beginning in 2016, CDOT required all projects to include a TSMO evaluation —consisting of a safety assessment, an operations assessment, and an ITS assessment—that recommended improvements to safety and mobility on the project. Using the evaluation on every project integrated the consideration of TSMO as a regular part of project development. The evaluation form is an online tool that takes input on crash data, current and proposed ITS infrastructure, operations data, and existing geometric conditions. The tool helps document current conditions and TSMO recommendations and identify projects for more in-depth operational and safety analyses.[52]

Similarly, in 2016 and 2017, Florida's DOT comprehensively reviewed its guidelines to identify where TSMO strategies had been included and what would be required to mainstream TSMO throughout the project development process. The agency also reviewed TSMO best practices across other State DOTs. Areas of focus included business processes, such as procurement, budgeting, and software development in ITS and TSMO projects. During the review of FDOT publications for TSMO language, FDOT revised its manuals, such as the Florida Intersection Design Guide and FDOT Design Manual, to incorporate TSMO. FDOT District 4 has created a checklist for use in the scoping of capital projects. The checklist includes a question on whether the relevant ITS master plan contains ITS needs for the project area that may be added to the project.

### TSMO Project Prioritization: Next Steps

To prioritize and develop TSMO projects, agencies may want to begin with the following steps:

1. Engage key agencies and stakeholders in a working group to prioritize TSMO projects. Connect with these agencies and stakeholders early in the process to ensure that all perspectives are represented and that all are committed to finding feasible solutions

52 Ibid.

that can address regional transportation system objectives.

2. Develop criteria for evaluating and selecting TSMO projects. Ensure that the criteria are consistent with regional objectives and that appropriate performance measures have been selected both to assess the potential benefits of TSMO strategies and to compare TSMO strategies with alternative approaches (e.g., capacity expansion).

Determine the data and analytical tools that will be used to evaluate TSMO strategies, whether these data and tools are available, and whether sufficient expertise is available to apply and interpret them correctly. Base the data on historical data or data generated from models that incorporate demand trends.

- Once the first three steps are completed—and depending on the situation and need—data and analysis tools may be used to identify TSMO opportunities, compare TSMO options, evaluate TSMO strategies compared with capacity expansion, and/or integrate TSMO strategies into capacity expansion projects. As necessary, recycle and refine through the three steps described above, including adding new stakeholders as appropriate, modifying or updating criteria and related performance measures, and integrating new data sources and analytical tools to assist in the prioritization and project development process. Finally, set up a post-deployment evaluation plan for evaluating the effectiveness of TSMO strategies and use the results of the evaluation to inform future decisions regarding TSMO strategies and related projects.

# 3 SECTION 3: Developing Operations Objectives

Operations objectives and their associated performance measures are the focal points for integrating operations into the planning process. They are contained in the transportation plan and guide the discussion about operations in the area.

While goals relate to the overall vision or desired end result, operations objectives are specific and measurable. Unlike goals, progress toward an operations objective and its achievement can be evaluated with performance measures. Operations objectives contain a specific desired performance result (often referred to as a *target*). This combines the objectives, performance measures, and targets that are separate in the typical performance-based planning and programming approach. Organizations may choose to keep these elements separate based on their preferences.

Goals reflect the area's values and vision for the future, and operations objectives should be developed to support one or more goals. This helps to ensure that projects developed based on operations objectives are responding to the explicit values and overall goals for the area. Operations objectives describe what needs to occur to accomplish a goal. The operations objectives state what an area plans to achieve concerning the operational performance of the transportation system, and they help determine what strategies and investments to include in the transportation plan.

Operations objectives typically place a focus on issues of congestion, reliability, safety and security, incident management, and work zone management, among other issues. Operations objectives aim to "optimize the performance of existing [and planned] infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and projects designed to preserve capacity and improve security, safety, and reliability of the transportation system."[53] Many of the sample objectives presented in this section suggest that agencies strive to improve performance over baseline conditions (e.g., examples of numerical thresholds or targets). However, depending on external constraints, such as funding levels, changes and growth in travel demand, past optimization, or other factors, practical objectives that reflect sustaining existing performance conditions or an approach to mitigate or better manage declining performance may be appropriate for a given region or agency.

## 3.1 Outcome-Based and Activity-Based Operations Objectives

The operations objectives contained in the appendix range from objectives that focus on high-level outcomes, such as system reliability, to objectives that focus on low-level operations activities or tactics, such as signal timing. Operations objectives span a continuum between outcome-oriented (higher-order) to activity-oriented (lower-order) objectives. While there is no strict boundary between the two primary orientations, most fit within one label or the other.

Given that the fundamental purpose of TSMO strategies is to improve the transportation system, operations objectives that guide operations throughout the plan are preferably described in terms of those system performance outcomes that users experience. Aspects of system performance that users experience include travel times, travel time reliability, and access to traveler information. The public cares about these measures, and in many areas, data may be available to develop

53 See 23 U.S.C. 101(a)(32).

specific outcome-based operations objectives. Areas also may develop operations objectives that are activity based and support desired system performance outcomes. Planners may find that the activity-based objectives are more appropriate for guiding the development of specific sections of the plan or for use in supporting documents such as the Regional Concept for Transportation Operations, TSMO program plan, or ITS strategic plan.[54 55] All lower-level, activity-oriented operations objectives typically support an existing outcome-oriented operations objective, providing a simple check to make sure that operations activities are performed in pursuit of a system performance outcome.

By establishing one or more activity-based objectives for each outcome-based objective, planners and operators further define how each outcome-based objective can be accomplished. Planners and operators can develop specific TSMO strategies or actions to support the objectives and, in turn, the goals by examining how the activity-based objectives can be accomplished.

## 3.2 Characteristics of Operations Objectives

By creating specific, measurable objectives for operations, transportation organizations can use these operations objectives for making investment decisions as well as tracking progress.

An operations objective has the SMART characteristics defined below:

- ***S*pecific.** The objective provides sufficient specificity (e.g., decrease travel time delay) to guide formulating viable approaches to achieving the objective without dictating the approach.
- ***M*easurable.** The objective facilitates quantitative evaluation (e.g., by 10 percent), saying how many or how much should be accomplished. Tracking progress against the objective enables an assessment of the effectiveness of an action or set of actions.
- ***A*greed.** Planners, operators, and relevant planning participants come to a consensus on a common objective. This is most effective when the planning process involves a wide range of stakeholders to facilitate collaboration and coordination.
- ***R*ealistic.** The objective can reasonably be accomplished within the limitations of resources and other demands. The objective may require substantial coordination, collaboration, and investment to achieve. Because determining the realism of the objective cannot occur until after strategies and costs are defined, the objective may need to be adjusted to be achievable.
- ***T*imebound.** The objective identifies a timeframe within which it will be achieved (e.g., within three years).

By selecting a performance target as part of the operations objective, transportation organizations make decisions, knowing the degree of improvement they are striving for rather than just the direction of improvement. For example, the objective "decrease travel time delay" conveys direction ("decrease") but does not indicate the desired degree of improvement. The objective "decrease travel time delay by 10 percent within five years" gives the transportation organization a specific and measurable target to reach.

It is common for transportation plans to have more-general objectives relating to the performance of the transportation system, such as, "Relieve congestion on the freeway and arterial systems in the region." This example objective provides the direction—to relieve congestion— but does not express to what degree congestion must be relieved for the objective to be met.

54 FHWA. 2022. "Regional Concept for Transportation Operations" (web page). https://ops.fhwa.dot.gov/plan4ops/focus_areas/trans_ops.htm, last accessed October 7, 2022.

55 FHWA. 2022. "Transportation Systems Management and Operations (TSMO) Plans" (web page). https://ops.fhwa.dot.gov/plan4ops/tsmo_plans.htm, last accessed October 7, 2022.

To make this objective SMART, it needs to define congestion in measurable terms. One measure used for congestion is the travel time index that compares travel during peak periods with travel at free flow or the posted speed limit. In addition, the objective needs a performance target for the region, such as a 0.10-point reduction in the index. The objective also must establish the timeframe in which it must be accomplished. Establishing a realistic objective and reaching agreement on it must be done within the context of the area and the participating organizations. Using the SMART characteristics as a guide, the general operations objective "Relieve congestion on the freeway and arterial systems in the region" can be transformed into a SMART objective: "Reduce the regional average travel time index on freeways and arterials in the region by 0.10 point within 10 years."

Incorporating SMART operations objectives into the plan provides the opportunity for decisionmakers to invest in near-term, relatively low-cost TSMO strategies that provide immediate improvements to the transportation system. These can complement longer term improvement strategies that may require time to study and fund. Thus, it would be appropriate for an operations objective to have a timeframe that is shorter than the horizon year of the plan. The cyclical updates of these plans provide the logical opportunities to determine if adjustments are needed to the timeframe or degree of the objective and help determine whether different or additional actions are appropriate.

## 3.3 Scope of Operations Objectives

An operations objective is the product of many decisions. As mentioned in the previous section, those who draft the objective must decide on what they want to improve or maintain, the direction of that improvement (e.g., increase), the degree of improvement desired (e.g., by 25 percent), and the timeframe for reaching the objective (e.g., within 10 years).

In the determination of what to improve, several dimensions often come into consideration. These dimensions determine the scope of the operations objective. One or more of the following dimensions may need to be addressed while developing or refining the objective. In the menu of objectives in the next section, the dimensions of the objective can be tailored to specific needs of the area.

- **Area.** This dimension defines the spatial aspect of the objective. What is the geographic area of focus? Does the objective aim to make improvements for the entire State, region, urban centers, corridors, freight-significant highways, work zones near major activity centers in the region? or another area?
- **Time.** What are the time periods of interest for operational improvements? Is there a focus on peak periods, off-peak periods, weekdays, during certain events, or all time periods?
- **Mode and facility type.** Is the objective mode neutral, or does it target one or more specific modes such as walking, bicycling, public transit, or facility types such as highways/arterials, rails, or local connectors?
- **User type.** Does this operations objective focus on a particular transportation system user type? Does the objective center on freight companies, single-occupancy-vehicle drivers, transit-only travelers, or others?

While defining operations objectives, developers must consider how best to measure progress toward the objective, because this impacts how the objective is stated and, subsequently, the improvements that are made. This process includes such considerations as whether the improvements are measured per person, per vehicle, per facility, or for the total population. Do the transportation organization and its partners want to improve the average performance or make strides toward reducing the worst performance? These are strategic decisions that must be made when developing operations objectives.

In the objectives in the appendix, the scope of the objective can be adjusted along these dimensions to fit an area's specific needs.

## 3.4 Connecting Operations Objectives

Using the structure of a tree to develop operations objectives and ensure that the supporting connections exist is a common technique in strategic planning and systems analysis. The method of developing an objectives tree is more fully described in other resources,[56] but an example can be found in figure 13, which illustrates the parts of an objectives tree. For the sake of brevity, the operations objectives are not written as full SMART objectives in the figure.

The objectives tree concept can be put to use in developing a logical set of operations objectives and in understanding the necessary connections between goals, operations objectives, and management and TSMO strategies.

An objective tree illustrates the logical hierarchy that exists between outcome-based objectives and activity-based objectives. It can be used to connect regional goals to objectives and objectives to TSMO strategies. It is also helpful in thinking through the interactions between operations objectives.

An objectives tree begins with a broad goal or high-order objective relating to the performance of the transportation system. This objective answers the question, "What do we ultimately want to achieve?" Examples may focus on improved system reliability, efficiency, system options, or high service quality. In the example shown in figure 13, the tree begins with the broad goal "Improve mobility in the corridor." Based on that goal, the higher order, outcome-based objective "Reduce traveler delays" was formed. This is how the region aims to achieve its goal of improving corridor mobility. From this high-order objective, the developers form more-specific and detailed operations objectives that answer the question, "How can this objective be accomplished?" These detailed or lower-order objectives are then linked to the higher order objective. This process is repeated for each goal or high-order objective until the developers reach the point where the lower order operations objectives can be acted upon. These are typically activity-oriented operations objectives that can be readily addressed through one or more TSMO strategies. Lower order operations objectives connected to a higher operations objective answer the question of how that higher objective can be accomplished. Similarly, the higher operations objective answers the question, "Why should the lower objective be accomplished?" TSMO strategies can be placed below each of the lowest objectives in the tree to indicate which strategies are needed to accomplish those objectives.

Areas can select which operations objectives in the objectives tree are most important to be included in the long-range transportation plan or other planning documents. Outcome-oriented objectives such as those that may be near the top of an objectives tree are used to guide the operations elements of the entire plan. Activity-based objectives are used in specific sections to guide the development of TSMO strategies.

56 J. Gibson and W. Scherer. 2007. "Chapter 3: Goal Development." In *How To Do Systems Analysis*, edited by W. Gibson. Hoboken, NJ: Wiley & Sons.

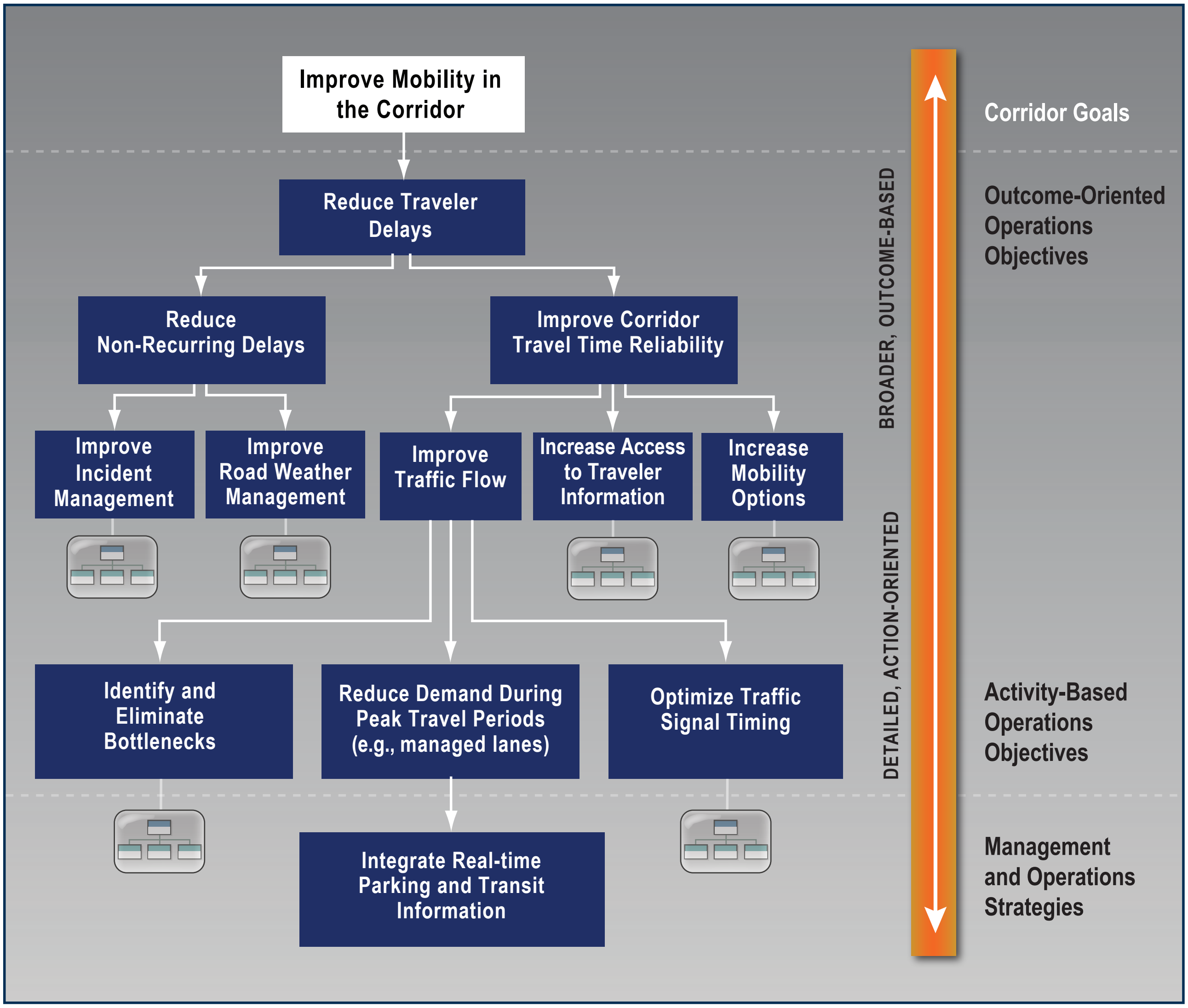


Figure 13. Example of an objectives tree

Source: FHWA.

## 3.5 Using Objectives To Identify and Select TSMO Strategies

Operations objectives are used within the transportation planning process to help select strategies that will be included in the plan and corresponding TIP. This occurs through a systematic process in which objectives lead to performance measures, data collection and analysis, and identification and prioritization of strategies. Each of the sample objectives in the appendix identifies sample performance measures; anticipated data needs, data resources, and partners; and TSMO strategies to consider.[57]

Specifically, developing operations objectives leads to performance measures that can be used to assess and track transportation system performance. These performance measures can be tracked and forecast under various plan scenarios. By identifying specific and measurable performance outcomes, operations objectives also can lead to developing performance measures at a micro level, such as to determine the performance of

57 The specific strategies to be included within a plan may be based on analysis of the conditions in each area.

corridors, road segments, intersections, or transit routes. For instance, while an operations objective might include a specific target for travel time reliability, different thresholds can be used to define unacceptable unreliability within the area based on location (e.g., urban or suburban), facility type (e.g., freeway, high-occupancy-vehicle (HOV) lane, transit route, arterial), and time period (e.g., peak commute periods, periods of special events).

Data are needed to use performance measures. Consequently, collecting data for performance measures is a key step in the planning process. Limitations in data are often of concern in selecting performance measures. However, many types of data currently are being collected by MPOs (e.g., census data on journeys to work, population, traffic counts, travel times). Transportation system operators such as transit agencies, State DOTs, local transportation agencies, and toll authorities are collecting a wealth of data. In particular, intelligent transportation systems (ITSs) such as toll tag readers, video detector systems, and transportation management systems offer the opportunity for more-detailed data for use in planning, which enables analysis of such issues as variations in travel speeds. Agencies can collaborate with other agencies to collect and use the data.

An analysis of system- and corridor-level deficiencies (e.g., problems in specific parts of the region and corridors, times of year, types of trips) and financial constraints should be used to help identify and select specific TSMO strategies to include in the plan and program. The assessment should consider cost effectiveness in meeting operations objectives along with co-benefits, such as improved safety, and ability to support other goals. Analysis tools, such as sketch-planning tools, travel demand forecasting model post-processors, and simulation modeling may be used to help forecast system deficiencies and analyze the potential benefits of operations strategies. Analysis tools give planners and operators the ability to assess TSMO strategies independently or in conjunction with other transportation investments. This supports the evaluation of different alternatives so that the right mix can be selected and objectives can be realized. Analysis and visualization tools enable planners and operators to communicate the analytical results of these kinds of comparisons with elected officials, other decisionmakers, and the public, helping them make better and more-informed decisions about transportation investments.[58]

It is important to recognize that TSMO strategies may be implemented as individual programs or projects, such as a regional incident management system, traveler information system, or transit smart card. They also can be implemented as part of transportation preservation projects, safety projects, or capacity improvements. For instance, as part of any new highway expansion, it may be useful to consider the role of transportation pricing, HOV lanes, flexible design to accommodate concurrent travel flows, or demand management programs.

58 For more information, see the FHWA's "Organizing and Planning for Operations" (web page). https://ops.fhwa.dot.gov/plan4ops/focus_areas/analysis_p_measure/analysis_p_measure.htm.

# 4 SECTION 4: Menu of Operations Objectives

This section provides an overview of the examples of operations objectives and their associated performance measures, data needs, and other related information found in the appendix. Many more potential operations objectives and performance measures could be used for TSMO. Practitioners can tailor the examples provided to their specific organizational needs.

The operations objectives are displayed in the TSMO (QR) sheets in the appendix. The objectives generally fall into two groups: system outcomes oriented and TSMO strategy focused. The objectives within the TSMO strategy areas are primarily activity based.

The objectives in the QR sheets have been organized into two main areas: system outcomes and TSMO areas.

Operations objectives related to system outcomes tend to be high level, crosscutting, and indicative of outcomes experienced by system users (e.g., delays and incidents), as opposed to activity-based objectives, which typically relate to the processes system operators manage that contribute to improved outcomes for system users. Outcome objectives are typically mode neutral. The six categories describing system outcomes were chosen based on major attributes that users of the transportation system expect.

The operations objectives under system outcomes have been subdivided into these six categories:

1. Efficiency (EF)
2. Travel Time Reliability (TTR)
3. Mobility Options and Equity (OE)
4. Sustainability (SU)
5. Resiliency (RE)
6. Safety (SA)

The operations objectives under the TSMO areas generally focus on one operational aspect of the system, such as arterial management. They include both outcome-based objectives (e.g., reduce delays on arterials) and activity-based objectives (e.g., reduce times between incident verification and posting of traveler alert). Operations objectives within the TSMO areas support the achievement of one or more high-level objectives for system outcomes, such as efficiency, reliability, or options.

Under the TSMO areas, the operations objectives have been subdivided into the following 12 categories:

1. Arterial Management (AM)
2. Emergency Management (EM)
3. Emerging Mobility Services (MS)
4. Freeway Management (FWM)
5. Freight Management (FRM)
6. Traffic Incident Management (TIM)
7. Special-Event Management (EVM)
8. Transit Operations and Management (TRM)
9. Transportation Demand Management (TDM)
10. Road Weather Management (RWM)
11. Traveler Information (TI)
12. Work Zone Management (WZ)

The following provides the definition used in this reference for each of the categories, as well as information regarding what types of objectives are referenced under each section.

## 4.1 System Outcome Objectives

**Efficiency (EF).** Efficiency is defined as maximizing the benefits of the transportation system to the user while minimizing user costs. Costs to consider include additional travel time, monetary costs, travel distance, and fuel consumption. Operations objectives in the category of efficiency focus on minimizing costs and managing several aspects of congestion: extent, duration, and intensity. The sample objective categories cover:

- EF1. Extent of Congestion
- EF2. Duration of Congestion
- EF3. Intensity of Congestion
- EF4. Travel Time
- EF5. Delay
- EF6. Energy Consumption
- EF7. Cost of Congestion
- EF8. Vehicle Miles of Travel
- EF9. Trip Connectivity

**Travel Time Reliability (TTR).** A reliable transportation system can be defined as one that provides the users with a consistent and predictable travel time. While reliability could be expanded beyond travel time to cost, comfort, route, and mode availability, those aspects are more appropriately handled in other sections of the menu. The sample objective categories cover:

- TTR1. Nonrecurring Delay
- TTR2. Travel Time Buffer Index
- TTR3. Travel Time 95th Percentile
- TTR4. Planning Time Index
- TTR5. Variability
- TTR6. Transit On-Time Performance

**Mobility Options and Equity (OE).** Mobility options and equity refers to the user's ability to select a mode of travel from among many that are available to make a trip within a given timeframe, for a specific purpose, and/or via a certain route. Availability and use of multimodal options—such as transit, ridesharing, bicycling, and walking—can be important components of a regional strategy to reduce traffic congestion and improve the operation of the transportation system. *Equity* refers to the need to provide access for all system users—especially those who may be underserved by mobility options that rely primarily on private vehicles or who may have been underrepresented in prior transportation decisionmaking. The sample objective categories cover:

- OE1. Mode Share
- OE2. Transit Use
- OE3. Travel Time: Transit Compared With Auto
- OE4. Bicycle, Pedestrian, Micromobility Accessibility and Efficiency
- OE5. Modal Options for Individuals With Disabilities
- OE6. Equitable Access to Services and Opportunities
- OE7. Equitable Access to Electrification Options
- OE8. Equitable Mitigation of Negative Effects (congestion, noise/air/land pollution and contamination)

**Sustainability (SU).** Sustainability is often described using the triple-bottom-line concept, which includes the consideration of three primary principles: social, environmental, and economic. The goal of sustainability is the satisfaction of basic social and economic needs both present and future and the responsible use of natural resources, all while maintaining or improving the well-being of the environment on which life depends. The sample objective categories cover:

- SU1. Technological
- SU2. Fiscal
- SU3. Environmental

**Resilience (RE).** Resilience can be defined as "the ability to anticipate, prepare for, or adapt to conditions or withstand, respond to, or recover rapidly from disruptions."[59] The sample objective categories cover:

RE1. System Vulnerability

RE2. Adaptation

RE3. Recovery Time

**Safety (SA).** Safety focuses on improving roadway safety performance for all users of the transportation system: saving lives and reducing injuries, including those from secondary crashes. The sample objective categories cover:

SA1. Fatalities and Serious Injuries

SA2. Nonmotorized Fatalities and Serious Injuries

SA3. Speed Management

SA4. Intersection Crashes

## 4.2 TSMO Objectives

This section identifies representative objectives associated with specific TSMO program areas. Note that many of these objectives are activity-based objectives in that they relate to the processes that system operators perform that support outcome-oriented objectives.

**Arterial Management (AM).** Arterial management is the management of arterial facilities in a manner that provides users with a safe, efficient, and reliable trip. The sample objective categories cover:

AM1. Delay

AM2. Access Management

AM3. Reliability

AM4. Traffic Monitoring and Data Collection

AM5. Traffic Signal Management

AM6. Complete Streets

**Emergency Management (EM).** Emergency management is designed to provide users with a safe and efficient transportation system during a large-event emergency situation. Transportation and other responders work together before, during, and following an event to support seamless coordination and communication and public safety. The sample objective categories cover:

EM1. Evacuation Times

EM2. Emergency Alert

EM3. Interagency Coordination

**Emerging Mobility Services (MS).** Emerging mobility services encompasses transformative technologies that allow data and information to better support the user experience of travel. These services provide seamless multimodal transportation, ease users' transit planning, collect meaningful data, and provide easy fare payment.

MS1. Mobility on Demand (MOD)

MS2. First-/Last-Mile Travel

MS3. Integrated Fare Payment

**Freeway Management (FWM).** Freeway management is the implementation of policies, strategies, and technologies to improve freeway performance. The overriding objectives of freeway management programs include minimizing congestion (and its side effects), improving safety, and enhancing overall mobility. The sample objective categories cover:

- Efficiency
- Reliability
- Integrated Corridor Management
- Managed Lanes
- HOV Lanes
- Pricing and Tolling
- Ramp Management
- Transportation Management Centers

**Freight Management (FRM).** Freight management is the effective management of the system

59 23 U.S.C. 101(a)(24).

for freight transportation. The goal of freight transportation is to move goods safely, efficiently, and reliably throughout the region. This may range from satisfying customers (e.g., freight shippers, receivers, carriers) to actual travel time on the system. The sample objective categories cover:

- Customer Satisfaction
- Travel Time Delay
- Travel Time Reliability
- Border-Crossing
- Intermodal Facilities
- Detours and Routing
- First-/Last-Mile Pickup/Delivery
- Truck Parking Management
- Freight Traveler Information

**Traffic Incident Management (TIM).** Traffic incident management consists of a planned and coordinated multidisciplinary process to detect, respond to, and clear traffic incidents so that traffic flow may be restored as safely and quickly as possible. Effective TIM reduces the duration and impacts of traffic incidents; improves the safety of motorists, crash victims, and emergency responders; and reduces the frequency of secondary crashes. The sample objective categories cover:

TIM1. Incident Duration
TIM2. Person-Hours of Delay
TIM3. Customer Satisfaction
TIM4. Traveler Information
TIM5. Interagency Coordination
TIM6. Training
TIM7. Responder Safety

**Special-Event Management (EVM).** Special-event management provides users with a safe and efficiently managed transportation system during a planned special event. Practitioners conduct advance planning and coordination to develop and deploy the operational strategies, traffic control plans, protocols, procedures, and technologies needed to control traffic and share real-time information with other stakeholders on the day of the event. The sample objective categories cover:

- Entry/Exit Travel Times
- Mode Shift From Single-Occupancy Vehicle (SOV)
- Traveler Information
- Parking Management
- Multiagency Coordination and Training
- Use of Technology

**Transit Operations and Management (TRM).** Transit operations and management is the operation and management of the transit system in a safe and efficient manner. The sample objective categories cover:

- Service Directness
- Loading Standards
- Traveler Information
- Customer Service/Safety
- Line-Haul Transit
- Transit Signal Priority
- Automated Fare Collection
- Park-and-Ride Support

**Transportation Demand Management (TDM).** Transportation demand management focuses on providing users with effective travel choices and supporting strategies that encourage travelers to shift or reduce their demand for travel in congested conditions. Traditional TDM has centered on managing recurring, commuter-based travel or travel associated with tourism. However, with TSMO-related tools and data, TDM is increasingly being seen as a critical element of work zone management, traffic incident management, emergency management, and network-disruption management. The objective categories in the menu cover:

- Leveling Demand
- Auto Commuter Trip Reduction Programs

- Commuter Shuttle Service
- Carpool/Vanpool
- Walking/Bicycling
- Parking Management
- Marketing

**Road Weather Management (RWM).** Travel weather management focuses on providing users with a safe and efficient transportation system during and after weather events. The sample objective categories cover:

- Clearance Time (Weather-Related Debris)
- Detours for Impacted Roadways
- Dissemination of Information
- Road Weather Information System Coverage
- Signal Timing Plans

**Traveler Information (TI).** Traveler information is designed to provide transportation system users with the information they need to choose the safest and most efficient mode and route of travel. The sample objective categories cover:

- Information Dissemination
- Trip-Planning Tools
- Data Collection and Sharing of Travel Conditions
- Customer Satisfaction

**Work Zone Management (WZ).** Work zone management involves organizing and operating areas impacted by road or rail construction to minimize traffic delays, maintain safety for workers as well as travelers, and accomplish the work efficiently. The sample objective categories cover:

- Travel Time Delay
- Extent of Congestion
- Travel Time Reliability
- Construction Coordination
- Traveler Information
- Customer Satisfaction

# 5 SECTION 5: Example Transportation Plan

## 5.1 One Size Does Not Fit All

The purpose of this section is to provide sample (or illustrative) transportation plan elements that demonstrate the effect of applying an objectives-driven, performance-based approach to operations during the transportation plan development process. The objectives driven, performance based approach complements or enhances the transportation-planning process rather than replacing it. The example plan detailed here is neither real nor a complete document; rather, it is an assembly of sample elements with an emphasis on operations, intended to provide insight into the benefits of applying this approach.

Each transportation-planning organization operates in a unique context with varying land-use laws and ordinances, regional congestion and air quality issues, staffing and funding constraints, levels of interagency collaboration, and visions, making a single example plan impractical. Fortunately, many organizations take similar steps in the transportation plan development process to meet their particular combination of needs and opportunities: goals lead to objectives; objectives lead to evaluation criteria (or performance measures); performance measures inform the selection of programs and projects; and the available type of funding sources in addition to other factors determine the feasibility and timing of implementation. Thus, it is possible to illustrate the effect of applying the objectives driven, performance-based approach through sample plan elements that follow these steps.

The systematic approach outlined in the sample chapters in Section 5 is consistent with FHWA's Performance-Based Planning and Programming Guidebook.[60] Performance-based planning and programming includes establishing transportation system performance goals, objectives, and measures and then using data, projections, and analytical tools to evaluate strategies and identify investment priorities. Once investment priorities are established, available funds from eligible funding sources can be allocated and programmed for specific projects and activities. Lastly, implemented projects and activities are monitored and evaluated to determine how well objectives are met and where performance gaps continue to exist, providing input to subsequent performance-based, objectives-driven planning activities.

Currently, some planning organizations are making significant strides toward integrating operations into their transportation plans, while others have only begun to consider operations. Planning organizations have found that different factors affect their ability to fully incorporate operations by using operations objectives and performance measures, such as revenue and cost, data availability, staff capabilities and resources, and stakeholder commitment.   Because of this, the example plan in Section 5 shows how operations projects and strategies may be incorporated at different levels of integration: basic, advancing, and comprehensive. Many planning organizations may be limited to loosely integrated planning involving communication and coordination but may find value from considering ways to advance integration of operations into the transportation-planning effort overtime. Even planning organizations that are comprehensive in their integration of operations into the planning approach should find value in reviewing the example plan and the samples offered at each level.

60 FHWA. 2023. Model Long-Range Transportation Plans: A Guide for Incorporating Performance-Based Planning and Programming Guidebook, Report No. FHWA-HEP-123-0418. Washington, DC: FHWA. https://www.fhwa.dot.gov/planning/performance_based_planning/mlrtp_guidebook/index.cfm

## 5.2 Example Plan Overview

The example plan illustrates how the approach affects who is involved in the planning process, how operations can help achieve regional goals and outcomes, and the value derived from applying measurable objectives to the decisionmaking and implementation phases of the planning process. It does not dictate or restrict how planning organizations should organize, format, or prepare their plans. Section 5.3 includes illustrative sample text drawn from three of the eight chapters of the example plan: "Goals and Objectives", "System Preservation and Maintenance", and "System Management and Operations." In addition to these two sample chapters, the example transportation plan table of contents illustrates how the two sample chapters fit into the entire transportation plan framework.

Samples from key chapters of the example plan demonstrate the effect of integrating operations into the components of the planning process discussed in those chapters. The sample chapters in Section 5.3 are written from the perspective of an organization that has fully integrated operations into its planning process. However, recognizing that planning organizations throughout the country function at different levels, call-out boxes within the samples also provide scaled examples to reflect a basic, advancing, or comprehensive approach to integrating operations into transportation planning.

Other samples illustrate how the approach could be applied to sections of a realistic transportation plan. They enable the reader to understand what content is included in the plan, how it was prepared, and why. Graphics and tables are included to explain and visualize the approach. Because transportation plans do not include the technical details on how the planning organization reached its final decisions, qualifying text boxes have been included to provide details that help the reader understand how a transportation plan gets from the beginning to the end of the approach.

## 5.3 Sample Language for Selected Chapters in Example Plan

*The following is an example table of contents. Samples for the chapters "Goals and Objectives", "Systems Preservation and maintenance", and "System Management and Operations" will be provided in the following sections.*

***Transportation Plan Table of Contents***

Chapter 1. Vision

Chapter 2. Goals and Objectives

Chapter 3. Financial Snapshot

Chapter 4. System Preservation and Maintenance

Chapter 5. System Management and Operations

Chapter 6. System Integration

Chapter 7. System Expansion

Chapter 8. Appendices

Note that these eight chapters track closely with the process described in FHWA's *Model Long-Range Transportation Plans: A Guide for Incorporating Performance-Based Planning.*[61] FHWA's model plan document describes seven elements typically included in a performance-based planning process (PBPP). The seven elements of the PBPP are listed below, and the corresponding chapters in the example transportation plan described in this section are shown in parentheses.

**Element 1: Context-Setting Information** – Information collected to inform the development or update of the metropolitan transportation plan (MTP) or long-range surface transportation plan, including existing system performance, anticipated changes in the planning area, potential challenges and opportunities, revenue availability, and other

61 FHWA. 2023. Model Long-Range Transportation Plans: A Guide for Incorporating Performance-Based Planning. Report No. FHWA-HEP-23-018. https://www.fhwa.dot.gov/planning/performance_based_planning/mlrtp_guidebook/, last accessed April 4, 2023

topics of importance to the planning area. (Chapters 3, 4, and 5)

**Element 2: Goals and Objectives** – Strategic elements of the transportation plan, including visioning to engage the public and stakeholders in imagining the desired future of the State, region, or community. Goals and objectives identify desired outcomes and are used as a basis for establishing performance measures, targets, and investment priorities. (Chapters 1 and 2)

**Element 3: Performance Measures and Targets** – Focal points in a performance-based plan that support long-range investment and policy decisionmaking. Performance measures in a plan include national measures established by USDOT, as well as community-driven measures, as desired. Targets associated with the national measures are incorporated, and the process of developing the plan may also include developing targets for other community-driven performance measures. (Chapter 2)

**Element 4: System Performance Report** – Existing performance of the transportation system in relation to established performance measures and targets. As ongoing data collection informs plan development over time, the system performance report will provide key information to communicate with the public and stakeholders. (Chapters 4 and 5)

**Element 5: Identification of Needs** – Based on an analysis of existing and expected performance outcomes. Data-driven analysis, supplemented with public and stakeholder engagement, occurs to identify needs for meeting desired outcomes or gaps in performance. (Chapters 4 and 5)

**Element 6: Strategies, Investments, and Financial Plans** – Connects planning to funding for project implementation. While a financial plan is not required to be included in the long-range surface transportation plan , a model performance-based plan at the State level typically considers available financial resources. MTPs include a financial plan and are fiscally constrained.[62] A model performance-based plan typically includes a prioritization process that uses performance measures to support the selection of projects for the plan. (Chapters 3, 6, and 7)

**Element 7: Connection to Programming** – Supports implementation of projects that meet desired planning goals and performance targets. A strong performance-based plan provides a framework to support programming decisions for the TIP and STIP. (Chapter 3, 6, and 7).

*Note: specific language in the example plan related to Chapters 1,3,6,7, and 8 is not provided as operations would typically not generate significant changes to those Chapters of a transportation plan. Thus, those chapters in the example plan are left blank below.*

*Text in the sample is color coded. Gray text is provided for context, establishing the topic discussed in the chapter. Boldface text illustrates the results of the planning organization having applied the objectives-driven, performance-based approach for operations during the transportation plan development process.*

## CHAPTER 1 — VISION

No assumed operations-specific changes to the plan for this Chapter.

## CHAPTER 2 — GOALS AND OBJECTIVES

*The following sample chapter, "Goals and Objectives," is intended to show the reader how the approach is incorporated into the early stage of the transportation plan development process where goals and outcome-based objectives are identified. Goals and objectives that emphasize operational characteristics are of particular interest in this chapter and are highlighted in red. Samples for the balance of the example plan flow directly from these highlighted goals and objectives.*

### 2.1 Goals

The transportation planning stakeholders of the area have established a clear vision and are now

62 23 CFR 450.324(f)(11).

prepared to construct goals and objectives that guide actions to achieve the vision. Coupled with the area's vision, the planning organization's mission is empowered by Federal and State authorization and fueled by the collaboration of public agencies and private stakeholders in the area. Therefore, the following goals reflect the union of vision, mission, authorization, and collaboration:

**Goal 1: Provide an efficient and reliable transportation system**

Goal 2: Support planned economic growth

Goal 3: Encourage vital communities and efficient land uses

Goal 4: Preserve and secure the transportation system

Goal 5: Reduce environmental impacts

Goal 6: Promote human health and safety

**Goal 7: Expand affordable, effective transportation choices**

**Goal 8: Provide effective communications to inform travel decisions**

> Goals 1, 7, and 8 have strong connections to the 23 CFR 450.206(a)(7) and 450.306(b)(7) planning factor of promoting efficient system management and operations. This factor serves as the foundation for integrating operations into the planning process.

These eight goals derive from careful consideration of the plans and goals of each partner responsible for planning, delivering, operating, and maintaining the transportation system and ensuring the safety and security of the traveling public. The transportation plan will present an integrated approach to achieving the goals in close coordination with the unique goals of each partner.

A business case that relates to the goals of partner departments and agencies can advance broad support for implementing the transportation plan and can help bring in such stakeholders as local businesses—which otherwise might not be engaged—to support TSMO efforts. For example, Nevada DOT developed a business case for transportation management and operations (TSMO), which expanded its relevance beyond traffic operations to foster agencywide integration and support (figure 14).

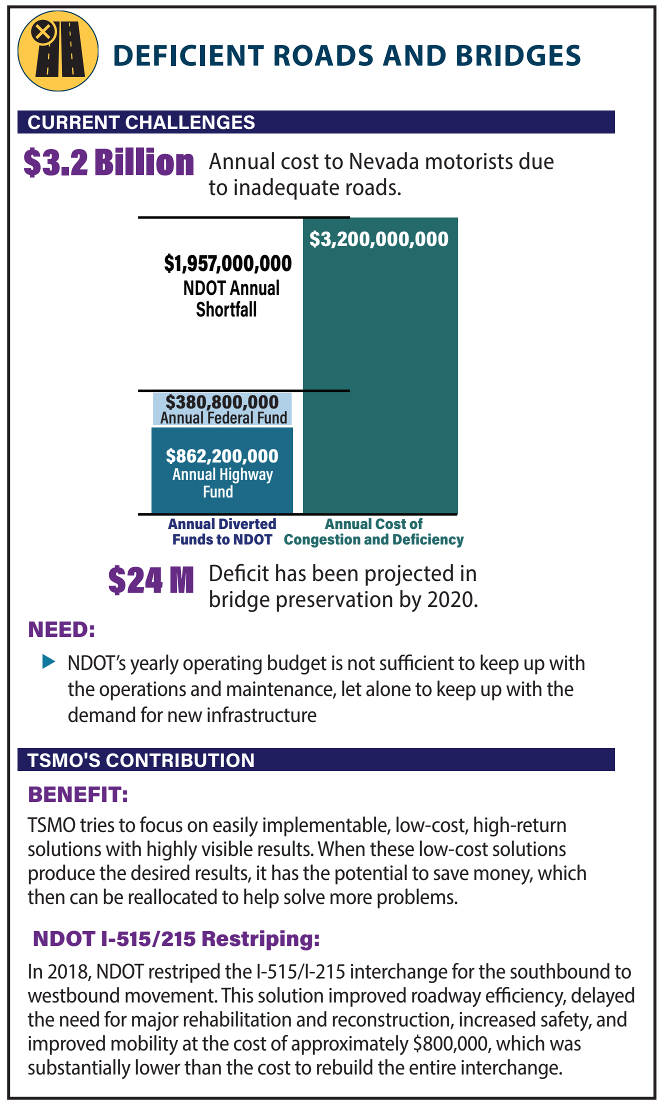


Figure 14. Screenshot. Example of a TSMO business case.

Source: Nevada Department of Transportation.

### *2.2 Coordination of Transportation Activities*

Achieving these goals involves many activities undertaken by many public agencies, private owners and operators, and not-for-profit associations, collectively and subsequently referred to as stakeholders. The stakeholders have considered their various activities and grouped them into categories for ease of communication and coordination. Table 3 summarizes the four activity categories and the goals they support. This simple tool helps consider the impact any one set of activities has on the effort to attain the regional goals. To that end, the entire transportation plan is organized around these categories.

This set of goals derives from carefully considering the plans and goals of each partner responsible for planning, delivering, operating, and maintaining the transportation system and ensuring the safety and security of the traveling public. The transportation related goals, objectives, performance measures, and targets described in other performance-based plans shall be integrated into the long-range statewide transportation plan and the metropolitan transportation plan in close coordination with each transportation planning stakeholder.

Table 3. Activity categories and the goals they support.

| Activity Category | Goal 1 | Goal 2 | Goal 3 | Goal 4 | Goal 5 | Goal 6 | Goal 7 | Goal 8 |
|---|---|---|---|---|---|---|---|---|
| System Preservation and Maintenance | ● | ● | | ● | | ● | | ● |
| System Management and Operations | ● | | | | | | ● | ● |
| System Integration | ● | ● | ● | | ● | ● | | ● |
| System Expansion | ● | ● | | | ● | | ● | ● |

Source: FHWA.

***2.3 Objectives***

Objectives reflect commitments by the stakeholders to achieving the common goals. Stakeholders declared sustainability as the core of the area's vision, and the planning organization board has emphasized efficiency as an overarching strategy to reach the vision. Goal 1, Provide an efficient and reliable transportation system, captures this strategy, and all five activity categories support it. Thus, all stakeholders can contribute to improving system efficiency and creating a more sustainable region.

Various technical and policy committees of the planning organization, in close coordination with the stakeholders, worked to develop a broad set of objectives that relate directly to the transportation system outcomes expressed in the area's goals. The objectives development process included direct input from transportation providers, operators, users, and policymakers. It also considered operational issues from past plans that still remain. Listed below is a resulting set of objectives specific to each goal.

| **Goal 1** Provide an efficient and reliable transportation system |
|---|
| **Objective 1.1 — Efficiency** Improve the average travel time during peak periods by 20 percent within 10 years and maintain at that level for the subsequent 10 years. |
| **Objective 1.2 — Reliability** Reduce the variability of travel time during peak periods by 15 percent within 10 years and 25 percent within 20 years. |

A manageable number of outcome-based operations objectives provide the foundation for fully integrating operations with the planning process. Decisionmakers and staff are able to trace plans and actions back to these objectives and the goals they support.

Goal 1: Provide an efficient and reliable transportation system

In an effort to place increased emphasis on traveler expectations for managing congestion and improving travel time consistency, Objective 1.1 addresses efficiency, while Objective 1.2 addresses reliability. These are defining characteristics of the multimodal transportation system and, as noted above, cut across all categories of activities (as summarized in table 4) undertaken by the planning organization and its area stakeholders. Both objectives focus on the peak period to deal directly with the adverse impacts of delays during the most-congested conditions.

Goal 2: Support planned economic growth

Goal 3: Encourage vital communities and efficient land uses

Goal 4: Preserve and secure the transportation system

Goal 5: Reduce environmental impacts

Goal 6: Promote human health and safety

Recognizing that planning organizations incorporating operations into transportation plans function at variable levels, multiple objective examples are shown. Scaled examples reflect the ability or intent to implement a basic, advancing, and comprehensive operations approach.

To see related performance measures and data needs for the varying levels, please refer to the relevant QR sheets in the appendix for the objectives identified in the table above.

Table 4. Examples for outcome-based objectives at different capability levels for Goal 1: Efficiency and Reliability.

| Objective | Basic Capabilities | Advancing Capabilities | Comprehensive Capabilities |
|---|---|---|---|
| 1.1 | Reduce vehicle miles traveled per capita by 10 percent in 10 years and 25 percent in 20 years. | Improve the average travel time during peak periods by 20 percent within 10 years and maintain at that level for the subsequent 10 years. | Improve the average travel time per person on high-volume arterials during peak periods for surface transportation modes by 20 percent within 10 years and maintain at that level for the remaining 10 years. |
| 1.2 | Reduce delay on major arterials by 3 percent per year. | Reduce the variability of travel time during peak periods by 15 percent within 10 years and 25 percent within 20 years. | Reduce the variability of travel time per person on high-volume arterials during peak periods for all surface transportation modes by 15 percent within 10 years and 25 percent within 20 years. |

Source: FHWA.

Goal 7: Expand affordable, effective transportation choices

Area stakeholders have concluded that providing affordable, effective transportation options is critical to ensuring the quality of life and economic vitality expected by citizens and employers. The intent of Goal 7 is to provide a range of choices that fit the context of the area (neighborhoods, centers, districts, and corridors) and serve the needs of users traveling within and between these areas. In addition, it is understood that the perceived cost and a multitude of other factors that relate to the quality or effectiveness of the trip often influence the choice of transportation options. Among these factors are safety, security, reliability, accessibility, duration, comfort, and convenience. The following objectives work in combination to achieve this goal (table 5).

**Goal 7**

Expand affordable and effective transportation choices

**Objective 7.1 — Choices**

Increase non-single-occupancy-vehicle mode share for all trips by 20 percent every 5 years.

**Objective 7.2 — Effectiveness**

Reduce the auto-to-transit travel time differential on major corridors by 15 percent over 5 years and maintain for the subsequent 10 years.

Table 5. Examples for outcome-based objectives at different capability levels for Goal 7: Choices.

| Objective | Basic Capabilities | Advancing Capabilities | Comprehensive Capabilities |
|---|---|---|---|
| 7.1 | Reduce per-capita single-occupancy-vehicle (SOV) commute trip rate by 5 percent every 5 years. | Increase non-SOV mode share for all trips by 20 percent every 5 years. | Achieve a 50 percent non-SOV mode share in transit station communities by 2025. |
| 7.2 | Improve non-SOV travel times by 25 percent over the next 10 years. | Reduce the auto-to-transit travel time differential on major corridors by 15 percent over 5 years and maintain for the subsequent 10 years. | Reduce the travel time differential between transit and auto during peak periods by 5 percent per year for 10 years and maintain thereafter. |

Source: FHWA.

To see related performance measures and data needs for the varying levels, please refer to the relevant QR sheets in the appendix for the objectives identified in the table above.

***Goal 8: Provide effective communications to inform travel decisions***

The effectiveness of the transportation system can be linked directly to the quality, extent, and timeliness of information that is available to users of the system, which in turn depends upon communications by transportation providers. Broad support is in place for continually improving and expanding effective communications to support the achievement of all other goals and the complementary plans of public agencies, service providers, emergency responders, and other stakeholders. Equally important is the support the planning organization and all stakeholders can provide to transportation users as they decide whether, when, how, and by what route to travel. Objective 8.1 identifies systemwide outcomes for effective communications among all operating agencies and to all users of the area's transportation system.

**Goal 8**

Provide effective communications to inform travel decisions

**Objective 8.1 — Communication**

Expand the capability to provide real-time travel condition information by 3 percent of existing lane mile coverage per year.

Table 6. Examples for outcome-based objectives at different capability levels for Goal 8: Communication.

| Objective | Basic Capabilities | Advancing Capabilities | Comprehensive Capabilities |
|---|---|---|---|
| 8.1 | Increase the availability of traveler information regarding alternative travel options during system disruptions by 25 percent in five years. | Expand the capability to provide real-time travel condition information by 3 percent of existing lane mile coverage per year. | At least 95 percent of travelers by 2025 are aware of significant delays, hazardous travel conditions, and alternative routes in time to affect travel decisions. |

Source: FHWA.

*To see related performance measures and data needs for the varying levels (table 6), please refer to the relevant QR sheets in the appendix for the objectives identified in the table above.*

*If this were a full transportation plan example, the following chapters would be detailed and incorporated into the plan per the table of contents. Not being operations related, these chapters will not be shown in this example plan.*

## *CHAPTER 3 — FINANCIAL SNAPSHOT*

No assumed operations-specific changes to the plan for this Chapter.

## *CHAPTER 4 — SYSTEM PRESERVATION AND MAINTENANCE*

The system preservation and maintenance of TSMO-related assets should be tied to other regional plans for preservation and maintenance. Several State DOTs are beginning to include TSMO and ITS equipment as part of the assets included in transportation asset management plans. Typically, these plans include the following elements:

- Inventory of ITS field elements and equipment, such as CCTVs, CMS, extinguishable message signs, detection, highway advisory radio, ramp meters, road weather information system (RWIS), and traffic signals
- Definitions of good, fair, and poor assets
- Estimates of service life and annual maintenance and operation costs
- Inventory of planned future deployment
- Performance targets and estimated future conditions
- Traffic management centers, buildings, software, and equipment
- Computers, software, and hardware for trip-routing systems

For example, the California Transportation Asset Management Plan for Fiscal Years 2017/18-2026/27 provides an estimate of additional maintenance and operation needs over those 10 years for nine different types of ITS equipment.[63]

63 California Department of Transportation. 2018. California Transportation Asset Management Plan – Fiscal Years 2017/18-2026/27. Sacramento, CA: Caltrans. https://dot.ca.gov/-/media/dot-media/programs/asset-management/documents/20190726-am-finalcaliforniatamp-a11y.pdf, last accessed July 6, 2022.

**Table 7. Excerpt from California Transportation Asset Management Plan. TMS Maintenance and Cost Estimates**

| TMS Element | Inventory | Service Life | Annual M&O Cost per Element | Total Annual M&O Costs | Expected New TMS per Year | Increase in Annual M&O Costs | 10-Year Increase in Estimated M&O Costs |
|---|---|---|---|---|---|---|---|
| Closed-Circuit Television | 2,825 | 10 | $4,300 | $12,147,500 | 61 | $262,300 | $2,623,000 |
| Changeable Message Signs | 896 | 25 | $5,600 | $5,017,600 | 19 | $106,400 | $1,064,000 |
| Traffic-Monitoring Detection Stations | 5,216 | 25 | $3,100 | $16,169,600 | 113 | $350,300 | $3,503,000 |
| Highway Advisory Radio | 186 | 15 | $6,200 | $1,153,200 | 4 | $24,800 | $248,000 |
| Freeway Ramp Meter | 2,855 | 25 | $4,700 | $13,418,500 | 62 | $291,400 | $2,914,000 |
| Roadway Weather Information System | 149 | 10 | $5,300 | $789,700 | 3 | $15,900 | $159,000 |
| Traffic Signals | 6,262 | 25 | $5,700 | $35,693,400 | 135 | $769,500 | $7,695,000 |
| Traffic Census Stations | 128 | 20 | $2,200 | $281,600 | 3 | $6,600 | $66,000 |
| Extinguishable Message Signs | 539 | 25 | $2,000 | $1,078,000 | 12 | $24,000 | $240,000 |
| **Total** | **19,056** | | | **$85,749,100** | **412** | **$1,851,200** | **$18,512,000** |

M&O = management and operations; TMS = transportation management system.

Note: Average estimated maintenance and operations costs include materials, equipment, training, lifecycle, and support costs. Does not include energy costs. Estimate for new TMS elements based on SHOPP-funded projects only. Assumed management and operations costs for traffic signals are the same for state and local; inventory and new elements estimate as of November 2017.

Source: Caltrans. 2022. *California Transportation Asset Management Plan – Fiscal Years 2021/22-2031/32*. Sacramento, CA: Caltrans. https://dot.ca.gov/-/media/dot-media/programs/asset-management/documents/2022-tamp-a11y.pdf, accessed February 8, 2023.

## *CHAPTER 5 — SYSTEM MANAGEMENT AND OPERATIONS*

*The following sample chapter, "System Management and Operations," is intended to show the reader how the objectives driven performance-based approach to operations can be incorporated into the Systems Management and Operations section of the transportation plan. In this section, specific TSMO strategies are selected to move the region in the direction of achieving the desired outcomes and goals from a system operations perspective.*

### *5.1 System Management and Operations Overview*

*5.1.1 Operations History*

The following text provides an overview of the typical plans and processes that provide inputs to set the background for the System Management and Operations section of the plan. To incorporate the approach, an understanding of the starting point is necessary. In this example, the history of operations in the area has been established.

> For the remainder of this example plan, only Goal 1, Provide an Efficient and Reliable Transportation System, is shown with the application of the objectives-driven performance-based approach; however, if this were a full plan example, all three goals would be carried throughout the entire chapter.

The system management and operations chapter is a critical element of the transportation plan that we developed in cooperation with our Technical Operations Task Force (TOTF), which consists of traffic, transit, and emergency management operators in the area. It is based on several previous planning efforts, including the following:

- Our Area's Intelligent Transportation System (ITS) Master Plan
- Our Congestion Management Process
- TSMO Strategic Plan
- TSMO Program Plan
- TSMO/ITS Investment Strategy: 10-Year Program
- Our Region's ITS Architecture

The ITS Master Plan was the first major effort focusing solely on ITS technology that formulated an area policy among transportation operations personnel. This transportation plan update takes a broader view, placing greater emphasis on planning and coordination as well as emerging ITS technologies. With operations as a critical element for the success of our system, this transportation plan will help ensure that funding is a priority for this area of transportation.

This chapter of the transportation plan consists of six major components. The system management and operations overview provides the context and motivation for TSMO in the region. Operations goals reviews operations-oriented goals that were established in chapter 2 of the transportation plan. The section on operations objectives and performance measures outlines the specific operational outcomes we hope to achieve as a region and identifies performance measures and data needs. TSMO strategies and implementation establishes the solutions the relevant agencies or stakeholders will implement to best achieve common, desired operational outcomes and explains how they may be implemented (including financial considerations). Monitoring describes an ongoing effort to regularly monitor progress toward the operations objectives, report the results, and evaluate activities for reaching those objectives. The programs, stakeholders, and responsibilities section presents ongoing programs, the stakeholders in the program, and their respective responsibilities to ensure accountability.

5.1.2 Operations Purpose

Transportation operations is not simply moving people and goods; it applies a combination of technology, robust planning, improved preparedness, and extensive interagency and intra-agency coordination, as follows:

*The following text is an excerpt from the Delaware Valley Regional Planning Commission's Transportation Operations Master Plan.*[64] *This gives a comprehensive overview regarding the strategic importance of operations planning. This information helps paint the picture of the different elements of a successful, objectives-driven, performance-based approach.*

- **Technology**. Technology is the backbone of transportation operations. It applies advanced tools such as computers, communications, electronics, and control systems to improve the efficiency and safety of the surface transportation system. Real-time surveillance systems monitor transportation facilities identifying unusual conditions that need immediate action, whether it is a bus running behind schedule or a crash on the Schuylkill Expressway. Technology enables transportation operations centers to impart accurate, up-to-date travel information to the public or to adjust traffic signal timing to handle a surge of traffic from a closed expressway. It enables first responders to overcome interoperability communication issues among themselves and with transportation personnel. Deploying technology also saves agencies money by automating functions like highway toll and transit fare collection.
- **Planning**. When an incident temporarily closes a highway or disrupts transit service, it is already too late to plan a response. Detour routes, traffic control points, signage, and potential response resources should be identified in advance. Agency and personnel roles and responsibilities also have to be predefined.
- **Preparedness.** This involves conducting training courses and tabletop exercises so that personnel can be fully prepared to respond to a highway or transit incident. It also involves pre-deploying traffic management equipment so that portable CMS or accident investigation equipment for emergency responders will arrive in a timely manner and not have to be transported across the region. Emergency service patrols offer immediate on-scene resources to mitigate minor incidents and provide traffic support in larger ones.
- **Coordination.** Operationally, the region is very fragmented, with three departments of transportation, three State police departments, multiple toll authorities and transit agencies, and hundreds of local police and fire departments. Institutional coordination, whether at the scene of an incident, between transportation operations centers, or across jurisdictions or modes, is a major undertaking. Incident command structures must be established, and situational information disseminated. Ongoing coordination is required to make sure everything runs smoothly and to correct problems that periodically occur.

Transportation operations and ITS projects have different funding needs as compared with traditional capacity improvements and infrastructure-heavy (e.g., road and bridge) projects. While operations and ITS projects are like other major transportation capital investments in that they can be funded through the region's transportation improvement program (TIP), they typically require frequent attention to optimize, integrate with other systems, and update project elements on a more frequent basis than traditional roadway projects. Operations, maintenance, and management costs tend to represent a relatively higher percentage of overall life-cycle costs. Hardware, software, and communication devices have to be continually maintained and may have to be updated to remain consistent with the latest IT technology standards.

Many transportation operations initiatives are programmatic (e.g., funding for service contracts, vehicles and equipment, training programs). In many instances, nontraditional transportation stakeholders like police and fire departments will be the primary beneficiaries of these programs. How to fund these types of programs and whether to use Federal transportation monies, State funds,

64 Delaware Valley Regional Planning Commission. 2009. Transportation Operations Master Plan. Philadelphia, PA: DVRPC. https://www.dvrpc.org/Reports/09049.pdf, last accessed July 6, 2022.

toll monies, or even Department of Homeland Security funding are unclear. As transportation agencies evolve from a design-build culture to an operations culture, decisions on how to fund, operate, and maintain these types of programs need to be resolved.

### *5.2 Operations in the Transportation Plan Framework*

All the transportation elements within this plan were prepared in coordination with one another. System management and operations is one of eight strategic factors our area plans for.

> Committees, task forces, subcommittees, and subtask forces are essential to developing an objectives-driven, performance-based approach plan. By coordinating and collaborating, these groups will build the plan on technically sound procedures that are realistic and feasible for the specific area the plan is being prepared for. Having these committees and task forces also creates a sense of trust for decisionmakers that the strategies being considered are the most appropriate ones.

#### *5.2.1 Stakeholders and Process*

This transportation plan was prepared under the framework of an objectives-driven, performance-based approach. From start to finish, multiple agencies within our area collaborated to produce a coordinated plan with a set of agreed-upon strategies selected to achieve our desired goals and objectives. The stakeholders, committees, and task forces that helped produce the outcomes identified within include the following:

- Transportation Plan Steering Committee. The steering committee is a group focused on ensuring coordination and collaboration across disciplines and agencies throughout our area. This group is charged with ensuring that the final adopted transportation plan is an agreed-to, consistent, comprehensive, and objective plan.
- Technical Operations Task Force (TOTF). This committee was formed to ensure technical accuracy and soundness in the planning for the area's operations process. The committee consists of traffic, transit, and emergency management operations representatives. Meeting monthly throughout the process, this group helped prepare an agreed-to, objective plan to meet our area's goals. The TOTF has the following subtask forces:
  - Transit Management and Operations Subtask Force
  - Traffic Incident Management Subtask Force
  - Work Zone Subtask Force
  - Arterial Management Subtask Force

The TOTF went through a rigorous process throughout the development of the operations plan, including testing, refining, and revising the objectives, performance measures, strategies, and monitoring techniques to match our area's desired outcomes while keeping in mind current limitations such as revenue and data sources. This was an iterative process that the area stakeholders undertook to produce a set of defensible, objective, transparent, agreed-upon TSMO strategies.

#### 5.2.2 Operations Goals

| |
|---|
| **Goal 1**<br>Provide an Efficient and Reliable Transportation System |
| **Goal 7**<br>Expand Affordable, Effective Transportation Choices |
| **Goal 8**<br>Provide Effective Communications to Inform Travel Decisions |

As summarized in chapter 2, the area has established eight goals to direct and guide how our area plans its transportation system, three of which directly influence the operations of the network. The main themes of the goals are Efficiency and Reliability, Choice, and Communications. The area derived this set of goals from careful consideration of the plans and goals of each stakeholder agency responsible for planning, delivering, operating, and maintaining the area's transportation system and ensuring the safety and security of the traveling public. The remaining sections within this chapter present an integrated approach to achieving the area's goals in close coordination with the unique goals of each stakeholder agency. Achieving these goals involves several public agencies, private owners and operators, and not-for-profit associations undertaking many activities.

*5.2.3 Operations Objectives and Performance Measures*

Operations objectives reflect commitments—by one or more of the area's stakeholder agencies—to achieving the goals. Stakeholders declared sustainability as the core of the area's vision, and the planning organization board has emphasized efficiency, reliability, options, and communication as the overarching strategies to reach the vision.

Various technical and policy committees of the planning organization, in close coordination with area stakeholders, worked to develop a broad set of objectives that relate directly to the transportation system outcomes expressed in the area's goals. The objectives development process included direct input from transportation providers, operators, users, and policymakers. The following sections summarize the resulting set of objectives specific to each goal.

Through the process of identifying and evaluating high-congestion locations in our area, the objectives became more refined and specific.

*5.2.4 Outcome-Based Objectives*

The TOTF has identified outcome-based objectives for each operations-related goal. Each objective is specific and measurable to ensure that progress may be tracked over time. In addition, each objective was tested and refined to select realistic and achievable targets and timelines.

> Some outcome-based operations objectives provide the foundation for fully integrating operations with the planning process. Decisionmakers and staff can trace plans and actions back to these objectives and the goals they support.

To achieve Goal 1, the area stakeholders created outcome-based objectives for both efficiency and reliability.

| |
|---|
| **Goal 1**<br>Provide an Efficient and Reliable Transportation System |
| **Objective 1.1 — Efficiency**<br>Improve the average travel time during peak periods by 20 percent within 10 years and maintain at that level for the subsequent 10 years. |
| **Objective 1.2 — Reliability**<br>Reduce the variability of travel time during peak periods by 15 percent within 10 years and 25 percent within 20 years. |

5.2.4.1 Efficiency

To address efficiency specifically, the TOTF identified an objective focused on improving travel time during peak periods. Peak-period travel time has been significantly affected during the past five years because of significant growth. The TOTF have chosen an aggressive objective to reverse this historical trend. Peak-period travel has a tremendous effect on our economy, bringing people to and from destinations. Based on historical data and projections, the TOTF suggest that a 20 percent improvement in travel time during the next 10 years is an achievable target and timeline.

After the 10-year timeline, the area stakeholders have assumed, maintaining the improvement is the most feasible and practical approach

5.2.4.2 Reliability

To address reliability specifically, the TOTF identified an objective focused on reducing the variability of travel time during peak periods at varying levels during the next 25 years. Although it is expected that population and employment growth will be occurring throughout the northeastern and southwestern portions of our area, the entire system needs to perform consistently for all users so they can plan their travels appropriately. The planning organization projects that as efficiency improves over time, the variability in travel time will diminish. Based on historical data and projections, the planning organization anticipates that a 15-percent reduction in variability within 10 years and 25-percent within 20 years are achievable targets and timelines.

Table 8. Examples of outcome-based objectives at different capability levels for Goal 1: Efficiency and Reliability (from chapter 2).

| Objective | Basic Capabilities | Advancing Capabilities | Comprehensive Capabilities |
|---|---|---|---|
| 1.1 | Reduce vehicle miles traveled per capita by 10 percent in 10 years and 25 percent in 20 years. | Improve the average travel time during peak periods by 20 percent within 10 years and maintain at that level for the subsequent 10 years. | Improve the average travel time per person during peak periods for all major modes by 20 percent within 10 years and maintain at that level for the remaining 10 years. |
| 1.2 | Reduce delay on major arterials by 3 percent per year. | Reduce the variability of travel time during peak periods by 15 percent within 10 years and 25 percent within 20 years. | Reduce the variability of travel time per person during peak periods for all major modes by 15 percent within 10 years and 25 percent within 20 years. |

Source: FHWA.

*The remainder of this section would give an overview of how and why the additional outcome-based objectives were developed for Goal 7 and Goal 8.*

*5.2.5 Performance Measures and Data Needs for Outcome-Based Objectives*[65]

The TOTF collectively identified performance measures and data needs for each outcome-based objective identified under Goals 1, 7, and 8. The performance measures and data needs associated with each of the Goal 1 objectives are listed below in Table 9. These performance measures will enable the TOTF to track and see whether it is meeting the area's short-term targets and provide insights into the likelihood of meeting future long term goals and objectives. The performance measurement and data collection will be supported by related efforts by the State DOT and metropolitan planning organization to monitor and report on Federally required national performance management measures (23 CFR Part 490).

65 Text under the Performance Measures and Data Needs section was derived from the Metroplan Orlando 2040 Long Range Transportation Plan, "Technical Document #4: Congestion Management Process." The document gives a comprehensive overview of performance measure identification and selection. See https://metroplanorlando.org/wp-content/uploads/2040-LRTP-TR4-Congestion-Management-Process.pdf to access the complete report.

In our area, the individual cities and counties currently undertake data collection efforts. They collect traffic volume and crash data consistently and comprehensively across the area. They are collecting ITS-related data currently on all principal arterial roadways in the area and 65 percent of major arterial roadways. Through the transportation plan update process, the area stakeholders continue to update the data collection efforts through new technology while maintaining consistency. Additional coverage also is sought throughout the area. When possible, the TOTF will continue using existing data sources. Currently, some stakeholder agencies' annual reporting systems are higher level analysis sources. In addition to those reports, the area references congested corridor studies being conducted routinely throughout the area each year. These data sources help the TOTF identify and prioritize locations within the area where the best progress can be made through TSMO strategies.

Table 9. Data needs for measuring performance in meeting outcome-based objectives.

| Outcome-Based Objective | Performance Measure | Data Needs |
| --- | --- | --- |
| **Objective 1.1**<br>Improve the average travel time during peak periods by 20 percent within 10 years and maintain at that level for the subsequent 10 years. | ▪ Average travel time per day during peak periods (minutes) | ▪ Peak-period and free-flow travel time or speeds. Person travel along links (e.g., vehicle volume X vehicle occupancy) |
| **Objective 1.2**<br>Reduce the variability of travel time during peak periods by 15 percent within 10 years and 25 percent within 20 years. | ▪ Variation in travel time as indicated by the buffer time index or planning time index | ▪ Travel time |

Source: FHWA.

*The remainder of this section would give a summary of the performance measures and data needs for Goal 7 and Goal 8.*

*5.2.6 Activity-Based Objectives*

Table 10. Activity-Based Objectives Related to the Goal 1 Operations Objectives

| Objective 1.1 — Efficiency |
| --- |
| Improve the average travel time during peak periods by 20 percent within 10 years and maintain at that level for the subsequent 10 years. |
| Objective 1.1.1 (activity based objective) |
| Evaluate and retime 95 percent of the traffic signals in the area (if needed) at least once every 3 years. |
| Objective 1.1.2 (activity based objective) |
| Implement a single, areawide automated fare collection system within 5 years that enables transit users to pay electronically for transit fare on all transit services with the same card. |
| Objective 1.2 — Reliability |
| Reduce the variability of travel time during peak periods by 15 percent within 10 years and 25 percent within 20 years. |
| Objective 1.2.1 (activity based objective) |
| Reduce the mean clearance time per incident by 25 percent in 5 years. (Clearance time defined as the time between awareness of an incident and restoration of lanes to full operational status.) |
| Objective 1.2.2 (activity based objective) |
| Reduce the average and maximum length of queues, when present, by 20 percent over 7 years. |

Our area has identified six activity-based objectives for the areas of reliability and efficiency. The TOTF and subtask forces tested and refined the objectives to create activities that will achieve our ultimate goals. Below is an overview of the activities. The activity-based objectives were selected to support the achievement of the goals and outcome-based objectives.

5.2.6.1 Efficiency

The TOTF identified two activity-based objectives related to the efficiency outcome. They are Objectives 1.1.1 and 1.1.2 in the table above. The TOTF agreed unanimously on the two identified activities as realistic and achievable given the ongoing activities throughout the area related to traffic signal retiming programs and automated fare collection visions. With the achievement of these two objectives, the target of travel time improvements by 20 percent within 10 years may be achieved.

5.2.6.1 Reliability

The TOTF identified two activity-based objectives related to the reliability outcome. They are Objectives 1.2.1 and 1.2.2 in the table above. The TOTF agreed unanimously on the two identified activities as realistic and achievable given the ongoing activities throughout the area related to incident management programs and work zone management discussions. With the achievement of these two objectives, the target of reducing travel time variability by 15 percent within 10 years and 25 percent within 20 years may be achieved.

Table 11. Examples for outcome-based objectives at different capability levels for Goal 1: Efficiency and Reliability (from chapter 2).

| Outcome Based Objective | Basic Capabilities | Advancing Capabilities | Comprehensive Capabilities |
|---|---|---|---|
| 1.1.1 | Increase the number of intersections running in a coordinated, closed-loop, or adaptive system by 10 percent in 5 years and 15 percent in 10 years. | Evaluate and retime 95 percent of the traffic signals in the area (if needed) at least once every 3 years. | Special timing plans are available for use during freeway incidents, roadway construction activities, or other special events for 55 percent of arterial miles in the area in 5 years and updated annually for the subsequent 10 years. |
| 1.1.2 | Within 5 years, at least 75 percent of transit trips can be made with no more than two transfers. | Implement a single, areawide automated fare collection system within 5 years that enables transit users to pay electronically for transit fare on all transit services with the same card. | Increase the routes meeting performance targets by 5 percent annually. |
| 1.2.1 | Increase percentage of incidents initially discovered and verified by motorist-assist roving patrols by 10 percent in 5 years. | Reduce the mean clearance time per incident by 25 percent in 5 years. | Reduce the person-hours (or vehicle-hours) of delay associated with traffic incidents by 15 percent within 10 years and 20 percent for the subsequent 10 years. |
| 1.2.2 | Reduce the percentage of vehicles traveling through work zones that are queued by 5 percent in 5 years. | Reduce the average and maximum length of queues, when present, by 20 percent over 7 years. | Reduce the average time duration (in minutes) of queue length greater than 0.5 miles by 15 percent in 10 years. |

Source: FHWA.

*To see related performance measures and data needs for the varying levels, please refer to the relevant QR sheets in the appendix for the objectives identified in table 10.*

*The remainder of this section would give an overview of how and why the additional activity-based objectives were developed for Goal 7 and Goal 8.*

### 5.2.7 Performance Measures and Data Needs for Activity-Based Objectives

Like the process described for outcome-based objectives, the area stakeholders collectively identified the following associated performance measures and data needs for each activity-based objective (table 11). These performance measures do not replace the measures identified in Table 9, but are used to measure the implementations of the activity-based objectives. Performance measures were established to identify and evaluate recurring and nonrecurring congestion. The stakeholders evaluated many potential performance measures, weighing their strengths and weaknesses in terms of their applicability to the unique characteristics of the planning area. These measures will enable area stakeholders to track progress toward our area's goals and objectives and see that they are on track to being met. The TOTF strategically chose performance measures that would depend solely on existing data. A very minor set of performance measures will require additional data collection procedures. In the following sections, the letter "X" represents the value of the data (i.e., number) and the Y represents the year by which the goal will be achieved.

Table 12. Data needs for measuring performance in meeting activity-based objectives.

| Activity-based Objective | Performance Measure | Data Needs |
| --- | --- | --- |
| **Objective 1.1.1**<br>Evaluate and retime 95 percent of the traffic signals in the area at least once every 3 years. | ■ Number of traffic signals retimed | ■ Reports from operating agencies on signal retiming, signal capabilities, special timing plans, and crash data reviews |
| **Objective 1.1.2**<br>Implement a single, areawide automated fare collection system within 5 years that allows transit users to pay electronically for transit fare on all transit services with the same card. | ■ Percentage of fares using automated fare collection | ■ Farebox data |
| **Objective 1.2.1**<br>Reduce the mean clearance time per incident by 25 percent in 5 years. | ■ Mean incident clearance time per incident | ■ The time of incident awareness and one or more of the following pieces of data: the time the last responder left the scene, the time when all lanes were reopened, the time when traffic returned to normal flow |
| **Objective 1.2.2**<br>Reduce the average and maximum length of queues, when present, by 20 percent over 7 years. | ■ Percentage of vehicles experiencing queuing in work zones<br>■ Length of average and maximum queues in work zones<br>■ Average duration in minutes of queue length greater than X miles | ■ Number of vehicles traveling through work zones<br>■ Number of vehicles traveling through work zones experiencing queuing<br>■ Average and maximum lengths of work zones<br>■ Duration of queue length greater than X miles |

Source: FHWA.

*If this were a complete transportation plan, the remainder of this section would give a summary of the performance measures and data needs for goals 7 and 8.*

### *5.3 TSMO Strategies and Implementation*

To meet the area's goals and associated objectives, TSMO strategies were identified for implementation. The identified strategies cut across multiple modes, agencies, and geographic locations in the area. The intent is that with these identified strategies implemented, the area's targets and timelines may be achieved through close coordination, collaboration, and technical excellence. Performance measures associated with each objective have been used to ensure that the selected strategies and improvements result in the quantitative benefits within each objective.

#### *5.3.1 Improvement and Cost Feasibility*[66]

For the selection of appropriate improvement strategies, cost is a major contributing factor. Cost is typically one of the main factors as to whether or not strategies are feasible. Other factors also affecting feasibility that the TOTF considered include the availability of right-of-way, technology infrastructure, safety, environmental constraints, equity, and system resiliency.

#### *5.3.2 Types of TSMO Strategies*

The following categories of strategies or combinations of strategies were considered for each area:

- Demand management measures, including managed lanes and dynamic parking strategies
- Operational improvements and low-cost engineering solutions
- Multimodal improvements, including transit and micromobility
- Freight management strategies
- Freeway, arterial, and parking management strategies
- ITS technologies as related to the regional ITS architecture
- Where necessary, additional system capacity

Based on the specific characteristics of each congested area in the area, the anticipated strategy benefits, project viability, cost, and potential funding sources available, the TOTF selected the following set of strategies relating to each objective (table 12).

66 Text under the Improvement and Cost Feasibility as well as the Types of TSMO Strategies sections is derived from the Metroplan Orlando 2040 Long Range Transportation Plan, "Technical Document #4: Congestion Management Process." See https://metroplanorlando.org/wp-content/uploads/2040-LRTP-TR4-Congestion-Management-Process.pdf to access the complete report.

Table 13. Strategies relating to each outcome-based objective selected by the Technical Operations Task Force.

| Goal | Objectives | Strategies | Priority |
|---|---|---|---|
| Provide an Efficient and Reliable Transportation System | **Objective 1.1 — Efficiency**<br>Improve the average travel time during peak periods by 20 percent within 10 years and maintain at that level for the remaining 10 years | Implement and finance the following programs annually in the TIP: Arterial Management and Transit Management and Operations. | High |
| | **Objective 1.1.1 — Arterial Management**<br>Evaluate and retime 95 percent of the traffic signals in the area (if needed) at least once every 3 years. | Implement program and finances for signal retiming every 3 years. | Medium |
| | **Objective 1.1.2 — Transit TSMO**<br>Implement a single, areawide automated fare collection system within 5 years that allows transit users to pay electronically for transit fare on all transit services with the same card. | ■ Involve integrating the system across multiple modes or services.<br>■ Implement a consistent system with other connecting transit services.<br>■ Implement a marketing campaign to increase awareness and use. | High |
| | **Objective 1.2 — Reliability**<br>Reduce the variability of travel time during peak periods by 15 percent within 10 years and 25 percent within 20 years. | Implement and finance the following programs annually in the TIP: Incident Management and Work Zone Management. | High |
| | **Objective 1.2.1 — Traffic Incident Management**<br>Reduce the mean clearance time per incident by 25 percent in 5 years. | ■ Responder training.<br>■ Quick-clearance laws.<br>■ Towing agreements.<br>■ Traveler information to reduce delay during incidents. | High |
| | **Objective 1.2.2 — Work Zone Management**<br>Reduce the average and maximum length of queues, when present, by 20 percent over 7 years. | ■ Shorten lane closure time (particularly during high-traffic hours).<br>■ Provide travelers with advance notice and real-time information to avoid the work zone. | Medium |

Source: FHWA.

*If this were a complete transportation plan, the remainder of this section would give a summary of the strategies and their priority levels for Goal 7 and Goal 8.*

### *5.4 Monitoring*

With adoption of this transportation plan, it is the area stakeholders' obligation to monitor and track the progress of our system's efficiency, reliability, communications, and choices. The TOTF has reached consensus on its specific targets and timelines, and the Transportation Plan Steering Committee is committed to working together to ensure that our area moves forward economically. This monitoring effort will occur annually, with results documented in our area's annual performance-monitoring report. Through the development of this transportation plan update, transit operators, traffic operators, and emergency-incident responders have committed to collecting, summarizing, and analyzing the generated data needed to indicate if targets have been achieved. As time progresses and monitoring is performed, the TOTF will assess the need for adjustments to the initial set of specific objectives and strategies. This intermittent assessment of the performance of implemented strategies represents the shift from a project-based solution process to an outcome-based solution process.

### *5.5 Programs, Stakeholders, and Responsibilities*

TSMO strategies identified herein will be included in the STIP, the TIP, or the funding programs of stakeholder agencies. This step is critical to ensuring that funding mechanisms are in place for the area's operations component of our transportation system. Currently, TSMO-related improvement strategies in our transportation plan have been allocated $10 million per year.

Four programs have been identified to ensure our area's objectives may be achieved. Two of the programs—incident management and arterial management—were established under the most recent transportation plan update. Two new programs—transit management and operations and work zone management—were created under this transportation plan update to assist us in making our system successful.

Table 14. Performance measures supporting outcome-based objectives.

| Goal | Outcome-Based Objectives | Performance Measures | Activity-Based Objectives | Performance Measures | Strategies |
|---|---|---|---|---|---|
| Goal: Provide an Efficient and Reliable Transportation System | Improve the average travel time during peak periods by 20 percent within 10 years and maintain at that level for the remaining 10 years. | Average peak-period travel time per day (minutes) | Evaluate and retime 95 percent of the traffic signals in the area (if needed) at least once every 3 years. | Number of traffic signals retimed | Implement program and finances for signal retiming every 3 years. |
| | | | Implement a single, areawide automated fare collection system within 5 years that allows transit users to pay electronically for transit fare on all transit services with the same card. | Percentage of fares using automated fare collection | Involve integrating the system across multiple modes or services.<br>Implement a system consistent with other connecting transit services.<br>Implement a marketing campaign to increase awareness and use. |
| | Reduce the variability of travel time during peak periods by 15 percent within 10 years and 25 percent within 20 years. | Variance of travel time | Reduce the mean clearance time per incident by 25 percent in 5 years. | Mean incident clearance time per incident | Responder training<br>Quick-clearance laws<br>Towing agreements<br>Traveler information to reduce delay during incidents |
| | | | Reduce the average and maximum length of queues, when present, by 20 percent over 7 years. | Percentage of vehicles experiencing queuing in work zones<br>Length of average and maximum queues in work zones<br>Average duration in minutes of queue length greater than X miles | Shorten lane closure time (particularly during high-traffic hours).<br>Provide travelers with advance notice and real-time information to avoid the work zone. |

Source: FHWA.

*The program description excerpts shown below were taken directly from the Delaware Valley Regional Planning Commission's Transportation Operations Master Plan (July 2009). The Commission's Master Plan gives more-detailed descriptions of the programs than a transportation plan covering multiple elements would entail. For additional program details, visit https://www.dvrpc.org/Reports/09049.pdf.*

*5.5.1 Incident Management*

Twenty-five percent of traffic congestion in large urban areas results from traffic incidents ranging from flat tires to overturned tractor-trailers. These unforeseen events cause havoc, making commuters late, affecting truck deliveries, and, ultimately, making the area less competitive economically.

Incident management is a multistep process involving incident detection and verification, emergency-responder response, management of onsite emergency personnel, traffic management, clearance of vehicles and debris, and recovery to normal traffic flow. It involves diverse technical skills and an assortment of different organizational entities. Incident management programs have to be sensitive to all phases of incident management and institutional relationships, many of which are outside the purview of the traditional transportation planning and funding processes.[67]

*5.5.2 Arterial Management*

In general, highways do not operate in isolation; they are usually part of larger travel corridors with parallel arterials, passenger rail lines, and bus routes. From a holistic perspective, the goal is to optimize travel in the whole corridor, not just expressways. Accomplishing this requires deploying ITS resources throughout the corridor and across modes. If traffic signals are optimized, parallel arterials can help relieve overcrowded expressways. Strategically located CMS at decision points can inform motorists of travel choices: what are the travel times via expressway versus arterials, or when is the next train arriving.[68]

*5.5.3 Transit Management and Operations*

Transit management programs include upgrading transit management centers and traveler information and fare collection systems and implementing security technology. A broad range of ITS technology is routinely incorporated into transit projects. New buses and rail vehicles, for example, typically come with diagnostic sensors and passenger information displays.

*5.5.4 Work Zone Management*

When a highway agency establishes a work zone,

". . . regardless of whether it is temporary maintenance activity or a long-term construction project, adequate precautions must be taken to warn motorists about changes in traffic patterns and potential bottlenecks. It is vital to minimize traffic delays and protect the safety of construction workers and motorists. Work zone plans and measures should be commensurate with the size and duration of the job and traffic volumes on the affected highway. Federal work zone regulations have enshrined these principals [sic]. Emerging technology is complementing these efforts, with portable devices to issue alerts and warnings to reckless drivers.

Departments of transportation and other highway operators routinely develop maintenance traffic plans

67 Delaware Valley Regional Planning Commission. 2009. *Transportation Operations Master Plan*. Philadelphia, PA: DVRPC. https://www.dvrpc.org/Reports/09049.pdf, last accessed July 6, 2022.

68 Ibid.

for construction projects and maintenance activities. Work zone traffic management elevates the level of planning and resources for projects that impact expressways and high-volume arterials. Depending upon the type of facility, duration of project, and impact on traffic, work zone initiatives may lead to formation of work zone management teams, predeployment of permanent or temporary CCTV cameras and speed detectors, and installation of warning devices and intrusion sensors." [69]

Table 15. Stakeholders by program area.

| Programs | Responsible Stakeholders |
|---|---|
| **Incident Management** | ▪ County operators<br>▪ Municipality operators<br>▪ Emergency responders |
| **Arterial Management** | ▪ State operators<br>▪ County operators<br>▪ Municipality operators<br>▪ Transit operators |
| **Work Zone Management** | ▪ County operators<br>▪ State operators |
| **Transit Management and Operations** | ▪ Transit operators<br>▪ County operators<br>▪ Municipality operators |

69 Delaware Valley Regional Planning Commission. 2009. Transportation Operations Master Plan. Philadelphia, PA: DVRPC. https://www.dvrpc.org/Reports/09049.pdf, last accessed July 6, 2022.

Source: FHWA.

Table 16. Strategies and objectives by program area.

| Goal | Provide an Efficient, Reliable Transportation System | | | |
|---|---|---|---|---|
| | Efficiency Focus | | Reliability Focus | |
| **Outcome Objectives** | | Improve the average travel time during peak periods by 20 percent within 10 years and maintain at that level for the remaining 10 years. | Reduce the variability of travel time during peak periods by 15 percent within 10 years and 25 percent within 20 years. | |
| **Activity Objectives** | Evaluate and retime 95 percent of the traffic signals in the area (if needed) at least once every 3 years. | Implement a single, areawide automated fare collection system within 5 years that allows transit users to pay electronically for transit fare on all transit services with the same card. | Reduce the mean clearance time per incident by 25 percent in 5 years. (Clearance time defined as the time between awareness of an incident and restoration of lanes to full operational status.) | Reduce the average and maximum lengths of queues, when present, by 20 percent over 7 years. |
| **Strategies** | Implement program and finances for signal retiming every 3 years. | Involve integrating the system across multiple modes or services.<br>Implement a consistent system with other connecting transit services.<br>Implement a marketing campaign to increase awareness and use. | Responder training Quick-clearance laws Towing agreements<br>Traveler information to reduce delays during incidents | Shorten lane closure time (particularly during high-traffic hours).<br>Provide travelers with advance notice and real-time information to avoid the work zone. |
| **Programs** | Arterial Management | Transit Management and Operations | Incident Management | Work Zone Management |

Source: FHWA.

*In a complete transportation plan example, an objectives tree summary would be prepared for Goal 7 and Goal 8.*

*If this were a full transportation plan example, the following chapters would be incorporated into the plan per* *the table of contents. Not being operations related, the following chapters will not be in this sample plan:*

### *CHAPTER 6 — SYSTEM INTEGRATION*

No assumed operations-specific changes to the plan for this Chapter.

### *CHAPTER 7 — SYSTEM EXPANSION*

No assumed operations-specific changes to the plan for this Chapter.

### *CHAPTER 8 — APPENDIXES*

## 5.4 Integrating TSMO into Programs and Work Plans

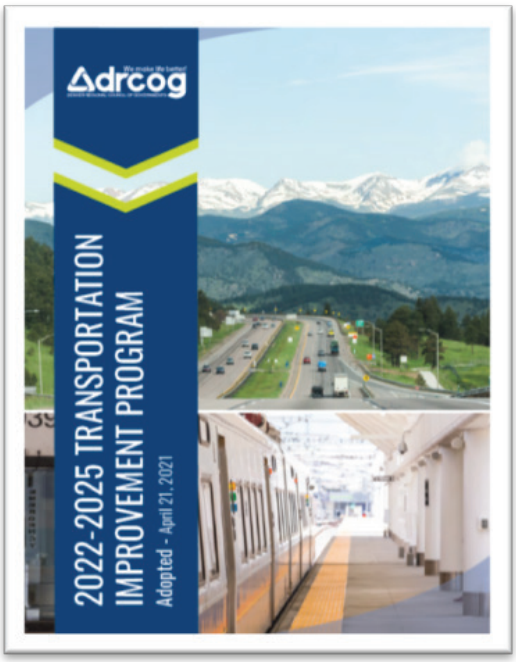


Figure 15. Screenshot. Cover of the Denver Regional Council of Governments 2022–2025 Transportation Improvement Program.

Source: DRCOG.

"Transportation programming is the process of selecting projects for funding, identifying funding resources and scheduling implementation."[70] Transportation planning organizations typically develop a programming document based on the transportation plan that lists the transportation projects for which the organization commits funds for expenditure. MPOs develop a four-year transportation improvement program (TIP) that contains transportation improvements that support the metropolitan transportation plan (figure 15). Likewise, a State DOT creates a statewide transportation improvement program (STIP) of transportation projects based on the long-range transportation plan for the State. Other transportation planning organizations such as city or county DOTs develop similar documents. Investments in TSMO can be found throughout programming documents, including freight ITS projects, CMS to promote safety and mobility, and micromobility pilots. TSMO can also be integrated into larger capital improvement projects such as managed lanes for part-time shoulder use.

Figures excerpted from the Denver Regional Council of Governments 2022-2025 Transportation Improvement Program illustrate how TSMO projects may appear in a TIP.[71] Figure 16 shows funding allocated to the interagency fare purchase and trip planning project sponsored by the regional transit agency. The TIP excerpt also shows that this project impacts the region's congestion performance measure.

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70 FHWA. 2013. *Programming for Operations: MPO Examples of Prioritizing and Funding Transportation System Management Operations Strategies*. Report No. FHWA-HOP-13-050. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop13050/fhwahop13050.pdf, last accessed September 1, 2022.

71 Denver Regional Council of Governments. *2021. 2022-2025 Transportation Improvement Program*, Denver, CO: DRCG. https://drcog.org/planning-great-region/transportation-planning/transportation-improvement-program/2022-2025, last accessed September 1, 2022.

Figure 16. Screenshot. Page from the Denver Regional Council of Governments 2022–2025 Transportation Improvement Program showing a project on an interagency phone application.

Source: DRCOG.

## 2022-2025 Transportation Improvement Program (Approved TIP)

Title: **App-Based Inter-Agency Fare Purchase and Trip Planning**

Project Type: **Transit Operational Improvements**

TIP-ID: **2020-095** STIP-ID: Open to Public: Sponsor: **R T D**

**Project Scope**

This project will offer a single transaction, multi-modal trip planning experience to riders of RTD, Bustang, local microtransit, and shared e-scooters through a Transit app. Funding is provided through the FTA Accelerating Innovative Mobility (AIM) grant.


| Affected County(ies) |
|---|
| Regional |

| | Performance Measures |
|---|---|
| ☐ | Bridge Condition |
| ☒ | Congestion |
| ☐ | Freight Reliability |
| ☐ | Pavement Condition |
| ☐ | Safety |
| ☐ | Transit Assets |
| ☐ | Transit Safety |
| ☐ | Travel Time Reliability |

| Amounts in $1,000s | Prior Funding | FY22 | FY23 | FY24 | FY25 | Future Funding | Total Funding |
|---|---|---|---|---|---|---|---|
| Federal (AIM) | | $687 | $0 | $0 | $0 | | |
| State | | $0 | $0 | $0 | $0 | | |
| Local | | $336 | $0 | $0 | $0 | | |
| Total | $0 | $1,023 | $0 | $0 | $0 | $0 | $1,023 |

| Date | Status | Description |
|---|---|---|
| 04/22/2021 | Amended | Proposed for adoption into 2022-2025 |
| 11/19/2020 | Amended | New Project. |

The next excerpt from the DRCOG TIP (figure 17) illustrates a project focused on operational improvements for corridor safety and mobility. This project is expected to impact the region's congestion, safety, and travel time reliability performance measures.

Figure 17. Screenshot. Page from the Denver Regional Council of Governments 2022–2025 Transportation Improvement Program showing a project for corridor safety improvements.

Source: DRCOG.

## 2022-2025 Transportation Improvement Program (Approved TIP)

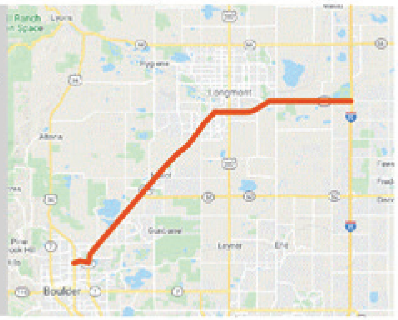
Title: **SH-119 Corridor Safety/Mobility Operational Improvements**

Project Type: **Roadway Operational Improvements**

TIP-ID: **2020-081** STIP-ID: **SDR5000** Open to Public: Sponsor: **CDOT Region 4**

**Project Scope**

This project will address safety and mobility through operational and traffic improvements on the SH-119 corridor, from Boulder to Longmont, including the intersection with SH-52. Project includes study, design, and construction.



| Affected County(ies) |
|---|
| Boulder |

| Performance Measures | |
|---|---|
| ☐ | Bridge Condition |
| ☒ | Congestion |
| ☐ | Freight Reliability |
| ☐ | Pavement Condition |
| ☒ | Safety |
| ☐ | Transit Assets |
| ☐ | Transit Safety |
| ☒ | Travel Time Reliability |

| Amounts in $1,000s | Prior Funding | FY22 | FY23 | FY24 | FY25 | Future Funding | Total Funding |
|---|---|---|---|---|---|---|---|
| Federal | | $0 | $0 | $0 | $0 | | |
| Federal (STBG-PAN) | | $3,200 | $0 | $0 | $0 | | |
| State | | $0 | $0 | $0 | $0 | | |
| State (Leg) | | $0 | $0 | $0 | $0 | | |
| State (PRI) | | $0 | $0 | $0 | $0 | | |
| State (R P P) | | $0 | $0 | $0 | $0 | | |
| Local | | $0 | $0 | $0 | $0 | | |
| Total | $3,859 | $3,200 | $0 | $0 | $0 | $0 | $7,059 |

Figure 18 is an excerpt from the Oregon DOT's Active 2021-2024 STIP Statewide Transportation Improvement Program with two projects that improve safety and mobility: upgrades to a variable-speed-limit system and traffic signal modifications to improve intersection flow.[72]

Source: Oregon DOT.

Figure 18. Screenshot. Page from Oregon DOT's active 2021–2024 STIP Statewide Transportation Improvement Program.

**2021-2024 Active STIP** | **BAKER** | **2021-2024 Active STIP**

Name: **OR86: Fish Creek** Key: **21873**

Description **Replace culvert and update the creek channel to improve fish passage.** Region: **5**
MPO: **Non-MPO** Work Type: **CULVRT**
Applicant: **ODOT** Status: **PROJECT SCHEDULED FOR CONSTRUCTION**

**Location(s)-**

| Mileposts | Length | Route | Highway | ACT | County(s) |
|---|---|---|---|---|---|
| 63.22 to 63.22 | 0.00 | OR-86 | BAKER - COPPERFIELD | NORTH EAST OREGON ACT | BAKER |

**Current Project Estimate**

| | Planning | Prelim. Engineering | Right of Way | Utility Relocation | Construction | Other | Project Total |
|---|---|---|---|---|---|---|---|
| Year | | 2020 | 2023 | | 2024 | | |
| Total | | $650,000.00 | $27,800.00 | | $5,176,207.00 | | $5,854,007.00 |
| Fund 1 | | Z240 $583,245.00 | ACP0 $24,944.94 | | Y240 $4,644,610.54 | | |
| Match | | $66,755.00 | $2,855.06 | | $531,596.46 | | |

**Footnote:**

**Most Recent Approved Amendment**

Amendment No: **21-24-2318** Approval Date: **7/17/2022**

Requested Action: **Increase the Construction phase estimate by $1,000,000, adding fix-it statewide culvert program funds.**

Name: **I-84: Baker Valley Variable Speed Limit upgrades** Key: **21878**

Description **Upgrade road & weather sensors and install variable speed limit signs to better manage speed limits, improve driver communication with real-time data and increase safety for the traveling public and freight industry.** Region: **5**
MPO: **Non-MPO** Work Type: **SAFETY**
Applicant: **ODOT** Status: **PROJECT SCHEDULED FOR CONSTRUCTION**

**Location(s)-**

| Mileposts | Length | Route | Highway | ACT | County(s) |
|---|---|---|---|---|---|
| 286.60 to 303.00 | 16.40 | I-84 | OLD OREGON TRAIL | NORTH EAST OREGON ACT | BAKER |
| 286.60 to 303.00 | 16.40 | I-84 | OLD OREGON TRAIL | NORTH EAST OREGON ACT | BAKER |

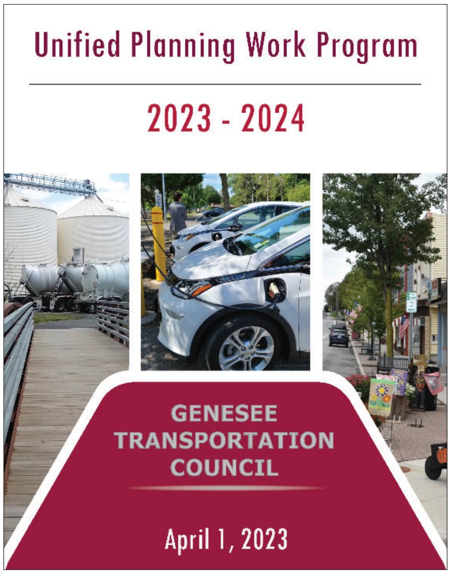
**Current Project Estimate**

| | Planning | Prelim. Engineering | Right of Way | Utility Relocation | Construction | Other | Project Total |
|---|---|---|---|---|---|---|---|
| Year | | 2022 | 2023 | | 2024 | 2024 | |
| Total | | $271,436.00 | $10,000.00 | | $813,782.00 | $1,100,000.00 | $2,195,218.00 |
| Fund 1 | | YS30 $271,436.00 | ZS30 $9,222.00 | | ZS30 $750,469.76 | ZS30 $1,014,420.00 | |
| Match | | | $778.00 | | $63,312.24 | $85,580.00 | |

**Footnote:**

72 Oregon Department of Transportation. 2022. *Active 2021-2024 STIP Statewide Transportation Improvement Program*. Portland, OR: ODOT. https://www.oregon.gov/odot/STIP/Documents/OnlineSTIP_Public.pdf, last accessed September 1, 2022.

In addition to the TIP and the STIP, another key document the transportation planning process produces is the unified planning work program (UPWP) (figure 19). The UPWP lists the planning tasks and studies with funding sources identified that an MPO's staff or member agency will conduct over a one- to two-year period. TSMO-related planning activities may also be called out in a UPWP. For example, the New York State Genesee Transportation Council has several TSMO-related planning activities funded in the UPWP. This includes a line item for TSMO planning, the development of the regional traffic operations center strategic plan, and a travel time data collection program (figures 20 and 21).[73]




Source: GTC.

Figure 19. Screenshot. Cover of the Genesee Transportation Council's 2023 – 2024 Unified Planning Work Program.

| Task | Title | | | | | |
|---|---|---|---|---|---|---|
| 5000 | Long Range Planning | | | | | |
| 5100 | UPWP Development and Management | 39,981 | 39,981 | 39,981 | 0 | --- |
| 5200 | LRTP Development and Implementation | 43,608 | 43,608 | 43,608 | 0 | --- |
| 5205 | Genesee-Finger Lakes Scenario Tool | 40,000 | 40,000 | 40,000 | 0 | --- |
| 5210 | Performance Measurement | 17,681 | 17,681 | 17,681 | 0 | --- |
| 5290 | Air Quality Planning and Outreach | 15,214 | 15,214 | 15,214 | 0 | --- |
| 5300 | Local Study Support | 112,707 | 112,707 | 112,707 | 0 | --- |
| 5301 | *Staff Technical Assistance* | 8,990 | 8,990 | 8,990 | | --- |
| 5361 | Implementing Complete Streets in the G-FL Region: A Guidebook | 10,548 | 10,548 | 0 | 10,548 | G/FLRPC |
| 5362 | *The Last Mile (or less): Site Plan Review for Multimodal Transportation* | 50,000 | 45,000 | 0 | 45,000 | G/FLRPC |
| 5400 | Regional Travel Demand Modeling | 96,387 | 96,387 | 96,387 | 0 | --- |
| 5421 | *Household Travel Data Collection* | 475,763 | 475,763 | 475,763 | 0 | --- |
| 5500 | Bicycle and Pedestrian Transportation Program | 57,178 | 57,178 | 57,178 | 0 | --- |
| 5540 | *Complete Streets Program* | 60,000 | 60,000 | 60,000 | 0 | --- |
| 5700 | Safety Planning | 18,600 | 18,600 | 18,600 | 0 | --- |
| 5710 | Security & Resiliency Planning | 13,549 | 13,549 | 13,549 | 0 | --- |
| 5752 | *Genesee-Finger Lakes Regional Resiliency Plan* | 150,000 | 150,000 | 150,000 | 0 | --- |
| 5900 | Transportation Systems Management & Operations (TSMO) Planning | 49,351 | 49,351 | 49,351 | 0 | --- |
| 5903 | Regional Traffic Operations Center (RTOC) Strategic Plan | 80,903 | 75,000 | 0 | 75,000 | NYSDOT |

Source: GTC.

Figure 20. Screenshot. Page from the Genesee Transportation Council's 2022–2023 Unified Planning Work Program with Long-Range Planning Activities.

**Table 1**
FY 2022-2023
Program Summary
Genesee Transportation Council UPWP

| | | Total Budget | Uses of Funds | | | |
|---|---|---|---|---|---|---|
| | | | Federal Funds Only - Excludes Match | | | |
| | | | | | Other Agency | |
| Task | Title | Federal Funds plus Match | Total Budget | GTC Budget | Budget | Agency |
| 7000 | Long Range Transportation Plan Refinement - Highways | | | | | |
| 7110 | Congestion Management Process (CMP) Implementation | 10,644 | 10,644 | 10,644 | 0 | --- |
| 7121 | Travel Time Data Collection Program | 44,000 | 44,000 | 44,000 | 0 | --- |
| 7213 | Rt. 96 over Rt. 14 Strategic Divestment Analysis | 111,500 | 100,000 | 100,000 | 0 | --- |
| 7578 | *Lakeville Corridor Strategic Plan* | 92,500 | 76,500 | 0 | 76,500 | Livingston County |
| 7620 | Genesee-Finger Lakes Regional Performance Measurement Monitoring and Evaluation System | 81,271 | 81,271 | 81,271 | 0 | --- |
| 7705 | Beh Industrial Park Traffic Optimization Study | 39,835 | 39,510 | 0 | 39,510 | Town of Ontario |
| 7706 | West Webster Hamlet | 100,000 | 90,000 | 0 | 90,000 | Town of Webster |
| 7900 | Transportation Performance Management Enahncement Project | 125,000 | 125,000 | 125,000 | 0 | --- |
| 7952 | Ramp Reconfiguration Study | 48,755 | 48,755 | 0 | 48,755 | NYSDOT |

Figure 21. Screenshot. Page from the Genesee Transportation Council's 2022–2023 Unified Planning Work Program with Long Range Transportation Plan Refinement - Highways.

New Mexico's Mid-Region Council of Governments (MRCOG) is home to the Albuquerque Metropolitan Planning Area (AMPA). MRCOG's planning activities center on transportation issues and the intersection between transportation and land use, the environment, and the economy.[74] MRCOG's Connections 2040 Metropolitan Transportation Plan (MTP) includes a section on optimized mobility, which monitors roadway system performance on all Federal-aid-eligible roadways in the region. The plan considers both infrastructure expansion projects and TSMO strategies for improving the performance of the existing transportation system.

73 Genesee Transportation Council. 2023. Unified Planning Work Program 2023-2024. Rochester, NY: GTC. https://www.gtcmpo.org/sites/default/files/pdf/2023/upwp_23-24_final.pdf, last accessed September 6, 2022

74 See Mid-Region Council of Governments, "Metro Planning" (website) at https://mrcog-nm.gov/149/Metro-Planning for more detailed information about MRCOG and AMPA.

# 6 SECTION 6: Supplemental Resources

MRCOG's ITS Subcommittee reviews transportation improvement program (TIP) projects and, as appropriate, formulates ITS projects needed in the region. All projects submitted for the TIP and MTP are evaluated to determine whether or not they include ITS elements, which are then mapped to the appropriate ITS services . Any project that includes ITS elements or connects with Federally funded ITS projects and that is seeking Federal transportation funds must be consistent with and include the ITS architecture. The ITS Subcommittee provides technical insight to the Congestion Management Process Committee regarding congested corridors, focusing on multiagency and multimodal operations. ITS applications vary in function and are designed to meet user needs as identified by member agency stakeholders.

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FHWA. 2022. "Organizing and Planning for Operations" (web page).

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Neudorff, Louis G., John Mason, and Jocelyn Bauer. 2009. "Glossary of Regional Transportation Systems Management and Operations Terms." Transportation Research Circular. Number E-C133. Washington, DC: Transportation Research Board of the National Academies.

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# A APPENDIX: Quick Reference Sheets

**This section contains Quick Reference (QR) sheets for the following categories (defined in Section 4):**

- Efficiency (EF)
- Travel Time Reliability (TTR)
- Mobility Options and Equity (OE)
- Sustainability (SU)
- Resiliency (RE)
- Safety (SA)
- Arterial Management (AM)
- Emergency Management (EM)
- Emerging Mobility Services (MS)
- Freeway Management (FWM)
- Freight Management (FRM)
- Traffic Incident Management (TIM)
- Special-Event Management (EVM)
- Transit Operations and Management (TRM)
- Transportation Demand Management (TDM)
- Road Weather Management (RWM)
- Traveler Information (TI)
- Work Zone Management (WZ)

**Each QR sheet contains the following information:**

- Category title
- General description
- Operations objectives
- Performance measures
- Anticipated data needs
- Data resources and partners
- TSMO strategies to consider

# **Efficiency:** EF1. Extent of Congestion

## General Description

The intent of these objectives is to manage the proportion of the transportation system that experiences recurring congestion (the spatial extent of congestion). Common expressions of recurring congestion are volume-to-capacity (V/C) ratio and level of service (LOS), which is measured in terms of travel speed or delay.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the percentage of facility miles (e.g., highway, arterial, rail) experiencing recurring congestion during the peak period by X percent by year Y<br>▪ Maintain the rate of growth in facility miles experiencing recurring congestion at less than the population growth rate (or employment growth rate)<br>▪ Reduce the share of major intersections operating at LOS Z by X percent by year Y<br>▪ Reduce the person-hours per day under congested conditions to at least X by year Y |
| **Performance Measures** | ▪ Percentage of lane-miles (or rail) operating at LOS F or V/C ratio > 1.0<br>▪ Percentage of intersections operating at LOS F or V/C ratio > 1.0<br>▪ Rate of increase in facility miles operating at LOS F or V/C ratio > 1.0<br>▪ Annual hours of peak-hour excessive delay per capita<br>▪ X number of jobs accessible within Y minutes<br>▪ X number of services, schools, hospitals accessible within Y minutes<br>▪ Person-hours per day under congested conditions (defined by V/C ratio, speed, or other measure of congestion) |
| **Anticipated Data Needs** | ▪ Hourly-volume data (e.g., traffic counts); inventory of facilities (e.g., number of lanes, presence and frequency of signals and intersections); calculations or estimates of capacity<br>▪ Travel times on road segments during peak travel hours<br>▪ Population, average vehicle control delay |
| **Data Resources and Partners** | ▪ Annual count programs, planning studies, engineering studies, and traffic impact studies<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data<br>▪ Geographic information system (GIS) or other database of system inventory<br>▪ State DOTs, transit agencies, MPOs, regional planning councils, highway districts, cities, counties, and traffic management centers |
| **TSMO Strategies To Consider** | TSMO strategies typically include those designed to reduce recurring congestion—such as traffic signal coordination—and travel demand strategies that encourage shifts in travel mode, time, or route. Bottleneck reduction could involve striping modifications, signage, lighting, ITS, traffic management, or integrated corridor management (ICM) to guide drivers through regularly congested areas. |

# **Efficiency:** EF2. Duration of Congestion

## General Description

These objectives focus on managing the duration of recurring congestion (roadway or intersection) on the transportation system. The duration of recurring congestion represents the length of time that a facility is congested. Common expressions of recurring congestion are V/C ratio and LOS, which is measured in terms of travel speed or delay.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the daily hours of recurring congestion on major freeways from X to Y by year Z<br>▪ Reduce the number of hours per day that the top 20 most congested roadways experience recurring congestion by X percent by year Y |
| **Performance Measures** | ▪ Hours per day at LOS F or V/C ratio > 1.0 (or other threshold |
| **Anticipated Data Needs** | ▪ Hourly traffic volume data (e.g., traffic counts), inventory of facilities (e.g., number of lanes, presence and frequency of signals and intersections), calculations or estimates of capacity |
| **Data Resources and Partners** | ▪ ITS data (continuous traffic counters), traffic count programs, studies<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data<br>▪ GIS or other database of system inventory<br>▪ State DOTs, regional planning councils, MPOs, highway districts, cities, counties, transit agencies, and traffic management centers |
| **TSMO Strategies To Consider** | TSMO strategies typically include those designed to reduce recurring congestion, such as traffic signal coordination; travel demand strategies that encourage shifts in travel mode, time, or route; and congestion-pricing strategies that encourage shifts to off-peak periods. The duration of congestion can be reduced by other strategies such as striping modifications, signage, lighting, ITS, traffic management, or ICM to guide drivers through regularly congested areas. |

# **Efficiency:** EF3. Intensity of Congestion (Travel Time Index)

## General Description

This objective focuses on managing the intensity of traffic congestion experienced by the traveling public. Congestion is measured using a travel time index, which compares travel conditions in the peak period with travel conditions during free-flow or posted-speed-limit conditions. For instance, a travel time index of 1.30 indicates that travel typically takes 30 percent longer in the peak period than during the off-peak period. The objectives focus on the actual experience of travelers and can be multimodal if transit travel time is included in the measure.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the regional-average-travel-time index by X percent per year<br>▪ Achieve a travel time index of Y during peak periods on freeways, expressways, or principal arterials |
| **Performance Measures** | ▪ Travel time index (i.e., the average travel time during the peak period, using congested speeds divided by the off-peak period travel time, using posted or free-flow speeds)<br>▪ Planning time index and buffer index (BI) |
| **Anticipated Data Needs** | ▪ Travel speed data during peak and off-peak periods across a network of facilities (e.g., freeways, highways, arterials, light-rail transit, bus rapid transit, bus routes) |
| **Data Resources and Partners** | ▪ ITS data (e.g., continuous measurements of traffic speed), speed studies<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data<br>▪ State DOTs, regional planning councils, MPOs, highway districts, cities, counties, and traffic management centers |
| **TSMO Strategies To Consider** | TSMO strategies typically include those designed to reduce recurring peak-period congestion—such as traffic signal coordination—and travel demand strategies that encourage shifts in travel mode, time, or route. If the objective includes transit, strategies could include transit signal priority. Congestion reduction could involve striping modifications, signage, lighting, ITS, traffic management, or ICM to guide drivers through regularly congested areas. |

# **Efficiency:** EF4. Travel Time

## General Description

These objectives focus on reducing travel time experienced by travelers. Travel time is a measure of the average time spent in travel, reflecting travel speeds, distances, and wait times. Total travel time is calculated as the sum of individual segment time multiplied by the number of people experiencing that time. The objectives can be multimodal if they account for transit travel time.

| | |
|---|---|
| **Operations Objectives** | ▪ Achieve an annual rate of change in regional average commute travel time not to exceed regional rate of population growth through year Y<br>▪ Improve average travel time during peak periods by X percent by year Y<br>▪ Reduce travel time index to X |
| **Performance Measures** | ▪ Average commute trip travel time (minutes)<br>▪ Average travel time during peak periods (minutes)<br>▪ Average peak-period travel time index (calculated as the mean travel time divided by free-flow travel time) |
| **Anticipated Data Needs** | ▪ Peak-period and free-flow travel time or speeds<br>▪ Person travel along links (e.g., vehicle volume multiplied by vehicle occupancy)<br>▪ Trip length |
| **Data Resources and Partners** | ▪ Providers of travel data, including speeds and volumes, such as State DOTs, cities, counties, and traffic management centers<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data<br>▪ Transit agencies, which can provide transit travel time or speed data and passenger counts |
| **TSMO Strategies To Consider** | TSMO strategies typically include those designed to reduce recurring peak period congestion—such as traffic signal coordination—and travel demand strategies that encourage shifts in travel mode, time, or route. If the objective includes transit and nonmotorized modes, strategies could include transit signal priority, transit queue jumps, intersection bicycle boxes, and mobility on demand. |

# **Efficiency:** EF5. Delay

## General Description

These objectives focus on reducing the delay in travel experienced by travelers. Delay is a measure of excess travel time caused by congestion (i.e., in comparison to free flow time or relative to the posted speed limit). Traffic-delay-per-capita measures are more mode neutral than traffic-delay-per-driver or per-vehicle measures (i.e., focuses on the experiences of the entire population, not just drivers).

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce hours of delay per capita by X percent by year Y<br>▪ Reduce hours of delay per driver by X percent by year Y |
| **Performance Measures** | ▪ Hours of delay per capita or per driver<br>▪ Annual hours of peak-hour excessive delay per capita |
| **Anticipated Data Needs** | ▪ Peak-period and free-flow travel time or speeds<br>▪ Person travel along links (e.g., vehicle volume multiplied by vehicle occupancy) |
| **Data Resources and Partners** | ▪ Providers of travel data, including speeds and volumes, such as State DOTs, cities, counties, and traffic management centers<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data<br>▪ Transit agencies, which can provide transit travel time or speed data and passenger counts |
| **TSMO Strategies To Consider** | TSMO strategies typically include those designed to reduce recurring peak-period congestion–such as traffic signal coordination—and travel demand strategies that encourage shifts in travel mode, time, or route. If the objective includes transit, strategies could include transit signal priority. Delay reductions could involve striping modifications, signage, lighting, ITS, traffic management, or ICM to guide drivers through regularly congested areas. |

# **Efficiency:** EF6. Energy Consumption

## General Description

These objectives focus on reducing total energy consumed for purposes of transportation. Energy consumption reflects both the amount of travel and fuel efficiency. Excess energy consumption focuses specifically on the excess fuel consumed due to congestion (i.e., in comparison to free-flow conditions). Objectives that address total energy consumption may more effectively account for energy savings resulting from increasing bicycling, walking, and transit use compared with measures that focus solely on excess fuel consumption associated with traffic congestion.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce total energy consumption per capita for transportation by X percent by year Y<br>▪ Reduce total fuel consumption per capita for transportation by X percent by year Y<br>▪ Reduce excess fuel consumed due to congestion by X percent by year Y<br>▪ Achieve X number of publicly available electric-vehicle charging stations within Y distance of travel centers and gas stations by year Z |
| **Performance Measures** | ▪ Total energy consumed per capita for transportation<br>▪ Total fuel consumed per capita for transportation<br>▪ Excess fuel consumed (total or per capita) |
| **Anticipated Data Needs** | ▪ Regional fuel sales data or regional population, vehicle miles traveled (VMT), and average vehicle fuel economy<br>▪ Transit vehicle energy use and ridership<br>▪ Hours of excess delay and fuel economy associated with delay |
| **Data Resources and Partners** | ▪ Partners include State taxation, economic development, vital records, transit agencies, and transportation departments. Fuel sales associations can provide data on total fuel sold.<br>▪ Excess fuel requires regional measures of total delay, which typically come from partners such as State and local DOTs, ITS managers, and traffic management center operators. |
| **TSMO Strategies To Consider** | TSMO strategies typically include those designed to reduce congestion and single-occupancy-vehicle trips, such as (1) traffic signal coordination, first- and last-mile micromobility options, curb-use management, and traffic incident management; (2) travel demand strategies that encourage shifts in travel mode, time, or route; and (3) congestion-pricing strategies that encourage shifts to off-peak periods. |

# **Efficiency:** EF7. Cost of Consumption

## General Description

These objectives focus on reducing the annual monetary cost of congestion, which can be measured based on wasted time and fuel, increased vehicle-operating costs, increased accidents, and costs of pollution.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the annual monetary cost of congestion per capita for the next Y years by X percent each year |
| **Performance Measures** | ▪ Cost (in dollars) of congestion or delay per capita |
| **Anticipated Data Needs** | ▪ Peak-period and free-flow travel time or speeds<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data<br>▪ Traveler volumes, auto/transit occupancy (by link, if determining delay for a subnetwork)<br>▪ Costs per delay time (i.e., all of the cost components, including wasted time, fuel, vehicle operating costs, pollution, and incidents) |
| **Data Resources and Partners** | ▪ Providers of travel data, including speeds and volumes, such as State DOTs, cities, counties, and traffic management centers<br>▪ Transit agencies that can provide transit travel time or speed data and passenger counts<br>▪ A benefit–cost analysis tool, such as the Tool for Operations Benefit-Cost Analysis (optional)[75] |
| **TSMO Strategies To Consider** | TSMO strategies typically include those designed to reduce peak-period congestion as well as unexpected delay—such as traffic signal coordination and traffic incident management—and travel demand strategies that encourage shifts in travel mode, time, or route. If the objective includes transit, strategies could include transit signal priority. |

75 For more information, see the U.S. Department of Transportation's "Tool for Operations Benefit-Cost Analysis (TOPS-BC)" (web page). https://ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm.

# **Efficiency:** EF8. Vehicle Miles Traveled

## General Description

The intent of this objective is to reduce the number of VMT by users of the transportation system. Comparisons of performance are best facilitated by associating the VMT with the population that generates them (per capita). Note that this objective may be in conflict with tolled facilities whose operators want more VMT to increase revenues.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce VMT per capita by X percent by year Y |
| **Performance Measures** | ▪ Average VMT per capita per day, per week, or per year |
| **Anticipated Data Needs** | ▪ Traffic volumes by facility and segment<br>▪ System inventory that provides facility lane miles by segment<br>▪ VMT may be estimated based on travel-monitoring programs (e.g., the Highway Performance Monitoring System).<br>▪ Survey data such as the National Household Travel Survey or local surveys may also be used to address VMT and trip lengths for different types of trips. |
| **Data Resources and Partners** | ▪ Providers of system inventory information and traffic data, such as State and local DOTs |
| **TSMO Strategies To Consider** | TSMO strategies typically include those that focus on managing travel demand through trip elimination (e.g., telecommuting), trip chaining (i.e., combining trips to reduce trip lengths), mode shifts (e.g., shifts from driving alone to transit, bicycling, and walking), increasing vehicle occupancy, and land-use strategies. Transit strategies that make transit trips faster and more reliable for users likely will also encourage shifts from driving to transit. |

# **Efficiency:** EF9. Trip Connectivity

## General Description

The intent of these objectives is to improve the efficiency of intra- and intermodal connectivity on trips taken by the traveling public in terms of providing an alternative to the single-occupancy-vehicle trip. Optimization of trip connectivity is indicated by cost and travel time.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce door-to-door trip time by X percent by year Y<br>▪ Reduce cost of transfer fees paid by X percent by year Y |
| **Performance Measures** | ▪ Average door-to-door trip time<br>▪ Average cost of transfers |
| **Anticipated Data Needs** | ▪ Survey data of traveler behavior, including average door-to-door trip time<br>▪ Transfer-cost data from transit providers |
| **Data Resources and Partners** | ▪ Agencies conducting traveler behavior surveys, such as transit agencies, MPOs, and State and local DOTs<br>▪ Transit agencies for transfer data |
| **TSMO Strategies To Consider** | TSMO strategies typically include those designed to improve trip connectivity and focus on the end user: the traveling public. Transfers of trips should be minimized, and fare payments should be seamless. TSMO strategies such as HOV lanes, part-time shoulder use, and transit signal priority should also be considered to improve trip connectivity. |

# **Travel Time Reliability:** TTR1. Nonrecurring Delay

## General Description

This set of objectives aims at decreasing nonrecurring delay (i.e., travel time delay caused by transient events, as opposed to delay caused by geometric limitations or lack of capacity). These objectives focus on mitigating nonrecurring delay due to scheduled and unscheduled disruptions to travel.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce total person-hours of delay (or travel time delay per capita) by time period (i.e., peak, off-peak) caused by:<br>- (Option 1) Scheduled events, work zones, or system maintenance by X hours in Y years<br>- (Option 2) Unscheduled disruptions to travel by X hours in Y years<br>- (Option 3) All transient events such as traffic incidents, special events, and work zones by X hours in Y years |
| **Performance Measures** | ▪ Travel time delay per capita during scheduled and/or unscheduled disruptions to travel<br>▪ Total person-hours of delay during (or travel time delay per capita) during—<br>- (Option 1) Scheduled events, work zones, or system maintenance by X hours in Y years<br>- (Option 2) Unscheduled disruptions to travel by X hours in Y years<br>- (Option 3) All transient events such as traffic incidents, special events, and work zones by X hours in Y years |
| **Anticipated Data Needs** | ▪ Travel time by person or vehicle during transient events such as traffic incidents, special events, and work zones |
| **Data Resources and Partners** | ▪ Travel time data during transient events may be difficult to collect—particularly during unscheduled events such as incidents and severe weather. Public safety organizations are likely needed to assist in identifying the locations and times of traffic incidents. Road and track maintenance staff will be needed to identify upcoming work. Data on travel times during unscheduled events may need to be extracted—after collection—from ongoing travel time data based on the time and location of events. The National Weather Service may also need to be involved in identifying times and locations of severe weather that may have impacted travel.<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data |
| **TSMO Strategies To Consider** | TSMO strategies typically include those that reduce nonrecurring delay and that focus on reducing delay caused by incidents, work zones, special events, and other transient events that affect traffic flow. |

# **Travel Time Reliability:** TTR2. Travel Time Buffer Index

## General Description

Objectives in the area of travel time reliability aim to reduce variability in travel time so that transportation system users experience consistent and predictable trip times. Unexpected delay is reduced for people and goods. This sheet focuses on the buffer index, which reflects the amount of extra time that travelers need to add to their average travel times to account for nonrecurring delay.

### Operations Objectives

- Decrease the buffer index for (specific travel routes) by X percent over the next Y years
- Decrease the average buffer index (for multiple routes or trips) by X percent over Y year
- Reduce the average travel time buffer needed to arrive on time for 95 percent of trips (on specified routes) by X minutes over Y years

### Performance Measures[76]

- The buffer index represents the extra time (buffer) most travelers add to their average travel times when planning trips (figure 22). This is the extra time between the average travel time and nearly worst-case travel time (95th percentile). The buffer index is stated as a percentage of the average travel time.

$$\text{Buffer Index (\%)} = \frac{\text{95th percentile travel time (minutes)} - \text{average travel time (minutes)}}{\text{average travel time (minutes)}}$$

**Figure 22. Equation. Buffer index calculation.**

- Average buffer index or buffer time can be calculated using miles traveled as a weighting factor.
- Buffer time = 95th percentile travel time (min) – average travel time (min)
- The level of travel time reliability (LOTTR) ratio is calculated as the ratio of the 80th percentile travel time to the 50th percentile travel time, so the LOTTR ratio for a single segment and time interval is stated as shown in figure 23:

$$LOTTR = \frac{80\%\ TT}{50\%\ TT}$$

**Figure 23. Equation. Level of travel time reliability calculation.**

- The LOTTR ratio for a segment is calculated by calculating the LOTTR ratio for four time intervals: weekdays 6 to 10 a.m., 10 a.m. to 4 p.m., and 4 to 8 p.m. and weekends 6 a.m. to 8 p.m. The LOTTR ratio for the segment is the maximum of the ratios calculated across these four time periods. Any LOTTR ratio > 1.5 indicates that the segment is not reliable.
- The system LOTTR measure is the percentage of reliable (i.e., LOTTR ratio < 1.5) person-miles for the segments measured for (1) the interstate systems, and (2) the noninterstate National Highway System (NHS), calculated as shown in figure 24:

$$\text{System LOTTR} = \frac{\sum \text{(Reliable Person Miles)}}{\sum \text{(Total Person Miles)}}$$

**Figure 24. Equation. System level of travel time reliability calculation.**

76 Shawn Turner, Rich Margiotta, and Tim Lomax. 2004. *Monitoring Urban Freeways in 2003: Current Conditions and Trends From Archived Operations Data.* Report No. FHWA-HOP-05-018. Washington, DC: FHWA. https://rosap.ntl.bts.gov/view/dot/39877, last accessed July 6, 2022.

## **Travel Time Reliability:** TTR2. Travel Time Buffer Index (continuation)

| | |
|---|---|
| **Anticipated Data Needs** | ▪ Travel time by segment for the transportation system that is of interest<br>▪ Estimates of person-miles traveled in each segment based on number of vehicles and average occupancy |
| **Data Resources and Partners** | Travel time estimates can be calculated using probe vehicles, continuous point-based detectors, periodic special studies, or simulation.[77] Partners may include State and local DOTs, MPOs, transit agencies, highway districts, tolling authorities, and other agencies responsible for managing, operating, or coordinating transportation facilities and services. Vehicle counts and occupancy can be determined through automated vehicle classification technology and estimates of average occupancy based on surveys and vehicle classes.<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data<br>▪ Field-observed travel time and speed data provided by the National Performance Management Research Data Set established by FHWA and the National Pooled Fund Program |
| **TSMO Strategies To Consider** | Strategies for increasing travel time reliability are those activities that aim to improve nonrecurring delay such as traffic incident management, work zone management, and special-events management. |

77 George F. List, Billy Williams, Nagui Rouphail, et al. 2014. *Guide to Establishing and Monitoring Programs for Travel Time Reliability*. Report No. SHRP2 S2-L02-RR-2. Washington, DC: Transportation Research Board. https://transportationops.org/research/guide-establishing-monitoring-programs-travel-time-reliability, last accessed September 1, 2022.

# **Travel Time Reliability:** TTR3. Travel Time 95th Percentile

## General Description

These objectives focus on reducing the 95th percentile travel time for one or more routes or trips in the region. Per the nonregulatory Highway Capacity Manual, the 95th percentile travel time represents one of the worst travel times for that route or trip because it indicates that 95 percent of travel times for that route are shorter than the 95th percentile travel time.[78]

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the average of the 95th percentile travel times (for a group of specific travel routes or trips in the region) by X minutes in Y years<br>▪ Reduce the 95th percentile travel times for each route selected by X percent over Y years |
| **Performance Measures** | ▪ 95th percentile travel times for selected routes |
| **Anticipated Data Needs** | ▪ Travel time |
| **Data Resources and Partners** | ▪ Travel time estimates calculated using probe vehicles, continuous point-based detectors, periodic special studies, or simulation[79]<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data |
| **TSMO Strategies To Consider** | Travel time durations that are in the top 5 percent for a given route are likely caused by significant, nonrecurring events such as major traffic incidents, system maintenance failures, severe weather, and work zones that significantly reduce available capacity. Strategies to consider include those that work to prevent the more extreme delay-causing events or reduce the impact to travelers through traveler information. |

78 National Academies of Sciences, Engineering, and Medicine. 2022. *Highway Capacity Manual 7th Edition: A Guide for Multimodal Mobility Analysis*. Washington, DC: National Academies Press. https://doi.org/10.17226/26432, last accessed September 8, 2022.

79 George F. List, Billy Williams, Nagui Rouphail, et al. 2014. *Guide to Establishing and Monitoring Programs for Travel Time Reliability*. Report No. SHRP2 S2-L02-RR-2. Washington, DC: Transportation Research Board. https://transportationops.org/research/guide-establishing-monitoring-programs-travel-time-reliability, last accessed September 1, 2022.

# **Travel Time Reliability:** TTR4. Planning Time Index

## General Description

Objectives in the area of travel time reliability aim to reduce the variability in travel time so that transportation system users experience consistent and predictable trip times. Unexpected delay is reduced for people and goods. This sheet focuses on the planning time index, which reflects the amount of extra time that travelers need to add to free-flow (or posted-speed-limit) travel time in order to arrive on time in almost all situations. The planning-time index considers both recurring and nonrecurring sources of delay.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the average planning time (for specific routes in region) by X points over the next Y years<br>▪ Reduce the average planning time (for specific routes in region) by X minutes over the next Y years |
| **Performance Measures** | ▪ The planning time index, shown in figure 25, represents the time that must be added to travel time at free-flow speeds or the posted speed limit to ensure on-time arrivals for 95 percent of trips.<br>$$\text{Planning time index} = \frac{\text{95th percentile travel time (minutes)}}{\text{Travel time at a free-flow speed or posted speed limit (minutes)}}$$<br>**Figure 25. Equation. Planning-time-index calculation.**<br>▪ Planning time = 95th percentile travel time (minutes) – Travel time at free-flow speed or posted speed limit<br>▪ Average planning time index or planning time can be computed using a weighted average over person-miles traveled. |
| **Anticipated Data Needs** | ▪ Travel time |
| **Data Resources and Partners** | ▪ Travel time estimates calculated using probe vehicles, continuous point-based detectors, periodic special studies, or simulation[80]<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data |
| **TSMO Strategies To Consider** | TSMO strategies typically include those that aim to reduce both recurring and nonrecurring delay, such as high-occupancy-vehicle (HOV)/high-occupancy-toll (HOT) lanes, ramp metering, single-occupancy vehicles, transit, traffic incident management, work zone management, and special-events management. |

80 George F. List, Billy Williams, Nagui Rouphail, et al. 2014. Guide to Establishing and Monitoring Programs for Travel Time Reliability. Report No. SHRP2 S2-L02-RR-2. Washington, DC: Transportation Research Board. https://transportationops.org/research/guide-establishing-monitoring-programs-travel-time-reliability, last accessed September 1, 2022.

# **Travel Time Reliability:** TTR5. Variability

## General Description

Objectives in this section focus on improving travel time reliability by trying to reduce the variability of travel time.

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|---|---|
| **Operations Objectives** | ▪ Reduce the variability of travel time on specified routes by X percent during peak and off-peak periods by year Y<br>▪ Increase the percentage of reliable person-miles traveled on NHS interstate highways to at least X by year Y<br>▪ Increase the percentage of reliable person-miles traveled on non-NHS roadways to at least X by year Y |
| **Performance Measures** | ▪ Variance of travel time. Variance is the sum of the squared deviations from the mean. Can also be calculated as the standard deviation of travel time, where standard deviation is the square root of variance<br>▪ Percentage of person-miles traveled on NHS interstate highways with variances less than X<br>▪ Percentage of person-miles traveled on non-NHS roadways with variances less than X |
| **Anticipated Data Needs** | ▪ Travel time |
| **Data Resources and Partners** | ▪ Travel time estimates calculated using probe vehicles, continuous point-based detectors, periodic special studies, or simulation.[81] Travel time collected by the owner of the facility such as the State DOT or city or county DOT<br>▪ Travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data |
| **TSMO Strategies To Consider** | Strategies for reducing variance in travel time include those activities that aim to reduce delay caused by transient events such as incidents, work zones, and special events. |

81 George F. List, Billy Williams, Nagui Rouphail, et al. 2014. *Guide to Establishing and Monitoring Programs for Travel Time Reliability*. Report No. SHRP2 S2-L02-RR-2. Washington, DC: Transportation Research Board. https://transportationops.org/research/guide-establishing-monitoring-programs-travel-time-reliability, last accessed September 1, 2022.

# **Travel Time Reliability:** TTR6. Transit On-Time Performance

## General Description

These objectives focus on travel time reliability for transit users as measured by on-time performance. On-time performance often has a tolerance interval such that if a transit vehicle arrives at a stop within X minutes of scheduled arrival and does not depart from that stop more than Y minutes after scheduled departure time, it is considered on time.

| | |
|---|---|
| **Operations Objectives** | ▪ Improve average on-time performance for specified transit routes and facilities by X percent within Y years |
| **Performance Measures** | ▪ On-time performance of transit |
| **Anticipated Data Needs** | ▪ Arrival and departure times (if different) from a select number of stops at transit facilities of interest |
| **Data Resources and Partners** | ▪ Published transit schedules and actual travel times or on-time performance statistics<br>▪ The data coming primarily from transit operators |
| **TSMO Strategies To Consider** | Improvements to transit on-time performance may be achieved through reducing recurring and nonrecurring delay on transit routes by implementing transit signal preemption, designated lanes for transit, and electronic fare collection. |

# **Mobility Options and Equity:** OE1. Mode Share

## General Description

These objectives seek to increase the share of modes used other than the single-occupancy vehicle to improve the overall efficiency of the transportation system. In some cases, access to alternative modes may improve equitable outcomes. Accessibility improvements will need to be identified in collaboration with the users.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce per-capita single-occupancy-vehicle commute trip rate by X percent in Y years<br>▪ Increase alternative (non-single-occupancy-vehicle) mode share by X percent for each analysis zone within the next Y years<br>▪ Increase active (bicycle and pedestrian) mode share by X percent by year Y<br>▪ Reduce single-occupancy-vehicle trips by X percent through travel-demand-management strategies (e.g., employer or residential rideshare) by year Y<br>▪ Achieve X percent alternative (non-single-occupancy-vehicle) mode share in communities with access to transit services (or other areas) by year Y |
| **Performance Measures** | ▪ Single-occupancy-vehicle commute trips per capita<br>▪ Share of employees walking, biking, telecommuting, carpooling, vanpooling, riding transit, or driving alone<br>▪ Share of trips by each mode of travel<br>▪ Percentage of all trips made using alternative modes in transit station communities |
| **Anticipated Data Needs** | ▪ Survey data, such as those derived from the U.S. Census Bureau's Commuting (Journey to Work) survey, or other mode share data<br>▪ Employer surveys of employee commuting patterns<br>▪ Household surveys of travel behaviors, including mode choice, frequency of trip making, and vehicle occupancy |
| **Data Resources and Partners** | ▪ Employers, transportation management associations, travel-demand-management programs, transit agencies, State and local DOTs, commuters, nonauto advocacy groups, and research firms |
| **TSMO Strategies To Consider** | TSMO strategies typically include those that encourage the use of travel-demand-management, parking-management, and congestion-pricing strategies. |

# **Mobility Options and Equity:** OE2. Transit Use

## General Description

The primary intent of these objectives is to increase the use of transit for trips taken or transit mode share to reduce the use of single-occupancy vehicles and improve overall system efficiency; they may also address the efficiency of transit services in terms of the number of occupied seats per bus or train.

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| **Operations Objectives** | ▪ Increase transit mode share by X percent by year Y<br>▪ Increase transit mode share by X percent by year Y during peak periods<br>▪ Increase transit mode share by X percent by year Y for each analysis zone<br>▪ Increase average transit load factor by X percent by year Y<br>▪ Increase passenger miles traveled per capita on transit by X percent by year Y<br>▪ Increase population within 0.3 miles to nearest transit stop by X percent in year Y |
| **Performance Measures** | ▪ Percentage of all trips made by transit<br>▪ Percentage of disadvantages communities served by transit<br>▪ Percentage of all peak-period trips made by transit<br>▪ Number of riders on transit units per trip<br>▪ Number of passenger miles traveled per capita<br>▪ Percentage of non-single-occupancy-vehicle travel as defined by the FHWA Computation Procedure for Travel Time Based and Percent Non-Single Occupancy Vehicle (non-SOV) Travel Performance Measures<br>▪ Population within a certain distance of transit stop |
| **Anticipated Data Needs** | ▪ Travel behavior survey data<br>▪ Public transit system data (e.g., number of tickets purchased, number of trips made, passenger travel data for trip length, transit stop locations)<br>▪ Demographic information on groups making transit trips<br>▪ Residential locations |
| **Data Resources and Partners** | ▪ Survey participants and local transit providers |
| **TSMO Strategies To Consider** | TSMO strategies to increase the use of transit over single-occupancy-vehicle travel include marketing and rider incentive programs, electronic fare card systems, increased transit travel time efficiency and reliability, and ease of use. |

# **Mobility Options and Equity:** OE3. Travel Time: Transit Compared With Auto

## General Description

These objectives focus on improving the travel time (or speed) of public transit in comparison to average auto travel times (or speeds). The objective is designed to advance efficient transit operations and make transit more competitive with the auto to persuade system users to use transit, as opposed to single-occupancy vehicles.

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| **Operations Objectives** | ▪ Reduce the travel time differential between transit and auto during peak periods by X percent per year for Y years<br>▪ Maintain a travel time differential between transit and auto during peak periods of X percent for Y years<br>▪ Improve average travel time for transit compared with auto in major corridors by X minutes per year for Y years |
| **Performance Measures** | ▪ Transit-to-auto travel time differential for a given period (daily, hourly, or peak hours) on a given portion of the system (systemwide, by facility type, or by corridor) |
| **Anticipated Data Needs** | ▪ Transit travel time performance, average auto speeds, or auto travel times |
| **Data Resources and Partners** | ▪ Transit on-time performance records, measured travel speeds on key facilities, probes in traffic streams, and permanent traffic recorders that collect speed data<br>▪ State and local DOTs, transit agencies, traffic management centers, and ITS operators |
| **TSMO Strategies To Consider** | TSMO strategies are typically those designed to increase transit speeds, such as bus rapid transit, part-time shoulder use for buses, HOV lanes that buses can use, queue jump lanes at signalized intersections, and transit signal priority. |

# **Mobility Options and Equity:** OE4. Bicycle, Pedestrian, Micromobility Accessibility and Efficiency

## General Description

The objectives in this section focus on improving the accessibility and efficiency of bicycle, pedestrian, and micromobility modes to offer travelers feasible and attractive travel options.

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| **Operations Objectives** | ▪ Decrease average delay for pedestrians and bicyclists on primary pedestrian and bike routes by X percent in Y years<br>▪ Increase the share of roadways with bicycle lanes to X percent by year Y<br>▪ Increase miles of sidewalk and bike route network for bicyclists and pedestrians by X percent within Y years<br>▪ Increase the number of intersections with pedestrian features (e.g., countdown pedestrian signal heads, high-visibility crosswalk markings, curb extension) to X percent by year Y<br>▪ Increase average pedestrian or bicyclist comfort level by X points in Y years<br>▪ Increase the number of people and deliveries the curb provides access to by X percent for all modes of transportation in Y years<br>▪ Increase the number of bus stops with shelters by X percent by year Y<br>▪ Increase the number of available public bikeshare bicycles and micromobility vehicles by X percent by year Y |
| **Performance Measures** | ▪ Average delay for pedestrians and bicyclists on primary sidewalks and bike routes<br>▪ Percentage of roadways with sidewalks and bike routes<br>▪ Percentage of intersections with sidewalks and other pedestrian features such as benches<br>▪ Average pedestrian or bicyclist comfort level as measured by survey<br>▪ Percentage of people or deliveries the curb provides access to for all modes of transportation<br>▪ Number of bus stops with shelters<br>▪ Number of bikeshare bicycles or micromobility vehicles |
| **Anticipated Data Needs** | ▪ Wait time for pedestrians and bicyclists at intersections or path blockages<br>▪ An inventory of sidewalks, bike routes, bus stops, and other bicycle and pedestrian facilities<br>▪ Survey information on pedestrian or bicyclist comfort level |
| **Data Resources and Partners** | ▪ State and local DOTs, counties, cities, and highway districts<br>▪ Bicycle sensor data<br>▪ Bicycle and pedestrian counts |
| **TSMO Strategies To Consider** | TSMO strategies are typically pedestrian countdown signals, Americans with Disabilities Act (ADA)–compliant curbs, bicycle lanes, signage, and crossing signals where bicycles cross major roadways. |

# **Mobility Options and Equity:** OE5. Modal Options for Individuals With Disabilities

## General Description

The objectives in this sheet focus on increasing modal options for individuals with disabilities.

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| **Operations Objectives** | ▪ Increase the percentage of intersections with ADA provisions (such as ADA ramps and push buttons) to X percent by year Y<br>▪ Increase the availability of transit to individuals with disabilities by X percent by year Y<br>▪ Increase the percentage of transit stops with ADA provisions to X percent by year Y<br>▪ Decrease the average wait time for paratransit by X percent by year Y |
| **Performance Measures** | ▪ The percentage of intersections with ADA provisions<br>▪ The percentage of individuals with disabilities who can access transit<br>▪ The percentage of transit stops with ADA provisions<br>▪ Average wait time for a paratransit vehicle |
| **Anticipated Data Needs** | ▪ The number of intersections with and without ADA provisions<br>▪ The number of individuals with disabilities who can access transit<br>▪ The number of transit stops with and without ADA provisions<br>▪ Wait times for paratransit trips |
| **Data Resources and Partners** | ▪ State and local DOTs, transit agencies |
| **TSMO Strategies To Consider** | TSMO strategies typically include planning, programming, and constructing ADA improvements at intersections; expanding paratransit service; and purchasing transit vehicles with low-floor-boarding capabilities and other accommodations for individuals with disabilities |

# **Mobility Options and Equity:** OE6. Equitable Access to Services and Opportunities

## General Description

Underserved populations have historically been underrepresented in the planning, design, construction, and operations of transportation networks. Examples of underserved populations include low-income populations, older individuals, certain ethnic groups, and people with disabilities. The objectives in this section focus on ensuring that those populations have access to the services and opportunities that enable them to participate fully in the regional economy and society.

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| **Operations Objectives** | ▪ Provide affordable access to education (primary, secondary, post-secondary, vocational) to at least X percent of the underserved population (as locally designated) within the region of interest, with achievable travel times of no more than Y minutes through multiple transportation mode options (e.g., public transportation, shared rides and paratransit, private vehicle, and safe and secure pedestrian and bicycle)<br>▪ Provide affordable access to employment opportunities that offer a living wage based on local economic conditions for at least X percent of the underserved population (as locally designated) within the region of interest, with achievable travel times of no more than Y minutes through multiple transportation mode options<br>▪ Provide affordable access to appropriate primary health services for at least X percent of the underserved population (as locally designated) within the region of interest, with achievable travel times of no more than Y minutes through multiple transportation mode options<br>▪ Provide affordable access to goods and services (food, childcare, clothing, medicines, durable goods, etc.) for at least X percent of the underserved population (as locally designated) within the region of interest, with achievable travel times of no more than Y minutes through multiple transportation mode options |
| **Performance Measures** | ▪ The percentage of the underserved population with affordable access to educational resources<br>▪ The percentage of the underserved population with affordable access to employment opportunities<br>▪ The percentage of the underserved population with affordable access to primary healthcare services<br>▪ The percentage of the underserved population with access to essential goods and services |
| **Anticipated Data Needs** | ▪ Demographic data (income, housing, ethnicity, education, age, disability status, and employment characteristics) on the underserved population within the region of interest<br>▪ GIS data on locations of the variety of goods and services (including education and healthcare) as well as significant employment opportunities<br>▪ Inventory of transportation facilities and services, including transit services, roadways, bike routes, and sidewalks<br>▪ Travel time distributions by times of day to and from essential locations of interest by mode, including mode changes and associated delays within trips |
| **Data Resources and Partners** | ▪ State and local DOTs, transit agencies, local and regional planning agencies, regional employers, and service providers |
| **TSMO Strategies To Consider** | ▪ Smartphone apps to provide real-time traveler information (routes, modes, cost, travel time, schedules) and payment options (including eligible discounts) for underserved travelers<br>▪ Strategically located transit stops to serve historically underserved populations<br>▪ Subsidized mobility-on-demand and mobility-as-a-service options for historically underserved populations<br>▪ Outreach to underserved populations to identify and clarify transportation needs and restrictions<br>▪ Improvements in pedestrian and bicycle options (sidewalks, crosswalks, pedestrian and bicycle overpasses, protected bike lanes) in response to needs of underserved populations |

# **Mobility Options and Equity:** OE7. Equitable Access to Electrification Options

## General Description

Underserved populations have historically been underrepresented in the planning, design, construction, and operations of transportation networks. The growing proportion of both hybrid electric and plug-in electric vehicles (EV) reduces both noise and air pollution in areas where they are in use. The objectives in this section focus on providing the policies (e.g., rebates, car-sharing options), infrastructure, and operations needed to enable and encourage growth in EV usage and operation by historically underserved populations. Lack of access to fast charging can be a major impediment to EV use and can also lead to searching for available charging locations.

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| **Operations Objectives** | ▪ Provide at least X percent of the low-income, historically underserved population (as locally defined) with affordable access to vehicle fast-charging capacity within Y distance (feet or miles) of their primary residence<br>▪ Provide at least X percent of individuals living in high-density housing (e.g., apartment buildings and row houses) with access to vehicle fast-charging capacity within Y distance (feet or miles) of their primary residence<br>▪ Provide at least X percent of individuals in high-density housing with access to electric scooters and bicycles (privately owned or docked or distributed within easy access), including means for charging these options<br>▪ Deploy at least X percent of electric-charging stations in low-income areas |
| **Performance Measures** | ▪ The percentage of the low-income population with affordable access to fast-charging capacity, including both the time to charge and the availability of charging stations<br>▪ The percentage of the population in high-density housing (e.g., without access to personally owned vehicle-charging capability) with affordable access to vehicle-charging stations<br>▪ The percentage of the low-income population with access to electric-micromobility options (e.g., electric scooters and bicycles) to supplement other transportation options<br>▪ The percentage of electric-charging locations in low-income areas |
| **Anticipated Data Needs** | ▪ Demographic data (income, housing, education, and employment characteristics) on the low-income population within the region of interest<br>▪ GIS data on locations and types of EV-charging stations and their proximity to historically underserved populations<br>▪ Market penetration of electric vehicles into low-income neighborhoods and trends in hybrid-electric-vehicle and battery-powered-EV growth |
| **Data Resources and Partners** | ▪ State and local DOTs, urban planners, EV charging station providers, community associations, transportation network service providers and other shared-use options |
| **TSMO Strategies To Consider** | ▪ Smartphone apps to provide real-time information regarding the locations and status of EV charging stations<br>▪ Subsidized EV charging stations in areas with large traditionally underserved populations<br>▪ Outreach to underserved populations to identify and clarify transportation needs and restrictions with respect to EV adoption and use<br>▪ Facilitation of the formation of neighborhood cooperatives to own and operate EV charging stations and, potentially, shared-use EVs that can be connected to the electrical power grid to assist with meeting peak power demand when not in use |

# **Mobility Options and Equity:** OE8. Equitable Mitigation of Negative Effects

## General Description

Underserved populations have historically been underrepresented in the planning, design, construction, and operation of transportation networks. Consequently, many of these underserved populations were overlooked when roadways and related services were developed and delivered. The objectives in this section focus on ensuring that the way the transportation system is operated does not result in underserved populations bearing a disproportionate share of the negative effects of the transportation system, including, for example, noise, air pollution, stormwater runoff from roadways, flooding caused by poor stormwater management on roadways, poorly designed and managed work zones, and routine traffic congestion.

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| **Operations Objectives** | ▪ Reduce or eliminate traffic congestion by adopting and implementing congestion mitigation strategies in areas with large populations of traditionally underserved populations such that mobility (e.g., travel time reliability) is consistent with that of other roadway segments in the region<br>▪ Design, deploy, and enforce appropriate noise mitigation methods in areas with large populations of traditionally underserved populations (e.g., by erecting barriers, implementing vehicle-noise restrictions, prohibiting engine breaking by heavy vehicles)<br>▪ Implement stormwater runoff and flood control methods (e.g., pumping facilities and diversion) that prevent roadways and adjacent areas from flooding, or restrict mobility in traditionally underserved areas |
| **Performance Measures** | ▪ The percentage of traditionally underserved populations that is routinely exposed to traffic congestion due to traffic volume, frequent special events, poorly designed work zones or other roadway impediments in excess of that seen in other areas within the region<br>▪ The percentage of the traditionally underserved population that is exposed to noise and air pollution levels that exceed the levels found in other areas within the region<br>▪ The percentage of the traditionally underserved population whose property and/or means of access and egress are impeded by frequent stormwater runoff or roadway flooding |
| **Anticipated Data Needs** | ▪ Demographic data (income, housing, education, and employment characteristics) on the low-income populations within the region of interest<br>▪ Historical weather and flooding conditions in areas with high concentrations of traditionally underserved populations<br>▪ Historical data on congestion, including travel times, special events, work zones, weather events, incidents, and other contributors to congestion<br>▪ Data on ambient noise and air quality in areas of interest by time of day and other related factors (e.g., shift change at local employer and heavy vehicles arriving and departing warehouses) |
| **Data Resources and Partners** | ▪ State and local DOTs, urban planners, local meteorological professionals, floodwater management specialists, neighborhood associations, environmental specialists |
| **TSMO Strategies To Consider** | ▪ TSMO congestion mitigation process plans and related strategies such as traffic calming, road diets, and road closures<br>▪ Adaptive signal control systems to manage traffic flow more effectively<br>▪ Travel-demand-management strategies<br>▪ Roadway-access-management strategies that serve neighborhoods adjacent to major arterials<br>▪ Parking management and information systems, including curbside parking management<br>▪ Localized noise and air quality sensors and reporting systems<br>▪ Road-weather-management systems and related stormwater-management technology |

# **Sustainability:** SU1. Technological

## General Description

Sustainability is often described using the triple-bottom-line concept, which includes giving consideration to three primary principles: social, environmental, and economic. The goal of sustainability is the satisfaction of basic social and economic needs both present and future and the responsible use of natural resources, all while maintaining or improving the well-being of the environment on which life depends.[82] This objective focuses on the technological aspects of sustainability, including interoperability, open-source software, anticipating technological obsolesce, and design for maintainability. Technological sustainability contributes to economic and environmental sustainability by ensuring the most-efficient technologies are implemented and compatible with future developments that can improve economic and environmental efficiency.

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| **Operations Objectives** | ▪ Improve the technological sustainability of the transportation system by instituting the following objectives:<br>- Within the next Y years, implement policies that include interoperability among communication systems used by transportation and public safety agencies<br>- Within the next Y years, implement policies that involve open-source software to prevent restrictions on using proprietary technology<br>- Within the next Y years, include planned obsolescence of technology and subsequent replacements or upgrades as TSMO planning factors in anticipation of more cost effective and functionally advanced solutions<br>- Within the next Y years, include as a TSMO planning factor the personnel, supplies, and equipment needed to maintain technologies associated with TSMO (e.g., sensors, networks, servers, cameras, displays, communications) and consider system maintainability as part of the decisionmaking process<br>- Within the next Y years, develop appropriate ITS standards to document how systems and devices operate to deliver services for the transportation network |
| **Performance Measures** | ▪ Lifecycle costs associated with TSMO technologies<br>▪ Verification of backward and forward compatibility associated with TSMO technologies<br>▪ Evidence of preplanned product improvements to accommodate new features, upgrades, and replacements of TSMO technologies |
| **Anticipated Data Needs** | ▪ Product specifications from vendors and suppliers<br>▪ Industry technology forecast for near-term and longer term TSMO solutions<br>▪ Simulation models and analysis to predict impacts of anticipated upgrades on mobility and safety |
| **Data Resources and Partners** | ▪ Industry partners (e.g., for public–private partnerships), vendors, and suppliers can provide information on current and future TSMO technologies, including compatibility, proprietary restrictions, and anticipated upgrades and replacements.<br>▪ Industry publications and reports can keep DOT technical staff informed of emerging solutions.<br>▪ Peer-to-peer exchanges can provide current information regarding impacts of new technologies. |

82 Federal Highway Administration. n.d. "What is sustainability?" (website). https://www.sustainablehighways.dot.gov/overview.aspx#quest1, last accessed December 2, 2021.

## **Sustainability:** SU1. Technological (continuation)

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| **TSMO Strategies To Consider** | Typical TSMO strategies used to address system technological sustainability include procurement policies that support technological sustainability as a selection factor.<br>Due to the likely regional nature of many TSMO solutions—especially those that involve installation and maintenance of technology (e.g., hardware, software, algorithms, displays, networks)—multijurisdictional, multiagency, and multidisciplinary policies will likely be needed to communicate, coordinate, and collaborate to gather information and implement TSMO strategies.<br><br>Additional resources can be found in FHWA's resources to support Traffic Management Capability Maturity Framework (CMF) Users, which provides technology resources for the traffic CMF. Other operations CMFs also contain technology resources. These CMFs can be found at Resources to Support Capability Maturity Framework Action Planning: Business Process Frameworks for Transportation Operations - FHWA Operations, Resources to Support Traffic Management Capability Maturity Framework Users,[83] and related FHWA resources.[84] |

83 See the FHWA "Resources to Support Traffic Management Capability Maturity Framework Users" (web page). https://ops.fhwa.dot.gov/tsmoframeworktool/resources/tm_cmf_res.

84 Five additional operations CMFs contain technology resource examples. Access these examples at FHWA's Business Process Frameworks for Transportation Operations (web page). https://ops.fhwa.dot.gov/tsmoframeworktool/cmfsuptresources.htm.

# **Sustainability:** SU2. Fiscal

## General Description

Sustainability is often described using the triple-bottom-line concept, which includes giving consideration to three primary principles: social, environmental, and economic. The goal of sustainability is the satisfaction of basic social and economic needs both present and future and the responsible use of natural resources, all while maintaining or improving the well-being of the environment on which life depends.[85] This objective focuses on the fiscal aspects of sustainability, including adequate funding and revenue streams to manage and operate the transportation system. Fiscal sustainability contributes to economic, environmental, and technological sustainability by ensuring that adequate resources are programmed and revenue streams are developed to ensure effective management and operation of the system throughout its expected lifetime, including future upgrades and replacement.

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| **Operations Objectives** | ▪ Improve the fiscal sustainability of the transportation system by instituting the following objectives:<br>- Within the next Y years, establish criteria to identify ongoing funding sources for management and operation of TSMO strategies (including revenue streams)<br>- Within the next Y years, develop estimates for lifecycle costs and associated funding and revenue sources to cover lifecycle costs<br>- Within the next Y years, include as a TSMO planning factor the planned obsolescence of technology and subsequent replacements or upgrades |
| **Performance Measures** | ▪ Lifecycle costs associated with TSMO technologies<br>▪ Revenue generated through transactions and funding to support TSMO strategies, including shared-resource arrangements<br>▪ Actual cost of implementing, managing, and operating TSMO strategies |
| **Anticipated Data Needs** | ▪ Lifecycle cost estimates from modeling and analysis based on actual or forecast demand and associated operating costs<br>▪ Actual cost to plan, design, develop, implement, manage, and operate TSMO strategies<br>▪ Revenue produced through TSMO strategies, such as toll collection, pricing, and transit revenues, including electronic toll collection, transit fare collection systems, parking revenue collection systems, and other revenue sources that must be maintained to ensure effective management, operation, and maintenance of TSMO strategies |
| **Data Resources and Partners** | ▪ State and local DOT procurement and fiscal management offices, vendors and suppliers, private-sector partners |
| **TSMO Strategies To Consider** | Typical TSMO strategies used to address system fiscal sustainability include the following:<br>▪ Procurement policies that require lifecycle costing as a selection factor<br>▪ Transaction-based funding strategies (e.g., user fees based on VMT, other user-fee funding, including tolls)<br>Due to the likely regional nature of many TSMO solutions—especially those that require installation and maintenance of technology (e.g., hardware, software, algorithms, displays, networks)—multijurisdictional, multiagency, and multidisciplinary capabilities will likely be needed to communicate, coordinate, and collaborate to gather information and implement TSMO strategies. |

85 Federal Highway Administration. n.d. "What is sustainability?" (website). https://www.sustainablehighways.dot.gov/overview.aspx#quest1, last accessed December 2, 2021.

# **Sustainability:** SU3. Environmental

## General Description

Sustainability is often described using the triple-bottom-line concept, which includes giving consideration to three primary principles: social, environmental, and economic. The goal of sustainability is the satisfaction of basic social and economic needs both present and future and the responsible use of natural resources, all while maintaining or improving the well-being of the environment on which life depends.[86] This objective focuses on the environmental aspects of sustainability, including air quality, wetlands, runoff management, hazmat containment, and chemical applications.

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| **Operations Objectives** | ▪ Reduce total emissions.<br>▪ Improve the environmental sustainability of the transportation system by instituting the following objectives:<br>- Within the next Y years, reduce recurring delay to X minutes and associated emissions to no more than Z during peak periods in heavily congested corridors<br>- Within the next Y years, reduce fossil fuel consumption by vehicles to X gallons per 1,000 miles driven within urban centers (e.g., though reduced congestion, transition to renewable energy sources, improved fuel efficiency)<br>- Within the next Y years, reduce the quantity of chemicals applied to roadways through effective road sensors, better coordination with weather predictions, and more-precise application technology<br>- Within the next Y years, train and equip a well-equipped hazmat response team and deploy the team to hazmat spills and releases that have the potential for contaminating land or water<br>- Within the next Y years, reduce commercial vehicle idling in loading and unloading zones and tour bus waiting areas |
| **Performance Measures** | ▪ Level of air pollutants emitted<br>▪ Average speed during peak demand periods on freeway and arterial segments where recurring delay is prevalent<br>▪ Total delay due to recurring congestion during peak periods on freeways and arterials where recurring delay is prevalent<br>▪ Travel time reliability (TTR) during peak periods on freeway and arterial segments<br>▪ Truck travel time reliability (TTTR) on freeways and arterials, including access to ports and border crossings<br>▪ Percentage of VMT using renewable energy sources (e.g., electric vehicles with energy provided by renewable energy)<br>▪ Percentage of VMT by plug-in electric or hybrid vehicles<br>▪ Time that parked commercial vehicles (trucks, tour buses) run idle engines for heating or cooling |

86 Federal Highway Administration. n.d. "What is sustainability?" (website). https://www.sustainablehighways.dot.gov/overview.aspx#quest1, last accessed December 2, 2021.

## **Sustainability:** SU3. Environmental (continuation)

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| **Anticipated Data Needs** | ▪ Vehicles-in-use statistics and fleet characteristics (including micromobility)<br>▪ Travel times for specific freeway and arterial segments during peak periods<br>▪ Average speeds during peak periods for freeway and arterial segments<br>▪ Fuel consumption as a function of fleet characteristics<br>▪ Energy sources for mobility<br>▪ Commercial-vehicle (trucks and buses) idling time |
| **Data Resources and Partners** | ▪ Travel time data can be obtained from State and local DOTs. Vehicles-in-use data may be available from departments of motor vehicles or from local personal property tax rolls. Fuel consumption data may have to come from economic analysis regarding fuel sales in the area or a combination of VMT and fleet characteristics. |
| **TSMO Strategies To Consider** | Typical TSMO strategies used to address system environmental sustainability include the following:<br>▪ Speed restrictions (e.g., variable speed limits)<br>▪ Vehicle restrictions (e.g., truck restrictions or dedicated truck lanes to separate heavy and light vehicles)<br>▪ Electronic toll collection using radio frequency identification tags and license plate readers at posted speeds to reduce delays on toll roads (i.e., no delays at toll booths for cash collection)<br>▪ Traffic signal management to reduce delay on arterials<br>▪ Travel-demand-management strategies (e.g., HOV lanes, transit priority, parking restrictions)<br>▪ Congestion pricing for urban areas during peak periods (to encourage off-peak deliveries)<br>▪ Commercial vehicle (e.g., trucks and buses) idling restrictions in designated areas<br>Due to the likely regional nature of environmental effects, many TSMO approaches require multijurisdictional, multiagency, and multidisciplinary capabilities to communicate, coordinate, and collaborate to gather information and implement TSMO strategies. |

# **Resiliency:** RE1. System Vulnerability

## General Description

FHWA describes resilience as "the ability to anticipate, prepare for, and adapt to conditions or withstand, respond to, or recover rapidly from disruptions."[87] This set of objectives focuses on reducing the vulnerability of the transportation system to major disruptions resulting from extreme weather events as well as human-caused events (crashes, hazmat releases, terrorist attacks, access denial). Several FHWA publications related to system resilience provide more-specific information on resilience and strategies for improving system resiliency.[88, 89]

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| **Operations Objectives** | ▪ Reduce the vulnerability of the transportation system to disruptive events by instituting the following objectives:<br>- Within the next Y years, identify roadways, transit services, and facilities that are exposed to disruption due to extreme weather events and unintentional or intentional human-caused events—including cyberattacks and labor shortages—or actions that are likely to result in fatalities and injuries, major infrastructure damage, and/or major long-term disruptions to mobility (e.g., loss of critical nodes such as bridges or tunnels and disruption to critical supply chains due to interruptions at major facilities such as seaports or rail intermodal facilities)<br>- Within the next Y years, implement measures to reduce the exposure of critical facilities to extreme events through operational and maintenance strategies that prevent incidents and/or mitigate the effects of extreme events<br>- Within the next Y years, develop an emergency response plan to be executed when a major disruptive event occurs |
| **Performance Measures** | ▪ Change over time (trends) in response time and recovery time following major disruptive events<br>▪ Time required to activate alternative routes and management strategies following natural or human-caused major disruptive event<br>▪ Additional travel time required by alternative routes for diverted traffic when preferred routes unavailable due to major disruptive events<br>▪ Additional VMT and associated delay due to diversions related to major disruptive events |
| **Anticipated Data Needs** | ▪ Roadway status data, including road weather information service (RWIS) data, flooding, bridge conditions, vehicle volumes |

87 FHWA. "Order 5520 Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events," December 15, 2014. https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm#par6, last accessed December 2, 2021.

88 FHWA. 2020. "FHWA Resilience Resources." Presented June 29, 2020. https://environment.transportation.org/wp-content/uploads/2021/04/fhwa_update_for_june_29.pdf, last accessed July 6, 2022.

89 FHWA. 2015. *Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance*, FHWA-HOP-15-026, FHWA, Washington, DC. https://ops.fhwa.dot.gov/publications/fhwahop15026/, last accessed December 2, 2021.

## **Resiliency:** RE1. System Vulnerability (continuation)

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| **Data Resources and Partners** | ▪ Travel time data for preferred and alternative routes during transient events may be difficult to collect. Data collection challenges may particularly occur during unscheduled or unpredicted events such as severe weather events or system failures due to intentional or unintentional human-caused events. Public safety and emergency response agencies will likely be needed to assist in identifying the locations, extent, and times of major disruptions. Road and track maintenance staff will be needed to identify upcoming work to restore level of service (LOS). Data on travel times during major disruptive events may need to be extracted after collection from ongoing travel time data based on the times and locations of events. The National Weather Service may also need to be involved in identifying times and locations of severe weather that may have impacted travel.<br>▪ Trends over time will come from analysis of data collected during and following major events, including the frequency and severity of events, the effects of the events on the existing infrastructure, and user mobility during and following the event. These data will assist in identification and documentation of changing vulnerabilities as a result of changing climate effects as well as vulnerabilities to human-caused disruptions. |
| **TSMO Strategies To Consider** | Typical TSMO strategies used to reduce system vulnerability to extreme events include the following:<br>▪ Motorist alerts, advisories, and warnings, including roadside active warning systems and pretrip traveler information systems<br>▪ Speed restrictions (e.g., variable speed limits)<br>▪ Vehicle restrictions (e.g., truck restrictions during high winds)<br>▪ Route restrictions (e.g., road closures), including closures and restrictions in response to security or intelligence information<br>▪ Anti-icing or deicing road surface treatments<br>▪ Plowing<br>▪ Traffic signal management (e.g., weather-responsive traffic management)<br>Traffic incident management and emergency management practices can provide agencies with the ability to marshal resources to address adverse weather conditions effectively. Shared data regarding permitted vehicles (e.g., hazmat transport, oversize or overweight vehicles) can assist in monitoring travel that could result in infrastructure damage. Shared information can alert DOTs regarding potential threats to infrastructure and mobility. Due to the likely regional nature of major disruptive events, many TSMO approaches require multijurisdictional, multiagency, and multidisciplinary capabilities to communicate, coordinate, and collaborate before, during, and after the extreme events. Traffic incident management and emergency management collectively fall under the area of emergency transportation operations, which involves collaboration and coordination between transportation, public safety (i.e., fire, rescue, EMS, law enforcement), and emergency management communities.[90, 91, 92] Additionally, transportation demand management strategies can be used to reduce the volume of vehicles while maintaining essential movements of goods and people.[93] |

90 FHWA. 2015. *Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance*. Report No. FHWA-HOP-15-026. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop15026/, last accessed December 2, 2021.

91 FHWA. 2019. *Strengthening Linkages between Transportation Demand Management and Traffic Management.* Report No. FHWA-HOP-18-072. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop18072/form.htm, last accessed September 8, 2022.

91 FHWA. 2015. *Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance*. Report No. FHWA-HOP-15-026. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop15026/, last accessed December 2, 2021.

93 See FHWA publication "Strengthening Linkages between Transportation Demand Management and Traffic Management", *Context 1. Managing Demand and Traffic During Weather Events and Natural Disasters* for examples and case studies. https://ops.fhwa.dot.gov/publications/fhwahop18072/index.htm, last accessed December 2, 2021.

# **Resiliency:** RE2. Adaptation

## General Description

FHWA describes resilience as "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions."[94] This set of objectives focuses on adapting the transportation system to the increasing frequency and severity of major weather events that disrupt mobility and put travelers and others at risk.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the vulnerability of the transportation system to disruptive events resulting from climate change<br>- Within the next Y years, establish policies, procedures, and practices to monitor and manage changes in climate and the effects of these events on mobility, including disruptions and damage due to flooding (including storm surge), wildfires, hurricanes, tornadoes, mudslides, droughts, snowstorms, ice storms, and other weather-related events<br>- Within the next Y years, identify the roadway and public transit segments (including bridges and tunnels) that are most likely to be affected by climate change due to their vulnerability to major weather events (e.g., storm surge, mudslides, wildfires, strong winds) and develop appropriate mitigation measures to reduce their vulnerability and the risk to travelers due to these events (e.g., rerouting, traveler information, sensors, regional coordination)<br>- Within the next Y years, create a plan for adapting existing and planned facilities and operations to avoid or mitigate the effects of natural or human-caused extreme events |
| **Performance Measures** | ▪ Change over time (i.e., trends) in response time and recovery time following major disruptive events<br>▪ Additional travel time required by alternative routes for diverted traffic when preferred routes are not available due to major disruptive events<br>▪ Additional VMT and associated delay generated due to diversions related to major disruptive events |
| **Anticipated Data Needs** | ▪ Roadway status data, including RWIS, flooding, bridge conditions, and vehicle volumes |

94 FHWA. 2014. "Order 5520, Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events," December 15, 2014. https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm#par6, last accessed December 2, 2021.

## **Resiliency:** RE2. Adaptation (continuation)

| | |
|---|---|
| **Data Resources and Partners** | ▪ Travel time data for preferred and alternative routes during transient events may be difficult to collect—particularly during unscheduled or unpredicted events such as severe weather or system failures due to intentional or unintentional human-caused events<br>▪ Public safety and emergency response agencies are likely needed to assist in identifying the locations, extent, and times of major disruptions. Road and track maintenance staff will be needed to identify upcoming work to restore LOS<br>▪ Data on travel times during major disruptive events may need to be extracted after collection from ongoing travel time data based on the times and locations of events. The National Weather Service may also need to be involved in identifying times and locations of severe weather that may have impacted travel<br>▪ Sensor data from bridges, tunnels, roadways, and transit vehicles, as well as related infrastructure maintenance actions (including plowing/chemicals), may be needed that captures stresses from wind and surface conditions (e.g., ice, water, mud)<br>▪ Trends over time will come from analysis of data collected during and following major events, including the frequency and severity of events, the effects of the events on both the existing infrastructure, and user mobility during and following the events. These data will assist in identification and documentation of changing vulnerabilities as a result of changing climate effects as well as vulnerabilities to human-caused disruptions |
| **TSMO Strategies To Consider** | Typical TSMO strategies used to improve system resilience through adaptation to climate change include the following:<br>▪ Motorist alerts, advisories, and warnings, including roadside active-warning systems and pretrip traveler information systems<br>▪ Speed restrictions (e.g., variable speed limits)<br>▪ Vehicle restrictions (e.g., truck restrictions during high winds)<br>▪ Route restrictions (e.g., road closures)<br>▪ Anti-icing and deicing road surface treatments<br>▪ Plowing<br>▪ Traffic signal management (e.g., weather-responsive traffic management)<br>Traffic incident management and emergency management practices can provide agencies with the ability to marshal resources to address adverse weather conditions effectively. Due to the likely regional nature of major disruptive events, many TSMO approaches require multijurisdictional, multiagency, and multidisciplinary capabilities to communicate, coordinate, and collaborate before, during, and after the extreme events. Traffic incident management and emergency management collectively fall under the area of emergency transportation operations, which involves collaboration and coordination between transportation, public safety (e.g., fire, rescue, EMS), law enforcement, and emergency management communities.[95] |

95 FHWA. 2015. *Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance*. Report No. FHWA-HOP-15-026. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop15026/, last accessed December 2, 2021.

# **Resiliency:** R3. Recovery Time

## General Description

FHWA describes resilience as "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions."[96] This set of objectives focuses on reducing the time required to recover and restore the system to its nominal LOS following an extreme event due to natural or human-caused events. Several FHWA publications related to system resilience provide more-specific guidance on resilience and strategies for improving system resiliency.[97, 98]

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the time required for affected transportation systems to recover following major disruptive events<br>- (Option 1) Within the next Y years, reduce by X percent the time to restore nominal operations following a major natural or human-caused disruptive event (e.g., through prepositioned response and recovery assets; well-planned, coordinated, resourced, and validated response and recovery protocols; improvements in roadway maintenance practices; measures to prevent flooding and/or drain flooded roadways) |
| **Performance Measures** | ▪ Response time to emergency events that result in major disruption to regional mobility<br>▪ Time to restore LOS to the regional transportation following a major disruptive event<br>▪ Change over time (i.e., trends) in response time and recovery time following major disruptive events<br>▪ Time to reestablish nominal revenue flows from tolls, priced roadways, transit fares, parking fees, and other transportation-related user fees (e.g., at air terminals, seaports) |
| **Anticipated Data Needs** | ▪ Roadway status data, including RWIS, flooding, bridge conditions, and vehicle volumes |
| **Data Resources and Partners** | ▪ Travel time data for preferred and alternative routes during transient events may be difficult to collect—particularly during unscheduled or unpredicted events such as severe weather or system failures due to intentional or unintentional human-caused events. Public safety and emergency response agencies are likely needed to assist in identifying the locations, extent, and times of major disruptions. Road and track maintenance staff will be needed to identify upcoming work to restore LOS. Data on travel times during major disruptive events may need to be extracted after collection from ongoing travel time data based on the times and locations of events. The National Weather Service may also need to be involved in identifying times and locations of severe weather that may have impacted travel.<br>▪ Trends over time will come from analysis of data collected during and following major events, including the frequency and severity of events, the effects of the events on the existing infrastructure, and user mobility during and following the event. These data will assist in identifying and documenting changing vulnerabilities and response and recovery times as a result of changing climate effects as well as vulnerabilities to human-caused disruptions. |

96 FHWA. 2014. "Order 5520, Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events," December 15, 2014. https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm#par6, last accessed December 2, 2021.

97 Tina Hodges. 2020. "FHWA Resilience Resources." Presented June 29, 2020. https://environment.transportation.org/wp-content/uploads/2021/04/fhwa_update_for_june_29.pdf, last accessed July 6, 2022.

98 FHWA. 2015. Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance. Report No. FHWA-HOP-15-026. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop15026/, last accessed December 2, 2021.

## **Resiliency:** RE3. Recovery Time (continuation)

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|---|---|
| **TSMO Strategies To Consider** | Typical TSMO strategies used to address system resilience include the following:<br>▪ Motorist alerts, advisories, and warnings, including roadside active-warning systems and pretrip traveler information systems<br>▪ Prepositioned recovery assets for anticipated events (e.g., tow and recovery, winter maintenance assets, temporary CMS, work zone management)<br>▪ Speed restrictions (e.g., variable speed limits)<br>▪ Vehicle restrictions (e.g., truck restrictions during high winds)<br>▪ Route restrictions (e.g., road closures)<br>▪ Anti-icing and deicing road surface treatments<br>▪ Plowing<br>▪ Traffic signal management (e.g., weather-responsive traffic management)<br>Traffic incident management and emergency management practices can provide agencies with the ability to marshal resources to address adverse weather conditions effectively. Due to the likely regional nature of major disruptive events, many TSMO approaches require multijurisdictional, multiagency, and multidisciplinary capabilities to communicate, coordinate, and collaborate before, during, and after the extreme events. Traffic incident management and emergency management collectively fall under the area of emergency transportation operations, which involves collaboration and coordination between transportation, public safety (e.g., fire, rescue, EMS), law enforcement, and emergency management communities.[99] |

99 FHWA. 2015. Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance, Report No. FHWA-HOP-15-026. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop15026/, last accessed December 2, 2021.

# **Safety:** SA1. Fatalities and Serious Injuries

## General Description

Objectives in this section focus on improving safety by reducing fatalities and serious injuries on roadways (for all users of the roadway), including secondary crashes.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce number of fatalities in a State or other jurisdiction by X percent by year Y<br>▪ Reduce rate of fatalities per 100 million VMT by X percent by year Y<br>▪ Reduce fatalities at crash hotspots by X percent by year Y<br>▪ Reduce number of serious injuries in a State or other jurisdiction by X percent by year Y<br>▪ Reduce rate of serious injuries per 100 million VMT by X percent by year Y |
| **Performance Measures** | ▪ Number of fatalities<br>▪ Rate of fatalities per 100 million VMT<br>▪ Number of serious injuries<br>▪ Rate of serious injuries per 100 million VMT |
| **Anticipated Data Needs** | ▪ Crash data<br>▪ VMT |
| **Data Resources and Partners** | ▪ State highway safety offices<br>▪ Metropolitan planning organizations<br>▪ State DOT safety and planning staff<br>▪ FHWA Division Offices and FHWA Office of Safety<br>▪ FHWA Safety Performance Management website, https://safety.fhwa.dot.gov/hsip/spm/<br>▪ National Highway Traffic Safety Administration (NHTSA) regional office contact<br>▪ NHTSA website, https://www.nhtsa.gov/road-safety |
| **TSMO Strategies To Consider** | ▪ Traffic incident management program, motorist-assist program<br>▪ Multimodal safety features and improvements<br>▪ Work zone management strategies<br>▪ Road-weather-management strategies<br>▪ Variable speed limits<br>▪ Traffic signal timing improvements<br>▪ Barriers and rumble strips<br>▪ Access management strategies<br>▪ Transportation management centers<br>▪ Geometric improvements that enhance both operations and safety (e.g., roundabouts, reduced left-turn-conflict intersections, road diets, turn lanes, auxiliary lanes) |

# **Safety:** SA2. Nonmotorized Fatalities and Serious Injuries

## General Description

Objectives in this section focus on improving safety by reducing nonmotorized (e.g., pedestrians, bicyclists, scooter riders) fatalities and serious injuries on roadways, including secondary crashes.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce number of nonmotorized fatalities and serious injuries in a State or other jurisdiction by X percent by year Y<br>▪ Reduce number of nonmotorized fatalities and serious injuries on roadway X by Y percent by year Z<br>▪ Reduce number of fatalities at nonmotorized crash hotspots by X percent by year Y |
| **Performance Measures** | ▪ Number of nonmotorized fatalities and serious injuries |
| **Anticipated Data Needs** | ▪ Crash data<br>▪ Inventory of bicycle and pedestrian facilities<br>▪ Number of bicyclists<br>▪ Number of pedestrians |
| **Data Resources and Partners** | ▪ State highway safety offices<br>▪ Metropolitan planning organizations<br>▪ State DOT safety and planning staff<br>▪ FHWA division offices and FHWA Office of Safety<br>▪ FHWA Pedestrian and Bicycle Safety, Tools to Diagnose and Solve the Problem website, https://safety.fhwa.dot.gov/ped_bike/tools_solve/<br>▪ FHWA Safety Performance Management website, https://safety.fhwa.dot.gov/hsip/spm/<br>▪ NHTSA regional office contact<br>▪ NHTSA website, https://www.nhtsa.gov/road-safety<br>▪ Local bicycle and pedestrian advocacy groups |
| **TSMO Strategies To Consider** | ▪ Multimodal safety features and improvements (e.g., dedicated space, sidewalks, bicycle lanes, high-visibility and/or raised crosswalks, rectangular rapid-flashing beacons, pedestrian hybrid beacons, refuge islands)<br>▪ Work zone management strategies<br>▪ Traffic signal timing improvements (e.g., leading pedestrian intervals)<br>▪ Access management strategies<br>▪ Traffic-calming strategies or road diets |

# **Safety:** SA3. Speed Management

## General Description

Objectives in this section focus on improving safety issues related to speed.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce number of speed-related crashes in a State or jurisdiction by X percent by year Y<br>▪ Reduce number of speed-related crashes on roadway X by Y percent by year Z<br>▪ Reduce top-end speeders (greater than 10 mph over speed limit) on roadway X by Y percent by year Z |
| **Performance Measures** | ▪ Number of speed-related crashes<br>▪ Percentage of top-end speeders (greater than 10 mph over speed limit) |
| **Anticipated Data Needs** | ▪ Crash data<br>▪ Speed data (from ITS or other devices, third-party vendors)<br>▪ Speed citation data |
| **Data Resources and Partners** | ▪ State highway safety offices<br>▪ Metropolitan planning organizations<br>▪ State DOT safety and planning staff<br>▪ FHWA division offices and FHWA Office of Safety<br>▪ NHTSA regional office contact<br>▪ NHTSA website, https://www.nhtsa.gov/road-safety<br>▪ Third-party vendors |
| **TSMO Strategies To Consider** | ▪ Multimodal safety features and improvements<br>▪ Work zone management strategies<br>▪ Road-weather-management strategies<br>▪ Variable speed limits<br>▪ ITS devices (e.g., dynamic signage, speed feedback signs)<br>▪ Traffic signal timing improvements<br>▪ Automated speed enforcement (if the jurisdiction allows)<br>▪ Transportation management centers<br>▪ Road diets, turn lanes, and auxiliary lanes |

# **Safety:** SA4. Intersection Crashes

## General Description

Objectives in this section focus on improving safety at intersections.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce number of intersection crashes in a State or jurisdiction by X percent by year Y<br>▪ Reduce number of intersection crashes on roadway X by Y percent by year Z |
| **Performance Measures** | ▪ Number of intersection crashes<br>▪ Number of intersection crashes by intersection type<br>▪ Number of intersection crashes that involve vulnerable users<br>▪ Number of intersections with reduced conflict points (e.g., roundabouts, reduced left-turn-conflict intersections) |
| **Anticipated Data Needs** | ▪ Crash data<br>▪ Intersection type and location<br>▪ Speed data (from ITS or other devices, third-party vendors)<br>▪ Inventory of bicycle and pedestrian facilities<br>▪ Number of bicyclists<br>▪ Number of pedestrians |
| **Data Resources and Partners** | ▪ State highway safety offices<br>▪ Metropolitan planning organizations<br>▪ State DOT safety and planning staff<br>▪ FHWA division offices and FHWA Office of Safety<br>▪ NHTSA regional office contact<br>▪ NHTSA website, https://www.nhtsa.gov/road-safety<br>▪ Third-party vendors |
| **TSMO Strategies To Consider** | ▪ Multimodal safety features and improvements<br>▪ Road-weather-management strategies<br>▪ Traffic signal timing improvements<br>▪ Adaptive signal technology<br>▪ Access management<br>▪ Transportation management centers<br>▪ Turn lanes and auxiliary lanes<br>▪ Roundabouts, turn pockets, and reduced left-turn-conflict intersections |

# **Arterial Management:** AM1. Delay

## General Description

These objectives seek to address delay experienced on arterials. Arterial roads serve primarily through traffic and provide access to abutting properties as a secondary function.

| | |
|---|---|
| **Operations Objectives** | ▪ Decrease the seconds of control delay[100] per vehicle on arterial roads by X percent in Y years<br>▪ Increase the miles of arterials in the region operating at LOS Z by X percent in Y years<br>▪ X percent of intersection or major and minor arterials implementing advanced traffic signal performance measures by year Y<br>▪ Ensure the equitable distribution of green time in uncongested conditions by monitoring split and cycle failures to be less than X percent over Y years<br>▪ Promote smooth flow in coordinated networks by monitoring arrivals on green, stops, and travel time to be less than X target value Y over Z years<br>▪ In congested conditions, monitor and reduce the extent of queues in the network by monitoring green time use on X corridors over Y years |
| **Performance Measures** | ▪ Seconds of control delay per vehicle<br>▪ Percentage of arterial miles in region operating at LOS Z<br>▪ Number intersections or corridors implementing advanced traffic signal performance measures<br>▪ Green time<br>▪ Arrivals during particular signal phases<br>▪ Queue length |
| **Anticipated Data Needs** | ▪ Travel times on arterials near traffic signals<br>▪ Speed, volume and capacity, or other measures of LOS |
| **Data Resources and Partners** | ▪ Partner agencies that operate and maintain arterials in the region<br>▪ Arterial travel time information gathered via Bluetooth, cell phones, toll tags, license plates, probe data, or automated traffic signal performance measures |
| **TSMO Strategies To Consider** | TSMO strategies are typically those designed to address traffic management on arterial roads and include a blend of outreach, guidance, training, and research to advance four major types of strategies: traffic signal improvements, advanced traffic signal control, traffic monitoring, and access management. |

100 Control delay is defined as the portion of total delay attributed to traffic signal operation for signalized intersections.

# **Arterial Management:** AM2. Access Management

## General Description

These objectives seek to address access management issues experienced on arterials to improve the flow of traffic and reduce crashes and congestion.

| | |
|---|---|
| **Operations Objectives** | ▪ Maintain a distance of X feet between intersections on major arterials in the region for the next Y years<br>▪ Reduce driveway access by X percent on major arterials for all new developments for the next Y years |
| **Performance Measures** | ▪ Distance between intersections on major arterials in the region<br>▪ Percentage of driveway access on major arterials for new developments |
| **Anticipated Data Needs** | ▪ Distance between intersections<br>▪ Driveway access for new developments on major arterials |
| **Data Resources and Partners** | ▪ Partner agencies that approve new developments and operate and maintain arterials in the region<br>▪ Arterial travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data |
| **TSMO Strategies To Consider** | TSMO strategies designed to address access management on arterials can be outlined in an access management plan and include access spacing, driveway spacing, dedicated left- and right-turn lanes, roundabouts, two-way left-turn lanes, and nontraversable raised medians. |

# **Arterial Management:** AM3. Reliability

## General Description

These objectives aim to reduce the variability in travel time on arterials so that users experience more-consistent and predictable trip times.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce buffer index on arterials during peak and off-peak periods by X percent in Y years<br>▪ Reduce delay associated with incidents on arterials by X percent by year Y<br>▪ Monitor the uptime of signalized intersection equipment and execute preventative maintenance programs to reduce the percentage of signal failures by X percent over Y years<br>▪ Note: See QR sheets, "Travel Time Reliability: TTR2. Travel Time Buffer Index" and "Travel Time Reliability: TTR4. Planning Time Index" for additional information on buffer index, planning index, and other measures |
| **Performance Measures** | ▪ The buffer index (i.e., the extra time, or buffer, travelers add to their average travel times when planning trips in order to arrive on time 95 percent of the time)<br>▪ Hours of delay associated with incidents<br>▪ Signal equipment uptime |
| **Anticipated Data Needs** | ▪ Travel time (daily figures, to calculate 95th percentile travel time)<br>▪ Crash data<br>▪ Signal equipment availability |
| **Data Resources and Partners** | ▪ Providers of travel data on arterials, including State DOTs or transportation management centers<br>▪ Arterial travel time information gathered via Bluetooth, cell phones, toll tags, and license plates or probe data |
| **TSMO Strategies To Consider** | Strategies include traffic incident management, work zone management, special-events management, and traveler information. |

# **Arterial Management:** AM4. Traffic Monitoring and Data Collection

## General Description

These objectives focus on developing or improving traffic monitoring and data collection on arterials that is necessary for managing arterials through signalization or traveler information.

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|---|---|
| **Operations Objectives** | ▪ Conduct field data collection through either floating-car studies or other methods at least once every Y years on major signalized arterials and every X years on minor signalized arterials<br>▪ Increase to X percent the share of intersections in the region equipped and operating with traffic signals that enable real-time monitoring and management of traffic flows by year Y<br>▪ Increase to X percent the share of major and minor arterials equipped with and operating with automated traffic signal performance measures (ATSPMs) (or appropriate technology) by year Y<br>▪ Increase to X percent the share of major and minor arterials equipped with and operating with closed-circuit television (CCTV) cameras per Z distance by year Y<br>▪ Increase the number of traffic signals that are centrally managed and monitored from X percent to 100 percent over Y years |
| **Performance Measures** | ▪ Number of field-data-collection studies performed every Y and X years on major and minor signalized arterials, respectively<br>▪ Percentage of intersections in the region equipped and operating with traffic signals that enable real-time monitoring and management of traffic flows<br>▪ Percentage of major and minor arterials equipped and operating with traffic detection stations on arterial links (or appropriate technology) per Z distance<br>▪ Percentage of major and minor arterials equipped and operating with CCTV cameras per Z distance and number of intersections or corridors implementing advanced traffic signal performance measures<br>▪ Percentage of traffic signals centrally managed |
| **Anticipated Data Needs** | ▪ Number of field studies performed on signalized arterials<br>▪ Traffic signal capabilities inventory<br>▪ Inventory of arterial traffic detection stations<br>▪ CCTV camera inventory |
| **Data Resources and Partners** | ▪ Partner agencies that operate traffic signals in the region |
| **TSMO Strategies To Consider** | ▪ Install traffic-monitoring cameras<br>▪ Install advanced traffic signal systems<br>▪ Install midblock detection |

# **Arterial Management:** AM5. Traffic Signal Management

## General Description

These objectives improve the management of traffic signal systems through advanced technology, increased reviews, and planning.

| | |
|---|---|
| **Operations Objectives**[101] | ▪ Maintain a program for evaluating X percent of signals for retiming every Y years<br>▪ Increase the number of intersections running in a coordinated, closed-loop, adaptive system or equipped to collect ATSPMs by X percent in Y years<br>▪ Implement and update central traffic signal management, monitoring, and advanced operations systems every Y years<br>▪ Actively monitor the performance of traffic signals over time by collecting and evaluating ATSPMs, extending coverage from X percent to 100 percent of the system over Y years<br>▪ Special timing plans available for use during freeway incidents, roadway construction activities, or other special events for X miles of arterials in the region by year Y<br>▪ Crash data for all arterials in the region reviewed every X years to determine if signal adjustments can be made to address a safety issue |
| **Performance Measures** | ▪ Number of traffic signals evaluated for retiming<br>▪ Number of traffic signals equipped to collect ATSPMs<br>▪ Number of intersections running in a coordinated or adaptive system, where appropriate<br>▪ Number of miles of arterials that have at least one special timing plan for incidents, construction, or events<br>▪ Number of years between reviews of crash data on all arterials for possible signal timing impacts |
| **Anticipated Data Needs** | ▪ Reports from operating agencies on signal retiming, signal capabilities, special timing plans, and crash data reviews |
| **Data Resources and Partners** | ▪ Partner agencies that operate arterials in the region and police departments that maintain traffic crash records |
| **TSMO Strategies To Consider** | ▪ Install advanced traffic signal systems<br>▪ Adopt special signal timing patterns for use during incidents and special events |

101 Some operations objectives have been derived from the *2007 National Traffic Signal Report Card – Technical Report by the National Transportation Operations Coalition*, available at https://transportationops.org/publications/national-traffic-signal-report-card-technical-report-2007.

# **Arterial Management:** AM6. Complete Streets

## General Description

*Complete streets* refers to planning, designing, developing, constructing, and operating streets in a manner that "is safe, and feels safe, for all users."[102] A complete street is tailored to the needs of and context within the community and the users it serves. Complete streets provide safe mobility, connectivity for multiple mobility modes, and equitable mitigation of negative or harmful aspects of transportation (e.g., air pollution, traffic fatalities). The focus of these objectives is on ensuring that the mobility network addresses the full range of user needs—especially those of historically underserved populations.

| | |
|---|---|
| **Operations Objectives** | ▪ Ensure that X percent of neighborhoods and commercial districts (as defined locally) are connected through a multimodal (e.g., bicycle paths, walkways, roadways, public transit) network that enables travelers to travel safely and efficiently between origins and destinations within the region of interest<br>▪ Ensure at least X percent of historically underserved communities are connected through accessible, affordable, efficient, safe, secure, and environmentally friendly multimodal mobility options |
| **Performance Measures** | ▪ Percentage of frequently traveled origins and destinations within the region that are connected in ways that enable safe, secure, and reliable access by the use of multiple modes<br>▪ Percentage of historically underserved communities that are connected to frequently visited destinations in ways that enable safe, secure, and reliable access by the use of multiple modes<br>▪ Percentage of historically underserved communities that are exposed to noise and air pollution at levels that exceed levels found in other areas within the region |
| **Anticipated Data Needs** | ▪ Air quality and noise data throughout the region, including historically underserved communities<br>▪ Travel time by mode along frequently traveled routes by mode, hour of day, and day of week<br>▪ Demographic data for the region, including demographic data for historically underserved communities<br>▪ Safety data, including mobility-related injuries and fatalities of bicyclists (traditional and e-bicyclists) and pedestrians |
| **Data Resources and Partners** | ▪ State and local DOTs, local planning agencies, neighborhood associations, bicycle and pedestrian advocacy groups, local businesses, transit operators, environmental specialists |
| **TSMO Strategies To Consider** | ▪ Smartphone apps for micromobility resources (e-bikes, e-scooters) and related information sources<br>▪ Pedestrian walkways and overpasses for major arterials<br>▪ Restricted lanes for bicycles and, as appropriate, bicycle traffic signals when bicycles are in mixed traffic<br>▪ Restrictions on commercial vehicles and related accommodations to facilitate access to delivery and pickup locations<br>▪ Outreach to neighborhood associations to identify needs and opportunities to improve mobility within the context of users' needs (residential and commercial) |

102 FHWA. n.d. "Complete Streets in FHWA" (web page). https://highways.dot.gov/complete-streets/complete-streets-fhwa, last accessed July 6, 2022.

# **Emergency Management:** EM1. Evacuation Times

## General Description

This objective provides a focus on the safety and efficiency of emergency evacuation via surface transportation along designated emergency routes. The objective emphasizes per-capita time to evacuate and allows for evaluation of large and small events involving large and small geographic areas and/or numbers of people.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the modeled per-capita time to evacuate Z persons in the region by X percent over Y years |
| **Performance Measures** | ▪ Modeled per-capita time to evacuate |
| **Anticipated Data Needs** | ▪ Time to evacuate region (or subarea) |
| **Data Resources and Partners** | ▪ Data would likely need to be collected by emergency command staff and involve communication and coordination with field staff from all agencies involved with the evacuation.<br>▪ Resources would likely include emergency responders, police, fire, public safety, the Federal Emergency Management Agency, local and State DOTs, and public officials. |
| **TSMO Strategies To Consider** | Improvement of evacuation times can be achieved by implementing strategies addressing any part of the objectives in the Emergency Management: Traveler Information section. TSMO strategies for improving evacuation time in an emergency include interagency coordination and communication, responder training, and traffic engineering (e.g., contraflow lanes). |

# **Emergency Management:** EM2. Emergency Alert

## General Description

This section contains objectives that focus on providing travelers with accurate, timely, and actionable information about emergency situations.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce time between emergency verification and posting an alert to traveler information outlets (e.g., CMS, agency website, 511 system, radio, television) by X minutes in Y years<br>▪ Reduce the modeled per-capita time to evacuate Z persons in the region by X percent over Y years |
| **Performance Measures** | ▪ Time to alert motorists of an emergency<br>▪ Per capita time to evacuate |
| **Anticipated Data Needs** | ▪ The time of emergency identification and changeable-message-sign (CMS) posting, entry, traveler information website log of the number of visitors, and the time of transportation system recovery and travel alert removal<br>▪ Time to evacuate region or subarea |
| **Data Resources and Partners** | ▪ Data on the time of incident recovery could be collected by TMC operators with video of incident scene or through continuous collection of traffic speeds. Partners would need to include agencies that manage traveler information websites, CMSs, and emergency operations centers. Public safety partners may be needed for information on incident verification time.<br>▪ Data would likely need to be collected by emergency command staff and involve communication and coordination with field staff from all agencies involved with the evacuation.<br>▪ Resources would likely include emergency responders, police, fire, public safety, the U.S. Transportation Security Administration, local and State DOTs, and public officials. |
| **TSMO Strategies To Consider** | TSMO strategies to consider include training on disseminating traveler information on emergencies as well as deploying and managing CMSs and websites. |

# **Emergency Management:** EM3. Interagency Coordination

## General Description

This section contains objectives that focus on increasing coordination and communication between agencies with responsibilities for emergency traffic management.

| | |
|---|---|
| **Operations Objectives** | ▪ Hold at least X multiagency emergency planning meetings each year, with attendance by at least Y percent of the agencies involved in emergency response<br>▪ At least X percent of transportation operating agencies that have plans in place for a representative to be at the local or State emergency operations center (EOC) to coordinate strategic activities and response planning for transportation during emergencies by year Y |
| **Performance Measures** | ▪ Percentage of incident management agencies in the region participating in a multimodal information exchange network<br>▪ Number of agencies in the region with interoperable voice communications<br>▪ Number of participating agencies in a region with a coordinated incident response team<br>▪ Number of TIM corridors in the region covered by regional coordinated incident response teams<br>▪ Number of multiagency after-action reviews per year<br>▪ Percentage of responding agencies participating in after-action review<br>▪ Percentage of transportation operating agencies that have plans in place for a representative to be at the local (city or county) EOC or State EOC to coordinate strategic activities and response planning for transportation during emergencies |
| **Anticipated Data Needs** | ▪ Data needed for these measures include the number of agencies participating in a regional incident management program or activity, the number of corridors covered by a regional incident management team, and the number of after-action reviews conducted. Also needed is the number of transportation operating agencies in the region and the number that have plans in place for a representative to be at an EOC. |
| **Data Resources and Partners** | ▪ The data can be collected by observation of emergency or incident management programs or by asking TIM and other emergency management agencies to self-report |
| **TSMO Strategies To Consider** | The TSMO strategies to consider are inherent in these objectives. |

# **Emerging Mobility Services:** MS1. Mobility on Demand

## General Description

Mobility on demand (MOD) is an integrated, user-focused approach that prioritizes providing multimodal transportation options that are safe, reliable, and available to all users. New public and private transportation options are frequently emerging due to the advancements of technology and location-based services. Private-sector smartphone applications allow users to seamlessly plan, reserve, and purchase multimodal services at their convenience. MOD offers consumers the ability to make informed travel decisions about different transportation modes based on travel time, cost, and route optimization.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce single-occupant vehicle trips by X percent in Y years<br>▪ Increase by X percent the number of residents within one-half mile of one or more modes of transportation<br>▪ Improve connectivity between modes and services, having a connection available within X amount of time and within Y distance<br>▪ Improve transit ridership by X percent in Y years<br>▪ Increase the number of origin–destination pairs served by multimodal solutions<br>▪ Increase the number of trips with micromobility options by X percent in year Y<br>▪ Increase the number of trips by rideshare by X percent in year Y |
| **Performance Measures** | ▪ Percentage of trips that are not single-occupancy trips<br>▪ Percentage of transportation mode facilities available to residents within a one-half-mile radius<br>▪ Overall trip travel time across modes and services<br>▪ Percentage of transit ridership<br>▪ Number of origin–destination pairs with travel that can be completed by multimodal services<br>▪ Number of trips with micromobility options<br>▪ Number of trips completed by rideshare |
| **Anticipated Data Needs** | ▪ Data sharing among mobility service providers<br>▪ Travel time data<br>▪ Travel surveys |
| **Data Resources and Partners** | ▪ State department of transportation<br>▪ Regional agencies<br>  - Metropolitan planning organizations<br>  - Tolling authorities<br>▪ Public transit agencies<br>▪ Transportation network companies<br>▪ Public–private partnerships |
| **TSMO Strategies To Consider** | TSMO strategies to improve shared and active transportation use include developing mobility hubs for transportation services, increasing infrastructure for transit and car-sharing services like park-and-ride facilities, and providing micromobility options along with supporting infrastructure like bike lanes and signal timing for pedestrians and micromobility users. Strategies to enhance traveler information systems for MOD include providing real-time travel information to inform users of delays and average speeds to assist in selecting transportation modes. |

# **Emerging Mobility Services:** MS2. First-/Last-Mile Travel

## General Description

The *first-and-last-mile connection* refers to the beginning or end of an individual trip made primarily by public transportation. First-and-last mile is an important concept that focuses on improving access to and from transit for a broader range of people, creating a better catchment for transit ridership. This strategy includes providing more accessibility to transit for various transportation modes and introducing new travel options like mobility hubs and micromobility options to access transit facilities.

| | |
|---|---|
| **Operations Objectives** | ▪ Reuse existing infrastructure for transit access through X number of improvement projects<br>▪ Reduce VMT by X number by Y year and improve accessibility to jobs and households<br>▪ Expand transit services to X number of people every year<br>▪ Increase number of trips using bicycles to access transit stations by X percent |
| **Performance Measures** | ▪ Percentage of jobs and households within one-half mile of first-mile and last-mile solutions<br>▪ Number of single-rider trips<br>▪ Number of transit riders<br>▪ Decrease in congestion<br>▪ Number of bicycle trips leaving from a transit station |
| **Anticipated Data Needs** | ▪ Origin–destination data<br>▪ Area-based census data<br>▪ Transportation network data<br>▪ Existing transit routes and stations<br>▪ Bike lane and sidewalk inventories<br>▪ Bike and pedestrian data |
| **Data Resources and Partners** | ▪ State department of transportation<br>▪ Regional agencies<br>  - Metropolitan planning organizations<br>  - Tolling authorities<br>▪ Local agencies<br>  - Municipalities<br>  - Nongovernmental organizations<br>▪ Public transit agencies<br>▪ Transportation network companies |
| **TSMO Strategies To Consider** | ▪ Improving existing infrastructure, such as curbside management, sidewalk quality and connectivity, adequate pavement markings for crosswalks, pedestrian signals at large intersections, and adequate lighting on roadways and sidewalks for travelers<br>▪ Establishing transportation-network-company partnerships to provide first- and last-mile services<br>▪ Parking for micromobility options and bicycles |

# **Emerging Mobility Services:** MS3. Integrated Fare Payment

## General Description

Integrated fare payment, also known as mobility payment integration or multimodal payment convergence, is the use of the same payment medium or technology to pay for the services of multiple modes of transportation to provide a more seamless and convenient experience for users. Integrated fare payment incorporates a combination of common or shared payment media across the participating agencies and modes, creates common or linked payment accounts for customers, and uses comarketing, incentives for use, or both.

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| **Operations Objectives** | ▪ Provide one fare payment system that is operational between X modes and Y users each year<br>▪ Ensure accessibility for X users—regardless of income level and access to technology—each year by offering different payment options<br>▪ Provide X percent greater accuracy in fare payment accounting and consistent collection of revenue by year Y<br>▪ Increase transit ridership by X percent each year<br>▪ Allow for convenient sharing of user or ridership data between X modes and agencies while maintaining information security each year |
| **Performance Measures** | ▪ Number of total riders<br>▪ Percentage of total ridership compared with maximum capacity<br>▪ Evaluation of fare revenue<br>▪ Percentage of customers who return to the service |
| **Anticipated Data Needs** | ▪ Passenger count data<br>▪ Fare box data<br>▪ Modes used and usage (i.e., time, distance, number of stops)<br>▪ Payment data |
| **Data Resources and Partners** | ▪ Regional transportation planning organizations<br>▪ Public transit agencies<br>▪ Trip-generation-data providers<br>▪ Transportation network companies: bike share, scooter share, car share, ride-hailing<br>▪ Secure transactions (financial/bank account/credit card/debit card data)<br>▪ Digital wallet services |
| **TSMO Strategies To Consider** | Strategies like implementing mobile ticketing, incorporating payment apps, and deploying smart cards or establishing contactless payment systems or both will assist with streamlining deployment of an integrated fare payment system. |

# **Freeway Management:** FWM1. Efficiency

## General Description

These objectives seek to improve the overall efficiency of the freeway system and to address such issues as delay experience on freeways and the extent, duration, and intensity of congestion.

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| **Operations Objectives** | ▪ Reduce the number of person-hours (or vehicle-hours) of delay experienced by travelers on the freeway system<br>▪ Reduce the share of freeway miles at LOS X by Y percent by year Z [see QR Sheets, "Efficiency: EF1. Extent of Congestion and "Efficiency: EF2. Duration of Congestion" for other objectives that apply to freeways]<br>▪ Reduce the number of recurring bottlenecks by X percent in Y years<br>▪ Reduce the number of nonrecurring bottlenecks by X percent in Y years [see QR Sheet, "Efficiency: EF5. Delay." for other efficiency objectives that apply to freeways] |
| **Performance Measures** | ▪ Hours of delay (vehicle-hours or person-hours)<br>▪ Hours of delay per capita or per driver<br>▪ Average queue length<br>▪ Travel time data<br>▪ Miles at LOS or V/C ratio > 1.0 (or other threshold) |
| **Anticipated Data Needs** | ▪ Peak and off-peak periods and free flow travel times or speeds<br>▪ Person travel along links (e.g., vehicle volume multiplied by vehicle occupancy) |
| **Data Resources and Partners** | ▪ Providers of travel data on freeways, including State DOTs or transportation management centers |
| **TSMO Strategies To Consider** | Strategies include managed lanes, ramp management, part-time shoulder use, active traffic management, managed lanes, traveler information, and other strategies to improve freeway throughput and manage demand and traffic flow. |

# **Freeway Management:** FWM2. Reliability

## General Description

These objectives aim to reduce the variability in travel time on the freeway system so that users experience more consistent and predictable trip times.

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| **Operations Objectives** | ▪ Reduce buffer index on the freeway system during peak and off-peak periods by X percent in Y years<br>▪ Reduce delay associated with incidents on the freeway system by X percent by year Y (see QR sheets on "Travel Time Reliability: TTR2. Travel Time Buffer Index" and "Travel Time Reliability: TTR4. Planning Time Index" for additional information on buffer index, planning index, and other measures) |
| **Performance Measures** | ▪ The buffer index, representing the extra time, or buffer, that travelers add to their average travel times when planning trips in order to arrive on time 95 percent of the time<br>▪ Hours of delay associated with incidents<br>▪ Percentage of person-miles traveled on the relevant NHS areas that are reliable |
| **Anticipated Data Needs** | ▪ Travel time (daily figures, to calculate 95th percentile travel time)<br>▪ Crash data |
| **Data Resources and Partners** | ▪ Providers of travel data on freeways, including State DOTs or transportation management centers |
| **TSMO Strategies To Consider** | Strategies include managed lanes, traffic incident management, work zone management, special events management, and traveler information. |

# **Freeway Management:** FWM3. Integrated Corridor Management

## General Description

This objectives set focuses on balancing travel demand across corridor networks and providing multiagency management of events within a corridor.

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| **Operations Objectives** | ▪ Increase the number of corridor travelers receiving information on ICM strategies by X percent within Y years<br>▪ Increase customer satisfaction with ICM efforts by X percent over Y years<br>▪ Balance corridor trips so that each route and mode within the corridor operates at X percent capacity within Y years<br>▪ Improve average corridor travel time during peak periods by X percent by year Y<br>▪ Reduce the person-hours of total delay associated with nonrecurrent events by X percent over Y years<br>▪ Increase the percentage of agencies that participate in an ICM team by X percent in Y years<br>▪ Hold at least X multiagency, after-action review meetings following a corridor event each year, with attendance by at least Y percent of the agencies involved in the response<br>▪ Conduct X joint ICM training exercises for the corridor by year Y |
| **Performance Measures** | ▪ Total number of corridor travelers and percentage receiving information on ICM strategies<br>▪ Percentage of customers satisfied with ICM practices<br>▪ Volume-to-capacity ratios for corridor routes and modes<br>▪ Average corridor travel time during peak periods (minutes)<br>▪ Person-hours of delay for the corridor<br>▪ Number of agencies participating on an ICM team<br>▪ Number of multiagency after-action reviews per year<br>▪ Percentage of responding agencies participating in after-action review<br>▪ Number of joint ICM training exercises conducted |
| **Anticipated Data Needs** | ▪ Survey or count of travelers exposed to ICM information<br>▪ Corridor peak-period and free-flow volumes (i.e., vehicles and occupancy), travel times, and speeds by route and mode<br>▪ Person travel time along corridor links (e.g., vehicle volume multiplied by vehicle occupancy) during free-flow conditions and congested conditions<br>▪ Trip length<br>▪ Mode share and total trips for corridor<br>▪ Number of agencies participating on an ICM team<br>▪ Number of after-action reviews held<br>▪ Number of joint ICM training exercises conducted |

103 Refer to the ICM QR sheet from the 2016 FHWA report *Planning for Transportation Systems Management and Operations Within Corridors: A Desk Reference* (FHWA-HOP-16-037), which is available at https://ops.fhwa.dot.gov/publications/fhwahop16037.

## **Freeway Management:** FWM3. Integrated Corridor Management (continuation)

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| **Data Resources and Partners** | Data may need to be gathered from transportation management centers, State DOTs, cities, counties, toll authorities, transit agencies, public safety agencies, the National Weather Service, and other ICM partners. |
| **TSMO Strategies to Consider** | A wide variety of TSMO strategies may be considered to support ICM objectives. Refer to the other reference sheets on TIM, active transportation and demand management (ATDM), road weather management, work zone management, freeway ramp management, traffic signal management, and traffic signal performance for a detailed list of potential TSMO strategies in those areas. Providing ahead-of-time, real-time, and predictive multimodal traveler information tailored to the corridor is key to supporting balanced network demand in addition to route and mode diversion to parallel facilities, short-term ATDM strategies, and longer term ATDM strategies (e.g., rideshare, employer programs, commuter incentives). Additional TSMO strategies to consider for improving multiagency coordination include information clearinghouses, common event-reporting systems, event preplanning efforts, system coordination between ramp meters and traffic signals, and responsibility sharing for traffic operations functions (e.g., shared control of traffic signal timing plans). |

# **Freeway Management:** FWM4. Managed Lanes

## General Description

The objectives in this category focus on increasing the availability of or improving the operation of managed lanes. Managed lanes are intended to keep traffic flowing through techniques such as time-of-day restrictions, vehicle-type restrictions (e.g., high-occupancy-vehicle (HOV) lanes, truck-only tollways), pricing (charging motorists for access, e.g., by means of high-occupancy-toll (HOT) lanes).

| | |
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| **Operations Objectives** | ▪ Provide options for reliable travel times for certain types of travel (e.g., transit, carpools, trucks) on at least X percent of the freeway network by year Y<br>▪ Ensure that all managed lanes (e.g., HOV lanes, HOT lanes) operate at no less than X mph during their hours of operation<br>▪ Ensure that all managed lanes (e.g., HOV lanes, HOT lanes) operate with a volume of at least X vehicles per hour<br>▪ Ensure that all managed lanes (e.g., HOV lanes, HOT lanes) carry a throughput of at least Y persons per hour |
| **Performance Measures** | ▪ Share of freeway network with managed lanes (by class of traveler)<br>▪ Average speeds in managed lanes<br>▪ Vehicle volumes in managed lanes<br>▪ Passenger volumes in managed lanes |
| **Anticipated Data Needs** | ▪ System information (e.g., miles of managed lanes)<br>▪ Speed and/or volume data from ITS systems, transponders, etc. |
| **Data Resources and Partners** | ▪ Providers of travel data, including State DOTs, transit agencies, cities, counties, private operators, third-party operators, or transportation management centers |
| **TSMO Strategies To Consider** | TSMO strategies designed to offer time savings to various classes of road users could include truck-only lanes, HOV lanes, and HOT lanes and could be established as contraflow, or reversible, lanes. |

# **Freeway Management:** FWM5. HOV Lanes

## General Description

The objectives in this category focus on increasing the availability of or improving the operation of HOV lanes. HOV lanes are intended to provide faster and more-reliable travel times for carpools, vanpools, and buses, thereby encouraging higher levels of ridesharing and transit use.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase the number of HOV lane miles from X to Y by year Z<br>▪ Provide options for reliable travel times for carpools and transit on at least X percent of the freeway network by year Y<br>▪ Ensure that all HOV lanes operate at no less than X mph during their hours of operation<br>▪ Ensure that all HOV lanes operate with a volume of at least X vehicles per hour<br>▪ Ensure that all HOV lanes carry a throughput of at least Y persons per hour<br>▪ Increase the average vehicle occupancy rate in HOV lanes to X by year Y<br>▪ Increase the compliance rate for HOV lanes to X percent by year Y |
| **Performance Measures** | ▪ Total number of HOV lane miles in a region<br>▪ Share of freeway network with HOV lanes<br>▪ Minimum and average speeds in HOV lanes<br>▪ Vehicle volume and persons per hour per lane<br>▪ Percentage of vehicles violating HOV restrictions |
| **Anticipated Data Needs** | ▪ System information (e.g., miles of managed lanes)<br>▪ Speed and/or volume data from ITS systems, transponders, speed studies, etc.<br>▪ Vehicle violation data from law enforcement |
| **Data Resources and Partners** | ▪ Providers of travel data, such as State DOTs, cities, counties, and transportation management centers<br>▪ Law enforcement, which may provide information on HOV violations recorded |
| **TSMO Strategies To Consider** | TSMO strategies to consider include identification of underperforming HOV lanes, consideration of peak-hour operation only, HOV bypass lanes at ramp meters, access to park-and-ride facilities that provide locations for individuals to transfer from single-occupant vehicles to high-occupancy modes of travel, and strategies that incentivize ridesharing. |

# **Freeway Management:** FWM6. Pricing and Tolling

## General Description

The objectives in this section focus on (1) use of pricing to manage demand, such as by charging a premium to users who want to drive during peak periods, and (2) use of tolling to raise revenues. Note that pricing often has conflicting objectives and performance measures compared with tolling.

| | |
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| **Operations Objectives** | ▪ Increase the percentage of users carrying electronic-toll-collection (ETC) transponders by X percent by year Y<br>▪ Increase coverage of video tolling or license plate recognition to X percent of all tolled facilities by year Y<br>▪ Increase the share of toll roadways and bridges that are using variable pricing (e.g., congestion pricing) to X percent by year Y<br>▪ Increase the share of freeways that are priced to X percent by year Y<br>▪ Provide one fare payment system operational between X transportation modes and Y users each year |
| **Performance Measures** | ▪ Percentage of drivers with electronic-toll-collection transponders<br>▪ Coverage of video electronic-toll-collection tolling and license plate recognition systems<br>▪ Share of toll roads and bridges using variable pricing<br>▪ Lane miles that are priced |
| **Anticipated Data Needs** | ▪ Total number of users (annually) with ETC transponders<br>▪ System information (e.g., miles of priced facilities) |
| **Data Resources and Partners** | ▪ Providers of travel data, such as State DOTs, cities, counties, and transportation management centers |
| **TSMO Strategies To Consider** | TSMO strategies to consider include dynamic and congestion pricing, ETC, and automated enforcement. |

# **Freeway Management:** FWM7. Ramp Management

## General Description

The objectives in this section focus on the application of control devices—such as traffic signals, signage, and gates—to regulate the number of vehicles entering or leaving the freeway in order to achieve operations objectives.

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| **Operations Objectives** | ▪ Increase the percentage of freeway interchanges operating at LOS Z or higher during peak periods by X percent by year Y<br>▪ Reduce the number of congestion-inducing incidents occurring at freeway ramps by X percent by year Y<br>▪ Increase the number of freeway ramps currently metered by X percent by year Y |
| **Performance Measures** | ▪ Percentage of interchanges operating at LOS Z or above during peak periods (per year)<br>▪ Total number of congestion-inducing incidents at freeway interchanges during peak periods (per year)<br>▪ Total number of ramp meters (by year of installation) |
| **Anticipated Data Needs** | ▪ Traffic volume and LOS data (e.g., traffic counts) at selected interchanges<br>▪ Total number of congestion-related incidents at selected interchanges<br>▪ Number of freeway ramp meters and year of installation |
| **Data Resources and Partners** | ▪ Providers of travel data, including traffic volumes and incidents, such as State DOTs, cities, counties, and transportation management centers |
| **TSMO Strategies To Consider** | Ramp management strategies typically encompass ramp metering, ramp closure, special-use treatments (e.g., HOV, special events), and ramp terminal treatments. |

# **Freeway Management:** FWM8. Transportation Management Centers

## General Description

The objectives in this section focus on monitoring the operation of the freeway system and initiating control strategies that effect changes in the operation of the network.

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| **Operations Objectives** | ▪ Increase the hours of TMC operation and level of staffing by X percent by year Y<br>▪ Increase the percentage of the transportation network mileage (including arterials, transit routes) monitored by the TMC for real-time performance<br>▪ Increase the percentage of modal agencies in the area contributing and receiving real-time operations information to and from the TMC |
| **Performance Measures** | ▪ Number of hours of TMC operation and number of staff working in and supporting the TMC<br>▪ Percentage of area's transportation network monitored by the TMC for real-time performance<br>▪ Percentage of modal agencies in the area contributing and receiving real-time operations information to and from the TMC |
| **Anticipated Data Needs** | ▪ TMC operational data (e.g., level of performance monitoring, number of events managed, level of services provided to aid motorists) |
| **Data Resources and Partners** | ▪ Transportation management center and multimodal transportation agency partners |
| **TSMO Strategies To Consider** | Strategies include managing the operation of the transportation system by communicating travel condition information, making necessary modifications to traffic and transit control systems, and directing response activities. |

# **Freight Management:** FRM1. Customer Satisfaction

## General Description

The intent of this objective is to improve freight shipper, receiver, and carrier satisfaction with freight mobility in the region.

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|---|---|
| **Operations Objectives** | ▪ Increase ratings for customer satisfaction with freight mobility in the region among shippers, receivers, and carriers by X percent in Y years |
| **Performance Measures** | ▪ Percentage of customers satisfied with region's freight management practices |
| **Anticipated Data Needs** | ▪ Customer satisfaction surveys tailored to specific target audiences (e.g., carriers, shippers, receivers) |
| **Data Resources and Partners** | ▪ Data would be gathered through surveys among users and providers of the region's freight-related transportation system. |
| **TSMO Strategies To Consider** | TSMO strategies to consider for improving customer satisfaction with freight management include infrastructure and technology improvements such as downhill weight and speed monitoring as well as advisories and context-sensitive traffic signal operations (e.g., delayed red light to allow heavy vehicles in close proximity to pass through). Additional strategies for managing efficiency, safety, and operations for commercial vehicles include referencing the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) service packages for commercial vehicle operations, such as Carrier Operations and Fleet Management, Road Weather Information for Freight Carriers, and the Intelligent Access Program. |

# **Freight Management:** FRM2. Travel Time Delay

## General Description

The objectives in this section focus on reducing travel time delay for regional freight transportation.

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| **Operations Objectives** | ▪ Increase the mobility index (defined below) by X percent in Y years<br>▪ Decrease the annual average travel time index for freight by X points in Y years<br>▪ Decrease point-to-point travel times on selected freight-significant highways by Y minutes within Y years<br>▪ Decrease hours of delay per 1,000 VMT on selected freight-significant highways by X percent in Y years |
| **Performance Measures** | ▪ Truck-hours of delay per mile. Delay is calculated for each 15-minute period as the difference between actual travel time and reference travel time. Delay for each 15-minute period is multiplied by 15-minute truck volumes. Truck volumes are estimated from annual average daily truck traffic by using typical time-of-day traffic volume profiles. Delay for each 15-minute time period is aggregated to get annual truck-hours of delay. The total number of truck-hours of delay is then divided by the segment length to get total truck-hours of delay per mile, allowing for the comparison of all roadway sections across the NHS.<br>▪ Mobility index for system users defined as ton miles of travel divided by vehicle-miles of travel multiplied by average speed[104]<br>▪ Travel time index: ratio of observed average travel time to free-flow travel time<br>▪ Point-to-point travel times on selected freight-significant highways<br>▪ Hours of delay per 1,000 vehicle miles on selected freight-significant highways |
| **Anticipated Data Needs** | ▪ Ton miles of travel for freight, vehicle miles of travel for freight, and average speed (can be derived from travel time, if necessary)<br>▪ Observed travel time and free-flow travel time<br>▪ Point-to-point travel time on selected freight-significant facilities<br>▪ Average travel time and traffic volumes on selected freight-significant facilities |
| **Data Resources and Partners** | ▪ Data would need to be collected by agencies responsible for operation of the roadways or freight operators responsible for operation of the vehicles (e.g., trucks and trains)<br>▪ State and local DOTs and freight carriers would likely be involved<br>▪ National and State trucking associations that collect data. For example, data from the American Transportation Research Institute of the American Trucking Associations, Owner-Operator Independent Drivers Association, and National Private Truck Council would likely be involved |
| **TSMO Strategies To Consider** | Regions can reduce travel time delay for freight by increasing traveler information across the region, weigh-in-motion weigh stations, travel-demand-management programs, and freight-only lanes. |

104 Harry Cohen, Alan Horowitz, and Ram Pendyala. 2008. NCHRP Report 606: *Forecasting Statewide Freight Toolkit*. Washington, DC: Transportation Research Board of the National Academies, National Cooperative Highway Research Program. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_606.pdf, last accessed February 25, 2010.

# **Freight Management:** FRM3. Travel Time Reliability

## General Description

Objectives in the area of travel time reliability for freight aim to reduce the variability in travel time so that users experience consistent and predictable trip times to ensure on-time delivery of goods on the surface transportation system.

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|---|---|
| **Operations Objectives** | ▪ Reduce buffer index on regional freight routes during peak and off-peak periods by X percent in Y years<br>▪ Achieve a truck travel time reliability index for the area's transportation system of X by Y year<br>▪ See Reliability for additional information on buffer index |
| **Performance Measures**[105] | Buffer index on regional freight routes during peak and off-peak period: The buffer index represents the extra time (buffer) freight travelers add to their average travel times when planning trips. This is the extra time between the average travel time and near-worst-case travel time (95th percentile). The planning time index represents the extra time between the free-flow travel time and the near-worst-case travel time (95th percentile). The buffer index is stated as a percentage of the average travel time. The buffer index is stated as a percentage of the average travel time.<br><br>TTTR is measured in each roadway segment at five designated time periods. Federal regulation requires States to report TTTR metrics and the corresponding 95th and 50th percentile travel times for each time period and interstate system reporting segment.[106] Federal regulation does not set a threshold for TTTR but instead provides an index in which the higher the number, the less reliable a roadway segment, and the lower the number, the more reliable.[107] TTTR is based on data collected at five time periods in each road segment: weekdays from 6 to 10 a.m., 10 a.m. to 4 p.m., and 4 to 8 p.m.; weekends from 6 a.m. to 8 p.m.; and overnight (all days) from 8 p.m. to 6 a.m.[108] Figure 26 shows the calculation for the TTTR ratio for a specific time period for a segment.<br><br>$$\frac{\text{Longer Truck Travel Time (95th)}}{\text{Normal Truck Travel Time (50th)}} = \frac{\text{seconds}}{\text{seconds}} = \text{TTTR Ratio}$$<br>**Figure 26. Equation. Truck travel time reliability calculation.**<br><br>TTTR for a segment is calculated as the maximum TTTR ratio over the five time periods for the segment. As shown in figure 27, the TTTR index for the system is calculated as the weighted average of the segment TTTR values, weighted by segment length.<br><br>$$\text{TTTR Index} = \frac{\sum \text{All segment length weighted TTTR}}{\sum \text{All segment lengths}}$$<br>**Figure 27. Equation. Truck travel time reliability index calculation.**<br>While the TTTR index is reported as a systemwide measure, the segment-level TTTR metric data can also be used to identify specific roadway segments with reliability problems. |
| **Anticipated Data Needs** | ▪ Travel time during designated time periods along segments with significant freight travel |

105 Shawn Turner, Rich Margiotta, and Tim Lomax. 2004. *Monitoring Urban Freeways in 2003: Current Conditions and Trends from Archived Operations Data*. Report No. FHWA-HOP-05-018. Washington, DC: FHWA. https://rosap.ntl.bts.gov/view/dot/39877, last accessed July 6, 2022.
106 23 CFR 490.611.
107 23 CFR 490.613.
108 23 CFR 490.611(a)(1).

## **Freight Management:** FRM3. Travel Time Reliability (continuation)

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| **Data Resources and Partners** | ▪ Travel time estimates are calculated directly from continuous probe vehicle data, estimates from continuous point-based detector data, data collected in periodic special studies, or estimation created through simulation[109]<br>▪ Other data sources may be important for measuring TTTR and identifying possible causes of unreliable travel times, such as:<br>- Travel time data (e.g., National Performance Management Research Data Set, American Transportation Research Institute data collection for instrumented vehicles, other public and private sources)<br>- Goods movement volume data by commodity (e.g., from freight analysis framework)<br>- Weather data (e.g., from the National Oceanic and Atmospheric Administration, other sources)<br>- Work zone and construction schedules (from DOTs and contractors)<br>- Crash data (from the Federal Motor Carrier Safety Administration (FMCSA) Fatal Accident Report System and other sources)<br>- Traffic incident data (e.g., TMCs, police reports) |
| **TSMO Strategies To Consider** | Strategies to consider include traveler information tailored for heavy vehicles, road-weather-management practices, quick clearance of incidents, truck-only lanes, truck-only toll facilities, electronic screening for size/weight/safety enforcement, queue management at intermodal transfer points, reserved truck parking for staging and deliveries, safe and secure parking areas for driver rest breaks, and designated loading zones in urban areas. |

109 FHWA. 2005. *Travel Time Reliability: Making It There On Time, All The Time*. Publication No. FHWA-HOP-06-070. Washington, DC: FHWA. https://transportationops.org/publications/travel-time-reliability-making-it-there-time-all-time#downloads, last accessed October 7, 2022.

# **Freight Management:** FRM4. Border Crossing

## General Description

The intent of this objective is to reduce travel time delay at international border crossings for freight transportation in the region.

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| **Operations Objectives** | ▪ Decrease average crossing times at international borders by X minutes for each border in the region over Y years<br>▪ Increase the use of electronic credentialing to X percent of weigh stations and border crossings by year Y |
| **Performance Measures** | ▪ Average border crossing time for freight at international borders per yea<br>▪ Percentage of weigh stations and border crossings in the region that use electronic credentialing |
| **Anticipated Data Needs** | ▪ Time between freight vehicle entering border area to the time freight vehicle exits border area<br>▪ Count of weigh stations and border crossings using electronic credentialing |
| **Data Resources and Partners** | ▪ Potential data resources are trucking companies that use trucks equipped with automatic vehicle location. Potential partners include U.S. Customs and Border Protection and other agencies operating at the border. |
| **TSMO Strategies To Consider** | TSMO strategies to consider include the use of traveler information to alert commercial vehicle drivers of delays at borders and possible alternatives. Additional strategies include installation, maintenance, and training in the use of electronic credentialing and dynamic pricing. ARC-IT's service packages for commercial vehicle operations provide information about registration for expedited and automated clearance at border crossings in the International Border Registration, International Border Electronic Clearance, and International Border Coordination service packages. |

# **Freight Management:** FRM5. Intermodal Facilities

## General Description

The intent is to reduce the frequency and duration of delays at intermodal facilities where goods can transfer between modes.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the frequency of delays per month at intermodal facilities by X percent in Y years<br>▪ Reduce the average duration of delays per month at intermodal facilities by X percent in Y years |
| **Performance Measures** | ▪ Frequency of delays per month at intermodal facilities where a delay is defined as an addition of Z minutes to free-flow conditions<br>▪ Average duration of delays per month at intermodal facilities |
| **Anticipated Data Needs** | ▪ Travel time of goods through intermodal facilities in the region |
| **Data Resources and Partners** | ▪ Freight carriers and port authorities would be potential sources of data and partners in measuring performance. |
| **TSMO Strategies To Consider** | Strategies include onsite weight-in-motion facilities at intermodal hubs, automated inspection technology, presorting of containers by complexity of inspection, and other logistical actions. |

# **Freight Management:** FRM6. Detours and Routing

## General Description

The intent is to reduce the impact on freight when detours and rerouting are necessary due to incidents, emergencies, events, construction, weather, or choke points.

| | |
|---|---|
| **Operations Objectives** | ▪ X percent of freeway and major arterial detours that can accommodate commercial vehicles by year Y<br>▪ Provide freight operators with traveler alerts and alternative routes in the case of incidents, special events, weather, construction, and severe congestion at choke points on X percent of freight-significant routes by year Y |
| **Performance Measures** | ▪ Percentage of detours of freeways and major arterials that can accommodate commercial vehicles<br>▪ Percentage of freight-significant routes where traveler alerts and alternative-route information are provided in the case of incidents, special events, weather, construction, and severe congestion at choke points |
| **Anticipated Data Needs** | ▪ Number of detours accommodating commercial vehicles<br>▪ Freight traveler information coverage |
| **Data Resources and Partners** | ▪ State DOTs, local DOTs, freight carriers, and port authorities would be potential sources of data and partners in measuring performance |
| **TSMO Strategies To Consider** | Strategies include detection of incidents and congestion and the dissemination of traveler alerts and detours. Strategies also include developing regionwide maps of potential freight detours, including multistate detours when disruptions make major routes or key facilities impassable or highly restricted with respect to vehicle size and weight or trailer combinations. |

# **Freight Management:** FRM7. First-/Last-Mile Pickup/ Delivery

## General Description

First- and last-mile pickup and delivery represents the first and final legs of the supply chain as goods are picked up or delivered between production and consumption—generally at building loading docks, driveways, or curbside. Bringing goods to markets is an important driver of a city's economy, and therefore, the delivery of goods is a key component of urban life. Last-mile delivery issues affect the entire transportation system, and they occur in complex environments involving the interaction of several elements. These elements include producer operations, delivery company services, consumers, buildings, delivery space, streets, and vehicles. Because of this, last-mile deliveries deal with congestion issues in transit and must compete for limited space as delivery vehicles park and goods are received.[110]

Last-mile delivery challenges are of two basic types:

- Delivering goods on time, intact, efficiently, and safely
- Minimizing disruption and external costs to the community and the environment
- However, major delivery industry challenges and trends are exacerbating these issues:
- Smaller, more frequent shipments for business customers
- Densification of commercial and industrial space
- Trucking industry issues such as driver shortage, hours-of-service rules, driver retention, electronic logging mandates, and truck parking
- Urban congestion affecting deliveries
- E-commerce increasing the frequency of small deliveries and rapid delivery through fulfillment systems
- Use of collocated online distribution centers and retail sales that generate both commercial traffic and private vehicles
- Alternative systems and modes such as drones, robots, 3D printing, cargo bikes, and autonomous vehicles
- Gig economy participants[111]

| | |
|---|---|
| **Operations Objectives** | ▪ Within X years, implement restrictions on noise and emissions related to first- and last-mile pickup and delivery<br>▪ Within X years, eliminate all lane blockages in central business districts due to first-and last-mile pickup and delivery during peak periods<br>▪ Within X years, implement enforceable loading and unloading zones during peak periods<br>▪ Within X years, implement programs to encourage off-peak pickup and delivery for eligible carriers and receiver locations in urban areas |

110 Adapted from Southern California Association of Governments (SCAG). 2020. *Last-Mile Freight Delivery Study*. Los Angeles, CA: SCAG, p. ES-2. https://scag.ca.gov/sites/main/files/file-attachments/2958_lastmilefreightstudy-final.pdf, last accessed December 2, 2021. This report is an excellent resource for understanding the many perspectives and issues associated with first- and last-mile delivery and offers multiple strategies for addressing these issues.

111 Southern California Association of Governments (SCAG). 2020. *Last-Mile Freight Delivery Study*. Los Angeles, CA: SCAG, p. ES-3. https://scag.ca.gov/sites/main/files/file-attachments/2958_lastmilefreightstudy-final.pdf, last accessed December 2, 2021.

## **Freight Management:** FRM7. First-/Last-Mile Pickup/Delivery (continuation)

| | |
|---|---|
| **Performance Measures** | ▪ Number of loading and unloading lane blockages in central business districts during peak periods<br>▪ Additional noise caused by heavy trucks in or near residential zones during after-hours delivery measured by calculating after-hours miles of heavy-truck operation<br>▪ Emissions related to idling trucks and buses during loading and unloading or waiting periods measured by idling duration<br>▪ Number of designated loading and unloading zones available during peak periods |
| **Anticipated Data Needs** | ▪ Observations (CCTV, lane sensors) of lane blockages by commercial vehicles in central business districts during peak hours<br>▪ Noise and emissions data in delivery zones, including during off-peak hours |
| **Data Resources and Partners** | ▪ Local DOTs, public works departments, air-quality-monitoring agencies, retailers, distribution and consolidation centers, local delivery services, consumers (e.g., surveys regarding delivery options) |
| **TSMO Strategies To Consider[112]** | TSMO strategies to consider for improving first-/last-mile delivery include common practices currently in use:<br>▪ Designating truck parking in certain locations with enforceable restrictions in other locations<br>▪ Prohibiting standing by trucks except for loading and unloading<br>▪ Limiting trailer parking<br>▪ Making zoning or building requirements for off-street loading areas and mail rooms<br>▪ Setting pricing for the use of curb space<br>▪ Identifying specific truck routes within the city<br>▪ Developing a pilot off-hour truck-delivery program that restricts truck deliveries to certain hours with low traffic<br>▪ Setting weight and size limits on streets<br>▪ Setting limitations on noise<br><br>Innovative practices that can reduce conflicts associated with first-and last-mile delivery include the following:<br>▪ Off-peak delivery programs<br>▪ Combined-use lanes<br>▪ Low-emission zones<br>▪ Urban consolidation centers<br>▪ Commercial-loading-zone permits and meter payments<br>▪ Time-of-day dedicated parking and loading zones available to noncommercial vehicles at other times<br>▪ Delivery and service plans<br>▪ Cargo bicycles<br>▪ Electric delivery fleets<br>▪ Common-carrier lockers |

112 Southern California Association of Governments (SCAG). 2020. *Last-Mile Freight Delivery Study*. Los Angeles, CA: SCAG. p. ES-3. https://scag.ca.gov/sites/main/files/file-attachments/2958_lastmilefreightstudy-final.pdf, last accessed December 2, 2021.

# **Freight Management:** FRM8. Truck Parking Management

## General Description[113]

Commercial truck drivers need access to safe, secure, and accessible truck parking to meet hours-of-service break requirements. Demand for truck parking continues to outpace the supply of public and private parking facilities and exacerbates truck-parking problems experienced in many regions.

Tired truck drivers may continue to drive because they have difficulty finding places to park for rest. If they are unable to locate official, available parking, truck drivers may choose to park at unsafe locations, such as on the shoulder of the road, on exit ramps, or in vacant lots.

Numerous studies have found expected growth in truck activity, severe shortages of parking for trucks, lack of information on truck-parking opportunities, and challenges due to limited delivery windows and specific rest requirements.

| | |
|---|---|
| **Operations Objectives** | ▪ Within the next X years, provide truck drivers with real-time information regarding the availability of truck parking at safe, secure, and legal public and private parking areas<br>▪ Within the next X years, eliminate illegal truck parking on shoulders, exit/entrance ramps, and unsafe parking areas<br>▪ Within the next X years, increase the availability of truck parking in public and private parking areas such that drivers find acceptable parking Y percent of the time they need to park their vehicles |
| **Performance Measures** | ▪ Percentage of the time that accurate, real-time truck-parking information is available through multiple communication channels (e.g., DMS, onboard communications)<br>▪ Percentage of time that safe, secure, and legal parking is available to commercial vehicle operators (CVOs) at the times they need it<br>▪ Number of truck parking spaces relative to truck VMT and nominal travel patterns (e.g., time-of-day and day-of-week demand pattern) |
| **Anticipated Data Needs** | ▪ Real-time occupancy data on truck-parking availability at public rest stops<br>▪ Third-party, real-time parking availability data from private truck stops |
| **Data Resources and Partners** | ▪ Third parties, including NATSO (formerly, National Association of Truck Stop Operators) and major truck stop operators<br>▪ State DOTs with data on truck-parking availability at public truck rest areas<br>▪ Public and third-party data aggregators and disseminators |

113 FHWA. n.d. "Truck Parking" (web page). https://ops.fhwa.dot.gov/Freight/infrastructure/truck_parking, last accessed July 6, 2022.

## **Freight Management:** FRM8. Truck Parking Management (continuation)

| | |
|---|---|
| **TSMO Strategies To Consider** | ▪ Developing smartphone applications with parking availability information<br>▪ Updating DMSs with information about truck-parking availability (distance and available spaces)<br>▪ Using predictive models for estimating truck-parking availability during specific time periods or based on commercial-vehicle traffic density<br>▪ Implementing truck-parking reservation systems<br>▪ Monitoring truck-parking facilities with sensing technologies such as video, in-ground sensors, infrared sensors, aboveground radar, and side laser scanners to provide space occupancy, entrance and exit counts, or areawide truck identification<br>▪ Integrating third-party data on anonymized commercial-vehicle-location data<br>▪ Coordinating with owners of private truck stops to provide truck-parking-availability information<br>▪ Coordinating with owners of safe and secure public and private parking locations (e.g., large parking lots at major venues or big-box stores)<br>▪ Coordinating with major distribution centers and manufacturers to permit onsite parking before pickup and delivery time slots<br>▪ Referencing ARC-IT's Commercial Vehicle Operations service package for commercial vehicle parking |

# **Freight Management:** FRM9. Freight Traveler Information

## General Description[114]

Freight routing, scheduling, and dispatch decisions are sometimes made without adequate data—particularly for small-to-medium-size firms that may not invest as much in technology as larger companies. This category includes many drayage operators, over-the-road owner-operators, and small fleets.

Resources that can help with dispatch and routing decisions exist, but they vary in coverage and quality. They do not always provide freight-specific information. For example, regional 511 traveler information systems are generally designed with private vehicles in mind. They typically do not contain information relevant for freight operations, such as queue times at marine or rail terminal gates, size or weight limitations, or other route restrictions.

| | |
|---|---|
| **Operations Objectives** | ▪ Within X years, all traveler information for commercial vehicles (e.g., weather, work zones, route restrictions, parking availability, weigh station status, incidents, queue delays at marine and intermodal terminals) are integrated into a single platform (e.g., smartphone application, 511 systems specific to CVOs, highway advisory radio)<br>▪ Within X years, Y percent of CVOs and drivers have access to real-time, accurate, truck-specific travel information that can be used for trip planning and en route updates and decisionmaking<br>▪ Within X years, analytical models and predictive analytics enable agencies to provide accurate estimates of near-future road conditions, parking availability, route restrictions, congestion/delays/reliability, queue delays, and alternative-route conditions |
| **Performance Measures** | ▪ Percentage of freeway, toll road, and arterial lane-miles included in truck-specific traveler information<br>▪ Percentage of CVOs with access to truck-specific traveler information<br>▪ Accuracy of predicted conditions in near future (parking availability, road conditions, weather, route restrictions, work zones, detours)<br>▪ Types of truck-specific information available to commercial vehicle operators |
| **Anticipated Data Needs** | ▪ Current and predicted weather data, current and planned road restrictions and work zones, current and predicted status of truck-parking availability, and incident locations and associated delays |
| **Data Resources and Partners** | ▪ State DOTs, truck stop operators, meteorologists, in-road sensors, truck-parking sensors (e.g., CCTV), travel time data from TMCs, tow and recovery operators, carriers, and drivers |
| **TSMO Strategies To Consider** | ▪ Integrated truck-specific information accessible via smartphone applications<br>▪ Roadside DMS with truck-specific information (e.g., parking, route restrictions, incidents)<br>▪ Predictive models for future road conditions for long-haul route planning |

114 Mark Jensen, Roger Schiller, Tammy Duncan, Ed McCormack, Ed McQuillan, Jason Hilsenbeck, and Pete Costello. 2012. *Freight Advanced Traveler Information System Concept of Operations, Final Report*. Report No. FHWA-JPO-12-065. Washington, DC: FHWA. p. 6. https://rosap.ntl.bts.gov/view/dot/3461, last accessed July 6, 2022.

# **Traffic Incident Management:** TIM1. Incident Duration

## General Description

This set of objectives focuses on reducing the duration of traffic incidents on the transportation system. Two different categories are covered: (1) notification and response time and (2) clearance time.[115]

| | |
|---|---|
| **Operations Objectives** | Notification and Response Time<br>▪ Reduce mean time for needed responders to arrive on scene to every incident after notification by X percent over Y years<br>Time to Clear Incident and Roadway<br>▪ Reduce mean incident clearance time per incident by X percent over Y years (defined as the time between awareness of an incident and the time the last responder has left the scene)<br>▪ Reduce mean roadway clearance time per incident by X percent over Y years (defined as the time between awareness of an incident and restoration of lanes to full operational status)<br>▪ Reduce mean time of incident duration (from awareness of incident to resumed traffic flow) on transit services and arterial and expressway facilities by X percent in Y years |
| **Performance Measures** | ▪ Average time to notify necessary response agencies about incidents<br>▪ Mean time for needed responders to arrive on scene after notification<br>▪ Mean incident clearance time per incident<br>▪ Mean roadway clearance time per incident<br>▪ Mean time of incident duration |
| **Anticipated Data Needs** | ▪ For each incident of interest in the region, on scene arrival time<br>▪ The time an agency first becomes aware of an incident and one or more of the following pieces of data: the time the last responder leaves the scene, the time when all lanes are reopened, and the time when traffic returns to full operational status |
| **Data Resources and Partners** | ▪ Data would need to be tracked by the incident responders or operators at a traffic management center or emergency operations center with access to video of the scene. The partners needed for these measures would be all incident responders willing to support the objectives. |
| **TSMO Strategies To Consider** | TSMO strategies to consider include enhancing interagency voice and data communications systems, expanding the use of roving patrols, and using CCTV cameras. |

115 See NTIMC, "Anatomy of a Traffic Incident," at https://ntimc.transportation.org/Documents/AnatomyofaTrafficIncident.pdf for information on the stages of traffic incident management.

# **Traffic Incident Management:** TIM2. Person-Hours of Delay

## General Description

The intent is to reduce person-hours of delay due to traffic incidents.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the person-hours (or vehicle-hours) of total delay associated with traffic incidents by X percent over Y years |
| **Performance Measures** | ▪ Person-hours (or vehicle-hours) of delay associated with traffic incidents |
| **Anticipated Data Needs** | ▪ Total travel time in person-hours (or vehicle-hours) of travel impacted by incidents<br>▪ Total travel time in person-hours (or vehicle-hours) of travel during free-flow conditions |
| **Data Resources and Partners** | ▪ Due to the unpredictable nature of traffic incidents, travel time may need to be collected, stored, and then analyzed after incident times and locations are obtained. Partners needed include public safety agencies and departments of transportation. |
| **TSMO Strategies To Consider** | Reductions in travel time delay can be achieved by implementing strategies addressing any part of the TIM timeline shown in the objectives in the Traffic Incident Management: Incident Duration section. Regions can reduce travel time delay due to incidents by shortening incident clearance time and providing travelers with information to avoid the incident area. |

# **Traffic Incident Management:** TIM3. Customer Satisfaction

## General Description

The intent is to improve customer satisfaction with traffic incident management in the region.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase customer satisfaction with the region's traffic incident management by X percent over Y years |
| **Performance Measures** | ▪ Percentage of customers satisfied with region's traffic incident management practices |
| **Anticipated Data Needs** | ▪ Customer satisfaction surveys |
| **Data Resources and Partners** | ▪ These data would be gathered through surveys of transportation system users that had been using the system during the time of a traffic incident |
| **TSMO Strategies To Consider** | TSMO strategies to consider for improving customer satisfaction with TIM include gathering extensive traveler information during incidents and reducing incident duration. |

# **Traffic Incident Management:** TIM4. Traveler Information

## General Description

This section contains objectives that focus on providing travelers with accurate, timely, and actionable information about incidents.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce time between incident verification and posting an alert to traveler information outlets (e.g., CMS, agency website, 511 system) by X minutes in Y years<br>▪ Increase number of repeat visitors to traveler information website or application by X percent in Y years<br>▪ Increase number of private service partnerships, like crowdsourced data, by X percent in Y years<br>▪ Reduce the time between recovery from incident and removal of traveler alerts for that incident |
| **Performance Measures** | ▪ Time to alert motorists of an incident<br>▪ Time between recovery from incident and removal of traveler alerts |
| **Anticipated Data Needs** | ▪ Data needed for these measures include the time of incident verification and changeable-message-sign (CMS) posting, entry, traveler information website log of the number of visitors, and the time of transportation system recovery and travel alert removal |
| **Data Resources and Partners** | ▪ Data on the time of incident recovery could be collected by TMC operators with video of incident scene or through continuous collection of traffic speeds. Partners would need to include agencies that manage traveler information websites and CMSs. Public safety partners may be needed for information on incident verification time. |
| **TSMO Strategies To Consider** | TSMO strategies to consider include training on disseminating traveler information on incidents as well as deploying and managing CMS and websites. |

# **Traffic Incident Management:** TIM5. Interagency Coordination

## General Description

This section contains objectives that focus on increasing coordination and communication between agencies with responsibilities for traffic incident management.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase percentage of traffic incident management or emergency response agencies in the region that participate in a multimodal information exchange network, use interoperable voice communications, participate in a regional coordinated incident response team by X percent in Y years<br>▪ Increase the number of corridors in the region covered by regional coordinated traffic incident response teams by X percent in Y years<br>▪ Hold at least X multiagency after-action review meetings each year with attendance by at least Y percent of the agencies involved in traffic incident response |
| **Performance Measures** | ▪ Percentage of traffic incident management or emergency response agencies in the region participating in multimodal information exchange networks<br>▪ Number of agencies in the region with interoperable voice communications<br>▪ Number of participating agencies in a regional coordinated traffic incident response team<br>▪ Number of TIM corridors in the region covered by regional coordinated traffic incident response teams<br>▪ Number of multiagency after-action reviews per year<br>▪ Percentage of responding agencies participating in after-action review |
| **Anticipated Data Needs** | ▪ Number of agencies participating in a regional incident management program or activity, number of corridors covered by a regional traffic incident management team, and number of after-action reviews held |
| **Data Resources and Partners** | ▪ These data can be collected by observation of traffic incident management programs or asking TIM agencies to self-report |
| **TSMO Strategies To Consider** | The TSMO strategies to consider are inherent in these objectives. |

# **Traffic Incident Management:** TIM6. Training

## General Description

This section contains objectives that focus on training-incident-management staff.

| | |
|---|---|
| **Operations Objectives** | ▪ Conduct X joint training exercises among operators and emergency responders in the region by year Y<br>▪ By year Y, X number of first responders in region with incident management responsibilities who will have completed TIM training |
| **Performance Measures** | ▪ Number of joint training exercises conducted among operators and emergency responders<br>▪ Percentage of staff having completed TIM training |
| **Anticipated Data Needs** | ▪ Number of joint training exercises conducted in the region among operators and emergency responders<br>▪ Number of staff within each agency in the region that have incident management responsibilities as well as the number of staff that have completed TIM training |
| **Data Resources and Partners** | ▪ A simple count of incident management staff and those that completed TIM training would need to be collected from each TIM agency in the region |
| **TSMO Strategies To Consider** | TSMO strategies to consider would include making TIM training widely available to all relevant staff in the region. |

# **Traffic Incident Management:** TIM7. Responder Safety

## General Description

This section contains objectives that focus on reducing the number of traffic incident responders struck or nearly missed by vehicles at or near traffic incident scenes.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the number of traffic incident responders struck by vehicles at or near traffic incident scenes by X percent by year Y<br>▪ Reduce the number of near misses at or near traffic incident scenes by X percent by year Y |
| **Performance Measures** | ▪ Number of traffic incident responders struck at or near traffic incident scenes<br>▪ Number of near misses at or near traffic incident scenes |
| **Anticipated Data Needs** | ▪ Incident responder safety data |
| **Data Resources and Partners** | ▪ Safety data from incident responder agencies |
| **TSMO Strategies To Consider** | TSMO strategies to consider include public service announcements, safe-driving laws, increased enforcement, TIM training, and next-generation TIM technology[116] |

116 FHWA. 2021. Center for Accelerating Innovation, Every Day Counts Next Generation TIM: Integrating Technology, Data, and Training, webpage. https://www.fhwa.dot.gov/innovation/everydaycounts/edc_6/nextgen_tim.cfm, last accessed October 7, 2022.

# **Special-Event Management:** EVM1. Entry/Exit Travel Times

## General Description

The objectives in this category focus on reducing the travel time for entering and exiting a special event. This section includes related objectives such as customer satisfaction of event management, event clearance, and the reliability of travel time to events.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce average travel time into and out of the event by X percent in Y years<br>▪ Reduce average time to clear event's exiting queue by X percent in Y years<br>▪ Reduce non-special-event VMT in the event area during events by X percent in Y years<br>▪ Reduce buffer time index for travelers to multiple similar special events by X percent in Y years |
| **Performance Measures** | ▪ Average travel time to selected special events from a set of locations in the area over a year<br>▪ Average travel time away from selected special events to a set of locations over a year<br>▪ Average time to clear event's exiting queue by year per event<br>▪ Non-special-event VMT in the event area during events over a year<br>▪ Buffer time index for travelers to multiple similar special events |
| **Anticipated Data Needs** | ▪ Travel time to and from a set of special events<br>▪ Time to clear an event's exiting queue in terms of vehicles as well as people exiting via transit, walking, or biking<br>▪ VMT for vehicles not associated with special event |
| **Data Resources and Partners** | ▪ Example methods of obtaining travel times include probes in the traffic stream (MAC reader technology, automatic-vehicle-location technology on transit vehicles, CCTV surveillance, etc.), speed sensors and segment lengths, and intercept surveys of arriving event patrons.<br>▪ Non-special-event VMT would likely be recorded for key facilities providing access to the event. Facility operators (DOTs, transit agencies, etc.) would collect counts at key locations that allow differentiation between event and nonevent traffic.<br>▪ Agencies that may be involved in collecting data would include highway, arterial, and transit facility operators, signal system operators, public safety officials, parking authorities, and special-event management staff. |
| **TSMO Strategies To Consider** | TSMO strategies to consider include making efforts to encourage transit, biking, walking, and carpooling and other non-single-occupancy-vehicle modes of transportation and providing ways to improve entry and exit travel times to events. Other strategies include creating a special-event signalization or special-event-management plan, traffic- and parking-management-staff training, traveler information, and route management for event and nonevent traffic. |

# **Special-Event Management:** EVM2. Mode Shift from Single Occupancy Vehicle

## General Description

The intent is to minimize the use of single-occupancy vehicles by special-event attendees by encouraging the use of other modes.

| | |
|---|---|
| **Operations Objectives** | ▪ Decrease the percentage of special-event attendees traveling to the event in single-occupancy vehicles by X percent in Y years<br>▪ Increase the percentage of special-event attendees using park-and-ride lots by X percent in Y years<br>▪ Increase the percentage of special events with dedicated shuttle service by X percent in Y years |
| **Performance Measures** | ▪ Percentage of special-event attendees using single-occupancy vehicles each year for selected events<br>▪ Percentage of special-event attendees using park-and-ride lots each year for selected events<br>▪ Percentage of special events with dedicated shuttle service for selected events during a one-year period |
| **Anticipated Data Needs** | ▪ Number of special-event attendees and number of single-occupancy vehicles arriving at event<br>▪ Number of special-event attendees and number of attendees using park-and-ride lots for a sample of events<br>▪ Number of special events in region and number of events with dedicated shuttle service |
| **Data Resources and Partners** | ▪ The data resources needed include counts at special events for single-occupancy vehicles and the number of people using park-and-ride lots. Estimates for park-and-ride lots could be developed though automatic passenger counters (or manual counts) on park-and-ride lot shuttles.<br>▪ Special-event managers and park-and-ride operators would be the key partners for these objectives. |
| **TSMO Strategies To Consider** | Strategies include park-and-ride lots, shuttle service, restricting parking availability, and pricing as well as locating special events at sites that are accessible to transit, walking, and biking. |

# **Special-Event Management:** EVM3. Traveler Information

## General Description

The objectives in this sheet focus on the use of traveler information to manage the movement of people and goods into and out of special events safely and efficiently.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase the methods of effectively disseminating special-event information to travelers by X percent in Y years (e.g., media releases, private information service providers, crowdsourcing, highway advisory radio, CMS, commercial AM and FM radio)<br>▪ Increase the percentage of planned special events (with attendance above Z) with information on anticipated and actual travel conditions being disseminated to the traveling public at least X hours before the events |
| **Performance Measures** | ▪ Number of effective methods to disseminate special-event information to travelers<br>▪ Percentage of special events with expected attendance over Z for which traveler information is disseminated at least X hours before the events |
| **Anticipated Data Needs** | ▪ A count of the available traveler information dissemination channels<br>▪ A count of major special events with and without the dissemination of traveler information ahead of the events |
| **Data Resources and Partners** | ▪ Data could be collected through surveys of special-event-management agencies on methods used for information dissemination and the use of traveler information at major events |
| **TSMO Strategies To Consider** | Strategies include the range of communication techniques to support traveler information for special events as well as creating a special-event signalization plan or a special-event-management plan with components on disseminating traveler information. |

# **Special-Event Management:** EVM4. Parking Management

## General Description

The objectives in this sheet focus on the use of parking management during special events to encourage a more efficient use of existing parking facilities and to improve the quality of service for users.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase the number of special events that use shared parking facilities (e.g., parking lots of nearby businesses or organizations) by X percent in Y years<br>▪ Increase the use of flexible pricing mechanisms near special-event locations on X percent of parking spaces in Y years<br>▪ Increase on-street parking restrictions on X percent of widely used routes during special events in Y years<br>▪ Decrease the time spent clearing special-event venue parking lots of vehicles by X percent in Y years following each event |
| **Performance Measures** | ▪ Number of special events that use shared parking facilities<br>▪ Percentage of parking spaces near special-event locations that use flexible pricing mechanisms<br>▪ Percentage of routes widely used during planned special events with on-street parking restrictions<br>▪ Percent decrease in time to clear parking lots |
| **Anticipated Data Needs** | ▪ A count of special events using shared use parking facilities<br>▪ Count of parking spaces near special-event locations with and without flexible pricing mechanisms<br>▪ Determination of the most widely used routes during special events and count of those routes with on-street parking restrictions<br>▪ Time to clear special-event parking lots following each special event |
| **Data Resources and Partners** | ▪ Staff time or technology would be needed to count the number of available parking spaces, assess widely used commuter routes during special events, and record clearance time for parking lots after events |
| **TSMO Strategies To Consider** | Strategies include shared parking with nearby facilities, priced parking, transportation demand management, dynamic overflow transit parking, dynamic parking reservations, dynamic wayfinding, dynamic priced parking, and park and ride. These strategies could be outlined within a special-event-management plan. |

# **Special-Event Management:** EVM5. Multiagency Coordination and Training

## General Description

This section contains objectives that focus on efforts to improve multiagency collaboration and training for special-event management.

| | |
|---|---|
| **Operations Objectives** | ▪ Encourage participation of relevant special-event stakeholder disciplines in a regional-event-management team<br>▪ Increase the number of disciplines with special-event management responsibilities that use interoperable communications<br>▪ Increase the percentage of special events that include a pre-event and post-event briefing by X percent in Y years<br>▪ Increase the number of special event-related exercises performed among stakeholders by X percent in Y years |
| **Performance Measures** | ▪ Percentage of stakeholder agencies participating agencies in a regional special-event management team<br>▪ Number of agencies special-event management responsibilities using interoperable communications<br>▪ Percentage of special events that include a pre-event and post-event briefing<br>▪ Number of special event-related exercises performed among stakeholders |
| **Anticipated Data Needs** | ▪ The number of special-event management stakeholder agencies and, of them, the number that participate each year in a regional-event management team<br>▪ A count of special events with pre- and post-event briefings, number of special event-related exercises, and number of special-event management agencies using interoperable communication systems |
| **Data Resources and Partners** | ▪ The data for these objectives would need to come from the agencies involved in special-event management. It could be gathered through phone calls or surveys of these agencies. |
| **TSMO Strategies To Consider** | TSMO strategies to consider include developing a special-event-management plan with components on multiagency coordination and training efforts. |

# **Special-Event Management:** EVM6. Use of Technology

## General Description

The objective in this section focuses on deploying and using technology to improve special-event management.

| | |
|---|---|
| **Operations Objectives** | ▪ Encourage the use of ITS-related assets (e.g., roadside cameras and vehicle speed detectors) to detect and manage special-event entry or exit bottlenecks and incidents at special events<br>▪ Implement special-event traffic signal timing plans at X percent of major special events each year beginning in year Y |
| **Performance Measures** | ▪ Percentage of special events using ITS-related assets to detect and manage incidents or bottlenecks at entry or exit routes of the events<br>▪ Percentage of major special events each year in which a special-event traffic signal timing plan was implemented |
| **Anticipated Data Needs** | ▪ Number of special events in the region and number of special events with ITS assets used for detecting and managing bottlenecks and incidents at entry or exit routes of events<br>▪ Number of major special events whose signal timing plans were and were not implemented |
| **Data Resources and Partners** | ▪ Special-event managers who would potentially use ITS for monitoring travel and disseminating information<br>▪ State and local DOTs, ITS operators, emergency responders, and special-event managers who would need to coordinate event planning, routing, and information dissemination |
| **TSMO Strategies To Consider** | Strategies include ITS deployment to support special-event management, development of a special-event signalization plan or special-event-management plan that identifies areas of the system that could benefit from technology improvements to coordinate special events, special-event-management planning and coordination among regional partners; monitoring, response to special-event-related incidents, postevent debriefs, and implementation improvements. |

# **Transit Operations and Management:** TRM1. Service Directness

## General Description

This sheet contains objectives on improving transit service with limiting the number and time of transfers.

| | |
|---|---|
| **Operations Objectives** | ▪ At least X percent of trips can be made with no more than Y transfers<br>▪ Scheduled transfer times between routes should be no longer than X minutes |
| **Performance Measures** | ▪ Percentage of trips with no more than Y transfers<br>▪ Scheduled transfer times between routes |
| **Anticipated Data Needs** | ▪ Transit trip origin and destination data is needed<br>▪ Scheduled arrival and departure times at transfer points between routes |
| **Data Resources and Partners** | ▪ The data resources will likely come from transit schedules and transit rider surveys for origin and destinations. |
| **TSMO Strategies To Consider** | TSMO strategies to minimize the number of transfers rely on the determination of transit trip characteristics, which allows transit routes to be adjusted to reduce the number of transfers. |

# **Transit Operations and Management:** TRM2. Loading Standards

## General Description

This sheet contains objectives on improving transit loading standards.

| | |
|---|---|
| **Operations Objectives** | ▪ Load factors for (route type) routes at each route's busiest point should not exceed X on any vehicle (or on the average vehicle) during peak/off-peak periods<br>▪ Passenger loads on (route type) routes at each route's busiest point should not exceed X passengers on any vehicle (or on average) during the hour during peak/off-peak periods<br>▪ No more than X standees should be present at each route's busiest point on any vehicle (or on the average vehicle) during peak/off-peak periods<br>▪ No passenger will have to stand for more than X minutes during their journey |
| **Performance Measures** | ▪ Load factor<br>▪ Maximum passenger loads<br>▪ Maximum standees<br>▪ Duration of standee time |
| **Anticipated Data Needs** | ▪ Transit ridership data (required)<br>▪ Passenger standing time |
| **Data Resources and Partners** | ▪ The transit agency is the key partner for these objectives. |
| **TSMO Strategies To Consider** | TSMO strategies include strategic infrastructure improvements to match with the busiest points along transit routes. |

# **Transit Operations and Management:** TRM3. Traveler Information

## General Description

This sheet contains objectives on improving passenger shelters and platforms and amenities.

| | |
|---|---|
| **Operations Objectives** | ▪ Equip X shelters and platforms with real-time arrival displays annually<br>▪ Increase the number of web-based trip planner requests each year by X percent<br>▪ All stops have up-to-date schedule information available within X days of schedule changes<br>▪ Transit traveler information is available in the region via 511 web and phone service or incorporated into a regional MOD app by year Y<br>▪ Install 5G service on X number of routes annually |
| **Performance Measures** | ▪ Number of shelters and platforms equipped with real-time arrival displays per year<br>▪ Number of web-based trip planner requests per year<br>▪ Percentage of stops with up-to-date schedule information available within X days of schedule changes<br>▪ Availability of transit traveler information on 511 web and phone service<br>▪ The number of routes on which Wi-Fi service was installed |
| **Anticipated Data Needs** | ▪ Count of shelters and platforms with arrival displays<br>▪ Web page usage statistics for trip-planning requests<br>▪ Count of stops with up-to-date schedule information (within a specified timeframe)<br>▪ Inclusion of transit traveler information on 511 services<br>▪ Count of routes on which Wi-Fi service was installed per year |
| **Data Resources and Partners** | ▪ The transit agency is the key partner for this objective. |
| **TSMO Strategies To Consider** | TSMO strategies are inherent in the objectives. |

# **Transit Operations and Management:** TRM4. Customer Service/Safety

## General Description

The objectives in this section focus on improving transit customer service, improving personal safety (e.g., reducing crime on transit vehicles that affects customer perceptions of safety), and improving security related to reducing vandalism and graffiti in a region.

| | |
|---|---|
| **Operations Objectives** | ▪ Decrease by X percent on an annual basis the number of complaints per 1,000 boarding passengers<br>▪ Increase the number or area of facilities (platforms, park-and-ride lots, vehicles, and other transit facilities) automatically surveilled by X percent in Y years<br>▪ Increase customer service and personal safety ratings by X percent within Y years<br>▪ Decrease the number of personal safety incidents by X percent within Y years |
| **Performance Measures** | ▪ Complaint rate<br>▪ Number or area of platforms, park-and-ride lots, vehicles, and other transit facilities automatically surveilled by CCTV cameras or other methods<br>▪ Personal safety and customer service ratings<br>▪ Number of reported personal safety incidents |
| **Anticipated Data Needs** | ▪ Count of complaints made by customers to transit agencies and number of total transit boardings by agency<br>▪ Customer satisfaction survey evaluating safety and customer service<br>▪ Transit boardings<br>▪ Reported number of safety incidents |
| **Data Resources and Partners** | ▪ These data would be provided by the transit agencies in the region. |
| **TSMO Strategies To Consider** | TSMO strategies to improve customer service and safety could involve additional police and security staff around transit stations, improved staff and security training, better information about vehicle arrivals, and more-frequent cleaning of transit vehicles and facilities. |

# **Transit Operations and Management:** TRM5. Line-Haul Transit

## General Description

The objectives in this section focus on improving line-haul transit service in a region.

| | |
|---|---|
| **Operations Objectives** | ▪ Improve average travel speeds by X percent for specified line-haul transit routes every Y years<br>▪ Improve average on-time performance for specified line-haul transit routes by X percent annually<br>▪ Provide line-haul transit travel times equal to or less than average auto travel times on same corridors and parallel corridors for X number of routes over Y years |
| **Performance Measures** | ▪ Average line-haul transit travel speeds for specified line-haul transit routes<br>▪ Average line-haul transit on-time performance for specified line-haul transit routes<br>▪ Number of line-haul transit routes operating with travel times equal to or less than average auto travel times on same corridors and parallel corridors |
| **Anticipated Data Needs** | ▪ Travel speeds of transit vehicles for specified line-haul transit routes<br>▪ Percentage of on-time arrivals and departures for specified line-haul transit routes<br>▪ Average travel time for transit vehicles on specified line-haul transit routes and average auto travel time for same corridor or parallel corridor |
| **Data Resources and Partners** | ▪ These data would be provided by the transit agencies and the MPO in the region. |
| **TSMO Strategies To Consider** | TSMO strategies to improve line-haul transit service could include making improvements to existing infrastructure (stations and platforms, exclusive bus lanes, etc.), vehicles, fare collection systems, and scheduling. |

# **Transit Operations and Management:** TRM6. Transit Signal Priority

## General Description

The objectives in this section focus on implementation of transit signal priority systems to improve transit performance and reliability in a region.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase implementation of transit signal priority strategies on X number of routes (or X number of intersections) over the next Y years<br>▪ Decrease systemwide signal delay on transit routes by X percent per year<br>▪ Decrease delay by X percent per year by increasing the use of queue jumping and automated vehicle location |
| **Performance Measures** | ▪ Number of transit routes and intersections equipped with transit signal priority capability<br>▪ Systemwide signalized stop delay on transit routes<br>▪ Travel time delay on routes with queue jumping and automated vehicle location in use |
| **Anticipated Data Needs** | ▪ Count of transit routes and intersections with transit signal priority capabilities<br>▪ Automatic-vehicle-location data with location and travel time delay<br>▪ Signal operations and green time reports |
| **Data Resources and Partners** | ▪ These data would be provided by the transit agencies and traffic signal operating agencies in the region |
| **TSMO Strategies To Consider** | TSMO strategies to increase transit signal priority implementation could involve identification and prioritization of routes or transit corridors that are candidates for implementing transit signal priority systems. Another strategy may include collaboration with the traffic management agency to leverage transit signal priority implementation with traffic signal system upgrades. |

# **Transit Operations and Management:** TRM7. Automated Fare Collection

## General Description

The objectives in this section focus on implementing and integrating automated fare collection in a region.

| | |
|---|---|
| **Operations Objectives** | ▪ Implement an automated fare collection system in Y years for X percent of transit providers in the region<br>▪ Integrate X additional modes and services into automated fare collection system by Y years<br>▪ Increase use of system by X percent per year<br>▪ Increase by X percentage points every Y years the percentage of transfers performed with automated fare cards<br>▪ Provide one fare payment system operational between X transportation modes and Y users each year |
| **Performance Measures** | ▪ Percentage of transit providers using the region's automated fare collection system<br>▪ Number of additional modes and services integrated into the fare collection system<br>▪ Percentage of fares collected using automated fare collection<br>▪ Percentage of total transfers performed with automated fare cards |
| **Anticipated Data Needs** | ▪ Number of transit providers and additional modes and services implementing automated fare collection system<br>▪ Farebox data: number of fares collected through automated system<br>▪ Number of transfers performed using automated fare card |
| **Data Resources and Partners** | ▪ These data would be provided by the transit agencies in the region |
| **TSMO Strategies To Consider** | TSMO strategies to increase implementation and use of automated fare collection could involve integrating the system across multiple modes or services, implementing a system consistent with other connecting transit services, and implementing a marketing campaign to increase awareness and use. |

# **Transit Operations and Management:** TRM8. Park-and-Ride Support

## General Description

The objectives in this section focus on improving knowledge of and support for park-and-ride lot connections to transit service in a region.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase traveler awareness of park-and-ride lots by X percent within Y years<br>▪ Increase pedestrian and bicycle access to park-and-ride lots by X percent within Y years<br>▪ Increase the number of automobile and bicycle spaces by X percent within Y years for lots currently experiencing X percent use |
| **Performance Measures** | ▪ Number of users aware of park-and-ride lots in their region<br>▪ Percentage of park-and-ride lots with pedestrian and bicycle access<br>▪ Number of auto and bicycle spaces at the park-and-ride lots |
| **Anticipated Data Needs** | ▪ Customer survey measuring knowledge of regional park-and-ride lots<br>▪ Number of secure bicycle storage areas<br>▪ Number of bicycle routes<br>▪ Number of crosswalks<br>▪ Number of park-and-ride lots meeting ADA standards<br>▪ Parking utilization studies for bicycle and auto spaces |
| **Data Resources and Partners** | ▪ Data would need to be collected by transit agencies to determine amenities of the park-and- ride lots<br>▪ Partners needed include departments of transportation, intermodal facility operators, and transit agencies to coordinate the expansion of park-and-ride lots as well as bicycle and pedestrian facilities |
| **TSMO Strategies To Consider** | Strategies to consider include those that make park-and-ride lots easier to use, with technologies such as electronic payment systems and park-and-ride space finders. Additionally, strategies that increase transit use would also increase park-and-ride-lot use. |

# **Transportation Demand Management:** TDM1. Leveling Demand

## General Description

Transportation demand management (TDM) is a comprehensive approach to providing safer and more-reliable mobility as well as more-efficient use of the available transportation infrastructure, including both roadways and mobility choices (e.g., bicycle, transit, pedestrian, shared mobility). TDM applies operational strategies and policies that impact and change the level of demand placed on the transportation network. These changes often occur (1) by shifting demand to another mode, at different times, or to alternative routes or (2) by reducing the need to travel.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce demand on oversaturated modes and system assets<br>▪ Increase availability and convenience of multiple modes<br>▪ Encourage behavior that reduces demand on certain modes<br>▪ Reduce congestion and increase safety and reliability |
| **Performance Measures** | ▪ Percentage of travelers who use other modes: transit, pedestrian, bicycle<br>▪ Evaluation of traffic volume data, congestion, crash data, and reliability factors before and after TDM implementation |
| **Anticipated Data Needs** | ▪ Roadway hourly volumes<br>▪ Mode usage statistics<br>▪ Travel time reliability<br>▪ Traveler surveys |
| **Data Resources and Partners** | ▪ State department of transportation<br>▪ Regional transportation-planning organizations<br>▪ Local agencies<br>▪ Travelers<br>▪ Public transit agencies and mode operators<br>▪ Private transportation network companies |

## **Transportation Demand Management:** TDM1. Leveling Demand (continuation)

| | |
|---|---|
| **TSMO Strategies To Consider** | TSMO strategies can be integrated into TDM and either enable or support them. FHWA's Active Demand Management Capability Maturity Framework (CMF) offers assistance in identifying strategies that employ TSMO to reduce or relocate demand. Strategies designed to evaluate demand relocation include the following:<br>▪ Implement congestion pricing and high-occupancy tolling<br>▪ Improve access to other modes, such as transit using mobility hubs and multimodal hubs<br>▪ Improve and add bike trails and bike lanes to provide safer routes for bike commuters<br>▪ Implement pedestrian-oriented designs of local roads and streets to improve pedestrian safety and walkability<br>▪ Encourage employers to incorporate flextime work schedules or work-from-home hours<br>▪ Implement curb-space management policies and parking-information systems<br>▪ Consider opportunities for dynamic rideshare at park-and-ride lots<br>▪ Evaluate peak-period part-time shoulder use for buses, HOVs, or all vehicles<br>▪ Establish relationships with travel-disadvantaged-advocacy groups to identify common travel barriers and multimodal strategies to mitigate access issues<br>TDM strategies should be linked to specific goals and objectives such as those listed above and in the following TSMO QR sheets related to transportation demand management. TDM works best when significant inter- and intra-agency communication and collaboration are in place. TDM typically requires policies and flexibility that permit strategies that either (1) encourage and reward shifting travel times, modes, or routes or (2) discourage or penalize single-occupancy-vehicle (SOV) use or travel during peak demand periods or on highly congested routes. TDM offers a variety of traveler choices and dynamic facility management strategies (e.g., high-occupancy-toll and high-occupancy-vehicle transit priority) that discourage SOV use. To be effective, TDM requires interagency and multijurisdictional data sharing and should be promoted through consistent messaging and outreach programs that market travel options to travelers, taking into account the need for equitable access to community resources (e.g., education, employment, healthcare, essential goods and services).<br><br>Additional resources that provide information on TSMO strategies for transportation-demand-management strategies can be found in FHWA's Active Demand Management Capability Maturity Framework. |

# **Transportation Demand Management:** TDM2. Auto Commuter Trip Reduction Programs

## General Description

The objectives in this sheet focus on commuter-trip-reduction programs for employers.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase the percentage of major employers (employers with at least Z employees) actively participating in transportation-demand-management programs by X percent within Y years<br>▪ Reduce commuter VMT per regional job by X percent in Y years |
| **Performance Measures** | ▪ Percentage of major employers with active TDM programs<br>▪ Commuter VMT per regional employee |
| **Anticipated Data Needs** | ▪ Number of major employers with and without active TDM programs<br>▪ Number of regional employees and total commute VMT |
| **Data Resources and Partners** | ▪ Departments of labor, transportation management associations, business licensing bureaus<br>▪ Travel behavior surveys for commute mode choice, U.S. Census Bureau |
| **TSMO Strategies To Consider** | TSMO strategies include guaranteed-ride-home programs; commuter financial incentives (parking cash out and transit allowances); alternative scheduling (flextime and compressed workweeks); telework; bicycle parking and changing facilities at major employer locations; worksite amenities such as onsite childcare, restaurants, and shops to reduce the need to drive for errands; company travel reimbursement policies for bicycle or transit mileage for business trips; company vehicles to eliminate the need for employees to drive to work in order to have their cars for business travel; proximate commuting, which allows employees to shift to worksites that are closest to their homes (for employers who have multiple work locations, such as banks and other large organizations); worksite locations that reflect location-efficient development principles; and employer strategies to encourage bicycling and walking, including both safe and secure storage for bicycles and shower and locker facilities. |

# **Transportation Demand Management:** TDM3. Commuter Shuttle Service

## General Description

The objective in this sheet focuses on promoting commuter shuttle services.

| | |
|---|---|
| **Operations Objectives** | ▪ Annually promote shuttle service between X major activity centers and major destinations that are not already accommodated within 0.25 mi by other transit services |
| **Performance Measures** | ▪ Percentage of residents in region receiving marketing material on shuttle service opportunities |
| **Anticipated Data Needs** | ▪ Shuttle service and transit route maps<br>▪ Count of residents in applicable areas receiving shuttle marketing materials |
| **Data Resources and Partners** | ▪ Employers, transportation management associations, travel-demand-management programs, transit agencies, and State and local DOTs |
| **TSMO Strategies To Consider** | The TSMO strategy is inherent in the objective. |

# **Transportation Demand Management:** TDM4. Carpool/ Vanpool

## General Description

The objectives in this sheet focus on carpool and vanpool travel.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase the number of carpools by X percent over the next Y years<br>▪ Increase use of vanpools by X percent over the next Y years<br>▪ Provide carpool and vanpool matching and app-based dynamic ridesharing information services by year Y<br>▪ Reduce trips per year in region by X percent through carpools and vanpools<br>▪ Create and share regional carpool and vanpool database with Z number of employers per year |
| **Performance Measures** | ▪ Share of household trips by each mode of travel<br>▪ Number of trips in region<br>▪ Availability of carpool and vanpool matching and app-based dynamic ridesharing information services<br>▪ Number of employers with access to regional carpool and vanpool database |
| **Anticipated Data Needs** | ▪ Mode share and total trips in region<br>▪ Count of employers with access to regional carpool and vanpool database |
| **Data Resources and Partners** | ▪ Survey data, such as the U.S. Census Bureau's Commuting (Journey to Work) survey or other mode share surveys<br>▪ Employer surveys of employee commuting patterns<br>▪ Household surveys of travel behaviors, including mode choice, frequency of trip making, and vehicle occupancy<br>▪ Partners such as employers, transportation management associations, transportation network companies, travel-demand-management programs, transit agencies, State and local DOTs, commuters, nonauto advocacy groups, and research firms |
| **TSMO Strategies To Consider** | The TSMO strategy is inherent in the objectives. |

# **Transportation Demand Management:** TDM5. Walking/Bicycling

## General Description

The objectives in this sheet focus on walking and bicycling incentives.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase the number of trips completed via walking and/or bicycling by X percent over Y years<br>▪ Annually update bicycle and pedestrian map for accuracy<br>▪ Increase the number of available tools for travelers that incorporate a bicycle and/or pedestrian component by X percent by year Y |
| **Performance Measures** | ▪ Number of travelers commuting via walking and/or bicycling<br>▪ Number of months since the last update of the bicycle and pedestrian map<br>▪ Number of traveler tools with a bicycle and pedestrian component |
| **Anticipated Data Needs** | ▪ Count of commuters walking and/or bicycling<br>▪ Date of bicycle and pedestrian map update<br>▪ Count of traveler tools with a bicycle and pedestrian component |
| **Data Resources and Partners** | ▪ Employers, transportation management associations, travel-demand-management programs, transit agencies, and State and local DOTs<br>▪ Commuters, nonauto advocacy groups, and research firms |
| **TSMO Strategies To Consider** | The TSMO strategies are inherent in the objectives. |

# **Transportation Demand Management:** TDM6. Parking Management

## General Description

The objectives in this sheet focus on managing parking in support of managing travel demand.

| | |
|---|---|
| **Operations Objectives** | ▪ Implement X number of shared parking stalls over Y years<br>▪ Implement X number of priced parking stalls over Y years<br>▪ Install parking meters along X corridors by year Y in the urban core/transit supportive areas<br>▪ Increase the number of residents and commuters receiving information on parking pricing and availability within Y years<br>▪ Increase park-and-ride-lot capacity by X percent over Y years<br>▪ Biannually increase preferred parking spaces for carpool and vanpool participants within downtown, at special events, and among major employers by X percent within Y years |
| **Performance Measures** | ▪ Number of shared parking stalls<br>▪ Number of priced parking stalls<br>▪ Number of corridors in urban core/transit supportive areas with parking meters<br>▪ Number of residents and commuters receiving information on parking pricing and availability<br>▪ Capacity of park-and-ride lots<br>▪ Number of preferred parking spaces for carpool and vanpool participants |
| **Anticipated Data Needs** | ▪ Count of shared parking and priced parking stalls<br>▪ Count of corridors with parking meters<br>▪ Count of residents and commuters exposed to parking information<br>▪ Park-and-ride-lot capacity data<br>▪ Count of preferred parking spaces |
| **Data Resources and Partners** | ▪ Employers, county and city staff, transit agencies, and special-event managers |
| **TSMO Strategies To Consider** | TSMO strategies are inherent in the objectives. |

# **Transportation Demand Management:** TDM7. Marketing

## General Description

The objectives in this sheet focus on using marketing and communications to manage demand for travel.

| | |
|---|---|
| **Operations Objectives** | ▪ Develop and provide travel option services for X identified communities and audiences within Y years<br>▪ Construct visitor information centers in X communities by year Y<br>▪ Create a transportation access guide that provides concise directions to reach destinations by alternative modes (transit, walking, bike, etc.) by year Y<br>▪ Increase the number of visits to web-based traveler information tools to X by year Y<br>▪ Develop comprehensive regional marketing plans for X travel modes by year Y |
| **Performance Measures** | ▪ Number of communities receiving travel option services<br>▪ Number of communities in which visitor information centers are constructed<br>▪ Implementation of transportation access guide<br>▪ Number of visits to web-based traveler information tools |
| **Anticipated Data Needs** | ▪ Count of communities with travel option services and visitor information centers<br>▪ Count of web-based traveler information tools |
| **Data Resources and Partners** | ▪ Employers, transportation management associations, travel-demand-management programs, transit agencies, and State and local DOTs |
| **TSMO Strategies To Consider** | TSMO strategies are inherent in objectives. Additional resources can be found in FHWA's Active Demand Management Capability Maturity Framework tool.[117] |

117 https://ops.fhwa.dot.gov/tsmoframeworktool/available_frameworks/index.htm

# **Road Weather Management:** RWM1. Clearance Time (Weather-Related Debris)

## General Description

The intent is to improve the time needed to clear the transportation system of weather-related debris (fallen limbs and trees, snow and ice, power lines and poles, etc.) so that safe and efficient travel can resume.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce average time to complete clearing (mode, hierarchy of facilities, or subarea of region) of weather-related debris after weather impact by X percent in Y years<br>▪ Reduce average time to complete clearing (interstates, freeways, expressways, all roads, main tracks, and main sidewalks) of weather-related debris after weather impact by X percent in Y years |
| **Performance Measures** | ▪ Average time to clear selected surface transportation facilities of weather-related debris after weather impact |
| **Anticipated Data Needs** | ▪ The time in which the transportation facility surface has been impacted by the debris and the time required to clear selected facilities and restore them to full operation |
| **Data Resources and Partners** | ▪ Resources include road or rail weather sensors and observations by meteorologists or road maintenance staff on the roads. Data on the time to clear would need to be obtained from road maintenance managers and staff. |
| **TSMO Strategies To Consider** | TSMO strategies to consider in the quick clearance of roads impacted by weather would include prepositioned debris removal vehicles, collaboration with weather forecasting services, dissemination of weather information to travelers, and preventative techniques such as spreading deicing material before a storm. |

# **Road Weather Management:** RWM2. Detours for Impacted Roadways

## General Description

This category addresses making improvements in helping travelers avoid sections of roadway that are dangerous and would cause them substantial delay.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase by X percent the number of significant travel routes covered by weather-related diversion plans by year Y<br>▪ Increase the percentage of agencies that have adopted multiagency weather-related transportation operations plans and that are involved in transportation operations during weather events to X percent by year Y |
| **Performance Measures** | ▪ Percentage of significant travel routes covered by weather-related diversion plans<br>▪ Percentage of agencies involved in transportation operations during weather events that have adopted multiagency, weather-related transportation operations plans |
| **Anticipated Data Needs** | ▪ Number of weather-related diversion plans<br>▪ Total number of agencies involved in transportation operations during weather events and the number of those agencies that have adopted multiagency diversion plans |
| **Data Resources and Partners** | ▪ Operators (including public safety) of the impacted roads and owners of the diversion plans |
| **TSMO Strategies To Consider** | Successfully developing plans for alternative routes during weather events requires significant preparations and collaboration between jurisdictions and modes. |

# **Road Weather Management:** RWM3. Disseminating Information

## General Description

The objectives in this category focus on getting relevant information to travelers as soon as possible regarding the impact of weather on travel in the region.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce time to alert travelers of travel weather impacts (using CMS, 511, private traveler information systems, road weather information systems, public information broadcasts, the agency's website, social media technologies, etc.) by X (time period or percent) in Y years |
| **Performance Measures** | ▪ Time from beginning of weather event to posting of traveler information on CMS, 511, private traveler information systems, RWIS, and public information broadcasts<br>▪ Time from beginning of weather event to posting of traveler information on agency website |
| **Anticipated Data Needs** | ▪ Time of the start of a weather event and the time in which information is given to the traveler by various methods (CMS , 511, private traveler information services, road weather information systems, public information broadcasts, agency website) |
| **Data Resources and Partners** | ▪ Partners needed to collect these data would include those with information on the timing and trajectory of weather events such as the National Weather Service, transportation agencies (DOTs, transit agencies, ports, etc.), and broadcasters that disseminate traveler information using different technologies |
| **TSMO Strategies To Consider** | TSMO strategies include CMS on key corridors, 511 systems, private traveler information services, road weather information systems, agency websites, and communication links with broadcasters. |

# **Road Weather Management:** RWM4. Road Weather Information System Coverage

## General Description

The intent is to increase coverage of the road system with weather sensors and communications systems. This approach can be applied to the transit system and has the potential for application to regional bicycle facilities.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase the percentage of major road network (or transit network or regional bicycle network) covered by weather sensors, private weather services, or a RWIS by X percent in Y years as defined by an RWIS station within Z miles |
| **Performance Measures** | ▪ Percentage of major road (transit or bicycle) network within Z miles of an RWIS station |
| **Anticipated Data Needs** | ▪ Data needed for this performance measure would be the deployment locations of each RWIS station in the region and location and length of major road (transit or bicycle) network |
| **Data Resources and Partners** | ▪ Partners needed for these data would be the agencies responsible for deployment of the RWIS stations and those responsible for maintaining an inventory of the roadway (transit or bicycle) network. This information is often stored in a geographic information system or other mapping database in a central data repository for sharing with all public agencies and public broadcasting groups involved with weather information dissemination. |
| **TSMO Strategies To Consider** | Strategies include maintaining and sharing current information on the extent of the system (roadway, transit, bicycle), the locations of weather sensors, the sharing of weather data, the installation of additional sensors, and the sharing of operational actions related to a weather event. |

# **Road Weather Management:** RWM5. Signal-Timing Plans

## General Description

The intent is to improve the management of traffic signal systems during inclement weather conditions.

| | |
|---|---|
| **Operations Objectives** | ▪ Special timing plans are available for use during inclement weather conditions for X miles of arterials in the region by year Y |
| **Performance Measures** | ▪ Number of miles of arterials that have at least one special timing plan for inclement weather events |
| **Anticipated Data Needs** | ▪ Reports from operating agencies on signal retiming, signal capabilities, and special timing plans |
| **Data Resources and Partners** | ▪ Partner agencies that operate arterials in the region |
| **TSMO Strategies To Consider** | TSMO strategies flow directly from the objectives. |

# **Traveler Information:** TI1. Information Dissemination

## General Description

This sheet contains objectives for improving the delivery of traveler information to the public, businesses, and other users of the transportation system.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase number of 511 calls per year by X percent in Y years<br>▪ Increase number of visitors to traveler information website per year by X percent in Y years<br>▪ Increase number of users of notifications for traveler information (e.g., e-mail and text message) by X percent in Y years<br>▪ Increase number of social media (e.g., Twitter and Facebook) followers for traveler information by X percent in Y months<br>▪ Increase the accuracy and completeness of traveler information posted (on CMS, websites, and/or social media technologies) by reducing the number of incomplete and inaccurate reports by X percent in Y years |
| **Performance Measures** | ▪ Number of 511 calls per year<br>▪ Number of visitors to traveler information website per year<br>▪ Number of users of notifications for traveler information (e.g., e-mail and text message) per year<br>▪ Number of social media (e.g., Twitter and Facebook) followers<br>▪ Number of complaints received from system users about inaccurate or missing information |
| **Anticipated Data Needs** | ▪ Data for these performance measures is a count of users for the traveler information dissemination channels<br>▪ Number of customer complaints regarding incomplete or inaccurate traveler information |
| **Data Resources and Partners** | ▪ These data would be gathered through call logs, website logs, and other systems that record information on access history or membership |
| **TSMO Strategies To Consider** | TSMO strategies to improve information dissemination include polling target audiences to determine the most-effective ways to reach them with information and providing accurate, timely, and useful information. |

# **Traveler Information:** TI2. Trip-Planning Tools

## General Description

The objectives in this section focus on promoting system awareness among users so they have direct knowledge and awareness of current and forecast system operating and safety conditions, route choices, and mode choices.

| | |
|---|---|
| **Operations Objectives** | ▪ Enhance data sources available for regional multimodal trip-planning tools<br>▪ Increase the ease of use of trip-planning tools by X percent by year Y<br>▪ Increase the number of uses of multimodal trip-planning tools by X percent by year Y |
| **Performance Measures** | ▪ Breadth of service attributes covered by data sources that provide information for multimodal trip-planning tools<br>▪ Trip-planning tools ease-of-use rating<br>▪ Number of uses of trip-planning tools |
| **Anticipated Data Needs** | ▪ Identification of all multimodal trip-planning tools and their data sources<br>▪ Trip-planning tool ease-of-use rating obtained by customer survey<br>▪ Number of uses of trip-planning tools |
| **Data Resources and Partners** | ▪ All operating agencies within the region |
| **TSMO Strategies To Consider** | TSMO strategy is inherent in objective. |

# **Traveler Information:** TI3. Data Collection and Sharing of Travel Conditions

## General Description

This sheet contains objectives on improving the detection of travel conditions by operators and sharing traveler information between jurisdictions and modes.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase the percentage of the transportation system in which travel conditions can be detected remotely via CCTV, speed detectors, etc., to X percent by Y year<br>▪ Increase the percentage of transportation facilities whose owners share their traveler information with other agencies in the region to X percent by Y year<br>▪ Increase the percentage of modes in the region that share their traveler information with other modes in the region to 100 percent by Y year |
| **Performance Measures** | ▪ Percentage of the transportation system in which travel conditions can be detected remotely via CCTV, speed detectors, etc.<br>▪ Percentage of transportation facilities whose owners share their traveler information with other agencies in the region<br>▪ Percentage of modes in the region that share their traveler information with other modes |
| **Anticipated Data Needs** | ▪ Number of miles of roads or rails that are covered by remote detection<br>▪ Number of transportation facilities in the region<br>▪ Count of jurisdictions sharing traveler information with other agencies in the region<br>▪ Count of modes in the region sharing traveler information with other modes |
| **Data Resources and Partners** | ▪ The data for these performance measures would come from querying each of the transportation facility owners and operators in the region on their detection systems and information-sharing practices |
| **TSMO Strategies To Consider** | The TSMO strategies to consider are inherent in the objectives. |

# **Traveler Information:** TI4. Customer Satisfaction

## General Description

The objective in this sheet focuses on improving customer satisfaction with the timeliness, accuracy, and usefulness of traveler information in the region.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase customer satisfaction rating of the timeliness, accuracy, and usefulness of traveler information in the region by W, X, and Z percent, respectively, over Y years |
| **Performance Measures** | ▪ Customer satisfaction ratings of timeliness, accuracy, and usefulness of traveler information |
| **Anticipated Data Needs** | ▪ Customer ratings of traveler information per year |
| **Data Resources and Partners** | ▪ These data would be gathered through surveys among the public and businesses that use the transportation system to move goods and deliver services |
| **TSMO Strategies To Consider** | TSMO strategies to improve customer satisfaction with traveler information include increasing the detection of travel conditions; improving multiagency, multimodal sharing of travel data; and relying on convenient, accessible means of information distribution such as cell phones and websites. |

# **Work Zone Management:** WZ1. Travel Time Delay

## General Description

The objectives in this section focus on reducing travel time delay for travelers within work zones in the region.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the person-hours (or vehicle-hours) of total delay associated with work zones by X percent over Y years<br>▪ Increase the rate of on-time completion of construction projects to X percent within Y years<br>▪ Increase the percentage of construction projects that employ night or off-peak work zones by X percent in Y years |
| **Performance Measures** | ▪ Person hours (or vehicle hours) of delay associated with work zones<br>▪ Percentage of construction projects completed on-time according to established schedule<br>▪ Percentage of construction project employing night or off-peak work zones |
| **Anticipated Data Needs** | ▪ Total travel time in person-hours (or vehicle-hours) of travel impacted by work zones<br>▪ Traffic volume in select work zones<br>▪ Travel times in select work zones<br>▪ Length of work zones<br>▪ Number of construction projects employing night or off-peak work zones<br>▪ Number of construction projects completed on time<br>▪ Total travel time in person-hours (or vehicle-hours) of travel during free-flow conditions<br>▪ Similar data (volume, times, length) on work zones during nonwork time periods |
| **Data Resources and Partners** | ▪ Data would need to be collected by agencies responsible for maintenance and operation of the roadways<br>▪ Partners needed include public safety, departments of transportation, contractors, and utility companies |
| **TSMO Strategies To Consider** | Regions can reduce travel time delay in work zones by shortening lane closure time (particularly during high-traffic hours) and providing travelers with information ahead of time and in real time to avoid the work zone. Other options include smart work zone strategies, such as dynamic lane merges, queue warning systems, and variable speed control.[118] |

118 FHWA. 2014. *Work Zone Intelligent Transportation Systems Implementation Guide*. Report No. FHWA-HOP-14-008. Washington, DC: FHWA. https://ops.fhwa.dot.gov/publications/fhwahop14008/, last accessed September 30, 2022.

# **Work Zone Management:** WZ2. Extent of Congestion

## General Description

The objectives in this section focus on reducing the extent of congestion for travelers within work zones in the region.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce the percentage of vehicles traveling through work zones that are queued by X percent in Y years<br>▪ Reduce the average and maximum length of queues, when present, by X percent over Y years<br>▪ Reduce the average time duration (in minutes) of queue length greater than some threshold (e.g., 0.5 mile) by X percent in Y years |
| **Performance Measures** | ▪ Percentage of vehicles experiencing queuing in work zones<br>▪ Lengths of average and maximum queues in work zones<br>▪ Average duration in minutes of queue length greater than X miles |
| **Anticipated Data Needs** | ▪ Number of vehicles traveling through work zones<br>▪ Number of vehicles traveling through work zones experiencing queuing<br>▪ Average and maximum lengths of work zones<br>▪ Duration of queue length greater than X miles |
| **Data Resources and Partners** | ▪ Data would need to be collected by agencies responsible for operation of the roadways<br>▪ Partners needed include public safety, departments of transportation, contractors, and utility companies |
| **TSMO Strategies To Consider** | Regions can reduce the extent of congestion in work zones by shortening lane closure time (particularly during high-traffic hours) and providing travelers with advance notice and real-time information to avoid the work zones. |

# **Work Zone Management:** WZ3. Travel Time Reliability

## General Description

Objectives in the area of travel time reliability in work zones aim to reduce the variability in travel time so that transportation system users experience consistent and predictable trip times.

| | |
|---|---|
| **Operations Objectives** | ▪ Reduce vehicle-hours of total delay in work zones caused by incidents (e.g., traffic crashes within or near the work zone) |
| **Performance Measures** | ▪ Vehicle-hours of delay due to incidents related to work zones |
| **Anticipated Data Needs** | ▪ Traffic volume through work zones<br>▪ Hours of incident-related delay in work zones |
| **Data Resources and Partners** | ▪ Data would need to be collected by agencies responsible for operation of the roadways<br>▪ Partners needed include public safety, departments of transportation, contractors, and utility companies |
| **TSMO Strategies To Consider** | Regions can improve travel time reliability in work zones by shortening lane closure time (particularly during high-traffic hours) and providing travelers with advance notice and real-time information to avoid work zones. Proper temporary traffic control devices and practices minimize the opportunity for crashes and therefore shorten the incident-related delay in work zones. |

# **Work Zone Management:** WZ4. Construction Coordination

## General Description

Objectives in the area of construction coordination in work zones aim to reduce the potential overlap in construction projects so that transportation system users are not burdened with significant increases in travel time due to multiple construction projects along the same or parallel routes or corridors.

| | |
|---|---|
| **Operations Objectives** | ▪ Establish a process to evaluate opportunities for regional coordination by year Y<br>▪ Consolidate work zones along parallel routes or same corridor<br>▪ Establish a work zone management system within X years to facilitate coordination of work zones in the region |
| **Performance Measures** | ▪ Percentage of capital projects whose project schedules have been reviewed<br>▪ Percentage of work zones on parallel routes or along the same corridor<br>▪ Presence of an established work zone management system |
| **Anticipated Data Needs** | ▪ Capital projects submitted for review<br>▪ Capital project anticipated and actual schedules<br>▪ Map of work zones along area maps |
| **Data Resources and Partners** | ▪ Data would need to be collected by agencies responsible for maintenance and operation of the roadways<br>▪ Partners needed include public safety, departments of transportation, contractors, and utility companies |
| **TSMO Strategies To Consider** | TSMO strategies are implied in the operations objectives. |

# **Work Zone Management:** WZ5. Traveler Information

## General Description

Objectives in the area of traveler information for work zones aim to inform transportation system users of ongoing work zones along routes and corridors in order to reduce the impacts of travel time delay on travelers.

| | |
|---|---|
| **Operations Objectives** | ▪ Provide real-time traveler information regarding work zones by using CMS, 511, traveler information websites, and/or social media technologies for at least X percent of work zones on major arterials, freeways, and transit routes over the next Y years<br>▪ Provide travelers with information on multimodal alternatives to avoid work zones for at least X percent of work zones on major arterials, freeways, and transit routes over the next Y years<br>▪ Provide work zone information (for upcoming and ongoing construction projects) for all impacted businesses or tenants of business centers with X or more employees by year Y |
| **Performance Measures** | ▪ Percentage of work zones on major arterials, freeways, and transit routes for which traveler information is available via CMS, 511, traveler information websites, and/or social media technologies<br>▪ Percentage of work zones on major arterials, freeways, and transit routes for which information on multimodal alternatives to avoid work zones is available to travelers<br>▪ Number of impacted businesses or tenants of business centers of X or more employees receiving work zone information (for upcoming and ongoing construction projects) |
| **Anticipated Data Needs** | ▪ Availability of traveler information for work zones (including multimodal travel alternatives) |
| **Data Resources and Partners** | ▪ Data would need to be collected by agencies responsible for the maintenance and operation of roads and transit routes |
| **TSMO Strategies To Consider** | TSMO strategies are implied in the operations objectives. |

# **Work Zone Management:** WZ6. Customer Satisfaction

## General Description

The objectives in this section focus on improving customer satisfaction with work zone management in the region.

| | |
|---|---|
| **Operations Objectives** | ▪ Increase customer satisfaction with region's work zone management by X percent over Y years |
| **Performance Measures** | ▪ Percentage of customers satisfied with region's work zone management practices |
| **Anticipated Data Needs** | ▪ Customer satisfaction surveys |
| **Data Resources and Partners** | ▪ These data would be gathered through surveys among transportation system users who had used the system while an active work zone was in place |
| **TSMO Strategies To Consider** | TSMO strategies to consider when looking to improve customer satisfaction with work zones include extensive traveler information in advance of work zones and minimizing the effect on travelers during periods when work zones are active. |

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