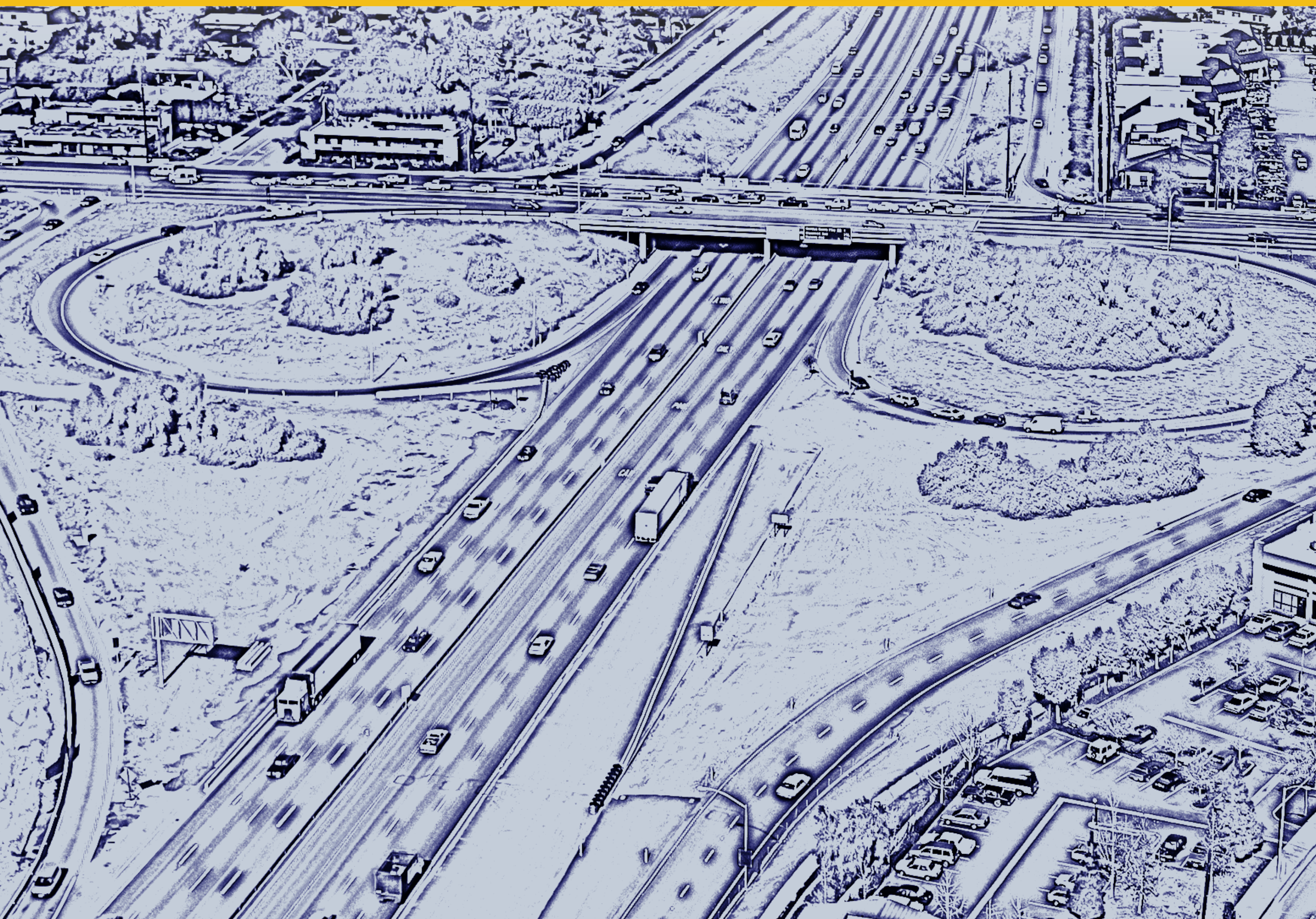
Planning for Transportation Systems Management and Operations

WITHIN CORRIDORS



A DESK REFERENCE

U.S. Department of Transportation
Federal Highway Administration

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7. Authors Jocelyn Bauer, Deena Platman, Michael Grant, Michael Smith, Renee Hurtado, Lindsay Martin, Peng Su, Jiaqi Ma		8. Performing Organization Report No.
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16. Abstract This Desk Reference is designed to equip State, regional, and local transportation operations and planning professionals with the knowledge and tools necessary to effectively plan for and implement transportation systems management and operations (TSMO) within a corridor. Its purpose is to support transportation planners and operations staff to plan for and apply TSMO activities within corridors to achieve a more reliable, efficient, and livable outcome from their existing and planned transportation infrastructure. This document highlights a planning for operations approach at a corridor level to focus on issues, such as mobility, reliability, and safety, from a multimodal perspective and provides a variety of tools to advance TSMO within corridors.		
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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* (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

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LIST OF ACRONYMS

ATDM	active transportation and demand management
ATM	active traffic management
DOT	department of transportation
DTA	dynamic traffic assignment
FHWA	Federal Highway Administration
ICM	integrated corridor management
ITS	intelligent transportation systems
LOS	level of service
MPO	metropolitan planning organization
PennDOT	Pennsylvania Department of Transportation
RCTO	regional concept for transportation operations
SHRP2	Strategic Highway Research Program 2
SMART	specific, measurable, agreed-upon, realistic, and time-bound
SSP	safety service patrol
TDM	transportation demand management
TIM	traffic incident management
TIM-BC	Traffic Incident Management-Benefit-Cost Analysis
TIP	transportation improvement program
TMC	transportation management center
TSMO	transportation systems management and operations
TSP	transit signal priority
TOPS-BC	Tool for Operations Benefit CostAnalysis

CHAPTER 1. INTRODUCTION

OVERVIEW OF DESK REFERENCE

Over the past decade, transportation agencies have increasingly integrated transportation systems management and operations (TSMO) in planning at the statewide and metropolitan levels. Using an objectives-driven, performance-based approach, State departments of transportation (DOTs) and metropolitan planning organizations (MPOs) around the country are working with local jurisdictions, transit agencies, law enforcement, toll authorities, and other partners to manage traffic congestion, improve system reliability, increase safety, and enhance multimodal options using operations solutions. Rather than relying solely on new highway and transit capacity, this approach recognizes that TSMO strategies (e.g., enhanced incident management, traffic signal coordination, transit signal priority (TSP), and traveler information) can often be low in cost, highly effective, and implemented in concert with infrastructure to enhance transportation system performance.

Planning for operations involves identifying operations objectives and performance measures, which guide the identification, prioritization, and selection of investments, programs, and strategies. The result is implementation of programs, projects, and collaborative efforts to better manage and operate transportation systems and services to preserve capacity and improve security, safety, and reliability of the transportation system. Today, many State DOTs and MPOs have policies to improve transportation operations by first managing travel demand and applying management techniques prior to considering additional capacity for a roadway.

While many statewide and regional policies and programs are advancing implementation of effective TSMO strategies, more benefits will occur when TSMO is considered and applied strategically at a smaller scale where many critical implementation decisions are made. Transportation within corridors presents opportunities for agencies to plan for operations at a more-refined geographic scale and at a level where specific and actionable plans can be developed.

Increasingly, transportation agencies are recognizing the value of a corridor approach instead of looking at individual transportation projects on a piecemeal or single facility basis. A corridor approach takes a broad view of the interconnected factors that influence travel and enables more creative and collaborative approaches for addressing transportation problems. While, traditionally, corridor planning has often focused on improving the performance of an individual highway facility, increasingly, transportation planners and operators view corridors as an interconnected network of facilities and services. Managing mobility on a corridor by leveraging all modal choices and assets is called integrated corridor management (ICM), an approach to managing corridors that is being used on several major corridors across the United States.[1] This Desk Reference describes an approach for planning for TSMO within corridors that incorporates the ICM concept of looking beyond a single highway facility to parallel routes and transit services and focuses on the performance of the corridor travel-shed from the customer's perspective.

1 U.S. Department of Transportation, *Integrated Corridor Management (ICM) Knowledge and Technology Transfer Factsheet*, FHWA-JPO-14-151 (Washington, DC: 2014). Available at: http://www.its.dot.gov/factsheets/pdf/ICM_KTT_V5.pdf.

Transportation agencies and stakeholders, however, often have started corridor studies from a perspective that focuses on investment needs to address traffic level of service (LOS) or other issues that result in proposals for expensive capital investments that may be outside the available resources. Moreover, while TSMO may be identified as a priority from a statewide or regional perspective, strategies are often applied at a broad scale (e.g., through a statewide incident management program, a regional ridesharing program, or traveler information systems) without further connecting these programs to corridor operations or designing TSMO strategies and investments that are targeted to address unique corridor challenges and conditions.

This Desk Reference is designed to equip State, regional, and local transportation operations and planning professionals with the knowledge and tools necessary to effectively plan for and implement TSMO within a corridor context. Its purpose is to support transportation planners and operations staff in planning for and applying TSMO activities within corridors to achieve a more reliable, efficient, and livable outcome from their existing and planned transportation infrastructure. Utilizing a planning for operations approach at a corridor level can help to focus on issues (e.g., mobility, reliability, and safety) from a multimodal perspective and bring to light cost-effective demand management and operations solutions that may not otherwise have been fully considered.

The document describes planning for TSMO at the corridor level so that readers can tailor and apply this approach in a variety of corridor contexts. This Desk Reference is founded upon three themes for success that cut across all TSMO planning efforts:

- Use of an objectives-driven, performance-based approach.

Transportation Systems Management and Operations is…?

> *"…[a set of] integrated strategies to optimize the performance of existing 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."*

It "includes - (i) actions, such as traffic detection and surveillance, corridor management, freeway management, arterial management, active transportation and demand management, work zone management, emergency management, traveler information services, congestion pricing, parking management, automated enforcement, traffic control, commercial vehicle operations, freight management, and coordination of highway, rail, transit, bicycle, and pedestrian operations; and (ii) coordination of the implementation of regional transportation system management and operations investments (e.g., traffic incident management, traveler information services, emergency management, roadway weather management, intelligent transportation systems, communication networks, and information sharing systems) requiring agreements, integration, and interoperability to achieve targeted system performance, reliability, safety, and customer service levels."

Source: 23 United States Code Section 101(a)(30).

- Collaboration across agencies, jurisdictions, and modes.
- Linking to overarching planning processes at the metropolitan or statewide level.

The Desk Reference connects readers to other tools and resources developed by the Federal Highway Administration (FHWA) and partners to support a more in-depth understanding of several topics introduced in this document. It draws upon concepts, such as ICM and active transportation demand management (ATDM), that are increasingly focusing attention on collaboration across multimodal system operators and planners to address corridor conditions. Quick reference sheets provide examples of corridor operations objectives, performance measures, and the management and operations strategies that can be applied as readers move forward in applying the components of planning for and implementing TSMO within corridors.

This Desk Reference is a companion to the FHWA *Planning for Transportation Systems Management and Operations within Subareas: A Desk Reference*, a resource that addresses the specific needs of organizations planning for TSMO at the local or subarea level.[2]

WHO SHOULD USE THIS DESK REFERENCE?

This Desk Reference is intended for the transportation planning or operations professional who is looking to address specific questions on planning for TSMO within corridors, as well as the professional who wants to gain a comprehensive understanding of how to successfully improve travel and goods movement on a corridor. This document brings together planning and operations approaches, practices, and lessons that have been developed over the past 10 years and provides consolidated assistance on planning for TSMO at the corridor level. Several sections serve as launching points to related FHWA documents that provide more in-depth information and tools. Readers will find links and references to technical assistance materials alongside related content introduced in this Desk Reference.

ORGANIZATION

The desk reference is organized into six sections:

Chapter 1: Introduction

Provides a brief introduction to TSMO within corridors and planning for TSMO in a variety of corridor contexts. Helps readers identify the need for TSMO planning at the corridor level.

Related technical assistance materials: Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach – A Guidebook.[3]

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2 Federal Highway Administration, *Planning for Transportation Systems Management and Operations within Subareas: A Desk Reference*. Available Spring 2016 at http://www.ops.fhwa.dot.gov/plan4ops/index.htm.

3 Federal Highway Administration and Federal Transit Administration, *Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach – A Guidebook*, FHWA-HOP-10-026 (Washington, DC: 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10026/.

Chapter 2: Planning for Transportation Systems Management and Operations within Corridors

Makes the case for TSMO planning to achieve coordinated and strategic implementation and ongoing use of TSMO strategies. Provides an overview of the planning context for TSMO on a corridor, and describes examples of current practice.

Related technical assistance materials:

- *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*.[4]
- *Performance Based Planning and Programming Guidebook*.[5]
- *Statewide Opportunities for Integrating Operations, Safety and Multimodal Planning: A Reference Manual.*[6]
- *The Collaborative Advantage: Realizing the Tangible Benefits of Regional Transportation Operations Collaboration.*[7]
- *Regional Transportation Operations Collaboration and Coordination: A Primer for Working Together to Improve Transportation Safety, Reliability, and Security.*[8]

Chapter 3: Approach to Corridor Planning for Transportation Systems Management and Operations

Lays out a common-sense approach to planning for TSMO on a corridor for a variety of corridor contexts. Takes the reader from building a team for the effort to selecting TSMO strategies that will best achieve the corridor operations objectives. Provides easy-to-use reference guides for a range of operational objectives relevant to multimodal corridors, including corridor travel time, traffic signal management, transit priority, and bicycle and pedestrian accessibility and efficiency.

Related technical assistance materials:

In addition to the resources listed for Chapters 1 and 2, this chapter draws from:

- *Operations Benefit/Cost Analysis Desk Reference*.[9]
- *The Role of Transportation Systems Management & Operations in Supporting Livability and Sustainability: A Primer*.[10]

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4 Federal Highway Administration and Federal Transit Administration, *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*, FHWA-HOP-10-027 (Washington, DC: 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10027/.

5 Federal Highway Administration, *Performance Based Planning and Programming Guidebook*, FHWA-HEP-13-041 (Washington, DC: September 2013). Available at: http://www.fhwa.dot.gov/planning/performance_based_planning/pbpp_guidebook/.

6 Federal Highway Administration, *Statewide Opportunities for Integrating Operations, Safety and Multimodal Planning: A Reference Manual*, FHWA-HOP-10-028 (Washington, DC: June 2010). Available at: http://www.fhwa.dot.gov/planning/processes/statewide/practices/manual/index.cfm.

7 Federal Highway Administration, *The Collaborative Advantage: Realizing the Tangible Benefits of Regional Transportation Operations Collaboration*, FHWA-HOP-08-001 (Washington, DC: August 2007). Available at: http://www.ops.fhwa.dot.gov/publications/benefits_guide/index.htm.

8 Federal Highway Administration, *Regional Transportation Operations Collaboration and Coordination: A Primer for Working Together to Improve Transportation Safety, Reliability, and Security*, FHWA-OP-03-008 (Washington, DC: 2003). Available at: http://ntl.bts.gov/lib/jpodocs/repts_te/13686.html.

9 Federal Highway Administration, *Operations Benefit/Cost Analysis Desk Reference*, FHWA-HOP-12-028 (Washington, DC: May 2012). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop12028/index.htm.

10 Federal Highway Administration, *The Role of Transportation Systems Management and Operations in Supporting Livability and Sustainability: A Primer*, FHWA-HOP-12-004 (Washington, DC: January 2012). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop12004/.

- *Guide for Highway Capacity and Operations Analysis of Active Transportation and Demand Management Strategies*.[11]
- *Integrated Corridor Management: Implementation Guide and Lessons Learned*.[12]
- PlanWorks: Linking Planning and Operations.[13]

Chapter 4: Moving to Implementation: Transportation Systems Management and Operations within Corridors

Offers information on how to go from plans for TSMO to implementation, monitoring, and maintenance of TSMO strategies. This includes obtaining funding for TSMO, agreeing upon organizational roles and responsibilities, applying systems engineering, and regularly evaluating the effectiveness of the implemented strategies in relation to the corridor objectives.

Related technical assistance materials:

- *Applying a Regional ITS Architecture to Support Planning for Operations: A Primer*.[14]
- *Programming for Operations: MPO Examples of Prioritizing and Funding Transportation Systems Management and Operations Strategies*.[15]
- *Designing for Transportation Management and Operations: A Primer*.[16]

Chapter 5: Toolbox for Effective Transportation Systems Management and Operations Planning

Introduces several tools to help ensure effective planning for TSMO at the corridor level, including scenario planning, analysis tools, and benefit-cost analysis.

Related technical assistance materials:

- *The Regional Concept for Transportation Operations: A Practitioner's Guide*.[17]

Chapter 6: Taking Action

Describes key actions that readers can take to jump start their efforts to advance TSMO on a corridor.

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11 Federal Highway Administration, *Guide for Highway Capacity and Operations Analysis of Active Transportation and Demand Management Strategies*, FHWA-HOP-13-042 (Washington, DC: June 2013). Available at: http://ops.fhwa.dot.gov/publications/fhwahop13042/fhwahop13042.pdf.

12 U.S. Department of Transportation, *Integrated Corridor Management: Implementation Guide and Lessons Learned*, FHWA-JPO-12-075 (Washington, DC: February 2010). Available at: http://ntl.bts.gov/lib/47000/47600/47670/FHWA-JPO-12-075_FinalPKG_508.pdf.

13 Federal Highway Administration, PlanWorks: Linking Planning and Operations, Web site. Available at: https://fhwaapps.fhwa.dot.gov/planworks/Application/Show/7.

14 Federal Highway Administration, *Applying a Regional ITS Architecture to Support Planning for Operations: A Primer,* FHWA-HOP-12-001 (Washington, DC: February 2012). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop12001/index.htm.

15 Federal Highway Administration, *Programming for Operations: MPO Examples of Prioritizing and Funding Transportation Systems Management and& Operations Strategies*, FHWA-HOP-13-050 (Washington, DC: September 2013). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop13050/index.htm.

16 Federal Highway Administration, *Designing for Transportation Management and Operations: A Primer,* FHWA-HOP-13-013 (Washington, DC: February 2013). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop13013/index.htm.

17 Federal Highway Administration, *The Regional Concept for Transportation Operations: A Practitioner's Guide*, FHWA-HOP-11-032 (Washington, DC: July 2011). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop11032/index.htm.

TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS WITHIN CORRIDORS

What is Transportation Systems Management and Operations?

TSMO encompasses a broad set of strategies that aim to optimize the safe, efficient, and reliable use of existing and planned transportation infrastructure for all modes. TSMO is undertaken from a systems perspective, which means that these strategies are coordinated with related strategies and across multiple jurisdictions, agencies, and modes. TSMO strategies range from regional traffic signal systems management to shared-use mobility initiatives (see Table 1 for an expanded list of strategies). TSMO includes efforts to operate the multimodal transportation system and activities to manage travel demand.

TSMO proactively addresses a variety of transportation system user needs by:[18]

- Influencing travel demand in terms of location, time, and intensity of demand.
- Effectively managing the traffic or transit crowding that results.
- Anticipating and responding to planned and unplanned events (e.g., traffic incidents, work zones, inclement weather, and special events).
- Providing travelers with high-quality traffic and weather information.
- Ensuring that the unique needs of the freight community are considered and included in all of the above.

TSMO strategies are supported by both institutional and technology-based activities. For example, TSMO is enabled by memoranda of agreement between agencies, operational policies and procedures, and shared resources (e.g., interoperable communications systems, centralized traffic signal operations, and closed circuit television video sharing).

What are the Benefits of Transportation Systems Management and Operations?[19]

TSMO strategies have allowed transportation agencies to address transportation issues in the near-term, with lower-cost solutions. TSMO strategies deliver a variety of benefits. These include:

- **Safer travel:** For example, freeway ramp metering has been demonstrated to reduce crashes by 15 to 50 percent.
- **More free time:** Among other time-saving TSMO strategies, traffic signal retiming decreases delay on roads by 13 to 94 percent, and TSP reduces transit delay by 30 to 40 percent.
- **Improved reliability:** Strategies that reduce unexpected delays (e.g., incident management, road weather management, and work zone management) enable the public and freight shippers to reduce unexpected delays. TSP improves transit on-time performance.

18 Federal Highway Administration, Office of Operations, "The Operations Story," Presentation, 2012, Jeffrey A. Lindley.

19 U.S. Department of Transportation, Intelligent Transportation Systems Joint Program Office, *Investment Opportunities for Managing Transportation Performance through Technology*, January 2009. Available at: http://www.its.dot.gov/press/pdf/transportation_tech.pdf.

- **Less wasted fuel:** Traffic incident management (TIM) programs help to clear incidents safely and quickly. They reduce time lost and fuel wasted in traffic backups. For example, Georgia's TIM program (NaviGAtor) reduced annual fuel consumption by 6.83 million gallons per year. National studies have shown that integrating traveler information with traffic and incident management systems could improve fuel economy by about 1.5 percent.
- **Cleaner air:** TSMO strategies result in cleaner air by encouraging alternative modes of transportation (e.g., transit, ridesharing, biking, walking, and telecommuting) and reducing excess idling due to congested bottlenecks. Electronic toll collection reduced harmful emissions at Baltimore, Maryland, toll plazas by 16 to 63 percent.

Sample of Transportation Systems Management and Operations Strategies Relevant to Corridors

Many TSMO strategies are applicable and effective at the corridor level. Table 1 lists TSMO strategies that agencies can consider when looking to improve the operation of their corridors.

Table 1. Sample of transportation systems management and operations strategies relevant to corridors.

TSMO Strategies	Supporting Activities
Traffic Management and Operations	• Active traffic management: ◦ Variable speed limits. ◦ Changeable lane assignment. • Freeway/arterial integrated corridor management. • Managed lanes (high-occupancy vehicle/toll lanes). • Ramp metering. • Traffic surveillance. • Traffic signal control: ◦ Enhanced multimodal traffic signal operations. ◦ Emergency vehicle preemption. ◦ Transit signal priority. ◦ Truck signal priority. • Warning systems (queue, curve, intersection, size, and speed). • Roadside truck electronic screening/clearance programs. • Bicycle and pedestrian crossing enhancements. • Use of connected vehicles for management.

Table 1. Sample of transportation systems management and operations strategies relevant to corridors. (Continued)

TSMO Strategies	Supporting Activities
Traveler Information	• Local/regional multimodal traveler information. • Roadside traveler information dissemination. • Predictive traveler information. • Real-time transit arrival information. • Trip planning and routing systems.
Road Weather Operations	• Road weather information systems. • Winter roadway operations.
Maintenance and Construction Management	• Maintenance and construction activity coordination. • Work zone management.
Incident and Emergency Management	• Traffic incident management. • Emergency management. • Computer-aided dispatch integration. • Emergency vehicle routing.
Public Transportation Management	• Advanced transit operations management. • Electronic fare collection and integration. • Transit surveillance and security. • Multimodal travel connections.
Transportation Demand Management	• Traveler information marketing campaigns. • Route planning tools. • Employer programs and commuter incentives. • Rideshare support. • Telecommuting. • Congestion pricing. • Corridor investments to support mode transfers or trip ends.
Complementary Strategies that Support TSMO	• Bottleneck removal. • Access management. • High performance transit.

TSMO = transportation systems management and operations.

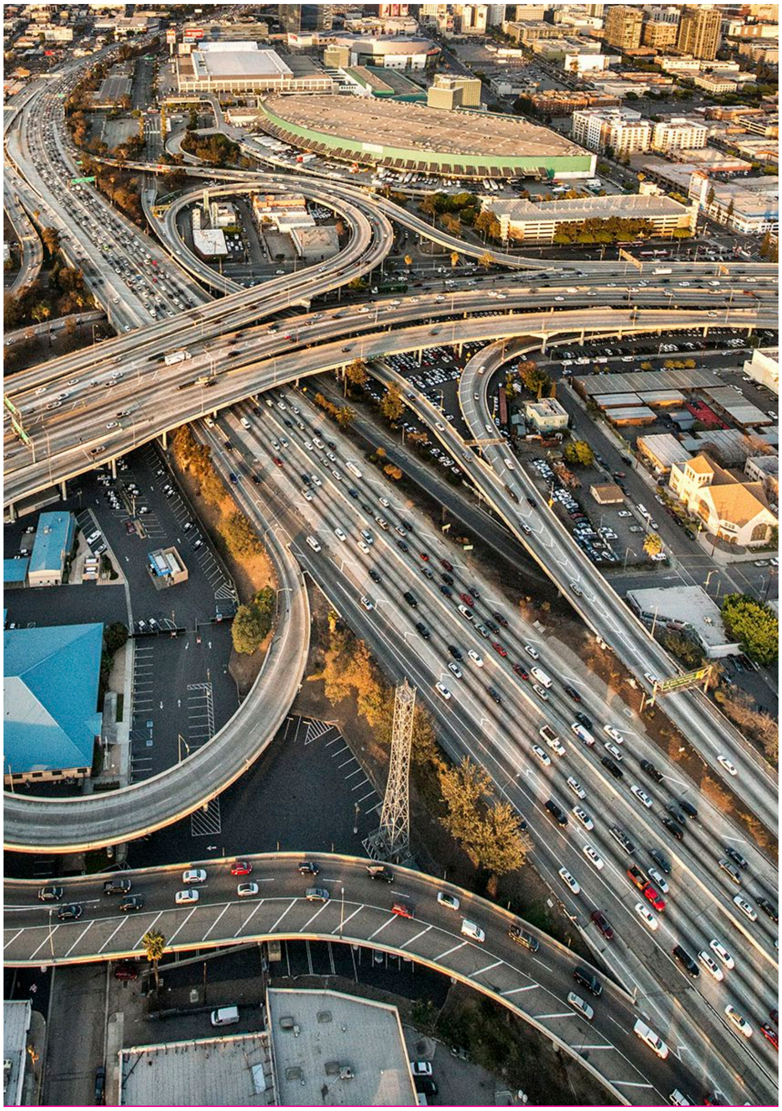
Transportation Systems Management and Operations within Corridors: Understanding the Corridor Contexts[20]

When developing strategies for TSMO within corridors, it is critical to understand the context for the corridor, including surrounding land uses and development patterns, available travel options (e.g., highway, road network, transit, and non-motorized options), and the types of system users (e.g., freight, commuters, and interstate travelers) and their needs and priorities. A corridor generally includes multiple freeways, arterial roadways, transit services, bicycle and pedestrian connections, park-and-ride lots, and rideshare services serving people traveling in similar directions.

Different types of corridors are found in urban, suburban, and rural contexts. Many corridors traverse multiple contexts. To optimize performance of the transportation system and meet user needs, TSMO within a corridor should reflect the unique form, use, and needs of the corridor.

Some typical types of contexts include:

A Complex Corridor in an Urbanized Area, with a Major Arterial and/or Transit Line "Spine"
Urban centers are dense areas with high levels of activity and where complex, multimodal transportation systems offer options for taking transit, walking, and biking. Corridor planning in urban centers may be focused on a major arterial roadway, a rail line or major bus corridor, or a combination. TSMO strategies for urban corridors may focus on multimodal system performance and managing travel demand and may include a wide array of strategies, including parking management, TSP, dynamic ridesharing, bikesharing, pedestrian count-down signals, real-time, multimodal traveler information, and traffic signal coordination.



Source: IStock/PVuckovic.

Figure 1. Photo. Corridor in urban area which may handle a dynamic mix of vehicle traffic, transit services, bicyclists, and pedestrians.

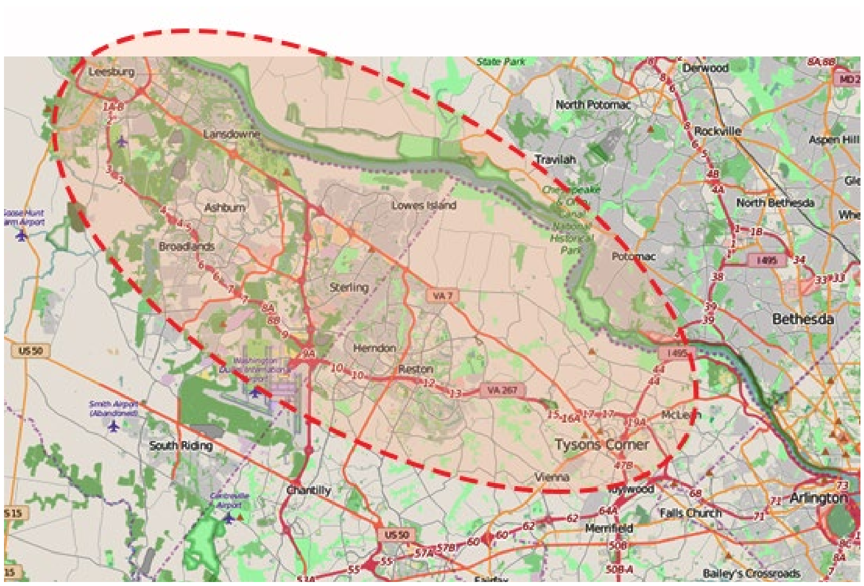
20 California Department of Transportation, *Smart Mobility, 2010. A Call to Action for the New Decade* (California: 2010). Available at: http://www.dot.ca.gov/hq/tpp/offices/ocp/smf_files/SmMblty_v6-3.22.10_150DPI.pdf.

A Complex Corridor in a Suburban or Urbanized Area, with a Major Freeway as a "Spine" and Associated Alternatives

Suburban communities are less dense than a downtown core, and corridors are often defined based on major highways or arterials that may serve a combination of commuters, other travelers, and freight. For these corridors, TSMO strategies may focus on managing traffic and incidents to provide predictable travel times, shifting demand to transit and ridesharing, and balancing travel loads across the network. Examples of TSMO investments may include adaptive ramp metering, dynamic high-occupancy vehicle or managed lanes, and dynamic merge or junction control.

Source: Michael Grant.

Figure 2. Photo. The Dulles Corridor in Northern Virginia is an example of a corridor defined around a major highway and passenger rail spine with adjoining roadways, park-and-ride facilities, and surrounding business and residential land uses.



Source: OpenStreetMap.

Figure 3. Map. Dulles Corridor includes multiple parallel roads, bus lines, rail, and a multi-use trail.

Corridors in Rural Areas

In rural areas, development is limited and dispersed, and travel options are often limited. While congestion is generally a minor concern, traffic safety and weather conditions (e.g., snow, ice, rain, and fog) are often significant concerns. Some rural areas also may experience seasonal, off-peak congestion due to tourism or events (e.g., festivals, etc.). In addition, in some small towns, stretches of State highways serve as main streets and may attract pedestrian and bicycle use. Given the infrequent congestion on rural roads, the more-aggressive TSMO strategies used in urban and suburban areas may not warrant deployment. TSMO strategies for corridors in rural areas require a flexible approach tailored to specific characteristics of the corridor and may include strategies such as road weather management and dynamic routing.


Source: Thinksock.

Figure 4. Photo. TSMO strategies within rural corridors may include multistate traveler information for long-haul truck drivers related to weather, incidents, and road closures.

These are just three examples of ways in which corridor contexts can differ. Many States and communities define corridor contexts in their own unique ways. For instance, in its Smart Mobility Framework, the California Department of Transportation (Caltrans) has defined seven “place types,” which are used to create distinct contexts for transportation investments and operational performance:

- Urban centers.
- Close-in compact communities.
- Compact communities.
- Suburban communities.
- Rural and agricultural lands.
- Protected lands.
- Special use areas.[21]

These different contexts are used to define appropriate sets of strategies, encompassing both infrastructure investments and operational strategies. For instance, Caltrans notes that reliability is a key objective guiding investment and operations in urban centers, providing people with the ability to conveniently use walk, bike, and high-capacity transit modes, as well as supporting street and intersection operations that focus on providing predictable travel times with traffic and incident management. Conversely, rural and agricultural lands have fewer modal options due to their more limited activity areas. It also is important to consider that the context may change throughout the length of a corridor, and the different segments may warrant different TSMO strategies.

21 California Department of Transportation, *Smart Mobility, 2010. A Call to Action for the New Decade* (California: 2010). Available at: http://www.dot.ca.gov/hq/tpp/offices/ocp/smf_files/SmMblty_v6-3.22.10_150DPI.pdf.

Typically, a corridor will span multiple jurisdictions and agencies responsible for different components of system operations, including traffic signals, traveler information systems, and maintenance functions. Consequently, involving a wide range of agencies with corridor responsibilities is critical to taking a successful corridor approach to TSMO.

Who Performs Transportation Systems Management and Operations within Corridors?

While the lead agencies in managing and operating the transportation system are typically the owners of the facilities (i.e., State and local DOTs, roadway authorities, and transit agencies), many other partners are involved in how corridors are managed, and these relationships are critical for corridor operations. For example, effective TIM involves coordination among several different groups, including responders from a variety of disciplines (e.g., law enforcement, fire and rescue, and towing and recovery), as well as the DOT or transportation management center (TMC) staff. Implementation of TSP requires coordination between transit agencies that operate services and DOTs that are responsible for arterial roadway operations. Work zone management involves coordinating alternate routes between agencies and their contractors involved in construction and infrastructure renewal, other transportation agencies and services that use the facility or connect to the facility, as well as TMC and public relations staff who provide information to the public. Transportation demand management (TDM) programs often work directly with employers to promote travel options to their employees and may include efforts to support customized travel planning in communities, support for school-based programs to support bicycling and walking, and other options.

At a regional level, MPOs play a critical role in TSMO, both by convening collaborative relationships among diverse agencies and organizations that play a role in transportation system operations, as well as through implementation of TSMO programs. For example, the Metropolitan Transportation Commission in the Bay Area of California operates the Bay Area 511 system. The Denver Regional Council of Governments provides engineering support to cities and counties in the region for signal retiming. The National Capital Region's Transportation Planning Board manages the region's Commuter Connections program, which supports ridesharing, transit, walking, biking, and other options.[22]

Over the past decade, TSMO has benefited from rapidly advancing technology and an increased emphasis on cost-effective transportation solutions. TSMO now appears to be headed into an era where State DOTs are elevating TSMO as a top priority and systematically increasing their operational capabilities. MPOs are consistently planning and programming for TSMO and spearheading regional collaboration for TSMO. Local governments, with responsibility for operating traffic signals, transit services, road maintenance and snow removal, local police forces, and other services, play an increasingly important role as TSMO strategies become part of corridor, local, and subarea plans. Advances in vehicle and infrastructure technology and communication systems promise to shift the paradigm of how infrastructure, people, vehicles, and operators interact to change the way safe, efficient, and reliable transportation is provided.

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22 National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, Commuter Connections, Web site. Available at: http://www.commuterconnections.org/.

A wide range of transportation-related agencies often plays a role in how transportation systems are managed and operated, such as:

- Local transportation agencies, which are responsible for arterial traffic signals, pedestrian signals, and crosswalks, as well as snow removal and winter weather operations.
- Transit agencies – regional and/or local – operate public transportation services along the corridor, which may include bus services, commuter rail, or other rail transit services.
- State DOTs typically operate freeway management systems, 511 traveler information, and park-and-ride lots, and often are responsible for snow removal on major freeways or other roadways within the corridor.
- MPOs may operate regional rideshare or TDM programs and may initiate targeted efforts to communities and businesses in the corridor.
- Local transportation management associations or organizations serve businesses or communities within the corridor.
- Toll authorities.

Even in cases where a TSMO strategy is being implemented or operated by a single entity or agency (e.g., a freeway management system that is managed by a State DOT), there are typically many different partners that should help to inform or play a role in those operations, such as:

- Law enforcement (responsible for incident management and parking enforcement).
- Fire and rescue.

Broad Range of Stakeholders Involved in I-95/I-395 Integrated Corridor Management (ICM) System Concept of Operations

The Virginia Department of Transportation worked with a broad range of stakeholders to develop an ICM Concept of Operations, for the I-95/I-395 corridor between Fredericksburg and the District of Columbia line. This effort engaged the Virginia Department of Rail and Public Transportation, three metropolitan planning organizations (Metropolitan Washington Council of Governments, Potomac and Rappahannock Transportation Regional Commission, and George Washington Regional Commission), city and county governments, the Northern Virginia Regional Commission, the Northern Virginia Transportation Commission, the U.S. Department of Defense, and other stakeholders. The corridor contains numerous options for transit (rail and bus), along with rideshare and carpool activities, and contains substantial employment centers associated with the Federal government, including Fort Belvoir, Quantico, the Mark Center, and the Pentagon. Strategies were developed to balance travel between private vehicles and public transit, encourage the use of carpool and rideshare options, and advance traffic management strategies.

Source: Virginia Department of Transportation, I-95/I-395 Integrated Corridor Management Initiative - See more at: http://www.itsa.wikispaces.net/file/view/ITSA_ICM+Workshop_Hari+Sripathi_VDOT.pdf/340972496/ITSA_ICM%20Workshop_Hari%20Sripathi_VDOT.pdf.

- Local governments (responsible for street and off-street parking policies, zoning, and access management).
- Local businesses and venues along a corridor that serve as activity centers.
- Ports, freight distribution centers, and other facilities.
- Neighborhood associations and other community groups.

TSMO strategies, whether or not they are implemented and operated by a single entity or agency, involve building consensus around needs, priorities, performance measures, resources, and responsibilities. As a result, the corridor planning or study process should recognize the importance of key stakeholders in the corridor who will be affected by—and whose support is needed to identify and advance—appropriate TSMO strategies in the corridor, including non-traditional stakeholders. Local businesses, neighborhood associations, bicycle/pedestrian advocates, and others will likely be engaged in the decision-making process and will need to be informed of alternatives, benefits, and potential or perceived negative effects of TSMO strategies under consideration. Rather than optimizing individual services or facilities, effective corridor operations involve optimizing from an overall system perspective.

CHAPTER 2. PLANNING FOR TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS WITHIN CORRIDORS

WHY IS PLANNING FOR TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS WITHIN CORRIDORS NEEDED?

The benefits of transportation systems management and operations (TSMO) within corridors are achieved through coordinated, strategic implementation and ongoing support through day-to-day operations and maintenance, and this requires planning. All TSMO strategies require some investment of resources, which could be in the form of funding, data, equipment, technology, or staff time. To obtain these resources and then make the best use of them, planning is needed. If TSMO is to be implemented effectively within corridors, there are a number of planning activities that need occur prior to implementation:

- Properly scoping the TSMO effort by obtaining input from all stakeholders in the corridor.
- Collaboration between all agencies or parties involved in the TSMO effort.
- Identification and agreement on the need for action and desired corridor objectives (or outcomes).
- Consideration of alternative solutions.
- Estimation of impacts (good and bad) on the corridor.
- Identification of resource needs and sources.
- Approval from relevant decisionmakers.
- Plan for ongoing corridor operations and maintenance.

Traditionally, transportation planning and TSMO have been largely independent activities. Planners typically focus on long-range transportation plans and projects programming. Operators are primarily concerned with addressing immediate system needs, such as incident response, traffic control, and work zone management. Planning for TSMO connects these two vital components of transportation, bringing operations needs and solutions to the corridor planning processes and likewise bringing longer-term, strategic planning to operations managers.

The following examples demonstrate the need for planning for TSMO within corridors. The examples are a small set of commonly missed opportunities for improving the operational performance of corridors through TSMO planning.

Incorporating TSMO as a Consideration into Corridor Planning Processes Led by Planning Groups

When planning groups conduct corridor-level plans, the TSMO perspective is often absent. This may occur because planners lack familiarity and experience with operations strategies. TSMO activities generally occur outside of the plan, design, and build functions for capital infrastructure investment. Often, TSMO is afforded a place alongside system maintenance activities in agency organizational charts, relegating TSMO activities to what happens after the planning, design, and build out is complete. In this way, agencies miss the opportunity to integrate TSMO with the tools that can help address community needs and achieve community goals. By incorporating TSMO planning practices and strategies into the stages of goal setting, existing conditions assessment, alternatives development and analysis, and project selection, the results include a balanced plan that has both operational and infrastructure investments that make it more financially feasible and achievable in the near term.

Linking Corridor Optimization Efforts Led by Operations Groups with the Overarching Policy Framework and Plans of Their Agency

Coordination activities and integration with long-range planning efforts are often overlooked when advancing transportation operations projects. For example, a regional traffic operations group initiates a process to provide real-time traveler information along a major corridor, including freeway and arterial travel times. Their vision is to install several variable message signs along the corridor facilities and support it with travel time data from a third-party data provider. By coordinating with the overarching planning process, the traffic operations group can align the operational benefits with the broader goals identified in long-range transportation plans to draw champions at the local and regional levels, who may, in turn, open doors to funding and other resources, including integration with other projects.

Using the Systems Engineering Process to Plan for ITS or TSMO

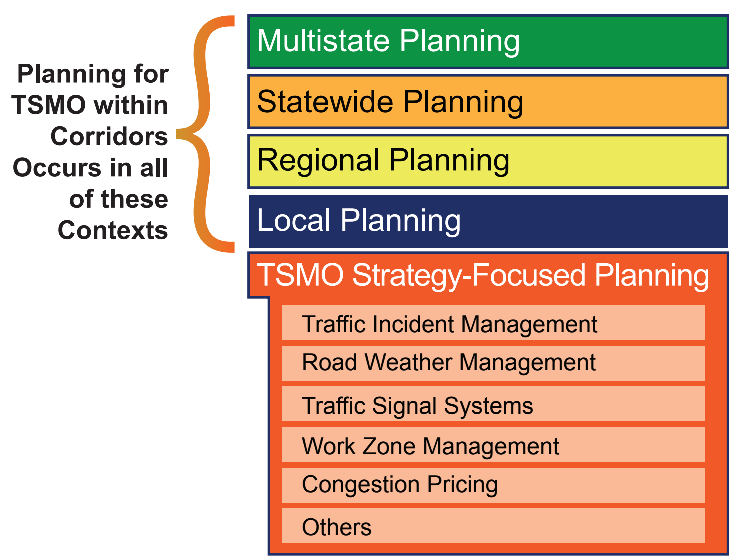
The use of the systems engineering process to support the implementation of intelligent transportation system (ITS) or TSMO deployments along a corridor is sometimes overlooked. As an illustrative example, agency planners forecast 50 percent traffic volume growth on a key corridor within 10 years. In response, the traffic operations group decides to install adaptive signal control technology. The agency procures equipment and software without completing a systems engineering process. Implementation falters with the discovery that the selected solution fails to meet key needs. Benjamin Franklin wrote, “If you fail to plan, you are planning to fail!” This holds particularly true for complex technology solutions like ITS. When agencies use good planning practices, like systems engineering, to clarify needs, goals, and requirements, they minimize the risk of failure. Failed projects, especially when highlighted by the media, make it harder to secure funding and to achieve buy-in from the public and key decisionmakers for future projects.

PLANNING CONTEXTS FOR TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS WITHIN CORRIDORS

Planning for TSMO occurs at the multistate, statewide, regional, subarea, local, corridor, and project levels. It may be a stand-alone effort at any of those levels, or it may be integrated into a more comprehensive planning process, such as the development of a State long-range transportation plan or metropolitan transportation plan. Operations may be incorporated in a regional or statewide safety plan, freight mobility plan, transit plan, or sustainability plan. TSMO planning efforts can range from informal to formal and cover a spectrum of temporal scales, from next week to the next 30 to 50 years. In addition, the functional scope of TSMO planning on a corridor may be a single TSMO strategy or program (e.g., regional signal coordination, transportation management centers (TMCs), and traffic incident management (TIM)) or a comprehensive set of TSMO strategies, and every combination in between.

Likewise, planning for TSMO at the corridor level is performed at a variety of scales and scopes and in several institutional contexts. For example, some State departments of transportation (DOTs) (e.g., Pennsylvania DOT) and metropolitan planning organizations (MPOs) (e.g., Puget Sound Regional Council) use corridors as the geographic basis for their TSMO planning or congestion management process. In other cases, agencies focus on operations improvements for a single corridor.

This section explores the range of planning contexts for TSMO within corridors (Figure 5). These contexts include multistate, statewide, regional, and local planning. That includes planning that is focused on one or more TSMO strategies such as traffic incident management or road weather management. Below is a description of the common contexts for TSMO planning and how planning for TSMO within corridors has been involved. Following these descriptions is a more in-depth look at the corridor planning contexts in terms of four dimensions: the motivation or impetus for the corridor TSMO planning effort ("why"), the lead organization ("who"), the timeframe for the plan ("when"), and the geographic extent of the corridor ("where").



TSMO=Transportation Systems Management and Operations.

Figure 5. Diagram. Transportation systems management and operations planning within corridors occurs in a range of planning contexts and includes planning for a specific TSMO strategy.

Advancing Transportation Systems Management and Operations within Corridors in Several Planning Contexts

At the **statewide** level, planning for TSMO takes many forms. Planning for how TSMO will be conducted may be incorporated broadly in the State's long-range transportation plan, which is developed by the State DOT in collaboration with the State's MPOs and other transportation stakeholders. The State's long-range transportation plan may contain TSMO elements that are part of a larger multistate initiative that individual States agree to support (e.g., a multistate road-weather information system or traveler information system). TSMO planning also may be performed at the district level, across a state, where each State DOT district develops its own strategic operations plan in coordination with the MPOs and local agencies in the DOT district. Alternatively, TSMO planning may occur at the corridor level, across the state, especially where a State has identified priority corridors where there are specific needs (e.g., improved goods movement from a seaport; more efficient commuter options to and from major employment areas; or better access to major entertainment, recreational, or sports venues). The 2012 Surface Transportation Authorization Act, Moving Ahead for Progress in the 21st Century, requires that "[t]he statewide transportation plan and the transportation improvement program developed for each State shall provide for the development and integrated management and operation of transportation systems and facilities…"[23] States are encouraged to include TSMO in their long-range transportation plans developed through performance-based planning.[24] For more information on planning for TSMO at the Statewide level, readers should consult the Federal Highway Administration's (FHWA's) *Statewide Opportunities for Integrating Operations, Safety and Multimodal Planning: A Reference Manual*.[25]

At the **metropolitan** level, planning for TSMO often is led or facilitated by the MPO, which convenes a group of TSMO stakeholders, typically including State DOT district or regional offices, to advance TSMO in the region. Metropolitan planning for operations is frequently conducted in coordination with the development of the metropolitan transportation plan as a means of including TSMO priorities and strategies into the overall metropolitan transportation plan and including TSMO program and projects in the transportation improvement program (TIP). The FHWA recommends that planning for TSMO at the metropolitan (as well as statewide) level be driven by outcomes-oriented objectives and performance measures. Rather than focusing on projects and investment plans, the planning for operations approach emphasizes, first, developing objectives for transportation system performance, and then using performance measures and targets as a basis for identifying solutions and developing investment strategies. This is called the "objectives-driven, performance-based approach." The FHWA provides more information on using this approach to integrate TSMO into the metropolitan transportation planning process in a key document: *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*.[26] Planning for TSMO within corridors occurs at the metropolitan level when MPOs use corridors as the geographic unit for conducting the congestion management process or other operations related planning.

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23 Title 23 United States Code Section 135(a).

24 Federal Highway Administration, *Model Long-Range Transportation Plans: A Guide for Incorporating Performance-Based Planning,* FHWA-HEP-14-046 (Washington, DC: August 2014). Available at: http://www.fhwa.dot.gov/planning/performance_based_planning/mlrtp_guidebook/.

25 Federal Highway Administration, *Statewide Opportunities for Integrating Operations, Safety and Multimodal Planning: A Reference Manual,* FHWA-HOP-10-028 (Washington, DC: June 2010).Available at: http://www.fhwa.dot.gov/planning/processes/statewide/practices/manual/index.cfm.

26 Federal Highway Administration and Federal Transit Administration, *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*, FHWA-HOP-10-027 (Washington, DC: 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10027/.

Local or subarea planning refers to planning which addresses

> *"A defined portion of a region (such as a county) in more detail than area-wide or regional plans. Subarea studies are similar to corridor studies, with the distinction that a subarea study generally addresses more of the total planning context and the broader transportation network for the area."*[27]

Because subarea planning addresses a fairly broad planning context, this often involves a larger number of potentially affected stakeholders and comprehensive visioning for the area. Local studies may address a municipality (city or county) or other area, and may include a wide array of different issues, including transportation, land use, and urban design. Corridor planning for TSMO also occurs at the local level (e.g., when one or more local agencies want to address mobility issues on an individual corridor).

Corridor planning focuses on planning for a linear system of multimodal facilities in which an existing roadway or transit facility will typically serve as the "backbone" of the corridor. The travel-shed helps determine the length and breadth of a corridor area, which usually connects major activity centers or logical destinations. Corridors can range in length from a few miles in an urban location to hundreds of miles for State or multistate corridors. In addition to different spatial scales, corridors also may have different modal foci (e.g., freight rail corridor, high capacity passenger rail corridor, limited-access highway corridor, or bus rapid transit corridor). Usually, corridor planning focuses on a combination of modes and a network of facilities.

Statewide and metropolitan long-range transportation plans establish the policy framework for corridor, local, and subarea planning and provide guidance in terms of regional and statewide priorities related to goals, objectives, strategies, and transportation investments. MPOs, counties, and cities commonly lead local and subarea planning efforts. Corridor studies and planning activities are often performed by State DOTs and MPOs.

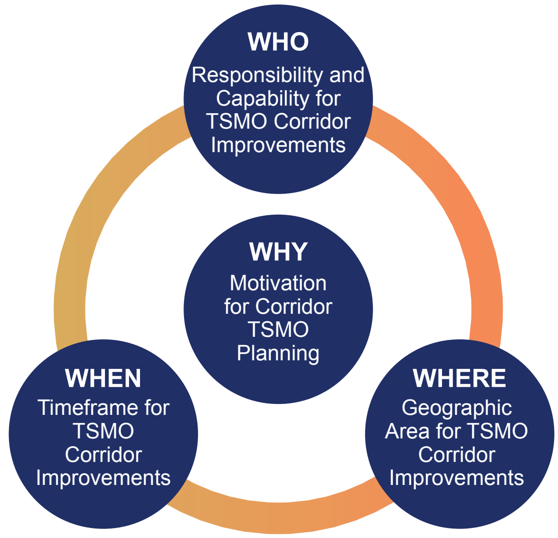
Corridor improvements to achieve goals and objectives may include major capital investments in new capacity or infrastructure, which are typically incorporated into the State or MPO long range transportation plan. They also may take the form of improvements in the way the existing capacity in the corridor is managed, including investments in TSMO strategies that also may require capital investment and should be included in State and MPO long-range plans and TIPs as part of the planning for operations approach.

Statewide and regional TSMO or ITS plans and associated architectures are a resource that can inform corridor, local, and subarea planning activities. These plans typically include existing and planned TSMO strategies that have been identified for statewide or metropolitan area use. Some include suggested TSMO strategies or implementation projects for specific subareas or an entire toolbox of potential strategies to consider.

27 Federal Highway Administration, *Guidance on Using Corridor and Subarea Planning to Inform NEPA* (Washington, DC: April 2011). Available at: http://environment.fhwa.dot.gov/integ/corridor_nepa_guidance.asp#toc212.

The Who, Why, When, and Where of Transportation Systems Management and Operations Planning within Corridors

The contexts for corridor TSMO planning can be understood in the simple terms of who, why, when, and where (Figure 6).



TSMO=transportation systems management and operations.

Figure 6. Graphic. Context for transportation systems management and operations planning within corridors.

Why?

The why provides the **primary motivation for considering TSMO strategies within the corridor**. The motivation can be the result of the regional planning process where a specific corridor is identified as an area requiring significant improvements or corrections (as in Example Context 1), or it could come through a multistate coalition that identifies a particular corridor as critical to mobility and economic activity throughout the corridor. For example, prior to the 2002 Winter Games in Salt Lake City, Utah, major improvements were made in corridors likely to carry heavy traffic during the Games, and these improvements included upgrades to traveler information and other TSMO-related enhancements. The need for corridor improvements also could come from within operating agencies that see opportunities for providing a higher level of service (LOS) to travelers in the corridor (e.g., through more accurate and timely traveler information, better synchronized signals, or improved incident management in the corridor). Investments required to implement these improvements may be integrated into regional transportation plans and may provide the motivation for implementing TSMO strategies and tactics in a corridor.

Example Context 1: *Strong regional planning for operations supports corridor planning.*

- ***Why*** – The need for a specific corridor planning study has been identified as part of a regional or agency transportation systems management and operations (TSMO) planning effort based on operational deficiencies within the corridor.
- ***Who*** – The key stakeholders who operate transportation systems or emergency management within the corridor have probably been identified as part of the intelligent transportation system architecture and should be used as a starting point. A regional TSMO committee also may provide a sounding board for input throughout the study.
- ***Where*** – The corridor limits help identify expanded stakeholders (e.g., businesses, neighborhoods, freight, etc.) within the corridor that are impacted.
- ***When*** – The planning includes TSMO from start to finish.

The *why* also might be the result of growing concerns about congestion, safety, air quality, reliability, or other recurring problems within a corridor, which may or may not be addressed in regional transportation plans. The motivation also might come as a result of a major incident that resulted in significant delays or that highlighted deficiencies in the existing corridor capacity (see Example Context 2). Interest in TSMO strategies in a corridor also might arise in conjunction with new capacity expansion projects when integrating TSMO strategies and tactics can be most cost effective (see Example Context 3).

Example Context 2: *Transportation systems management and operations applications are largely outside the regional planning process, such as traffic incident management (TIM).*

- ***Why*** – Data indicate a high number of incidents are causing lane closures on a State urban arterial.
- ***Who*** – Existing freeway TIM teams led by the State agency are used as a starting point to identify the potential arterial TIM team. Other potential stakeholders include local agency traffic operations staff, if they operate any part of the arterial, and local police, fire, and medical responders. See Example Context 1 for expanded stakeholders.
- ***Where*** – The corridor limits (in this case, defined by past high-incident locations) help identify the specific stakeholders that may be required, such as city police instead of State police.
- ***When*** – Initiate the planning process as soon as performance metrics first indicate an issue on the arterial.

Example Context 3: *Corridor or facility study does not include transportation systems management and operations (TSMO) as initial focus, such as a rural corridor safety audit.*

- ***Why*** – A corridor study is initiated to examine high-crash locations along a corridor and identify geometric or capacity improvements.
- ***Who*** – The initial team may only include transportation planners. A regional or statewide TSMO champion could reach out to the study team and offer education and assistance with an evaluation of TSMO strategies that may help address the problem. See Example Context 1 for expanded stakeholders.
- ***Where*** – The project limits inform operational responsibilities. For example, a county without an electrical crew may need help from their State department of transportation to operate and maintain a TSMO strategy, such as a curve warning system.
- ***When*** – As soon as a TSMO champion is aware of the corridor study, they should approach the project team about incorporating TSMO into the study. If a champion is in place at the executive level, they may be able to add TSMO to the study during the scoping process.

Who?

The who for TSMO planning for corridors **establishes responsibility for planning and implementing TSMO strategies** within a corridor that, in many cases, spans multiple jurisdictions and requires interagency and multijurisdictional agreements regarding responsibilities for planning, designing, implementing, operating, monitoring, and maintaining TSMO strategies and tactics. This could be an authority acting on behalf of multiple entities (e.g., a toll authority or regional transit authority) or a single entity designated as the lead agency on behalf of other jurisdictions or agencies. Alternatively, if the corridor of interest is within a single jurisdiction, responsibility may lie with a single agency within the jurisdiction, but, even in this case, there are likely to be other agencies and jurisdictions that are affected by decisions made with respect to the corridor of interest, thus communication and coordination with these agencies and jurisdictions is important to the success of the TSMO improvements in the corridor.

The *who* in TSMO planning for corridors reflects **the capacity and experience of the responsible agency** or **agencies**. Agencies with considerable experience in TSMO planning will have tools needed to evaluate various TSMO strategies and will understand the data available to evaluate these strategies. Agencies with less institutional knowledge and experience with TSMO strategies and tactics can draw on external expertise to assist in integrating TSMO into corridor planning. Moreover, those with less experience may find institutional resistance to considering and committing resources to TSMO improvements and may need to enlist the support of champions who can help make the case for TSMO as a means for improving transportation system performance within the corridor.

In many, perhaps most, cases, a regional entity, such as an MPO or the major jurisdiction (e.g., city, county, or parish), will serve as the lead or facilitating entity for convening multiple agencies and jurisdictions to develop operations objectives for the corridor under consideration. State DOT district or regional offices also are likely to be involved because, in many states, the State DOT is responsible for maintenance and operations on major arterials. Other local and State agencies, such as law enforcement, also may be engaged, because they are often the entities most visible to the traveling public and will have significant responsibility for implementing and enforcing new operations strategies.

Where?

The *where* of TSMO planning for corridors is critical both to identifying key entities responsible for planning and implementing TSMO strategies and tactics and to determining who will benefit or be otherwise affected by TSMO strategies and tactics considered for the corridor. For example, the I-95 Corridor Coalition, a multistate coalition on the east coast, was originally formed as a way to coordinate major construction projects and inform motor carriers so that they could anticipate delays and plan their routes and schedules accordingly. However, the coalition has expanded to provide extensive traveler information to all travelers in the corridor; to coordinate formation of a seamless multistate electronic toll collection system (EZPass); and to collect and disseminate information regarding emergencies and incidents up and down the corridor, including advisories regarding delays and alternative routes. Other multistate corridor coalitions have been formed to provide traveler information to motor carriers and other travelers, especially in areas subject to frequent and severe weather events.

More often, however, corridors of interest are within or between major population centers and are critical to moving goods and people that are essential to economic activity along the corridor and in the broader region. For example, the I-80 Integrated Corridor Mobility Project in California addressed a highly congested, 20-mile stretch of I-80 on the eastern side of the San Francisco Bay Area, extending from Carquinez Bridge to Bay Bridge (see Figure 7).[28] In this case, geographical features and developed areas prevented further expansion of the facility; therefore, a multimodal, systems management approach was necessary. The corridor management project, planned and implemented through a partnership including Caltrans, the Alameda County Congestion Management Agency, and the Contra Costa County Transportation Authority sought to:

- Create a well-balanced system.
- Maintain optimal operational viability.
- Avoid flow breakdown by using proactive measures.
- Detect and respond to congestion events faster.
- Improve safety and security.
- Manage congested flow when it does occur.
- Promote transit ridership and mode shifts.
- Protect local arterials from unnecessary diversion.
- Minimize adverse social and environmental impacts.

Because of the geographic location of the portion of the I-80 corridor included in the project, 17 jurisdictions, agencies (Federal, State, and local), and regional authorities were involved in the corridor project as primary stakeholders. Consequently, the level of coordination required among the primary stakeholders and other interests (e.g., neighborhoods, commercial spaces, shippers, and carriers) was directly affected by the geographic location of the corridor.

Source: Caltrans.

Figure 7. Map. The Interstate 80 Integrated Corridor Mobility Project area map in California.

28 California Department of Transportation, I-80 Smart Corridor Project, Web site. Available at: http://80smartcorridor.org/.

When?

The *when* of TSMO corridor planning considers both the point at which TSMO planning takes place and the timeframe for TSMO strategies and tactics. TSMO corridor planning is most effective when integrated into the planning process for a new facility or when an existing facility is expanded or undergoing major renovation. At that time, plans for TSMO projects that require the installation of technology (e.g., cameras, fiber optics, and dynamic message signs) or roadway features (e.g., turn lanes and full-depth shoulders) can be included in the design most effectively. However, in many cases, TSMO strategies are considered only when available capacity no longer accommodates current or projected demand, and TSMO strategies and tactics are viewed as the most appropriate way to improve transportation system performance, as in the I-80 example above.

In addition to when the TSMO corridor plans are developed and implemented in a corridor, the TSMO corridor planning process considers the timeframe for implementation and operation of the TSMO investments. TSMO investments typically have short returns-on-investment (ROI) relative to other investments in transportation infrastructure and so can be justified based on much shorter life cycles than can major capacity expansion projects. On the other hand, such investments tend to be technology intensive and, with relatively rapidly changing technology, investments in these strategies must be made with an eye toward next-generation technologies and capabilities. As more advanced technologies emerge in sensors, vehicles, communications, visualization, and others, TSMO corridor planning should consider how current TSMO investments will accommodate future upgrades and new capabilities that may make past investments less attractive.

EXAMPLES OF CURRENT PRACTICES

Below are brief examples of current practices for TSMO planning at the corridor level. These help to illustrate the wide breadth of activities that are considered to be planning for TSMO within corridors:

- **Dynamic Corridor Congestion Management (California DOT [Caltrans], District 7)** – Caltrans, District 7 includes both Los Angeles and Ventura counties in Southern California. The Dynamic Corridor Congestion Management project focused on planning and implementing an integrated corridor management (ICM) approach to operations strategies to integrate freeway ramp operations with local street intersections and arterials to achieve corridor congestion relief for the region. To select a pilot project, Caltrans evaluated six corridors based on system demand, existing physical and ITS infrastructure, the possibility for institutional coordination, and ICM readiness. A single corridor, I-110, emerged as the top-rated corridor for a pilot project, and a Concept of Operations was prepared.[29]

  As part of TSMO policy for all of Caltrans, it has established the Connected Corridors Program and is reorganizing based on corridor management statewide. This is part of the path that Caltrans is pursuing to implement corridor management and operations strategies that optimize system capacity and meet the demands of all users in a real-time, multi-modal

29 California Department of Transportation, South Bay Corridor Study and Evaluation for Dynamic Corridor Congestion Management (DCCM), Presentation to Metro Streets and Freeways Subcommittee Meeting, October 17, 2013. Available at: http://media.metro.net/about_us/committees/sfs/images/sfs_item10_10_2013.pdf.

environment. As such, Caltrans is also emphasizing planning for operations, which requires strong partnerships among the traffic operations, planning, maintenance, and capital programs within Caltrans and its external partners at local and regional levels.

- **Harmony Road Enhanced Travel Corridor Master Plan (City of Fort Collins, Colorado)** – The city used a four-tier evaluation and screening process to analyze multimodal improvement alternatives, many of which included TSMO strategies, to reach a locally preferred alternative for the Harmony Road arterial corridor.[30]
- **Road Safety and Operations Audit (Delaware Valley Regional Planning Commission, Pennsylvania)** – This audit identified immediate safety and operational issues along a corridor and provided improvement recommendations. Although many improvements were related to safety and maintenance, TSMO strategies also were included.[31]
- **Statewide Active Arterial Management Needs Plan (Florida DOT)** – This plan identified the causes of congestion on arterials across the state and recommended arterial management strategies. It presented a two-pronged approach for implementing TSMO improvements based on the extent of the congestion problems. An enhanced maintenance plan was recommended for less-congested corridors, and a full active arterial management plan was recommended for congested corridors.[32]
- **I-805 South Active Transportation and Demand Management (ATDM) Strategy Plan (San Diego Association of Governments, California)** – Planning is currently underway to find solutions to congestion on the I-805 corridor by considering transportation system management and demand management strategies. The outcome of the study will be a prioritized set of ATDM strategies that includes the completion of a corridor program level concept of operations report. The concept of operations report presents a multimodal and multi-agency corridor vision and goals and provides an initial prioritized set of ATDM strategies.
- **I-580 Inter-Regional, Multimodal Corridor Study (San Joaquin Council of Governments, California)** – This study focused on identifying three types of multimodal strategies for the corridor: enhanced transportation demand management (TDM) programs, inter-regional goods movement strategies, and inter-regional transit services.[33]
- **United States 20/Oregon Road 34 Optimization Study (Oregon DOT, Corvallis) –** The primary goal of the study was to identify low-cost operational improvements to address safety and mobility within an arterial corridor that is a critical highway segment for commuter, freight, and recreational traffic. Potential TSMO strategies were screened against high-level criteria, and the top five were evaluated in detail based on benefits, cost, and how well they support the project goals and objectives. The top three strategies are currently moving forward for implementation.[34]

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30 City of Fort Collins, *Harmony Road ETC Master Plan,* June 2013. Available at: http://www.fcgov.com/transportationplanning/pdf/harmony-draft-report.pdf.

31 Delaware Valley Regional Planning Commission, I-95 Road Safety and Operations Audit (RSOA) – Delaware County, December 2011. Available at: http://www.dvrpc.org/reports/10011.pdf.

32 Florida Department of Transportation, "Statewide Active Arterial Management Needs Plan," (July 2013). Unpublished.

33 San Joaquin Council of Governments, *Final Report for: I-580 Interregional Multimodal Corridor Study*, Aug 2011. Available at: http://www.sjcog.org/DocumentCenter/View/44.

34 DKS Associates, US 20/OR 34 Optimization Study Final Report, February 2015. Prepared for Oregon Department of Transportation Region 2.

CHAPTER 3. APPROACH TO PLANNING FOR TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS WITHIN CORRIDORS

This chapter provides information on several fundamental activities that will typically need to occur when planning for transportation systems management and operations (TSMO) on a corridor regardless of the type of corridor and the planning context. Chapter 4 describes the activities that are needed to make the plans for TSMO a reality through key activities, such as programming, design, and systems engineering. All of these activities form the basis for an approach to planning and preparing for the implementation of TSMO strategies in corridors. This approach is outlined in Figure 8. This figure will be used throughout the next two chapters to highlight the major activities. The approach is based on the planning for operations approach developed for advancing TSMO at the metropolitan planning level. Adaptations were made to account for the broad range of contexts in which TSMO may be planned for within corridors (e.g., planning for road weather management on a multistate corridor conducted outside of a formal regional or statewide planning process).

This section covers:

- Getting started – scoping the effort and building a team.
- Gathering information on current and future context and conditions.
- Developing an outcome-oriented operational concept, including operations objectives.
- Identifying operations performance needs, gaps, and opportunities.

TSMO=Transportation Systems Management and Operations.

Figure 8. Diagram. Approach to planning for transportation systems management and operations within corridors.

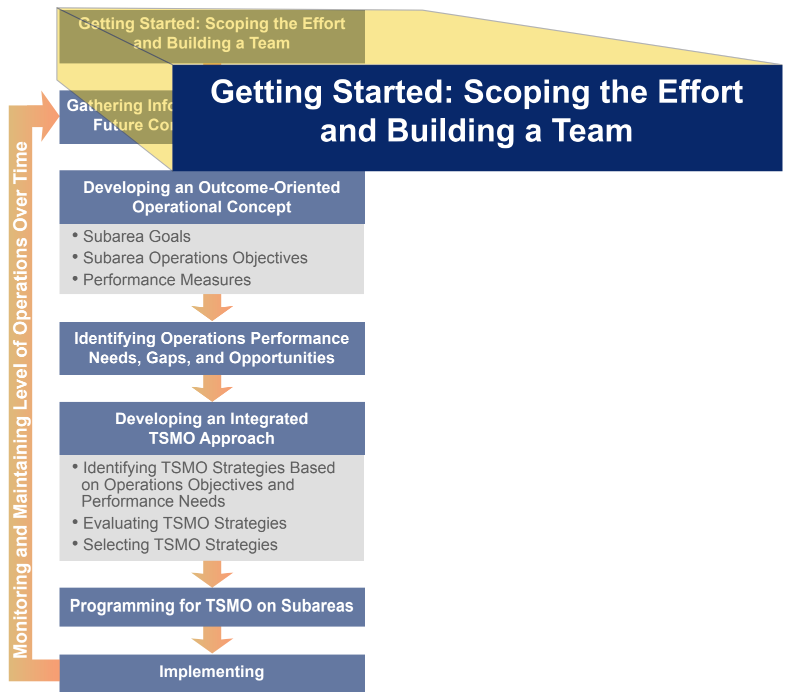
- Developing an integrated TSMO approach:
  - Identifying TSMO strategies based on operations objectives and performance needs.
  - Evaluating TSMO strategies.
  - Selecting TSMO strategies.

GETTING STARTED – SCOPING THE EFFORT AND BUILDING A TEAM

Developing an effective corridor plan or system management plan requires scoping the effort and building a team of partners and stakeholders to work together on its development (Figure 9).

Key questions to consider in scoping the effort include:

- What do we want to accomplish/address?
- What is the geographic area of the corridor? Does it include parallel roadways or transit lines? Are there any connectors along the corridor that also should be included?
- What are the pressing issues or desired areas of change?
- Who should be involved in this process? Why and how?
- How will the planning effort be conducted? What Federal, State, regional, or local procedures or guidelines are best suited to the effort regarding items such as outcome-oriented objectives, performance measurement, conditions analysis, strategy identification and evaluation, and public involvement?



TSMO=transportation systems management and operations.

Figure 9. Diagram. The "Getting Started – Scoping the Effort and Building a Team" activity of the approach for planning for transportation systems management and operations within corridors.

Tools that can be leveraged to scope the effort and build a team include:[35]

- **Statewide or regional intelligent transportation system (ITS) architecture** – Most states and large metropolitan areas already have an ITS architecture in place. This framework for planning, defining, and integrating ITS can provide insights into the management and operations services, stakeholders, and performance data that may play a role in a corridor study.

35 For more information, see: Federal Highway Administration and Federal Transit Administration, *Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach – A Guidebook*, FHWA-HOP-10-026 (Washington, DC: 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10026/.

- **Regional concept for transportation operations (RCTO)** – An RCTO is an objectives-driven, performance-based approach to planning for one or more specific operations areas, such as traveler information or traffic incident management (TIM). The RCTO, which typically includes roles, responsibilities, and resources needed to achieve specific operations objectives, can be used as a tool to develop and implement TSMO strategies at the corridor level.
- **Statewide or regional corridor planning guide** – Some agencies, such as the Delaware Valley Regional Planning Commission, have developed guides for corridor planning that include planning process recommendations and a toolbox of available strategies that may be considered. Ideally, the toolbox should include TSMO strategies in addition to more traditional transportation strategies, such as complete streets.[36]

Partner Agencies Working Together on the I-495 Corridor Concept of Operations in New York/New Jersey

A wide array of partnering agencies in the New York/Northern New Jersey metropolitan region initiated a Concept of Operations study for the I-495 corridor, spanning from Northern New Jersey through the Lincoln Tunnel, Midtown Manhattan, the Queens-Midtown Tunnel, and I-495 through Queens. This complex corridor encompasses highways, principal and secondary arterial networks, bridges, tunnels, local street grids, and multiple transit services, and has engaged an extensive set of operating agencies and partners. In addition to primary partners, the agencies recognize the important role of emergency responders, private bus companies, event promoters, and the freight industry, among other stakeholders.

The team involved in a corridor planning study provides a forum for idea sharing, decision-making, and a commitment to improving operations. Chapter 1 includes a preliminary list of transportation-related stakeholders that should be considered. Effectively engaging the team involves developing a shared understanding of the roles, responsibilities, and needs of key constituencies (e.g., partnering agencies, authorities, network owners and operators, stakeholders, and the users of the corridor). The team will then work together to define needs in the corridor, agree upon goals and objectives, develop preliminary consensus on pragmatic concepts for strategies or combinations of strategies that realistically address specified goals and objectives, and develop viable operating scenarios under which the concepts and strategies can be analyzed.

36 For more information, see: Delaware Valley Regional Planning Commission, *Corridor Planning Guide: Towards a More Meaningful Integration of Transportation and Land Use*, September 2007. Available at: http://www.dvrpc.org/asp/pubs/publicationabstract.asp?pub_id=07028.

Although there is no one-size-fits-all approach to team building, these approaches have worked for some regions:[37]

- **Build on an existing collaborative group** – Use an existing operations group or a committee that has already been used to develop a regional ITS architecture or RCTO as a starting point for identifying stakeholders. An existing operations group may be able to incorporate the corridor project into its meeting agendas.
- **Ensure at least one committed champion** – Ideally, the champion has a clear vision of the desired outcome, brings the stakeholders together, ensures they are engaged, and works to get the support needed to achieve the desired outcomes.
- **Gather support from elected or appointed officials and agency leadership** – Identify an advocate for the effort at the executive leadership level to help influence the success of the team.
- **Engage participants** – It is important to identify and engage the array of operating agencies and stakeholders that will play a role in, and ultimately be critical to, operations within the corridor. Typically, this will include local transportation agencies, a State department of transportation (DOT), transit agencies, and representatives of local governments and community groups. Law enforcement, emergency responders, and major employers in a corridor also may be important participants. If some participants, such as emergency management agencies, are unable to attend project committee meetings, better success may be realized by taking the project to other established forums held by those stakeholders.[38]
- **Form a tiered collaborative structure with a strong mandate** – The use of a steering committee with agency leaders can provide project guidance and make high level decisions while a working group comprised of technical staff can help shape the technical approaches needed to deliver on the leaders' vision.

Benefits of Collaboration

Enhancing collaboration and coordination among agencies involved in systems management and operations within corridors is a key component of integrated corridor management (ICM) and is vital to developing solutions for optimizing corridor performance; this is particularly true in complex urban corridors with many different operators and choices of modes and routes. Collaboration produces tangible benefits both to participating agencies and jurisdictions, as well as to system users and other stakeholders who depend on effective corridor operations in moving people and goods. These benefits fall into three general groups: (1) access to and use of existing resources, (2) improvements in current operations, and (3) better outcomes for system users and other stakeholders.[39]

37 For more information, see: Federal Highway Administration, *The Regional Concept for Transportation Operations: A Practitioner's Guide*. Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop11032/.

38 For suggested stakeholders based on operational objectives, see: Federal Highway Administration and Federal Transit Administration, *Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach – A Guidebook*, FHWA-HOP-10-026 (Washington, DC: 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10026/.

39 For more information, see: Federal Highway Administration, *The Collaborative Advantage: Realizing the Tangible Benefits of Regional Transportation Operations Collaboration*, FHWA-HOP-08-001 (Washington, DC: August 2007). Available at: http://www.ops.fhwa.dot.gov/publications/benefits_guide/index.htm.

Expanded Access to Resources and More Efficient Use of Existing Resources

The visible and immediate benefits of collaboration among agencies and jurisdictions in a corridor may be realized through strategies, such as:

- Pooling funds to avoid duplicate investments or purchases.
- Participating in joint training activities.
- Taking advantage of special expertise or experience that may reside in some but not all agencies or jurisdictions.
- Negotiating group purchasing agreements with vendors and suppliers.
- Adopting common standards for technology that can simplify interagency and multijurisdictional interactions and mutual support.
- Acquiring and maintaining more current and more effective hardware and software systems.

Each of these approaches, or several in combination, can improve the use of available resources.

Improved Agency Operations

Beyond more efficient access to and use of resources, collaboration enables cooperating entities to perform their missions more effectively. These improvements can result in:

- Sharing information among system operators and owners so that they have greater awareness of current and anticipated events in adjacent jurisdictions or in other agencies.
- Developing standard protocols and procedures among agencies and jurisdictions that operate within the corridor.
- Improving responsiveness to events and incidents by sharing information, assets, and responsibilities.
- Working cooperatively to leverage all available assets, skills, and personnel to improve efficiency.

Each of these, and other strategies, can enhance working relationships during routine operations and offer the added benefit of providing the foundation for preparing for and responding to emergency situations, crashes, intentional attacks on transportation assets or other infrastructure, planned special events (e.g., sporting events, conventions, and festivals), or major natural events (e.g., hurricanes, snowstorms, tornados, earthquakes, mudslides, wildfires, etc.).

Better Outcomes or Results for Travelers, Suppliers or Shippers, and Other Stakeholders

Ultimately, system users and communities benefit through effects, such as:

- Safer corridor facilities (e.g., transit stations and bicycle/pedestrian paths and lanes).
- Lower fuel consumption through both more efficient operation of the corridor and more and better alternatives to private vehicle use.
- Shorter travel times achieved through congestion mitigation strategies and more effective corridor management and operation.

- More accurate, timely, and relevant information about past, current, and anticipated travel conditions, modes, schedules, travel times, and travel options so that travelers, shippers, and others can make more informed travel decisions.

These benefits will, over time, prove to be the most important, because they are the outcomes important to travelers, shippers, environmental agencies, neighborhood associations, bicycle/pedestrian advocates, and others who interact with the corridor.

A Framework for Collaboration and Coordination in a Corridor

Five key, or foundational, elements characterize the collaboration and coordination necessary for effective TSMO within corridors. As shown in Figure 10, these five elements are connected, interactive, iterative, and build upon foundational elements that can be applied at multiple scales.

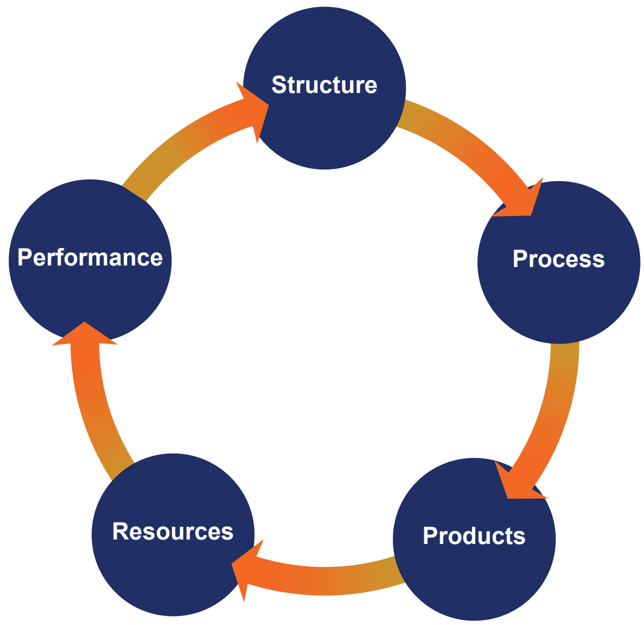


Figure 10. Diagram. The framework for collaboration and coordination within a corridor.

Source: Federal Highway Administration. *Regional Transportation Operations Collaboration and Coordination: A Primer for Working Together to Improve Transportation Safety, Reliability, and Security*, FHWA-OP-03-008.

The starting point for collaboration and coordination is the *structure*, or the means through which individuals, agencies, and jurisdictions come together to identify needs, establish priorities, make commitments, allocate resources, and evaluate performance. In a corridor, a structure might be formalized in an ongoing corridor coalition or working group, or it may be addressed as part of broader regional or State efforts that include a focus on key corridors.

The *process* is the course of action taken through which options are created and decisions are made; the process could involve formal activities like a structured set of meetings as part of a corridor planning process or informal activities.

The *products* are the agreements, arrangements, and commitments to move forward with agreed upon strategies. The product may include a corridor plan, a concept of operations, operating plans and procedures, or other documents.

Resources reflect the commitments made in terms of funding, people, equipment, facilities, support, and other assets needed to implement the strategies identified for the corridor.

Finally, *performance* measurement provides the feedback to determine how well the agreed upon strategies have been implemented and executed, and the effect these strategies have had on outcomes of interest in the corridor relative to the agreed-upon goals and objectives.

Connections to Broader Planning and Operations Efforts

Transportation planning in a corridor should build off of broader planning efforts for TSMO, as well as existing operations programs and strategies at a regional and State level. Regardless of the size of the corridor, planning for corridor operations should recognize and build upon existing programs that can benefit the corridor, including:

- Existing ITS infrastructure, such as fiber networks, variable message signs, and traffic cameras.
- State and/or regional traveler information systems, which can be utilized to help provide real-time information on incidents, speeds, and other aspects of operating conditions for highways, arterials, and transit in the corridor.
- Regional incident management and response programs, which can be expanded or targeted to address corridor-specific issues.
- Work zone management strategies used in transportation management plans for significant projects.
- Regional transportation demand management (TDM) programs, which often include ridematching services, employer outreach, and public outreach and incentives to encourage use of alternatives to driving alone.

In particular, transportation management centers (TMCs) use real-time information to support quicker incident management and communicate this information to the public through 511 systems, the Internet, and media to help travelers avoid delays. Employing active traffic management (ATM) and active transportation and demand management (ATDM) strategies in a corridor builds upon the foundation of monitoring, assessment, and response that takes place within TMCs. This may involve applying a wide range of strategies, such as opening shoulder lanes to transit vehicles or general-use traffic during congested periods, adjusting speed limits based on traffic levels, and dynamic ramp metering to control the flow of traffic at merging points.

TDM program services and incentives also could be targeted to specific corridors, particularly those with major construction activity. For instance, in the Washington, DC, metro area, the Virginia DOT and Maryland State Highway Administration partnered in developing the Bridge Bucks pilot program, which provided a 50-dollars-a-month incentive to commuters who switched out of their cars and into buses, trains, or vanpools during reconstruction of the Woodrow Wilson Bridge. The regional Commuter Connections program, operated by the Metropolitan Washington Council of Governments, was a resource that helped provide ridematching and a guaranteed ride home to participants.[40]

In developing corridor goals, operations objectives, and performance measures, and identifying and selecting appropriate strategies for application, the approach for planning for TSMO on a corridor should build upon existing planning efforts that relate to system operations, including:

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40 Metropolitan Washington Council of Governments, Committee Document, "A Transit/Ridesharing Initiative to Ease Commuting During Woodrow Wilson Bridge Project Construction," January 2004. Available at: http://www.mwcog.org/uploads/committee-documents/zFpaVg20040127141601.pdf.

- **Priorities identified in State and regional transportation plans** – Statewide and metropolitan transportation plans identify policies and priorities that can be used to inform identification of potential strategies for a corridor. For instance, some plans emphasize demand management or include a policy to prioritize strategies that increase transit, ridesharing, and non-motorized travel over single-occupancy vehicle travel.
- **State or metropolitan area TSMO plans** – Some State DOTs have developed TSMO plans, which identify priority corridors and sets of strategies that may be applicable for different types of corridors. For instance, Minnesota DOT's *Highway System Operations Plan* and Wisconsin DOT's *Traffic Operations Infrastructure Plan* generally outline Statewide operations infrastructure needs and opportunities.[41, 42] A number of metropolitan planning organizations (MPOs) also have developed regional TSMO plans. For instance, the Baltimore Metropolitan Council developed the *Baltimore Regional Management and Operations Strategic Deployment Plan*, which includes goals, objectives, and strategies, as well as screening factors, to suggest an implementation order for projects.[43] Metro, the MPO for Portland, Oregon, developed a *Regional Transportation System Management and Operations Plan*, which lays out a framework that includes a regional vision, planning goals and objectives, and guiding principles, and an action plan for regional and corridor investments.[44] Similarly, the Southeastern Wisconsin Regional Planning Commission completed its *Regional Transportation Operations Plan: 2012-2016* in 2012, which identifies short-range actions recommended for implementation over a 5 year period.[45] While these plans are often high level, where available, they will serve as a very strong basis for more-detailed, corridor-focused efforts.
- **Regional ITS architectures** – A regional ITS architecture provides a common framework for planning, defining, and integrating ITS across a state or region. A regional ITS architecture can be used by State and local planning agencies and organizations to identify integration opportunities and to support incorporation of operational needs in transportation planning. For instance, the North Jersey Transportation Planning Authority, in coordination with New Jersey DOT, is updating the regional ITS architectures for the region and state. A key component of this effort is development of an ITS strategic deployment plan, known as *The Connected Corridor*, that will serve as a shared vision by transportation agencies to more effectively plan, program, and operate the region's transportation system with operational strategies.[46] Consequently, these documents will help to inform ICM planning efforts.

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41 Minnesota Department of Transportation, *Highway Systems Operations Plan 2012-2015,* September 2012. Available at: http://www.dot.state.mn.us/maintenance/hsop/.

42 Wisconsin Department of Transportation, *WisDOT Traffic Operations Infrastructure Plan*, May 2008. Available at: http://worldcat.org/oclc/926983390/viewonline and http://www.topslab.wisc.edu/workgroups/toip.php.

43 Baltimore Metropolitan Council, *Baltimore Regional Management and Operations Strategic Deployment Plan*, March 2007. Available at: http://www.baltometro.org/phocadownload/Publications/Transportation/Plans/MandO_StrategicDeploymentPlan_2007.pdf.

44 Metro, *Regional Transportation System Management and Operations Plan*, June 30, 2010. Available at: http://www.oregonmetro.gov/regional-transportation-system-management-and-operations-plan.

45 Southeastern Wisconsin Regional Planning Commission, *Regional Transportation Operations Plan: 2012-2016*, May 2012. Available at: http://www.sewrpc.org/SEWRPC/Transportation/Regional-Transportation-Operations-Plan-2012-2016.htm.

46 North Jersey Transportation Planning Authority, *The Connected Corridor Final Report*, December 2014. Available at: http://www.njtpa.org/planning/regional-studies/intelligent-transportation/theconnectedcorridor.aspx.

- **Regional TDM plans** – Some metropolitan areas also have developed TDM plans, which can provide a basis for developing corridor-specific demand management efforts. For instance, the Atlanta Regional Commission developed the *Atlanta Regional Transportation Demand Management Plan* that defined a framework for developing and integrating TDM strategies into planning, project development, and system operations investment decision-making.[47] The plan identifies key goals and strategies, which are intended to be addressed with partners from Georgia DOT, the Georgia Regional Transportation Authority, local governments, and others.

Effectively planning for TSMO within corridors will build upon existing plans and programs and ensure that corridor plans are compatible with, and take advantage of, these broader efforts. It is important to recognize that a corridor is part of a larger transportation network, and the policies and strategies being identified at the regional and state levels should help to inform the more geographically focused effort. At the same time, the plans, strategies, and operational relationships that will be effective within a corridor will reflect the specific travel needs, constraints, and opportunities of the corridor.

GATHERING INFORMATION ON CURRENT AND FUTURE CONTEXT AND CONDITIONS

Gathering information about the corridor – the current conditions and the future context – is a key early step in the development of any corridor plan or strategy (Figure 11). Data, both qualitative and quantitative, play a vital role in a performance-based approach to planning for TSMO in a corridor.

Baseline information helps define the existing conditions in the corridor, including identification of challenges and problem areas. Data on expected changes in population, land use, and travel conditions also will help to inform understanding of potential future corridor challenges that should be addressed during a corridor planning process.

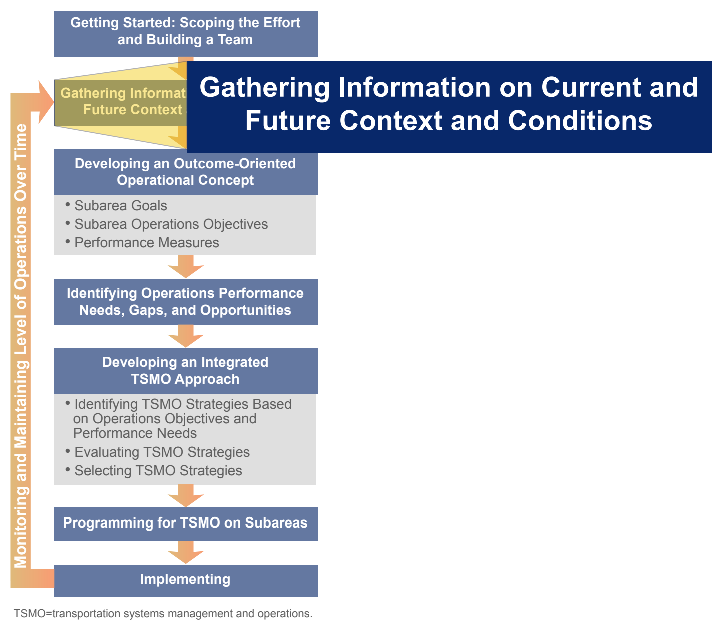


Figure 11. Diagram. The activity, "Gathering Information on Current and Future Contexts and Conditions," of the approach for planning for transportation systems management and operations within corridors.

47 Atlanta Regional Commission, *Atlanta Regional Transportation Demand Management Plan*, 2013. Available at: http://www.atlantaregional.com/transportation/commute-options/regional-tdm-plan.

Data gathered during this phase also are a starting point for identifying opportunities for potential operations strategies that may be applied within the corridor and are used in analysis tools and evaluation to assess the effectiveness of these strategies. Given the critical role of data in a performance-based approach, gathering quality data and accurate information is imperative.

Often, a technical advisory committee or some other type of stakeholder partner group will play a key role in defining corridor objectives and in providing guidance on data and information gathering. Members with operations data expertise will play an important role in bringing forth operations data to inform the corridor planning process, as well as to explain data limitations.

Common sources of information include previous plans and studies; data sets on current and past system performance, including archived operations data; and forecasts of future conditions.

Previous Studies, Reports, and Plans

A review of existing studies, reports, and plans provides information about the broader planning context and may include recent multimodal transportation plans, pedestrian and bicycle plans, land use and development plans, and infrastructure condition reports. These documents offer insight into the long-term, big-picture vision for the corridor and surrounding study area. They also can provide data on anticipated future conditions in a corridor, such as population, jobs, housing units, and vehicle or passenger trips.

A range of information may be available on the current transportation system components and features within the corridor study. For instance, topographical maps provide information about the corridor surface and geographical features. Documentation of the overall transportation network also is useful, including information about the existing multimodal transportation network, such as highways, transit services, and side and perpendicular streets (intersection types and traffic control measures used). Moreover, beyond the infrastructure, baseline information also should document existing operational assets, partnerships, relationships, and programs that affect system operations. Examples include ITS components, ramp metering, traveler information systems, incident management programs, and transit signal priority (TSP), among others. Documenting the current application of these system components or strategies will be important as a baseline for understanding the existing context in the corridor.

Understanding Users of the Corridor

Understanding travel markets and users of the corridor is important in defining both needs and possible strategies that will be effective. Some corridors carry significant freight truck activity, while others do not. Some also handle significant interstate through traffic, while others carry largely localized trips.

While some freeway management and incident management strategies (e.g., variable speed limits and queue warning) will benefit all travelers and help system operators to have better information to adjust system operations, it is important to consider the needs of different types of travelers. Understanding the unique characteristics of travelers in the corridor and their key concerns also will be useful in assessing potential strategies that may be targeted to specific types of travelers.

Recognizing how they access information and make travel decisions, some will aid in tailoring TSMO strategies. Possible traveler groups may include daily commuters traveling regularly to and from work or school, leisure travelers going to local destinations (e.g., running errands, entertainment, etc.), long-distance commuters or tourist travelers passing through, and freight or commerce vehicles transporting goods. Table 2 provides a sample of potential corridor users, their concerns, and TSMO strategies that planners and operators may consider to address those concerns.

Table 2. Developing a thorough understanding of the corridor users will help determine possible transportation systems management and operations strategies.

	Local Commuter	Leisure Traveler	Long Distance/ Interstate Traveler	Freight/Commerce
Description	Reside locally, travel regularly between work/ school.	Reside locally, traveling to local destinations (e.g., running errands, entertainment, recreation, etc.).	Non-local travelers traveling to or through the corridor, less familiar with local conditions or alternative routes.	Transportation of goods to local stores and businesses or to regional distribution centers.
Key Concerns	Reliability of route and avoidance of traffic delays, information about transportation options.	Avoiding traffic congestion, parking availability, information about transportation options.	Notification of travel delays due to construction or incidents, access to stopover points (e.g., rest stop, gas stations, restaurants, etc.).	Reliability of travel time for on-time delivery, availability of preferred routes (particularly those that can accommodate freight vehicles).
Possible Strategies	Dynamic ridesharing, predictive traveler information, real-time transit and parking information, dynamic shoulder lane use.	Dynamic parking reservation, real-time travel information, off-peak parking discounts.	Real-time travel information, advance information to take alternative route well in advance to avoid congested area.	Variable speed limits, queue warning, adaptive signal control.

Information on Current System Performance

In addition to information about the physical assets, corridor conditions, and traveler characteristics, data on current corridor performance are needed. Data on traffic volumes, peak hour volume, and travel patterns convey important information on corridor performance, and data may include average daily travel, peak-hour volume, and mode-split. Level of service (LOS), which is a function of traffic volumes, traffic composition, roadway geometry, and the traffic control at the intersection, is widely used in traffic studies and reports. However, LOS does not capture the source or extent of congestion, especially non-recurring congestion (due to traffic incidents, work zone, bad weather, special events, etc.). Better data on actual travel speeds and delay in a corridor can be critical to understanding existing conditions. To incorporate operations strategies into the corridor plan, a more detailed account of the causes and impacts of congestion along the corridor is needed.

Archived operations data, from ITS programs, also can be used to assess important operational conditions, including system reliability; on-time transit performance; and the role of factors, such as weather conditions, on traffic congestion. Archived travel time data form the basis for understanding a wide variety of performance metrics, such as congestion, reliability, and freight mobility. Chapter 5, Toolbox for Effective Transportation Systems Management and Operations Planning, contains additional information on archived operations data.

Safety data are very useful for identifying challenges and problem areas along the corridor that may be addressed by operations strategies. Types of safety data include incident data (e.g., fatalities, injuries, and property damage); crash data by type (e.g., rear-end, left-turn, etc.), weather conditions, and light condition (e.g., daylight, dusk, etc.); and the spatial distribution of crashes.

Information about Future Conditions and Contexts

Information about anticipated conditions and contexts is important as well. This includes forecasted data about socio-economic factors (e.g., population, density, employment, etc.), as well as information from transportation modeling in regard to future anticipated travel demand. It also is important to document improvements slated for implementation in the near future. Information on future projects may come from consulting the metropolitan transportation improvement program (TIP), the statewide TIPs, or local plans.

Stakeholder and Public Engagement

In addition to previous studies and information on current and future conditions, input from stakeholders and the public is critical; specifically, their opinions about the corridor and preferences for the future of the corridor. The public and stakeholders should play a key role in defining goals and objectives for the corridor, as well as the performance measures that will be used to assess system performance. In urban corridors, there often are tradeoffs to be made in terms of performance of the system in relation to passenger vehicles, public transit, bicycling, and walking, and the public and stakeholders should play a key role in defining the specific objectives for the corridor. The public, for instance, may be willing to accept lower average motor vehicle speeds to improve the safety and accessibility of pedestrian and bicycle activity. While optimizing system performance along urban and suburban highway corridors might involve diverting heavily

Questions to Gather Stakeholder Input

Below are sample questions to facilitate a dialogue with stakeholders and the public to capture input about incorporating operations into corridor planning:

- How do you travel in the corridor? Where do you go? What problems do you encounter?
- What is important to you, to your neighborhood, to the local area, and to the region (e.g., transportation, community, environment) in the corridor?
- Do you have any comment on the problems and opportunities that have already been identified for the corridor?
- How would improving the corridor through working with a private developer and considering options, such as tolling, impact your support of the solutions?

Source: Linking Planning and Operations Application, PlanWorks, Federal Highway Administration. Available at: https://fhwaapps.fhwa.dot.gov/planworks/.

congested freeway traffic to parallel arterials, there may be community concerns about the impacts on accessibility in neighborhoods, which need to be considered. Consequently, it is important to engage the public and stakeholders in clearly defining corridor goals and operations objectives and in articulating priorities and values.

Methods for gathering information from stakeholders and the public include conducting qualitative research (e.g., interviews, focus groups, and workshops) or quantitative research (e.g., polls, surveys), as well as hosting citizens' panels and town hall meetings. A comprehensive approach should be used for stakeholder public engagement to capture input from all affected parties along the corridor, including those traditionally underserved by the existing transportation system (e.g., low-income communities, persons with disabilities, minorities). Engaging with stakeholders and the public early in the process is important and also presents an opportunity to raise awareness about operations and the role that operational strategies can play along the corridor. Educating stakeholders and the public about operational strategies will make them better-informed participants throughout the remainder of the corridor planning process.

Once the information-gathering process is complete, there is solid understanding of the needs, deficiencies, and opportunities to address in the next step: developing an operational concept.

DEVELOPING AN OUTCOME-ORIENTED OPERATIONAL CONCEPT

An effectively managed corridor involves not only the provision of highway and transit infrastructure for movement of people and freight, but also efficient ways of operating these systems to support mobility, reliability, and safety. Consequently, while corridor planning may involve consideration of, or focus on, certain types of infrastructure improvements (e.g., streetscaping, bicycle and pedestrian infrastructure), the planning process should focus on desired outcomes for travelers and communities, including outcomes related to how the corridor is managed and operated.

An *outcome-oriented operational concept* provides the framework for developing and evaluating options for the corridor that reflect local and regional values, which may include mobility, air quality, sustainability, livability, safety, security, economic activity, and accessibility, among other considerations (Figure 12). The relative priority of these considerations may vary depending on the context, needs of system users and other stakeholders, and stakeholder groups that are affected by transportation in the corridor.

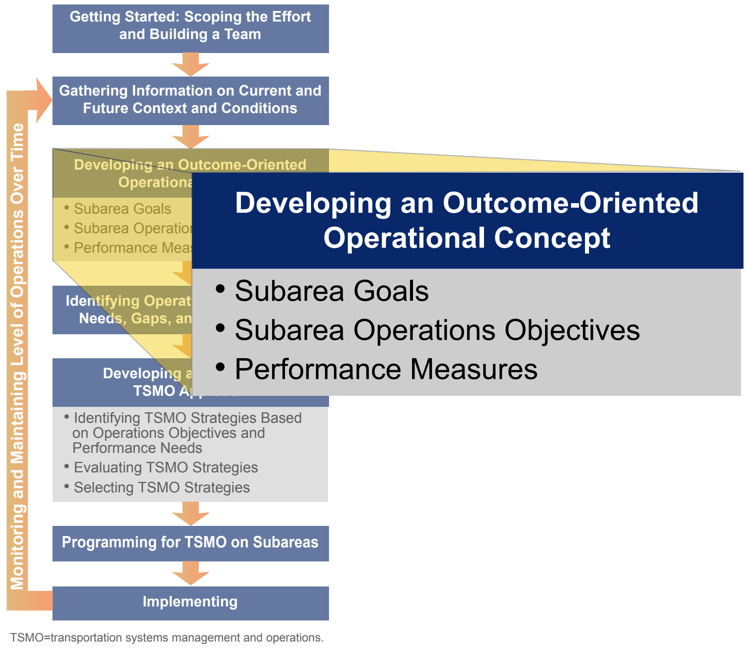


Figure 12. Diagram. The activity, "Developing an Outcome-Oriented Operational Concept," of the approach for planning for transportation systems management and operations within corridors.

Examples of outcomes commonly used in corridor studies include safety and mobility, often defined in terms of levels of traffic congestion or hours of delay. Other outcomes may include economic vitality, community livability, environmental quality, and other community goals.

Planning for TSMO involves considering a broad range of issues and outcomes associated with how transportation systems are managed and operated. For instance, a corridor plan with a greater focus on TSMO may include specific discussion of *reliability* as an outcome. In addition to general travel time, travelers and freight shippers often are very concerned about the variability in travel time from day-to-day or hour-to-hour. If it typically takes 20 minutes to travel a corridor off-peak and 30 minutes during peak congestion, travelers can plan for the extra travel time. However, if travel times are highly unpredictable, sometimes 30 minutes during rush hour but other times 60 minutes or more, this creates significant problems for making tightly scheduled appointments or delivery times. Studies show that travelers and freight shippers strongly value reliability in travel time; therefore, this is an important issue. High variability in travel times often is caused by traffic incidents, poor weather conditions, special events, and construction work zones, which can be considered in the context of corridors.

Substantial experience in TSMO planning at the regional level shows that rather than just defining goals and strategies, a key foundation for advancing TSMO in planning is to define an outcome-oriented operational concept that brings together goals, measurable operations objectives, and performance measures that are focused on outcomes important to the transportation system users. In a regional context, use of operations objectives and performance measures supports consideration and selection of TSMO strategies for the long-range transportation plan and TIP.[48]

48 For more information, see Federal Highway Administration and Federal Transit Administration, *Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach – A Guidebook*, FHWA-HOP-10-026 (Washington, DC: 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10026/.

Similarly, corridor-based operations objectives and performance measures help to focus attention on system performance outcomes within a corridor and are a key element to support consideration of TSMO strategies. Developing an outcome-oriented operational concept is, by nature, an iterative process that involves developing an understanding of regional values that affect or influence priorities in the corridor and translating those priorities into observable and measurable outcomes that guide development of outcome-oriented objectives.

The outcome-oriented operational concept describes, at a high level, how the corridor would operate to realize the desired outcome(s). The operational concept does not specify strategies to be implemented in the corridor. It will likely draw upon a collection of individual and complementary strategies in response to the operations objectives for the corridor and an assessment of the costs and benefits of each. In some corridors, ATDM concepts—active traffic management, active demand management, and active parking management—may prove to be attractive strategies; in others, other strategies that rely less on real-time data may prove effective (e.g., improvements in TIM, seamless integration of public transportation alternatives, and better integration of non-motorized alternatives).[49] These and other concepts can be incorporated into an overall operational concept for this corridor.

The operational concept can be formalized within the framework of *goals, objectives,* and *performance measures*. The goals and objectives translate the values and priorities into statements that describe what is to be achieved with respect to transportation in the corridor that supports higher-level regional goals. The corridor goals should link to these high-level regional goals, and then lead to objectives expressed in measurable terms that can be used to help develop and evaluate strategies for achieving the objectives.

Note that, in developing an outcome-oriented operational concept, specific solutions (strategies and tactics) are not considered, except to the extent that they may inform planners and operators about what is possible within available or anticipated technology solutions, legal and institutional arrangements, and fiscal constraints. Otherwise, the goals and objectives that characterize the operational concept should be open to new ideas about how to achieve the objective until after a range of feasible strategies and tactics is identified and evaluated using performance measures that relate directly to the objectives for the corridor.

Operations Goals

Operations goals are the high-level statements of what transportation in the corridor would look like if it reflects the needs, values, and priorities of the key stakeholders and transportation providers that use, depend upon, or operate transportation facilities and services. For example, the goals for the Interstate-880 Corridor in the Oakland, California area, as developed by the ICM Oakland Pioneer Site Team, are:

- "Improve the efficiency of their individual networks through shared information from, and collaborative operations with, the other networks.
- Balance demand across the networks to most efficiently utilize the available capacity.
- Enable travelers to make informed choices among transportation options, based on reliable information about travel conditions.

49 See: Federal Highway Administration, *Active Transportation and Demand Management – FHWA Operations*, Web site. Available at: http://ops.fhwa.dot.gov/atdm/index.htm.

- Respond quickly and effectively to service disruptions that may be planned or unplanned, whether based on human or natural causes."[50]

Led by Dallas Area Rapid Transit (DART), the multi-agency ICM team for US-75 in Dallas, Texas developed a vision statement for the corridor and then four primary goals for the integrated management of the corridor. The team defined the vision as: "Operate the US-74 Corridor in a true multimodal, integrated, efficient, and safe fashion where the focus is on the transportation customer." This led the team to identify the following goals for the corridor:

- "Increase Corridor Throughput.
- Improve Travel Time Reliability.
- Improve Incident Management.
- Enable Intermodal Travel Decisions."[51]

Specific Outcome-based Operations Objectives

The high-level goals are the starting point for developing operations objectives, the basis for corridor TSMO planning. Operations objectives define desired outcomes for the corridor in relation to how the transportation system will perform. Operations objectives go beyond broad statements of goals, which often are loosely defined and difficult to assess. Operations objectives are specific, measurable statements developed in collaboration with a broad range of partners who have interests or who are affected by corridor transportation systems performance. They may be multijurisdictional in nature if the corridor of interest extends beyond or affects more than a single jurisdiction. Operations objectives generally lead directly to measures of performance that can be used to assess whether or not the objective has subsequently been achieved.

Operations objectives should be specific, measurable, agreed-upon, realistic, and time-bound (SMART):

- **Specific** – The objective provides sufficient specificity to guide formulation of viable approaches to achieving the objective without dictating the approach.
- **Measurable** – The objective facilitates quantitative evaluation, saying how many or how much should be accomplished. Tracking progress against the objective enables an assessment of effectiveness of actions.
- **Agreed** – 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 among all parties that use or manage the corridor of interest.
- **Realistic** – 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. Factors, such as land use, also may have an impact

50 U.S. Department of Transportation, *Concept of Operations for the I-880 Corridor in Oakland, California*, FHWA-JPO-08-003 (Washington, DC: March 2008). Available at: http://ntl.bts.gov/lib/30000/30700/30766/14389.pdf.

51 U.S. Department of Transportation, *Concept of Operations for the US-75 Integrated Corridor in Dallas, Texas*, FHWA-JPO-08-004 (Washington, DC: April 2008). Available at: http://ntl.bts.gov/lib/30000/30400/30409/14390.htm.

on the feasibility of the objective and should be taken into account. Because how realistic the objective is cannot be fully evaluated until after strategies and approaches are defined, the objective may need to be adjusted to be achievable.

- **Time-Bound** – The objective identifies a timeframe within which it will be achieved (e.g., "by 2017").

Specifically, an operations objective identifies targets regarding a particular aspect of corridor performance, such as traffic congestion, travel time reliability, emergency response time, or incident response. By developing SMART operations objectives, system performance can be examined and monitored over time.

Examples of operations objectives that may be applicable or could be adapted to corridor management and operations are provided in Federal Highway Administration's (FHWA) *Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach – A Desk Reference* (Figure 13).[52]

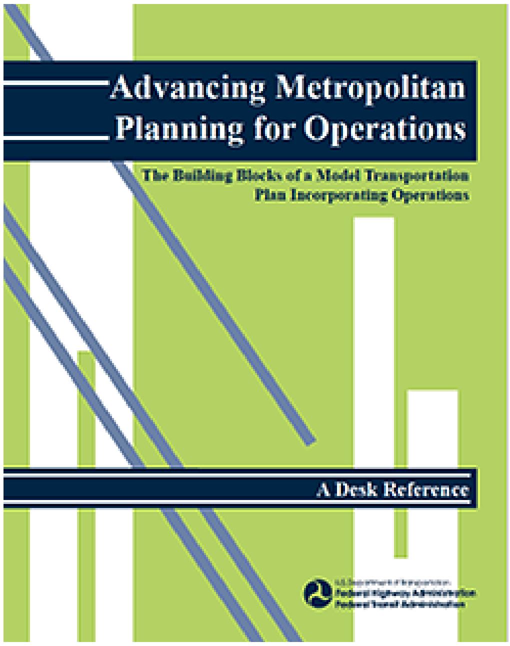


Figure 13. Image. Cover of Federal Highway Administration's Advancing Metropolitan Planning for Operations Desk Reference.

By including operations objectives that address system performance issues, such as recurring and non-recurring congestion, emergency response times, connectivity among modes, safety, and access to traveler information – rather than focusing primarily on system capacity – the planning effort for a corridor will elevate operations to play a more important role in investment planning, addressing both short- and long-range needs.

While outcome-oriented objectives are preferred because they are most closely related to the LOS provided to systems users, in some cases, outcomes are difficult to measure or observe directly. Corridor outcome-oriented objectives focused on outcomes to the user include corridor travel times, travel time reliability, and access to traveler information. The public cares about these measures, and in many regions, data may be available to develop specific outcome-based operations objectives.

In cases where developing outcome-based objectives is difficult, agencies may develop corridor operations objectives that are activity-based and support desired system performance outcomes. For example, it may not be possible for a region to develop a specific objective related to incident-based delay experienced by travelers in the corridor if data are unavailable for this type of delay. However, it may be possible to develop an objective that relates to incident response time in the corridor, which may be more easily established and measured.

52 Federal Highway Administration and Federal Transit Administration, *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*, FHWA-HOP-10-027 (Washington, DC: 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10027/.

Washington State Department of Transportation (WSDOT) US 195 Corridor Study – Spokane to the Idaho Border via Pullman – Clear Objectives and Data Analysis Lead to Innovative Lower-Cost Solutions

The WSDOT led the Target Zero US 195 Corridor Crash Analysis planning study in the eastern part of the state to identify the most common circumstances or trends that contribute to serious or fatal injury crashes on this rural two-lane highway. The WSDOT used robust community engagement and a data-driven process to identify the key causes of fatal and injury crashes on the corridor. Initial stakeholder engagement found that the community strongly preferred expansion to a four-lane divided roadway. However, a four-lane facility, a very costly improvement, would not provide a practical solution and would not address the primary crash causes like distracted and drowsy driving, speeding, driving under the influence, and aggressive (inappropriate passing) driving.

The WSDOT used a technical advisory committee composed of the regional transportation planning organization, cities, counties, universities, and law enforcement. The community was involved through a survey and various "listening posts," which were informal "meet and greets" at local gathering places like grocery stores, coffee shops, and post offices. Building on the crash data, the corridor study recommendations included a range of lower-cost operational and safety improvements, including enhanced intentional communication with travelers (e.g., variable message signs, brochures, public/private kiosks); improved striping; targeted maintenance to address real-time travel conditions; and enhanced emergency response, signage reflectivity, passing lanes, and geometric design to reduce the potential of severe and fatal crashes.

For more information, see http://www.wsdot.wa.gov/Projects/US195/.

Other examples of activity-based objectives include the percentage of traffic signals re-timed in the corridor, the number of variable message signs deployed, and the share of bus stops with real-time transit information. Although these objectives are not as ideal as outcome-based objectives because they tend to focus on specific strategies or approaches, they may serve as interim objectives until more outcome-based objectives can be established and measured. Working together to develop the objectives themselves may help to elevate management and operations discussions among planners and operators and lead to initiatives to collect additional data.

One technique for organizing outcome-oriented and activity-based objectives is to develop an *objectives tree* that structures objectives in a hierarchical manner, with each top-level objective supported by lower-level sub-objectives. The lower-level objectives, taken together, identify what must be achieved to realize the high-level objectives; the high-level objectives give the purpose for achieving the lower-level objectives. In many cases, the lower-level objectives will be activity-based objectives that relate to functions that must be performed to achieve high-level outcome-oriented objectives. Figure 14 illustrates how lower-level activity-based objectives support higher-level outcome-oriented objectives, all acting in support of goals for the corridor or region.

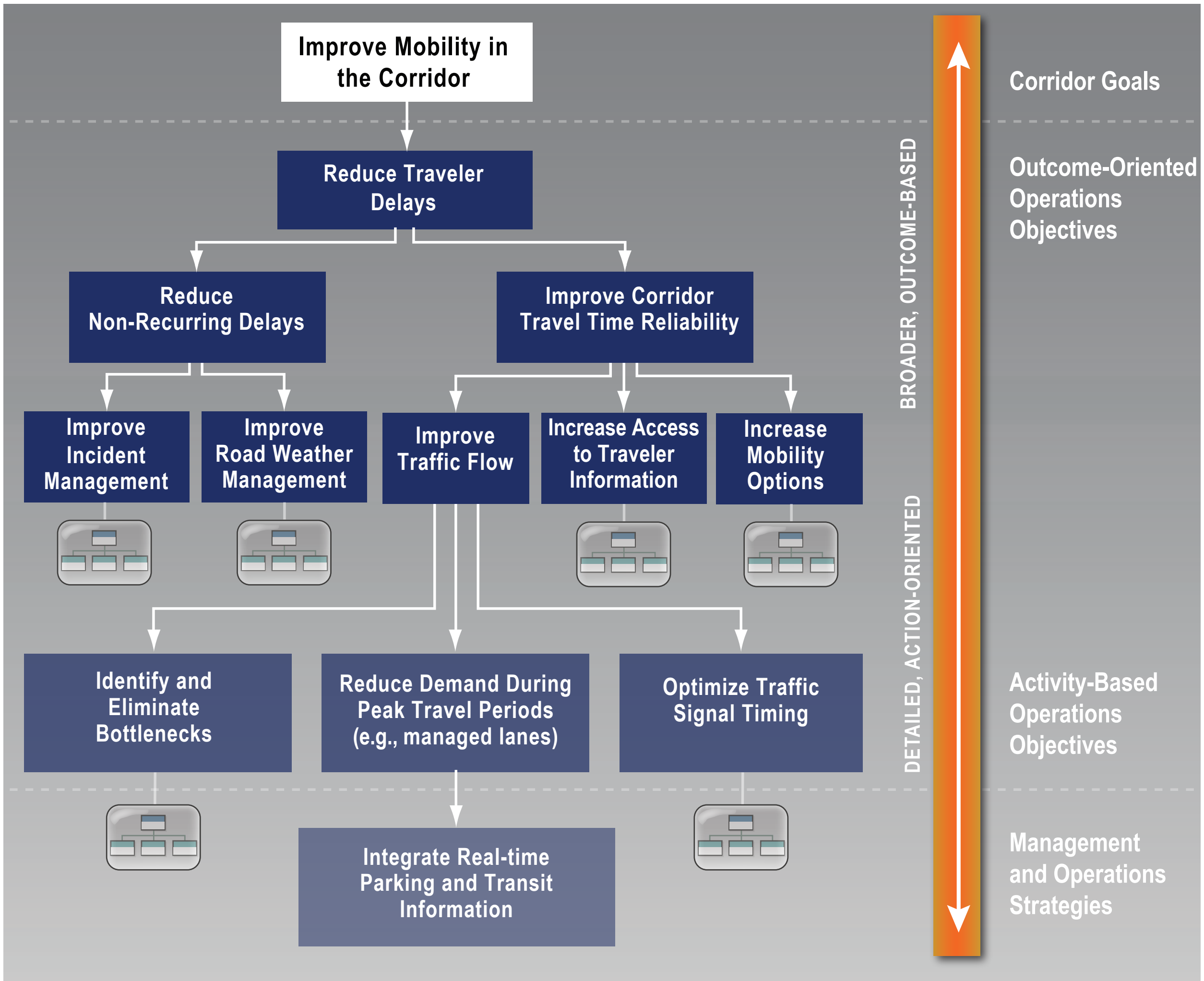


Figure 14. Diagram. Illustrative objectives tree for corridor-based transportation systems management and operations.

Performance Measures

One of the key attributes of SMART objectives is that they are *measurable*. *Performance measures* are associated with operations objectives and provide a measurable basis for:

- Understanding existing performance, including performance gaps.
- Assessing future projected gaps in performance.
- Supporting assessment of, and comparisons of, potential strategies to meet objectives.

The idea that "what gets measured gets managed," recognizes that performance measurement focuses the attention of decisionmakers, planners, stakeholders, and the public on important characteristics of the transportation system. Developing performance measures involves considering:

- How do we want to define and measure progress toward a certain operations objective? For instance, is transit ridership a key metric that is important for assessing livability and access? Or would bicycle/pedestrian activity be a better measure? Or do both provide value?

- What are the implications of selecting a specific measure? For instance, if travel speeds are a key measure of performance in a corridor, this would imply different strategies and results than focusing on improving reliability of travel times. Using a measure focused on person-travel rather than vehicle-travel might lead toward strategies that give more priority to high-occupancy modes like public transit or high-occupancy vehicle lanes than to those driving alone.

It is important to recognize that there are often tradeoffs among different goals and objectives (e.g., traffic throughput, increasing transit ridership, and enhancing pedestrian and bicycle access); therefore, defining an appropriate and balanced set of performance measures for a corridor is important.

Performance measures are indicators of how well the corridor transportation system is performing and are inextricably tied to operations objectives. A range of performance measures may come from developing operations objectives. The performance measures selected should provide adequate information to planners, operators, and decisionmakers on progress toward achieving their operations objectives.

However, this is an iterative process as operations objectives may be refined once performance measures are developed and baseline data have been collected.

Performance measures should be developed based on the individual needs and resources of each agency that provides services within the corridor. For example, transit agencies typically use a number of measures that are of interest to their customers, such as on-time performance, average passenger load, and total ridership. An MPO uses measures of mobility, such as facility LOS, travel time, and travel delay. These performance measures help planners focus on the day-to-day experience for their users. This provides important balance in settings where planners have focused exclusively on long-term development of the corridor. With greater focus on the day-to-day characteristics of the corridor, planners appreciate the issues faced by system operators. The result is that mid- and long-term planning now reflect greater consideration of operations and the associated investment needs within the corridor.

Some examples of performance areas and performance measures likely to be associated with corridor operations objectives are shown in Table 3. These performance measures are primarily drawn from the FHWA's *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*.[53]

53 See: Federal Highway Administration and Federal Transit Administration, *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*, FHWA-HOP-10-027 (Washington, DC: 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10026/chap_4.htm#fn15.

Table 3. Illustrative performance measures to guide corridor transportation systems management and operations planning.

Performance Area	Illustrative Performance Measures
Travel Time: Travel time measures focus on the time needed to travel along a selected portion of the corridor, and can be applied for specific roadways, corridors, transit lines, or at a regional level.	• Average travel time, which can be measured based on travel time surveys. • Average travel speeds, which can be calculated based on travel time divided by segment length or measured based on real-time information collection. • Travel time index: the ratio of peak to non-peak travel time, which provides a measure of congestion.
Congestion Extent: Congestion measures can address both the spatial and temporal extent (duration). Depending on how these measures are defined and data are collected, these measures may focus on recurring congestion or address both recurring and non-recurring congestion.	• Lane miles of congested conditions (defined based on volume to capacity (V/C) ratio, level of service (LOS) measures, or travel time index). • Number of intersections experiencing congestion (based on LOS). • Percent of roadways congested by type of roadway (e.g., freeway, arterial, collector). • Average hours of congestion per day. • Share of peak period transit services experiencing overcrowding.
Delay: Delay measures take into account the amount of time that it takes to travel in excess of travel under unconstrained (ideal or free-flow) operating conditions, and the number of vehicles affected. These measures provide an indication of how problematic traffic congestion is, and can address both recurring and non-recurring congestion-related delay.	• Vehicle-hours of recurring delay associated with population and employment growth. • Vehicle-hours of nonrecurring delay associated with incidents, work zones, weather conditions, special events, etc.
Incident Occurrence/Duration: Incident duration is a measure of the time elapsed from the notification of an incident until the incident has been removed or response vehicles have left the incident scene. This measure can be used to assess the performance of service patrols and incident management systems. Incident occurrence also can be used to assess the performance and reliability of transit services.	• Median minutes from time of incident until incident has been removed from scene. • Number of transit bus breakdowns. • Average number of transit rail system delays in excess of X minutes.

Table 3. Illustrative performance measures to guide corridor transportation systems management and operations planning. (Continued)

Performance Area	Illustrative Performance Measures
Travel Time Reliability: Travel time reliability measures take into account the variation in travel times that occur on roadways and across the system.	• Buffer time, which describes the additional time that must be added to a trip to ensure that travelers will arrive at their destination at, or before, the intended time 95 percent of the time. • Buffer time index, which represents the percent of time that should be budgeted on top of average travel time to arrive on time 95 percent of the time (e.g., a buffer index of 40 percent means that for a trip that usually takes 20 minutes, a traveler should budget an additional 8 minutes to ensure on-time arrival most of the time). • Percentage of travel when travel time is X percent (e.g., 20 percent) greater than average travel time. • Planning time index, defined as the 95th percentile travel time index. • 90th or 95th percentile travel times for specific travel routes or trips, which indicates how bad delay will be on the heaviest travel days. • Percentage of weekdays each month that average travel speed of designated facilities fall more than X MPH below posted speed limit during peak periods.
Transportation Demand Management (TDM): Transportation demand management measures examine demand in the corridor as well as the impact of strategies to manage that demand.	• Awareness – Portion of potential program participants aware of a TDM program. • Utilization – Number or percentage of individuals using a TDM service or alternate mode. • Mode split – Proportion of total person trips that uses each mode of transportation. • Vehicle Trips or Peak Period Vehicle Trips – The total number of private vehicles arriving at a destination.
Person Throughput: Examines the number of people that are moved on a roadway or transit system. Efforts to improve this measure are reflected in efforts to improve the flow of traffic, increase high occupancy vehicle movement, or increase transit seat occupancy on transit.	• Peak hour persons moved per lane. • Peak hour persons moved on transit services.

Table 3. Illustrative performance measures to guide corridor transportation systems management and operations planning. (Continued)

Performance Area	Illustrative Performance Measures
Customer Satisfaction: Examines public perceptions about the quality of the travel experience, including the efficiency of system management and operations.	• Percent of the population reporting being satisfied or highly satisfied with travel conditions. • Percent of the population reporting being satisfied or highly satisfied with access to traveler information. • Percent of the population reporting being satisfied or highly satisfied with the reliability of transit services.
Availability of or Awareness of Information: These measures focus on public knowledge of travel alternatives or traveler information.	• Percent of surveyed population aware of travel alternatives and related traveler information.

LOS = level of service.
TDM = transportation demand management.
MPH = miles per hour.

In summary, the performance measures (1) tie directly to the operations objectives, (2) provide the criteria for evaluating strategies and tactics for improving corridor performance, and (3) direct the gathering of data necessary to identify and prioritize needs and gaps.

IDENTIFYING OPERATIONS PERFORMANCE NEEDS, GAPS, AND OPPORTUNITIES

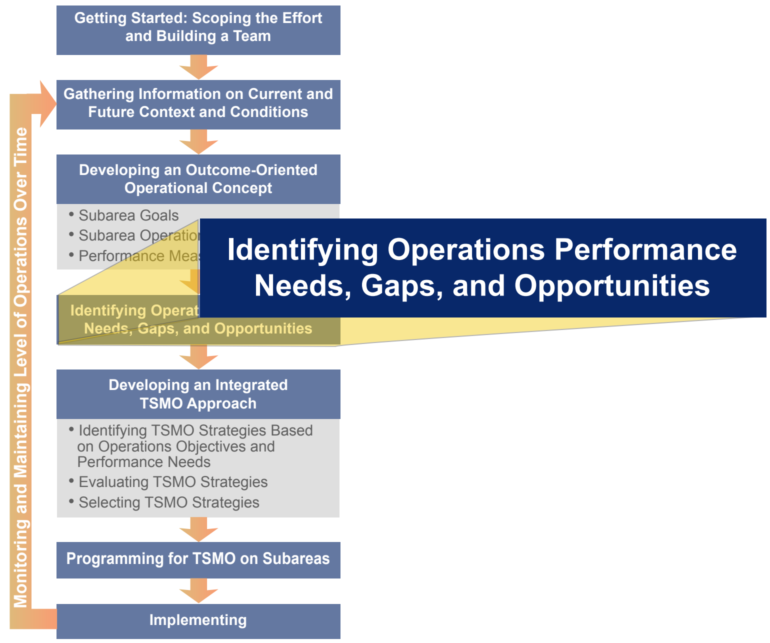
Gathering and analyzing data for performance measures is critical to identifying gaps between desired outcomes (objectives) and current conditions and in initially identifying potential opportunities for improvements (Figure 15).

Often, a key step following the definition of performance measures is to define scenarios, or to conduct a scenario planning exercise as a basis for understanding current performance gaps and potential opportunities. Operational scenarios should be defined by stakeholders in the corridor and may include (but are not limited to):

- **Normal or daily scenario** – to explore recurring congestion and typical challenges faced by travelers in the corridor, during peak and/or off-peak periods.
- **Incident scenario** – to address major or minor incidents along a highway, arterial, or transit service, to develop operational plans for how agencies work together and respond to these incidents.
- **Planned event scenario** – to address a major sporting event, festival, or activity that creates an atypical level of traffic demand along the corridor.

- **Weather-related, emergency, or evacuation scenario** – to consider unplanned events that may require more dynamic decisionmaking and coordination among stakeholders.
- **Major work zone scenario** – to address a major corridor construction or reconstruction project, and how transportation services, operations, and coordination will be conducted to minimize impacts on travelers, businesses, and the local community.

By defining scenarios, the participants in the corridor often can identify existing gaps, performance needs, and potential opportunities for improvements. Moreover, discussions to identify gaps aid planners and operators in clarifying and documenting problems within the corridor and highlight opportunities for improving corridor performance. In many cases, performance data are available that clearly demonstrate where problems exist and need attention, investment, and priority in the planning process, and may be tied to specific types of situations or scenarios where performance improvements would be most important.



TSMO=transportation systems management and operations.

Figure 15. Diagram. The activity, "Identifying Operations Performance Needs, Gaps, and Opportunities," of the approach for planning for transportation systems management and operations within corridors.

Planners and operators must be cautious in depending on performance measures alone to identify gaps and opportunities, especially activity-based performance measures, because the performance measures may be specific to existing systems and may focus attention on improving existing operations strategies rather than considering alternatives that take advantage of new operational concepts, new technology, new institutional arrangements, and new or emerging user expectations. For example, if the performance measures suggest the need to reduce delay in the corridor by increasing average speeds, planners and operators may be tempted to focus on strategies such as adaptive signal controls and may overlook opportunities for transportation demand management approaches that increase use of shared vehicles (e.g., transit, carpools, and parking) or shift demand to other times and routes, making more effective use of available capacity. This does not mean that adaptive signal controls are inappropriate; only that performance measures, if not taken in context, can result in focusing on "efficiency" of current approaches rather than in how well outcome-oriented objectives are achieved.

In the end, performance measures point toward deficiencies in achieving goals and objectives for the corridor and also can be helpful in identifying opportunities for improving corridor performance.

DEVELOPING AN INTEGRATED TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS APPROACH

Once the corridor TSMO planning team has agreed upon operations objectives for how the corridor should operate and identified the performance gaps, it can begin to identify a system of TSMO strategies that will be implemented on the corridor to reach the operations objectives. This system of TSMO strategies forms an integrated TSMO approach to improving performance on the corridor (Figure 16). It is important to consider TSMO strategies working together in the context of the corridor as opposed to selecting and implementing strategies in isolation. Planning for an integrated set of strategies allows planners and operators to leverage synergies between strategies. For example, the needs of first responders for managing traffic incidents should be considered when setting up work zones and, likewise, TIM plans may consider pre-positioning vehicles to support quick clearance in areas of reduced capacity due to work zones.

Key Considerations in Developing an Integrated Transportation Systems Management and Operations Approach

Ensuring a System Solution Rather than "Stand Alone" Activities

The traditional approach to transportation operations has traditionally involved individual agencies (State DOTs, local transportation agencies, toll authorities, transit service providers, etc.) managing their own assets and services (e.g., freeways, arterials, toll roads and bridges, and transit services). Yet, increasingly, a more effective and efficient approach is being used that involves a more holistic approach to managing operations on a corridor by viewing the corridor as a system, instead of a group of stand-alone assets. Under this approach, operators work together to make investments and real-time operations decisions to effectively shift travel demand across modes and routes to manage congestion, improve safety, and enhance system reliability. For instance, when a highway is severely congested due to a traffic incident, travelers may be directed to alternative routes, including parallel arterials, and traffic signal patterns may be adjusted to enable those arterials to better handle additional traffic.

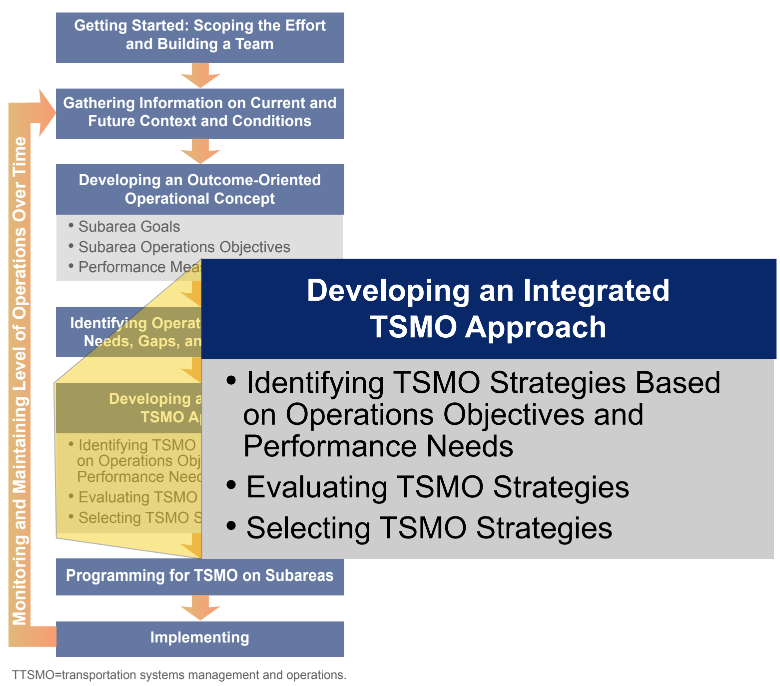


Figure 16. Diagram. The activity, "Developing an Integrated Transportation Systems Management and Operations Approach," of the approach for planning for transportation systems management and operations within corridors.

Moving Toward Active and Dynamic Transportation Systems Management

The use of operations strategies supports proactive and dynamic management of the transportation system, in which system performance is continuously assessed, and the system is managed through real-time implementation of adjustments (via traveler information, adjustments to signal timing, ramp metering, or other freeway operations) to achieve performance objectives (e.g., travel time reliability, corridor throughput, incident management). This approach requires collaboration, engaging partners to help influence travel choice and behavior along the corridor. Travel choice and behavior are influenced through active demand management (i.e., redistributing travel to less-congested routes or times of day and reducing overall trips by promoting mode choice); active traffic management (i.e., dynamically managing recurring and non-recurring congestion by improving travel throughput); and in urban areas, active parking management (i.e., optimizing the performance and utilization of available parking). Technology and innovation are critical to active and dynamic transportation systems management, supporting this data-driven approach implemented through information technology systems.

Focusing on the Traveler, Rather than Just Vehicles

A customer-focused perspective is the underpinning of an integrated approach to corridor management; rather than looking at enhancing vehicle throughput, a traveler-focused approach begins by examining traveler mobility needs and explores the most effective ways to meet those needs. This approach sets the context for developing a more efficient system for the end user. The TSMO approach is based on a fundamental understanding of how travelers decide which mode to use, what time to travel, which route to take, and at what time. Selecting operations strategies also requires segmentation of the travel market that differentiates between the various types of travelers (including commuters, non-commuter travelers, and freight movement), and understanding their travel behaviors, needs, and challenges to inform which operations strategies to implement.

Considering Community Values and Neighborhoods

Transportation within corridors plays a key role in mobility, but is more than just moving people and goods. Transportation within corridors is a lifeline for communities, often linking neighborhoods, businesses, and jobs. The context of corridors should reflect the character and values of the surrounding community. Integrating operational strategies into corridor planning is not a uniform approach; the set of strategies selected for an individual corridor should be customized and tailored to respond to the unique issues, challenges, and opportunities present. Therefore, successful TSMO integration into the planning process requires engaging the partners (i.e., the various agencies that operate along the corridor), as well as community stakeholders and the general public.

Recognizing Resource Constraints

Although TSMO strategies are typically low cost, especially in comparison to expansion projects, a successful approach to implementing operational strategies is including them as part of an integrated approach within a broader project or plan. In many cases, lower-cost solutions can be implemented, or TSMO strategies can be implemented over time, in phases, to advance operations improvements in stages over time. When prioritizing TSMO strategies for deployment, benefit-cost analysis, stakeholder and public input, and exploring the logical phasing of strategies are all useful analysis methods.

Developing an Incremental Approach to Transportation Systems Management and Operations

Transportation agencies engage in TSMO activities at varying degrees of complexity. For some agencies, a basic traffic signal system meets the management needs of its transportation network, while other agencies rely on a set of advanced and integrated TSMO strategies to meet the mobility needs of the community. In either case, planning for TSMO allows agencies to advance operational strategies in a measured, organized fashion, whether in a single corridor or across a city or region.

A key distinction in implementing TSMO strategies is that installation is just the starting point. Agencies must be prepared to expend the necessary resources to operate and maintain a collection of TSMO investments. The most effective TSMO activities are differentiated not by budgets or technical skills alone, but by the existence of critical processes and institutional arrangements tailored to the unique features of TSMO applications. Applying an incremental approach to TSMO strategies in a corridor is a clearer path to successful implementation by allowing time to both gain experience with the strategy and institute operational processes.

The sections below describe the main activities necessary for developing an integrated TSMO approach to TSMO on a corridor. One of the current areas of research is in analytical tools that support consideration of multiple TSMO strategies and is expected to provide more support in the future to developing an integrated TSMO approach. Currently, there are limited options for quantitatively examining the impacts of one TSMO strategy on another.

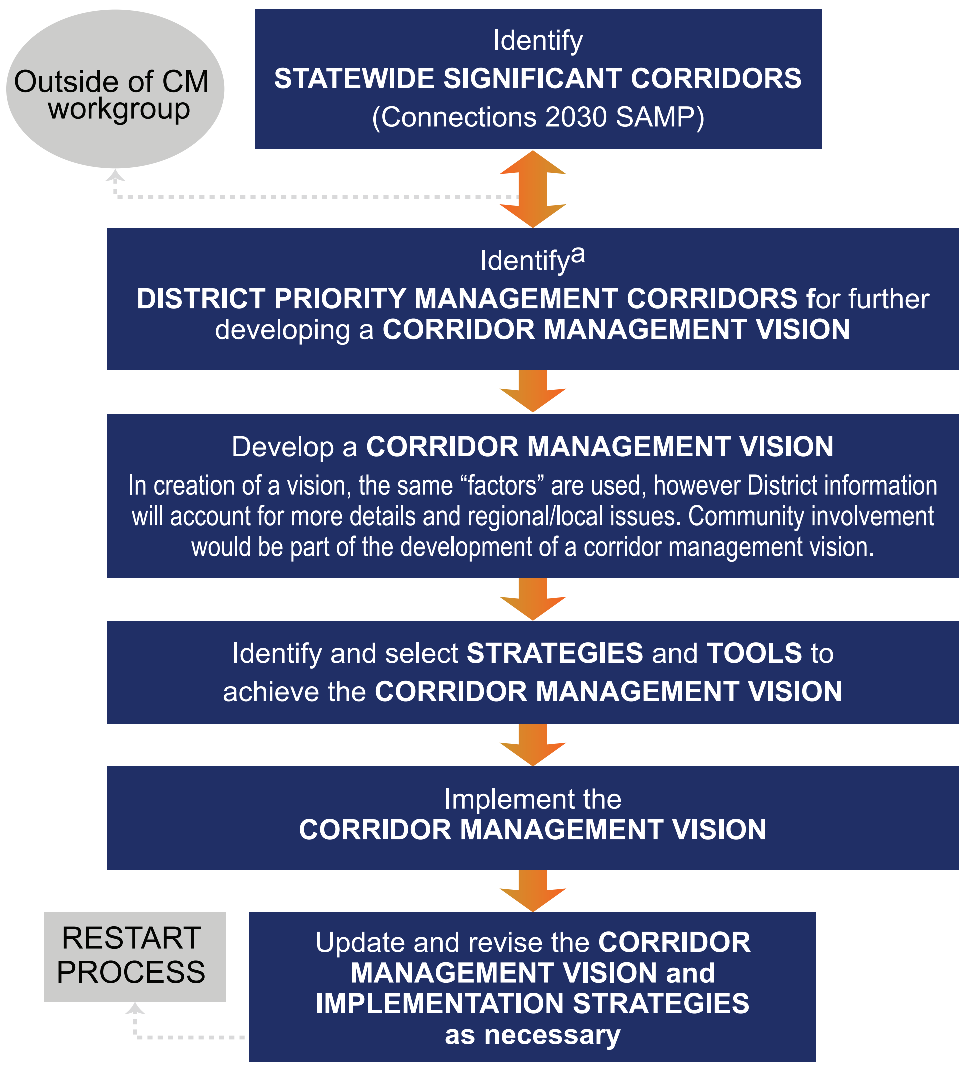
Identifying Transportation Systems Management and Operations Strategies Based on Operations Objectives and Performance Needs

There are a variety of ways to identify TSMO strategies that could be implemented to address causes of the shortfalls in performance or gaps. This section provides examples of methods or tools for identifying TSMO strategies based on operations objectives and performance needs in a corridor. While the FHWA has developed some basic mappings between goals or objectives and TSMO-related strategies, this also has occurred at the State and regional levels as well, as practitioners look to match strategies to needs within a specific context.

The Wisconsin DOT developed a Traffic Operations Infrastructure Plan in 2008 that offers a methodology for selecting TSMO strategies that begins with identifying significant corridors based on their strategic objectives, and then determines priority management corridors for which they develop a corridor management vision.[54] This process, illustrated in Figure 17, leads to selecting TSMO strategies that achieve the corridor management vision.

54 Wisconsin Department of Transportation, *WisDOT Traffic Operations Infrastructure Plan*, May 2008. Available at: http://worldcat.org/oclc/926983390/viewonline and http://www.topslab.wisc.edu/workgroups/toip.php.

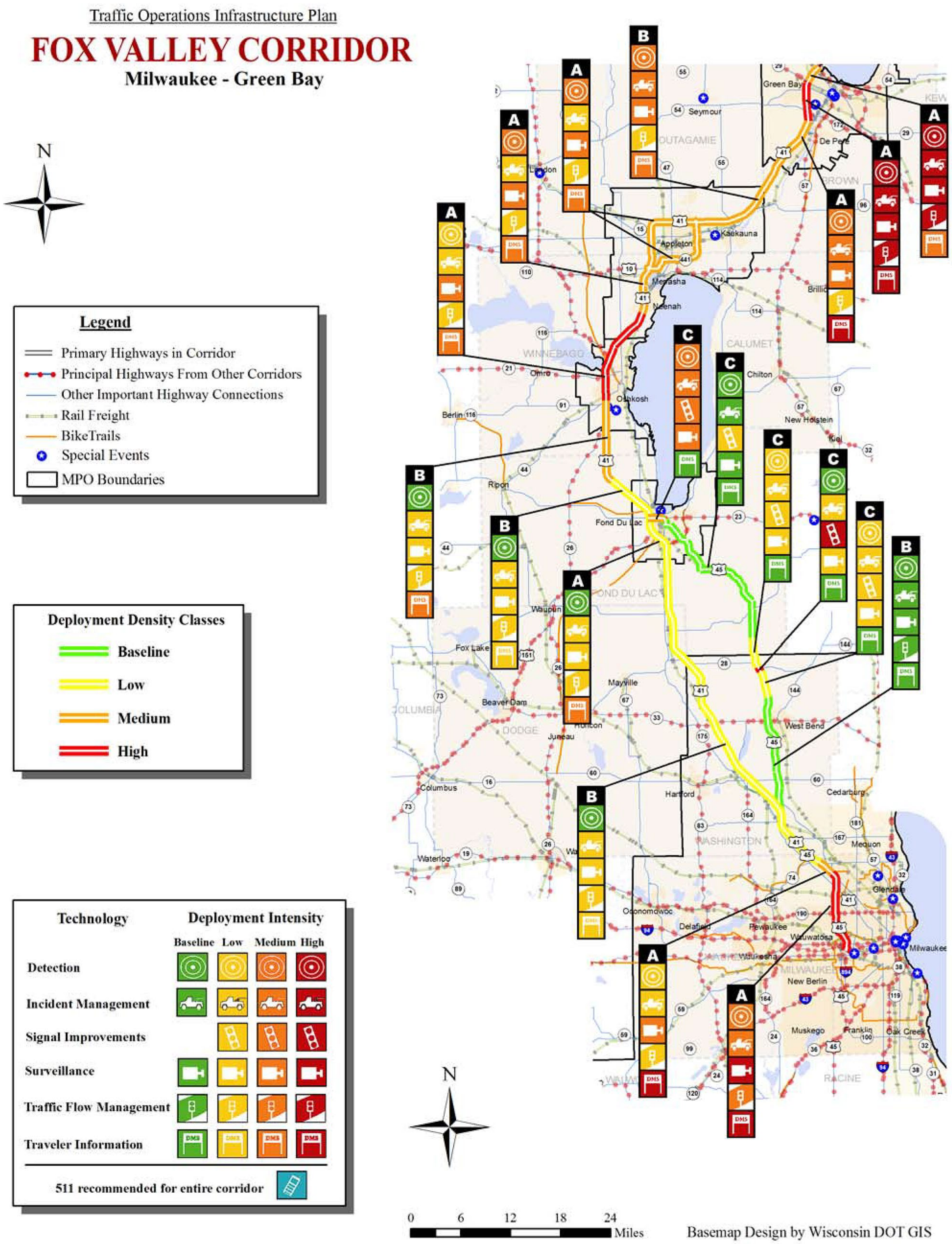
The approach results in a deployment density for TSMO strategies, such as is illustrated for the Milwaukee-Green Bay corridor in Figure 18. Note that the higher densities of TSMO deployment are concentrated in the most urbanized areas where traffic densities also are the greatest. WisDOT used this plan to strategically deploy ITS across the state. As WisDOT's TSMO program has evolved, the TOIP has been replaced it with a TMSO-Traffic Infrastructure Process, which is an deployment process that considers needs and solutions on an annual basis and uses a needs analysis and cost benefit tool.[55]



Source: Wisconsin Department of Transportation *Traffic Operations Infrastructure Plan*, May 2008.

Figure 17. Flowchart. Wisconsin Department of Transportation Traffic Operations Infrastructure Plan methodology for identifying priority corridors and related transportation systems management and operations strategies for achieving the corridor management vision.

55 Wisconsin Department of Transportation, Transportation Systems Management and Operations - Traffic Infrastructure Process, Web site. Available at: http://wisconsindot.gov/Pages/about-wisdot/who-we-are/dtsd/bto/stoc/tsmo-tip.aspx.



Source: Wisconsin Department of Transportation *Traffic Operations Infrastructure Plan*, May 2008.

Figure 18. Map. Milwaukee-Green Bay corridor transportation systems management and operations deployment density.

The FHWA's 2015 *Active Traffic Management Feasibility and Screening Guide* provides additional guidance in the form of a series of logic flowcharts that assist in determining the appropriateness of specific ATM strategies given well-defined mobility issues to be addresses by the TSMO strategies.[56] This document also describes methods for identifying and determining the capital investments required and expected operation and maintenance costs associated with various ATM strategies. Benefits are more difficult to predict, but the ATM Feasibility Guide suggests estimating benefits based on the experience of other locations where similar strategies were implemented in response to similar needs and objectives. In addition, the ATM Feasibility Guide suggests using the FHWA's Tool for Operations Benefit Cost Analysis (TOPS-BC) tool, a spreadsheet-based tool designed to assist practitioners in conducting benefit-cost analysis of operations strategies by providing four key capabilities, including:[57]

- The ability for users to investigate the expected range of impacts associated with previous deployments and analyses of many TSMO strategies.
- A screening mechanism to help users identify appropriate tools and methodologies for conducting a benefit-cost analysis based on their analysis needs.
- Framework and default cost data to estimate the life-cycle costs of various TSMO strategies, including capital, replacement, and continuing operations and maintenance costs.
- A framework and suggested impact values for conducting simple benefit-cost analysis for selected TSMO strategies.

In 2010, the FHWA took a qualitative approach to matching operations objectives to potential TSMO strategies through the development of the Fact Sheets in *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*.[58] Samples of these Fact Sheets tailored to corridors are at the end of this chapter. The Fact Sheets contain operations objectives that are SMART and can be tailored to an area, time period, mode or facility type, or user type. The Fact Sheets also identify TSMO strategies that could help realize the operations objectives. This is meant as a tool to assist planners and operators in generating ideas for TSMO strategies to support specific objectives. The Fact Sheets were not tailored for the specific operations context that each locality may encounter.

The current version of Turbo Architecture software, which is used to document regional ITS architectures, includes a "Planning" module that allows users to select operations objectives from the Fact Sheets or add custom objectives and link each of those to applicable service packages (essentially TSMO strategies) and performance measures.[59] The Turbo Architecture "Planning" module can be used to help identify TSMO strategies for corridors.

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56 Federal Highway Administration, *Active Traffic Management Feasibility and Screening Guide*, FHWA-HOP-14-019 (Washington, DC: May 2015). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop14019/index.htm.

57 Federal Highway Administration, *Tool for Operations Benefit Cost Analysis (TOPS-BC) Version 1.2*, Spreadsheet tool. Available at: http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm.

58 Federal Highway Administration and Federal Transit Administration, *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*, FHWA-HOP-10-027 (Washington, DC: 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10027/.

59 U.S. Department of Transportation, Office of the Assistant Secretary for Research and Technology, Intelligent Transportation Systems Joint Program Office, National ITS Architecture 7.1, Use In Transportation Planning, Web site. Available at: http://www.iteris.com/itsarch/html/archuse/planning.htm.

Regional ITS or TSMO plans commonly include a toolbox of TSMO strategies to support the identification of TSMO strategies for use. For example, the regional TSMO plan for the Portland, Oregon, region includes a TSMO Toolbox of Strategies organized by operational areas (e.g., arterials, freeways, and freight). Each strategy includes a description, example applications, potential benefits, estimated costs, and influencing factors (e.g., political, institutional, and technical).[60]

The Southwestern Pennsylvania Commission supports TSMO strategy identification in its congestion management process by rating corridors within the region against 25 strategies within their congestion management toolbox.[61] The strategies seek to improve demand management, modal options, transportation operations, and capacity. Each strategy is evaluated based on its suitability, reflecting ease of implementation, and applicability to a corridor. Each strategy also is given a benefit rating based on how significant its impact may be on reducing congestion. The ratings are used to categorize strategies into high, medium, and low priorities.

Several tools for screening TSMO strategies related to ATM are currently under development. The FHWA *Active Traffic Management Feasibility and Screening Guide* uses regional goals and associated issues and considerations to rate each potential TSMO strategy as offering a major improvement, some improvement, or neutral or not applicable.[62] Caltrans, District 7 developed an ATM assessment framework that can be applied to any freeway corridor in the state. The framework describes potential ATM strategies with associated costs and benefits, which will address deficiencies (e.g., safety/crashes, non-recurring congestion, recurring congestion) observed in a particular corridor. This tool will support District 7's implementation of an innovative corridor management approach to managing and optimizing performance on the freeway system.[63]

Sample Table for Identifying Transportation Systems Management and Operations Strategies for Corridors

Table 4 provides an example of TSMO strategies to consider based on operations objectives and performance gaps. This table focuses on objectives and strategies for an urban arterial that experiences recurring congestion. The desired outcome for improving corridor operations is the reduction of recurring congestion along the corridor. The middle column, "Performance Gap," documents the corridor's shortfalls in achieving any of the corridor's operations objectives. The last column, "TSMO Strategies to Consider," identifies potential TSMO strategies to address the deficiency or gap. To help ensure that an identified TSMO strategy will address the performance gap, the strategy should go through some type of screening and evaluation. The next section describes several options for doing this.

60 Metro, *Regional Transportation System Management and Operations Plan, Technical Appendix A*, June 30, 2010. Available at: http://www.oregonmetro.gov/regional-transportation-system-management-and-operations-plan.

61 For more information, see: Southwestern Pennsylvania Commission, *Congestion Management Process*, Web site. Available at: http://www.spcregion.org/trans_cong.shtml.

62 Federal Highway Administration, *Active Traffic Management Feasibility and Screening Guide*, FHWA-HOP-14-019 (Washington, DC: May 2015). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop14019/index.htm.

63 For more information, contact Caltrans, District 7, Division of Operations, at (213) 897-3656.

Table 4. Example transportation systems management and operations strategy identification for a desired outcome of reducing recurring congestion on arterials.

TSMO Area	Outcome-Oriented Operations Objectives	Performance Gap	TSMO Strategies to Consider
Emergency or Incident Management	• Improve emergency vehicle travel times by X percent in Y years.	Delay at traffic signals for emergency vehicles exceeds Z hours of delay per 1,000 vehicle miles traveled.	• Emergency vehicle preemption. • Emergency vehicle routing. • Traffic surveillance.
Transit Operations and Management	• For transit corridors, decrease delay by X percent per year. • Improve average on-time performance for corridor transit route by X percent within Y years.	Delay at traffic signals for transit exceeds Z hours of delay per 1,000 vehicle miles traveled.	• Transit signal priority. • Transit queue jump.
Freight Management	• For freight corridors, decrease hours of delay per 1,000 vehicle miles traveled by X percent in Y years.	Delay at traffic signals for trucks/freight exceeds Z hours of delay per 1,000 vehicle miles traveled.	• Truck signal priority.
Arterial Management: Delay and Signal Systems	• Decrease the seconds of control delay on the corridor by X percent in Y years. • Increase the number of intersections operating at level of service Z or higher by X percent in Y years. • Evaluate corridor signals for retiming every X years.	Delay at traffic signals for all modes exceeds Z seconds of control delay per traffic signal on the corridor.	• Enhanced traffic signal timing (e.g., re-timing/ optimization, adaptive systems, better detection). • Traffic surveillance.
Access Management	• Maintain a distance of X feet between corridor access points for the next Y years. • Reduce driveway access points by X percent for all new developments for the next Y years.	Delay at closely spaced intersections or driveways exceeds Z minutes per vehicle at each driveway.	• Access management.

Table 4. Example transportation systems management and operations strategy identification for a desired outcome of reducing recurring congestion on arterials. (Continued)

TSMO Area	Outcome-Oriented Operations Objectives	Performance Gap	TSMO Strategies to Consider
System Efficiency: Travel Time	• Improve average travel time during peak periods by X percent by year Y.	Delay at geometric bottlenecks exceeds Z minutes per vehicle per location.	• Bottleneck removal (e.g., turn lane additions).
		Directional imbalance of volume-to-capacity ratio that varies throughout day exceeds Z percent.	• Changeable lane assignment.
System Efficiency: Duration of Congestion	• Reduce the daily hours of recurring corridor congestion from X to Y by year Z.	Delay throughout corridor exceeds Z hours per day.	• High-capacity transit. • Traffic surveillance. • Traffic management center. • Transportation demand management.

TSMO = transportation systems management and operations.

Evaluating Transportation Systems Management and Operations Strategies

While many operations strategies (e.g., variable speed limits, queue warning systems, and dynamic ramp metering) have benefits, because they differ from conventional capacity investments in terms of cost, service life, and requirements, it is not always clear how to assess strategies. After identifying potential TSMO strategies for a corridor, there are several methods that are available to evaluate the strategies to determine which ones are most suitable to the corridor context and work together to provide the most benefit. This often takes place in two phases: screening the strategies for feasibility, and then conducting a more detailed evaluation prior to selecting strategies to move forward with funding and implementation. The evaluation factors may include technical and institutional feasibility, return on investment, or others relevant to the corridor stakeholders.

Numerous methods and tools are currently available to evaluate TSMO strategies as part of corridor planning. They vary in purpose served, complexity, input and output data, and the strategies that they analyze. Four main categories of analysis tools could apply to the evaluation of TSMO strategies: (1) travel demand models; (2) sketch-planning tools; (3) analytical/deterministic tools; and (4) simulation models, as well as many hybrid approaches. Sketch-planning tools allow for the basic screening of strategies, while deterministic tools and simulation typically go beyond the results of travel demand models to enable more detailed analysis of TSMO strategies. When selecting a tool, it is important to not only match the tool's capabilities to the corridor team's objectives, but also to consider other factors (e.g., budget, schedule, and resource requirements). The team should avoid trying to apply a tool that is more complex and time-consuming than needed. Conversely, the team should not use a tool that lacks the sensitivity or detail to address its need.

Travel demand models are useful in screening and evaluating corridor-wide strategies, such as congestion pricing and ridesharing programs, because they support an assessing mode choice and travel pattern or volume impacts. Travel demand models supply data to simulation models, sketch-planning tools, and post-processors that can analyze TSMO strategies. They are useful for generating traffic origin-destination patterns or volumes for input into simulation models. They are limited in their ability to analyze TSMO strategies, however, as they miss the impacts of incidents, work zones, and special events.

Sketch-planning tools are intended to provide quick analysis using generally available information and data. They provide a quick order-of-magnitude estimate with minimal input data in support of preliminary screening assessments. Sketch-planning tools are appropriate early on when prioritizing large numbers of strategies or investments for more detailed evaluation. They are typically spreadsheets or simple databases that are based on built-in assumptions of impacts and benefits for various strategies.

The FHWA developed the TOPS-BC, a benefit-cost analysis sketch-planning tool that is available to help corridor teams screen multiple TSMO strategies. It provides order-of-magnitude benefit cost estimates using default parameters that can be customized using local data. The TOPS-BC is available for download from the FHWA Planning for Operations Website.[64] The FHWA is continuing to develop products to assist practitioners in applying benefit-cost analysis for TSMO strategies.

Analytical or deterministic tools typically implement the procedures of the *Highway Capacity Manual*.[65] These tools quickly predict capacity, density, speed, delay, and queuing on a variety of transportation facilities and are validated with field data, laboratory test beds, or small-scale experiments. The primary example of a tool within this category is the Highway Capacity Software, which implements the procedures defined in the Highway Capacity Manual for analyzing capacity and determining LOS for signalized and unsignalized intersections, urban streets, freeways, weaving areas, ramp junctions, multilane highways, two-lane highways, and transit. These tools have somewhat-limited application for evaluating TSMO strategies for a corridor. They are mainly for individual intersections or small-scale facilities and are widely accepted for examining different types of traffic control strategies (e.g., uncontrolled, stop controlled, and signalized).

Simulation tools cover a range of software that is available to model transportation system operations and can be applied specifically to corridors. Simulation models are typically classified according to the level of detail at which they represent the traffic stream. Macroscopic simulation models simulate traffic flow, taking into consideration aggregate traffic stream characteristics (i.e., speed, flow, and density) and their relationships. Microscopic simulation models simulate the characteristics and interactions of individual vehicles. Mesoscopic simulation models simulate individual vehicles, but describe their activities and interactions based on aggregate (macroscopic) relationships.

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64 Tool for Operations Benefit CostAnalysis can be downloaded from: http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm.

65 Transportation Research Board, *Highway Capacity Manual 2010* (Washington, DC: 2010). Available from: http://www.trb.org/Main/Blurbs/164718.aspx.

Agencies use simulation tools to analyze operations of both traffic and transit to conduct needs assessments, alternatives analysis, and environmental impact studies. A key advantage of these tools is their ability to simulate conditions, such as incidents, and analyze conditions under multiple scenarios. Some specific strategies that can be simulated include ramp metering, express lanes, and variable speeds limits. Most simulation models also produce graphical or animated displays of the results. These can be invaluable in presenting key findings and results to a broad range of audiences beyond transportation professionals. The primary challenges associated with simulation tools are related to the resources required to develop and apply such models. These include the level of expertise needed, data and computing requirements, and the amount of time required to adequately and accurately calibrate models to real-world conditions.

Activity-based models are increasingly being used as a region's travel demand model and may be useful in evaluating TSMO strategies within corridors. They typically function at the level of individual traveler and represent how the person travels across the entire day. They provide detailed performance metrics but take much longer to run and have greater development and maintenance costs. They can evaluate pricing strategies, transportation demand management programs, and many other TSMO strategies.

Dynamic traffic assignment (DTA) also is emerging as a practical tool for numerous planning and operations applications. DTA is a type of modeling tool that combines network assignment models, used primarily in conjunction with travel demand forecasting procedures for planning applications, with traffic simulation models, used primarily for traffic operational studies. DTA involves the capability to assign or re-assign vehicle trip paths based on prevailing conditions. For example, a vehicle may be re-assigned to a different path in the middle of its trip due to the congestion on its original path. DTA enables evaluating operational strategies that are likely to induce a temporal or spatial pattern shift of traffic. It enables estimating travel behavior from various demand and supply changes and interactions. It is suitable for analyses involving incidents, construction zones, ATDM strategies, ICM strategies, ITS, managed lanes, congestion pricing, and other TSMO strategies. However, the application of DTA does generally require a significant investment of resources and expertise in both demand and simulation modeling.

Selecting Strategies to Best Achieve Objectives

Building on the assessment of potential strategies using analysis tools, the corridor plan will involve selecting a set of promising strategies to achieve the operations objectives for the corridor. Given the wide array of potential strategies to consider, including those that focus on highway/traffic operations, transit operations, demand management, and capacity, selecting strategies for a corridor often will involve both quantitative analysis, as well as qualitative assessments of what would work best to fit within the specific context of the corridor.

It is important to recognize that effective corridor management will typically involve implementation of a number of complementary strategies, rather than a single strategy, or even a set of strategies applied to different modes. One of the key values of exploring corridor operations is recognizing the interconnections between different roadway facilities, transit, and other modal options. Consequently, a number of individual strategies may be grouped together and considered as a package of improvements. For instance, improving arterial operations may involve a combination of traffic signal coordination, TSP, and parking management strategies. Typically, planners and operators will work together to identify and evaluate potential strategies, and then define a package or several possible packages of improvements. The alternative corridor strategies can then be evaluated in relation to their performance in relation to defined operations objectives, within the context of community values, and with recognition of available resources for implementation. Some strategies also may not require investments in infrastructure or technology deployment in the field, but could be fostered through improved data sharing and communications practices.

Prioritizing strategies or packages of strategies for selection often involves making tradeoffs in deciding what approach would be most effective to meet corridor objectives. For instance, use of a highway shoulder as a lane for buses could help improve transit reliability, but it needs to be considered in the context of road safety and the potential benefit for travelers in relation to the costs of upgrading the shoulder and lane markings, in comparison to other potential strategies. Similarly, on an urban arterial, traffic signal improvements, including retiming or TSP, need to consider an array of issues and potential impacts, including effects on road traffic, transit, and bicycles and pedestrians in terms of travel time and safety.

To the extent possible, using common evaluation methods for comparative assessments of strategy alternatives is valuable. For instance, if travel time reliability (i.e., consistent or predictable travel times and on-time transit performance) is a key objective for the corridor, then integrating reliability performance measures into the selection of strategies can help ensure that strategies are prioritized that best support the TSMO objectives for the corridor. TSMO strategies that improve reliability include a wide range of strategies: information systems, incident management, managed lanes, TSP, and transit and freight vehicle tracking. As a result, using reliability performance measures does not define a singular strategy but is helpful in comparing the estimating impacts of different strategies.

In addition to using the outputs of tools described above, approaches that can be used to compare strategies or packages of strategies include:

- **Analyzing cost-effectiveness:** Using a cost-effectiveness approach involves calculating the overall cost effectiveness (cost per unit of benefit) for each strategy based on defined benefits. Tools available to calculate reliability benefits include sketch planning, model post-processing, simulation, and multiresolution/multiscenario modeling. Once the cost effectiveness of each strategy is determined, strategies can be ranked in order from highest to lowest.
- **Benefit-cost analysis:** Benefit-cost analysis can be a useful tool for comparing different options, if sufficient data are available on key metrics, such as travel times and safety, to monetize these effects in relation to costs. Valuing travel time and delay is typically accomplished using surveys of travelers to determine their perceived benefit of travel time.[66]

66 Transportation Research Board, Strategic Highway Research Program, *Guide to Incorporating Reliability Measures into the Transportation Planning and Programming Processes* (Washington, DC: 2014). Available at: http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-L05-RR-2.pdf.

- **Multicriteria scoring:** Another approach is to use performance measures along with scoring criteria to assess how different alternatives support corridor performance objectives. For instance, if several key objectives have been defined for a corridor related to system operations (e.g., safety, transit on-time performance, highway reliability), then strategies are given scores in relation to each objective to prioritize the most promising strategies.

Commonly, the process of analyzing and selecting potential strategies or combinations of strategies will yield some approaches that are most promising.

PUTTING IT ALL TOGETHER

As described above, operations objectives are essential elements of TSMO planning. The following section provides a set of easy-to-use reference sheets for operations objectives that are relevant to corridors. Each reference sheet provides an overview of the operations objective area, a menu of operations objective statements and associated performance measures, a description of data needs and potential providers, and possible TSMO strategies to achieve the operations objective. They are intended as a resource for corridor TSMO planning teams who are searching for ideas for operations objectives and related TSMO strategies. The quick reference sheets draw from the FHWA's *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations – A Desk Reference*, and were adapted for application to corridor planning.[67]

67 Federal Highway Administration and Federal Transit Administration, *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*, FHWA-HOP-10-027 (Washington, DC: 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10027/.

System Efficiency: Corridor Travel Time

The objectives focus on reducing the amount of time it takes to travel through a corridor. Travel time is a measure of the average time spent in travel, which is a function of both travel speed and distance. The objectives can be made multimodal to account for transit, truck, and bicycle travel in the corridor, where appropriate.

Stakeholders	• State, county, or city agencies responsible for roadways. • Toll authorities. • MPOs. • Rideshare organizations. • Transportation management center(s). • Transit agencies. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Ports, if applicable. • Media.
Goals	• Reduce corridor travel time experienced by travelers.
Corridor Operations Objectives	• Improve average travel time during peak periods by X percent by year Y. • Improve average commute trip travel time by X percent by year Y.
Performance Measures	• Average travel time during peak periods (minutes). • Average commute trip travel time (minutes).
Anticipated Data Needs	• Peak period and free flow travel time and speeds. • Person travel along corridor links (e.g., vehicle volume multiplied by vehicle occupancy). • Trip length.
Data Resources and Partners	State DOTs, counties, cities, traffic management centers, and private sector sources can provide travel time data including speeds and volumes. Transit agencies can provide transit travel time, speed data, and passenger counts.
TSMO Strategies to Consider	Strategies designed to reduce recurring peak period congestion, such as traffic signal coordination, and transportation demand strategies that encourage shifts in travel mode, time, or route. If the objective includes transit or bicycles, strategies can include transit signal priority or bicycle traffic signals.

System Reliability: Non-Recurring Delay in Corridors

This set of objectives is focused on minimizing non-recurring delay in corridors. This type of travel-time delay is caused by transient events as opposed to delay caused by geometric limitations or a lack of capacity. These objectives focus on non-recurring delay due to scheduled and unscheduled disruptions to travel.

Stakeholders	• State, county, or city agencies responsible for roadways, including maintenance crews. • Toll authorities. • MPOs. • Transportation management center(s). • Transit agencies. • Incident responders. • Contractors. • Utility agencies/companies. • Weather forecast services. • 911 center(s). • Law enforcement. • Fire and rescue agencies. • Emergency medical agencies. • Tow industry. • Hazardous materials industry. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Ports, if applicable. • Media.
Goals	• Minimize non-recurring delay (scheduled and non-scheduled disruptions) in corridors.

Corridor Operations Objectives	• Reduce total person hours of delay in corridor by time period (peak, off-peak) caused by:
	  ◦ Scheduled events (i.e. work zones, system maintenance, special events) by X hours in Y years.
	  ◦ Unscheduled disruptions to travel (i.e. crashes, weather, debris) by X hours in Y years.
	  ◦ All transient scheduled and non-scheduled events by X hours in Y years.

Performance Measures	• Travel time delay during scheduled and/or unscheduled disruptions to travel in the corridor. • Total person hours of delay during scheduled and/or unscheduled disruptions to travel in the corridor.
Anticipated Data Needs	• Average travel time by person or vehicle during non-recurring events such as traffic incidents, special events, and work zones. • Average travel time by person or vehicle during free flow travel conditions in the corridor.

System Reliability: Non-Recurring Delay in Corridors (Continued)

Data Resources and Partners	Travel time data during non-recurring events may be difficult to collect, particularly during unscheduled events, such as incidents and severe weather. Transportation management centers and/or 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 also may need to be involved in identifying times and locations of severe weather that may have impacted travel.
TSMO Strategies to Consider	Strategies to reduce non-recurring delay include those that focus on reducing the delay caused by incidents, work zones, special events, weather, and other non-recurring events that affect traffic flow.

System Options: Bicycle and Pedestrian Accessibility and Efficiency

The objectives focus on improving the accessibility and efficiency of bicycle and pedestrian modes to offer travelers feasible and attractive travel options within a corridor.

Stakeholders	• State, county, or city agencies responsible for roadways. • Transportation management centers. • Transit agencies. • University research centers. • Ports, if applicable. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Pedestrian and bicycle advocacy groups.
Goals	• Improve bicycle and pedestrian accessibility and efficiency. • Provide attractive bicycle and pedestrian travel options in a corridor.
Corridor Operations Objectives	• Decrease average delay for pedestrians and bicyclists on primary pedestrian and/or bicycle routes by X percent in Y years. • Increase system completeness in corridor for pedestrians and/or bicyclists by X percent within Y years. • Increase the number of intersections with pedestrian and/or bicycle safety features (e.g., countdown pedestrian signal heads, bicycle signals, painted crosswalks/bike boxes) to X percent by year Y. • Increase average pedestrian (or bicyclist) comfort level by X points in Y years.
Performance Measures	• Average delay for pedestrians and bicyclists on primary pedestrian and/or bicycle routes in the corridor. • Percent of corridor with pedestrian and/or bicycle facilities. • The percentage of intersections with pedestrian and/or bicycle safety features. • Average pedestrian and/or bicyclist comfort level as measured by survey.
Anticipated Data Needs	• Average wait time for pedestrians and bicyclists at intersections or path impediments by time period. • An inventory of bicycle and pedestrian infrastructure. • Survey information on pedestrian and/or bicyclist comfort level.
Data Resources and Partners	State and local DOTs, MPOs, counties, cities, highway districts, and universities are sources for pedestrian and bicycle travel data. Private-sector crowd sourcing data also can be utilized to inventory conditions and comfort level. Pedestrian and bicycle advocacy groups can be a source of data.
TSMO Strategies to Consider	Pedestrian countdown signals, bicycle lanes, wayfinding signage, and crossing signals where bicycles cross major roadways.

Arterial Management: Traffic Signal Management

The objectives focus on improving the management of traffic signal operations in an arterial corridor through advanced technology, increased reviews, and planning.

Stakeholders	• State, county, or city agencies responsible for roadways. • Transportation management center(s). • Traffic signal technicians. • Incident responders. • Contractors. • Transit agencies. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Ports, if applicable.
Goals	• Improve arterial traffic signal operations for day-to-day operations during peak and off-peak periods. • Improve arterial traffic signal operations during scheduled or non-scheduled events.
Corridor Operations Objectives	• Evaluate signal timing in arterial corridor every Y years. • Increase the number of arterial corridor intersections running in a coordinated, closed-loop, or adaptive system by X percent in Y years. • Prepare and implement special arterial corridor timing plans for use during freeway incidents, roadway construction activities, or other special events by year Y. • Crash data for arterial corridor is reviewed every X years to determine if signal adjustments can be made to address a safety issue.
Performance Measures	• Number of years between traffic signal timing evaluation in arterial corridor. • Number of intersections running in a coordinated, closed-loop, or adaptive system. • Completion of at least one special timing plan for incidents, construction, or events in arterial corridor. • Number of times per year a special timing plan is used in arterial corridor. • Number of years between reviews of crash data on all arterials for possible signal timing impacts.
Anticipated Data Needs	• Reports from operating agencies on frequency of signal retiming evaluation, current traffic signal capabilities, special timing plans, and crash data reviews.
Data Resources and Partners	Partner agencies that operate arterials and agencies that maintain traffic crash records.
TSMO Strategies to Consider	Regular evaluation of corridor traffic signal timing, enhanced traffic signal systems, special corridor timing plans for events, incidents, and work zones, and regular review of corridor crash data.

Freeway Management: Ramp Management

The objectives focus on the application of traffic control devices, such as ramp meters, signing, and gates, to regulate the number of vehicles entering or leaving the freeway to achieve operations objectives.

Stakeholders	• State, county, or city agencies responsible for roadways. • Transportation management center(s). • Transit agencies. • 911 center(s). • Law enforcement. • Fire and rescue agencies. • Emergency medical agencies. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Ports, if applicable. • Media.
Goals	• Improve overall freeway corridor operations during peak periods and during scheduled or unscheduled events.
Corridor Operations Objectives	• Increase the percent of interchanges in a freeway corridor operating at LOS Z or higher during peak periods by X percent by year Y. • Reduce the number of congestion-inducing incidents occurring at freeway ramps by X percent by year Y. • Increase the number ramps in freeway corridor currently metered by X percent by year Y.
Performance Measures	• Number and percent of freeway corridor interchanges operating at LOS Z or above during peak periods (per year). • Total number of congestion-inducing incidents at freeway corridor interchanges during peak period (per year). • Number of freeway corridor interchanges with ramp meters (by year of installation).
Anticipated Data Needs	• Traffic volume and LOS data (e.g., traffic counts) at freeway corridor interchanges. • Total number of congestion-related incidents at freeway corridor interchanges. • Number of freeway corridor 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., High-Occupancy Vehicle (HOV), special events), and ramp terminal treatments.

Transit Operations and Management: Transit Signal Priority

The objectives focus on implementing TSP systems to improve transit performance and reliability within a corridor.

Stakeholders	• State, county, or city agencies responsible for roadways. • Transportation management center(s). • Traffic signal technicians. • Transit agencies. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Ports, if applicable.
Goals	• Improve transit service performance and reliability on corridors with traffic signals.
Corridor Operations Objectives	• Increase implementation of TSP at X number of intersections over the next Y years. • Decrease traffic signal delay on transit routes in corridor by X percent per year. • Decrease transit vehicle delay in corridor by X percent per year by increasing the use of queue jumping and automated vehicle location.
Performance Measures	• Number of transit routes/intersections equipped with TSP capability in corridor. • System-wide, signalized-stop delay on transit routes. • Travel time delay on routes with queue jumping and automated vehicle location in use.
Anticipated Data Needs	• Number of transit routes/intersections with transit signal priority capabilities. • Automated vehicle location data with location and travel time delay. • Signal operations/green time reports.
Data Resources and Partners	Transit agencies and traffic signal operating agencies in the region can provide information about implementation and performance of TSP. Automated vehicle location data can provide transit vehicle travel time.
TSMO Strategies to Consider	TSMO strategies to increase TSP implementation could involve identification and prioritization of transit routes and signalized intersections that are candidates for implementing TSP systems or queue jumping. Another strategy may include collaboration with the traffic management agency to leverage TSP implementation with traffic signal system upgrades.

Traffic Incident Management

The objectives focus on improving system efficiency, system reliability, traveler information, and agency efforts for managing traffic incidents within a corridor.

Stakeholders	• State, county, or city agencies responsible for roadways. • MPOs. • Transportation management center(s). • Transit agencies. • 911 center(s). • Law enforcement. • Fire and rescue agencies. • Emergency medical agencies. • Tow industry. • Hazardous materials industry. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Ports, if applicable. • Media.
Goals	• Reduce traffic incident duration and person hours of delay on a corridor. • Provide travelers with accurate, timely, and actionable information and improve customer satisfaction. • Increase coordination and communication between agencies. • Train incident management staff.
Corridor Operations Objectives	• Reduce corridor mean incident notification time by X percent over Y years. • Reduce mean time for needed corridor responders to arrive on-scene after notification by X percent over Y years. • Reduce corridor mean incident clearance time and mean roadway clearance time per incident by X percent over Y years. • Reduce mean time of incident duration on transit services and corridor facilities by X percent in Y years. • Reduce the person hours of total delay associated with corridor traffic incidents by X percent over Y years. • Reduce time between incident verification and posting a traveler alert to traveler information outlets by X minutes in Y years. • Reduce the time between recovery from incident and removal of traveler alerts for that incident. • Increase number of repeat visitors to corridor traveler information outlet by X percent in Y years. • Increase customer satisfaction with corridor incident management efforts by X percent over Y years. • Increase the percentage of incident management agencies that participate in a coordinated corridor incident response team by X percent in Y years. • Hold at least X multi-agency after-action review meetings each year with attendance from at least Y percent of the agencies involved in the response. • Conduct X joint training exercises among incident/emergency operators and responders for the corridor by year Y.

Traffic Incident Management (Continued)

Performance Measures	• Average incident notification time of necessary response agencies. • Mean time for needed responders to arrive on-scene after notification. • Mean incident clearance time and mean roadway clearance time per incident. • Mean time of incident duration. • Person hours of delay associated with corridor traffic incidents. • Time to alert travelers of a corridor incident. • Time between recovery from incident and removal of traveler alerts. • Number of repeat visitors to traveler information outlet. • Percentage of customers satisfied with corridor incident management practices. • Number of participating agencies in a corridor coordinated incident response team. • Number of multi-agency after-action reviews per year. • Percentage of responding agencies participating in after-action review. • Number of joint training exercises conducted among incident/emergency operators and responders.
Anticipated Data Needs	• For each incident of interest in the corridor, incident notification time and on-scene arrival time; specifically, the time of the awareness of an incident and one or more of the following pieces of data: the time the last responder left the scene, the time when all lanes were re-opened, and the time when traffic returned to full operational status. • Total travel time in person hours of travel (1) during free flow conditions, and (2) impacted by incidents. • Time of incident verification, time of traveler information outlet activation (e.g., dynamic message sign posting, 511 entry, and website log), time of corridor system recovery, and time of travel alert removal. • Customer satisfaction surveys. • Number of agencies participating in a corridor incident management program. • Number of after-action reviews held. • Number of joint training exercises conducted among incident/emergency operators and responders.
Data Resources and Partners	Data would need to be tracked by the incident responders, 9-1-1 dispatchers, or operators at a transportation 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.

Traffic Incident Management (Continued)

TSMO Strategies to Consider	Many of the incident management strategies are complementary and work together to achieve the objectives. For example, providing accurate and timely traveler information can help reduce travel time delay by encouraging travelers to avoid the incident area and also can help improve customer satisfaction. Increasing agency participation along the corridor, holding after action review meetings, and holding joint training can help improve incident detection and verification and help shorten incident clearance time. Other strategies to consider include enhancing inter-agency voice and data communications systems, using or expanding the use of roving corridor patrols, expanding surveillance camera coverage, and training on dissemination of corridor traveler information.

Road Weather Management

The objectives for managing road weather on a corridor focus on improving system efficiency, system reliability, traveler information, and traffic signal management within a corridor.

Stakeholders	• State, county, or city agencies responsible for roadways, including maintenance crews. • Weather forecast services. • MPOs. • Transportation management center(s). • Transit agencies. • 911 center(s). • Law enforcement. • Fire and rescue agencies. • Emergency medical agencies. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Ports, if applicable. • Media.
Goals	• Improve the clearance time of weather-related debris (e.g., fallen limbs and trees, snow and ice, and power lines and poles) from the corridor transportation facilities. • Help travelers avoid corridor segments that are dangerous and would cause them substantial delay. • Disseminate relevant information to travelers in a timely manner regarding the impact of weather on corridor travel. • Increase the coverage of the corridor (e.g., roadway, transit, or bicycle facilities) with weather sensors and communications. • Improve traffic signal management during inclement weather conditions.
Corridor Operations Objectives	• Reduce average time to clear corridor of weather-related debris after weather impact by X percent in Y years. • Increase by X percent the number of significant corridor segments covered by weather-related diversion plans by year Y. • Increase the percent of agencies that have adopted multi-agency, weather-related corridor transportation operations plans and are involved in operations during weather events to X percent by year Y. • Reduce time to alert travelers of travel weather impacts using traveler information outlets (e.g. dynamic message signs, 511, websites, social media) by X (time period or percent) in Y years. • Increase the percent of the corridor covered by weather sensors or a road weather information system by X percent in Y years, as defined by a road weather information system station within Z miles. • Special timing plans are available for use during inclement weather conditions for X miles of the corridor by year Y.

Road Weather Management (Continued)

Performance Measures	• Average time to clear selected corridor surface transportation facilities of weather-related debris after weather impact. • Percent of significant corridor segments covered by weather-related diversion plans. • Percent of agencies involved in transportation operations during weather events that have adopted multi-agency, weather-related corridor transportation operations plans. • Time from beginning of weather event to posting of information to traveler information outlets. • Percent of corridor within Z miles of a road weather information system station. • Number of miles of corridor that have at least one special signal timing plan for inclement weather events.
Anticipated Data Needs	• Time in which the corridor surface transportation facilities have been impacted by the debris, and the time required to clear the corridor and restore it to full operation. • Number of weather-related diversion plans. • Total number of agencies involved in transportation operations during weather events that have adopted multi-agency, weather-related corridor transportation operations plans. • Time of the start of a weather event and the time in which information is given to travelers by traveler information outlets. • Deployment locations of each road weather information system station near the corridor and length of the corridor. • Reports from operating agencies on corridor signal retiming, signal capabilities, and special timing plans.
Data Resources and Partners	Field data may come from fixed road or airport weather sensors (road weather information systems), observations from meteorologists, National Weather Service data, or mobile observations from connected vehicles.
TSMO Strategies to Consider	Many TSMO strategies for road weather management are complementary and work towards achieving multiple objectives. TSMO strategies that support agency operations, and in turn help with system reliability and efficiency, include weather sensors/stations at key corridor locations; pre-positioned debris removal vehicles; preventative techniques, such as spreading de-icing material prior to a storm; collaboration with weather forecasting services; and development of alternate route plans in preparation for events through collaboration between jurisdictions and modes. System efficiency also can be improved by developing and implementing special signal timing plans for typical travel demand during weather events. Traveler information strategies that help travelers make informed decisions include current corridor weather and facility information, weather forecasts, status information on operational activities (e.g., map of snow plow activities), and the use of dynamic message signs on the corridor or approaches to the corridor.

Work Zone Management

The objectives focus on improving system efficiency, system reliability, traveler information, and agency coordination efforts for managing work zones within a corridor.

Stakeholders	• State, county, or city agencies responsible for roadways, including maintenance crews. • Contractors. • Utility agencies/companies. • MPOs. • Transportation management center(s). • Transit agencies. • 911 center(s). • Law enforcement. • Fire and rescue agencies. • Emergency medical agencies. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Ports, if applicable. • Media.
Goals	• Reduce travel time delay within corridor work zones. • Reduce the extent of congestion for travelers within work zones. • Reduce the variability in travel time within work zones. • Reduce the overlap in corridor construction projects to reduce the burden on transportation system users. • Inform travelers of ongoing corridor work zones to reduce travel time delays. • Improve customer satisfaction with work zone management.
Corridor Operations Objectives	• Reduce the person hours of total delay associated with corridor work zones by X percent over Y years. • Increase the rate of on-time completion of corridor construction projects to X percent within Y years. • Increase the percentage of corridor construction projects that employ night/off-peak work zones by X percent in Y years. • Reduce the percentage of vehicles traveling through corridor work zones that are queued by X percent in Y year. • Reduce the average and maximum length of queues, when present by X percent over Y years. • Reduce the average time duration (in minutes) of queue length greater than Z miles by X percent in Y years. • Reduce vehicle hours of total delay in work zones caused by incidents (e.g., traffic crashes within or near the work zone). • Increase the number of capital projects reviewed for corridor construction coordination by X percent in Y years. • Decrease the number of work zones on parallel routes/along the same corridor by X percent in Y years.

Work Zone Management (Continued)

Corridor Operations Objectives (continued)	• Establish a work zone management system within X years to facilitate coordination of work zones in the corridor. • Provide work zone information and multimodal alternatives to traveler information outlets for at least X percent of corridor work zones over the next Y years. • Increase customer satisfaction with corridor work zone management efforts by X percent over Y years.
Performance Measures	• Person hours of delay associated with corridor work zones. • Percent of corridor construction projects completed on-time. • Percent of corridor construction projects employing night/off-peak work zones. • Percent of vehicles experiencing queuing in corridor work zones. • Length of average and maximum queues in corridor work zones. • Average duration in minutes of queue length greater than Z miles. • Vehicle hours of delay due to incidents related to work zones. • Percent of corridor capital projects whose project schedules have been reviewed. • Percent of work zones on parallel routes/along the same corridor. • Presence of an established work zone management system. • Percent of corridor work zones for which traveler information and multimodal alternatives are available through traveler information outlets. • Percentage of customers satisfied with corridor work zone management practices.
Anticipated Data Needs	• Total travel time in person hours of travel: (1) during free flow conditions, and (2) impacted by work zones. • Work zone information for work and non-work time periods (e.g., traffic volumes, travel time, and work zone length [average and maximum]). • Number of construction projects completed on time. • Number of construction projects employing night/off-peak work zones. • Number of vehicles traveling through work zones. • Number of vehicles traveling through work zones experiencing queuing. • Duration of queue length greater than Z miles. • Hours of incident-related delay in work zones. • Corridor capital projects submitted for review. • Corridor capital project anticipated and actual schedules. • Map of work zones along area maps. • Availability of traveler information and multimodal alternatives for work zones. • Customer satisfaction surveys.

Work Zone Management (Continued)

Data Resources and Partners	Data would need to be collected by agencies responsible for maintenance and operation of the transportation facilities. Partners needed may include DOTs, public safety agencies, contractors, and utility companies.
TSMO Strategies to Consider	Many of the TSMO strategies for work zone management work together in a complementary fashion to achieve the objectives. For example, providing ahead-of-time and real-time multimodal traveler information can help reduce travel time delay and extent of congestion by providing travelers with tools to help them avoid or minimize their exposure to the work zone. This strategy, along with shortening lane closure times particularly during high travel demand periods, also helps improve customer satisfaction. Multi-agency coordination, such as scheduling different work zones for different construction seasons, can help minimize the overall corridor travel impacts. Other strategies to consider include using temporary traffic control devices and practices that minimize the opportunity for crashes, which in turn shortens the incident-related delay in work zones, and using dynamic message signs or portable variable message signs to disseminate traveler information along the corridor or on approaches to the corridor.

Active Transportation and Demand Management

This objective set focuses on actively influencing traveler choices to better manage travel supply and demand. Active management includes proactive, predictive, and reactive elements.

Stakeholders	• State, county, or city agencies responsible for roadways. • Toll authorities. • Parking providers. • MPOs. • Rideshare organizations. • Transportation management center(s). • Transit agencies. • Law enforcement. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Ports, if applicable. • Media. • Travelers.
Goals	• Actively manage travel supply and demand, traffic operations, and parking by influencing traveler choices related to destination, time of day, mode, route, and facility/lane to improve system efficiency and reliability.
Corridor Operations Objectives	• Increase the number of corridor travelers receiving information on ATDM strategies by X percent within Y years. • Increase customer satisfaction with ATDM efforts by X percent over Y years. • Improve average corridor travel time during peak periods by X percent by year Y. • Reduce corridor trips per year by X percent through dynamic ridesharing and active transit management within Y years. • Increase the percentage of corridor travelers with electronic toll collection transponders by X percent by year Y. • Increase the share of corridor segments or lanes that are using dynamic pricing to X percent by year Y. • Reduce the number of congestion-inducing crashes occurring on the corridor and at corridor freeway ramps by X percent by year Y. • Implement active parking management for X percent of the corridor within Y years.

Active Transportation and Demand Management (Continued)

Performance Measures	• Total number and percent of corridor travelers receiving information on ATDM strategies. • Percent of customers satisfied with corridor ATDM practices. • Average corridor travel time during peak periods (minutes). • Share of household trips by each mode of travel before and after availability of dynamic ridesharing and active transit management. • Percent of corridor travelers with electronic toll collection transponders. • Share of corridor segments or lane miles using dynamic pricing. • Total number of congestion-inducing crashes on corridor and at freeway ramps (per year). • Percent of corridor parking stalls with active parking management.
Anticipated Data Needs	• Survey/count of travelers exposed to ATDM information. • Customer satisfaction surveys. • Corridor peak period and free flow travel times and speeds. • Person travel time along corridor links (e.g., vehicle volume multiplied by vehicle occupancy) during free flow conditions and congested conditions. • Trip length. • Mode share and total trips for corridor. • Total number of corridor users (annually) with electronic toll collection transponders. • System information (e.g., miles of dynamically priced lanes or facilities). • Total number of congested-related crashes by location on corridor. • Count of total and actively managed parking stalls.
Data Resources and Partners	• Data may need to be gathered from transportation management centers, State DOTs, cities, counties, toll authorities, transit agencies, and parking providers.

Active Transportation and Demand Management (Continued)

TSMO Strategies to Consider	• There are numerous TSMO strategies to consider to achieve ATDM objectives. The strategies are typically categorized as they relate to demand, traffic, or parking: • Active Demand Management: ◦ Corridor monitoring. ◦ Corridor specific traveler information (including predictive information). ◦ Dynamic ridesharing. ◦ Active transit management: dynamic fare reduction, dynamic transit capacity assignment, on-demand transit, transfer connection protection. ◦ Dynamic/congestion pricing (also electronic toll collection). • Active Traffic Management: ◦ Dynamic/variable speed control. ◦ Dynamic lane use control and reversal. ◦ Adaptive ramp metering. ◦ Dynamic merge control. ◦ Dynamic queue warning. ◦ Hard shoulder running. ◦ Dynamic re-routing. ◦ Dynamic truck restrictions. • Active Parking Management: ◦ Dynamic overflow transit parking. ◦ Dynamic parking reservation. ◦ Dynamic wayfinding. ◦ Dynamically priced parking. • Automated enforcement may also be considered to complement some of the strategies such as dynamic pricing and dynamic speed control.

Integrated Corridor Management

This objective set focuses on balancing travel demand across corridor networks and providing multi-agency management of events within a corridor.

Stakeholders	• State, county, or city agencies responsible for roadways, including maintenance crews. • MPOs. • Transportation management center(s). • Transit agencies. • Incident responders. • Contractors. • 911 center(s). • Law enforcement. • Fire and rescue agencies. • Emergency medical agencies. • Corridor businesses, freight distribution centers, event centers, and neighborhood associations. • Ports, if applicable. • Media.
Goals	• Balance travel demand across networks (freeway, arterial, transit, parking). • Provide multi-agency management of events such as incidents, special events, inclement weather, and work zones.
Corridor Operations Objectives	• Increase the number of corridor travelers receiving information on ICM strategies by X percent within Y years. • Increase customer satisfaction with ICM efforts by X percent over Y years. • Balance corridor trips so that each route and mode within the corridor operate at X percent capacity within Y years. • Improve average corridor travel time during peak periods by X percent by year Y. • Reduce the person hours of total delay associated with non-recurrent events by X percent over Y years. • Increase the percentage of agencies that participate in an ICM team by X percent in Y years. • Hold at least X multi-agency, after-action review meetings following a corridor event each year, with attendance from at least Y percent of the agencies involved in the response. • Conduct X joint-ICM training exercises for the corridor by year Y.

Integrated Corridor Management (Continued)

Performance Measures	• Total number of corridor travelers and percent receiving information on ICM strategies. • Percent of customers satisfied with ICM practices. • Volume-to-capacity ratios for corridor routes and modes. • Average corridor travel time during peak periods (minutes). • Person hours of delay for the corridor. • Number of agencies participating in an ICM team. • Number of multi-agency after-action reviews per year. • Percent of responding agencies participating in after-action review. • Number of joint ICM training exercises conducted.
Anticipated Data Needs	• Survey/count of travelers exposed to ICM information. • Corridor peak period and free flow volumes (i.e., vehicles and occupancy), travel times, and speeds by route and mode. • Person travel time along corridor links (e.g., vehicle volume multiplied by vehicle occupancy) during free flow conditions and congested conditions. • Trip length. • Mode share and total trips for corridor. • Number of agencies participating in an ICM team. • Number of after-action reviews held. • Number of joint-ICM training exercises conducted.
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, ATDM, road weather management, work zone management, freeway ramp management, traffic signal management, and TSP 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/mode diversion to parallel facilities, short-term ATDM strategies, and longer-term transportation demand management strategies (e.g., rideshare, employer programs, and commuter incentives). Additional TSMO strategies to consider for improving multi-agency coordination include information clearinghouses, common event reporting systems, event pre-planning 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).

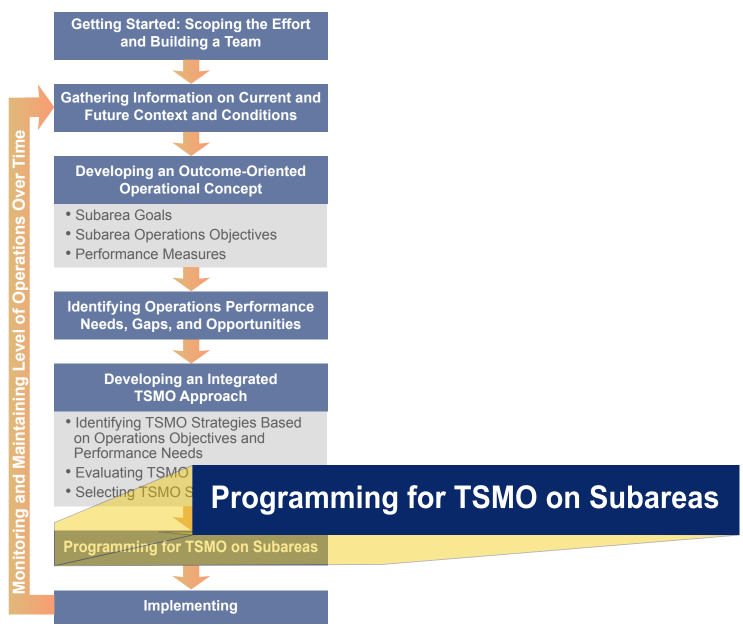
CHAPTER 4. MOVING TO IMPLEMENTATION: TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS WITHIN CORRIDORS

This chapter presents several components that are critical to successfully implementing the plans for transportation systems management and operations (TSMO) on a corridor and maintaining those strategies over time. This includes identifying funding for the selected TSMO strategies and using the overarching systems engineering process and regional intelligent transportation systems (ITS) architecture to further define the TSMO strategies into specific, implementable systems that work with each other and connect to relevant operations systems already in place. This chapter also highlights the need to consider designing transportation infrastructure and ITS installations to enable and support planned TSMO strategies.

PROGRAMMING FOR TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS WITHIN CORRIDORS

Programming funds for TSMO strategies is a necessary step in making TSMO strategies a reality on corridors (Figure 19). TSMO investments and strategies within a corridor can be funded by a combination of Federal, State, and local funding sources. Monies may come from general funds, local sales taxes dedicated to transportation, toll revenues, vehicle registration fees, or specialized taxes on local businesses or residents in a defined geographic area to fund local improvements, including corridor improvements.

There are a few potential approaches for programming TSMO projects, including the following:[68]



TSMO=transportation systems management and operations.

Figure 19. Diagram. The activity, "Programming for Transportation Systems Management and Operations within Corridors," of the approach for planning for transportation systems management and operations within corridors.

68 Federal Highway Administration, *Programming for Operations: Metropolitan Planning Organization Examples of Prioritizing and Funding Transportation Systems Management and Operations Strategies*, FHWA-HOP-13-050, 2013. Available at: http://ops.fhwa.dot.gov/publications/fhwahop13050/index.htm.

- **TSMO funding set-aside** – Some agencies set aside funding for TSMO projects such that a portion of the available funding is restricted and spent only on TSMO projects. With this approach, amounts may be set aside for specific projects (e.g., highway emergency local patrol, ITS) or individual TSMO projects. Strategies are selected for funding based on pre-established selection criteria. Some regions have specific operations-focused plans that inform the development of the selection criteria, such as a regional operations strategy, a regional concept for transportation operations, or an ITS strategic plan.
- **Open competition** – Many TSMO projects might compete with other types of projects for funding. In this approach, the merits of each project are evaluated using criteria that address broad transportation needs. The long-range transportation plan should guide the selection of projects that are funded in the transportation improvement program (TIP). In this way, when all projects compete for general funds, project selection criteria should prioritize projects according to a performance-based approach that aligns with the regional long-range transportation plan. One evaluation approach is to rank all projects using a set of common criteria, as well as mode-specific criteria (TSMO can be a category with mode-specific criteria). For example, out of a scale of 100, 70 points may be attributed to common criteria and 30 from mode-specific criteria.
- **A combination or hybrid approach** – Some areas use a combination of set-aside funding for some types of projects, but also with the ability for TSMO projects to compete for general funds.

In addition, it is important to consider prioritization processes used for State and local funding sources, which may serve as a match for Federal funding or may be used entirely to fund operational improvements. For instance, the Northern Virginia Transportation Authority is responsible for prioritizing regional revenues for regional transportation improvement projects in the congested Northern Virginia region. Northern Virginia Transportation Authority uses a systematic project selection procedure, which includes preliminary screening (to ensure projects meet basic criteria for funding), development of a quantitative score for each project using weighted selection criteria, calculation of a Congestion Reduction Relative to Cost (CRRC) ratio, and consideration of qualitative factors. The quantitative scoring is conducted in relation to defined goals using a rating scale and the assignment of points to each project. The scoring assigns points based on an evaluation of how each project rates in terms of factors, such as improving the management and operation of existing facilities through technology applications, reducing vehicle miles traveled, and improving the safety of the transportation system.[69] While the Northern Virginia Transportation Authority cannot directly fund operations, it can fund infrastructure related to operations, such as transit signal priority technology.

As another example, the San Diego Association of Governments administers funds from TransNet, a county-wide half-cent sales tax generated for local transportation projects, with a focus on addressing traffic congestion and improving mobility. The program provides funding for specific projects pulled from the Regional Transportation Plan; these were selected as high priority through public surveys and focus groups and were named in the program ballot measures approved by voters. In addition to these specific projects, some TransNet funds are allocated to the San Diego Association of Governments' member jurisdictions for local street and road projects and awarded

69 Northern Virginia Transportation Authority, Project Implementation Working Group Memorandum, NVTA FY2017 Program Project Selection Criteria, November 9, 2015. Available at: http://www.thenovaauthority.org/wp-content/uploads/XVI-Approval-of-FY2017-Program-Project-Selection-Criteria1.pdf.

to other projects through a competitive process. An Independent Taxpayer Oversight Committee is charged with ensuring that expenditures from the TransNet fund support the implementation of the program's intent to reduce congestion and improve regional mobility.[70]

Prioritizing Transportation Systems Management and Operations Strategies for Funding

The goals and objectives of the long-range transportation plan should guide funding decisions and the selection of projects at the State and regional levels. Regions that place importance on system operations in the long-range transportation plan have a strong basis for allocating funding for TSMO strategies.

Regional goals, objectives, and performance measures relevant to system operations and management provide a foundation for setting aside funding for TSMO strategies, developing a project prioritization process that enables TSMO strategies to be competitive for general funds, or a combination of both. In addition to the long-range transportation plan, some metropolitan planning organizations (MPOs) develop regional operations or ITS plans. These specific operations-focused plans can further advance the implementation of TSMO strategies. For example, the Puget Sound Regional Council,[71] the MPO for the Seattle, Washington, area, has developed a regional ITS implementation plan that identifies 25 key arterial multijurisdictional corridors and the recommended ITS physical improvements for each corridor (e.g., signal improvements). The 25 corridors were selected using criteria, such as roadway characteristics (e.g., vehicle miles traveled and congestion

70 San Diego Association of Governments, *TransNet Extension Ordinance and Expenditure Plan*. Available at: http://www.sandag.org/uploads/projectid/projectid_341_8806.pdf. Additional information on TransNet at: http://www.sandag.org/?projectid=341&fuseaction=projects.detail.

71 Puget Sound Regional Council, Regional ITS Implementation Plan, August 2009. Available at: http://www.psrc.org/transportation/its/ritsip-docs/.

Virginia Department of Transportation (VDOT) I-66 and I-95 Corridor Projects: Phase-in Approach to Deploying Operational Strategies

The purpose of the I-66 active traffic management (ATM) initiative is to relieve congestion and improve safety on a 34-mile stretch of interstate in Northern Virginia. The project was prioritized by political leadership and awarded 30 million dollars to expedite implementation, through operational and technological strategies (roadway improvements and widening are not included in the initiative). Key transportation systems management and operations strategies selected include use of existing shoulders, dynamic messaging signs, improved monitoring of incidents and bottlenecks, adaptive ramp metering, and speed harmonization. The implementation schedule is determined by the funding available, which varies by fiscal year. As a result, the project planners developed a phased-in approach for implementing the project incrementally.

VDOT's strategy initially focused on facilities it has control over, rather than beginning with a large program that may never be implemented. For instance, the I-66 project is focusing on ATM, and then will explore broader efforts, such as converting the existing high-occupancy vehicle lanes to high-occupancy toll lanes. VDOT also is initially looking at active parking management on the I-95 corridor, focusing on its own commuter lots. Implementing the full corridor vision will require additional partnerships (e.g., working to install sensors at Virginia Railway Express parking lots to provide real-time parking information will involve additional coordination by multiple agencies, as well as funding agreements).

For more information: http://www.virginiadot.org/projects/northernvirginia/i-66_atms.asp.

level), regional significance, and stakeholder significance (e.g., identified by transit agencies as an existing or planned route for bus rapid transit service or transit signal priority (TSP)).

Aligning the corridor plan with the goals and objectives outlined in the long-range transportation plan and developing regional operations or ITS plans will improve the likelihood that the strategies identified in a corridor study receive funding for implementation.

Prioritization of Transportation Systems Management and Operations Projects among All Project Types

The potential for TSMO projects to be selected in an open competition process is highly dependent on the selection criteria used for evaluation. Criteria that address mobility, reliability, and cost-effectiveness help TSMO initiatives compete effectively for funding.

Project Prioritization Method at Genesee Transportation Council

As an example, the Genesee Transportation Council, the Metropolitan Planning Organization for the Rochester, New York area, ranks project using a set of common criteria (up to 100 points) and mode-specific criteria (up to 30 points). The set of common project selection criteria relate to the broader transportation goals and objectives identified in the *Long Range Transportation Plan for the Genesee Finger-Lakes Region 2040*, which include promoting efficient system management and operations, safety for motorized and non-motorized users, and accessibility and mobility options, among others. There also is a set of mode-specific criteria for transportation systems management and operations (TSMO) that focuses on outcomes (see Figure 20). The other mode specific categories are highway and bridge, public transportation, bicycle and pedestrian, and goods movement.[72] Given the overall ranking of common and mode-specific criteria, TSMO projects are typically competitive with public transportation and highway projects. Genesee Transportation Council's project evaluation criteria allow for smaller TSMO projects to be competitive for funding.

System Management and Operations

1. Reduce travel times on major roadways	0	2	4	6	8	10
2. Reduce incident clearance times	0	2	4	6	8	10
3. Increase the productivity of regional transportation agencies/ providers (e.g., cost savings, times savings, etc.)	0	1	2	3	4	5
4. Support or advance existing and/or proposed ITS elements	0	1	2	3	4	5

ITS = intelligent transportation systems

Source: Genesee Transportation Council's *Transportation Improvement Program Guidebook.*

Figure 20. Chart. Genesee Transportation Council's mode-specific project evaluation criteria for transportation systems management and operations projects.

72 Genesee Transportation Council, *Long Range Transportation Plan for the Genesee-Finger Lakes Region 2040* (New York: June 2016). Available at: http://www.gtcmpo.org/LRTP.

Prioritization of Projects with Funding Dedicated to Transportation Systems Management and Operations Projects

When a region decides to set aside or dedicate funding for TSMO initiatives, criteria that link to key regional objectives are often used for prioritizing that funding. In addition, a TSMO plan can be used to prioritize funding. For instance, Metro, the Portland, Oregon, metropolitan area MPO developed a 10-year regional TSMO plan to guide operations investments in the region.[73] 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 region-wide 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 multi-use paths, high-capacity transit, and frequent bus services that connect major activity centers, as defined by the regional growth concept.

Incrementally Funding Transportation Systems Management and Operations Strategies within a Corridor

Investments to support TSMO do not have to be implemented at one time as part of a large corridor capacity project. Recognizing the scarcity of funding and the value that different TSMO strategies can have, agencies can develop a multiphased approach to implement strategies incrementally. Phasing can have the benefit of not only allowing small investments to proceed more quickly, but also can recognize that some potentially effective strategies may require more partner cooperation and more complex institutional arrangements (see the Virginia Department of Transportation I-66 and I-95 Corridor Projects: Phase-In Approach to Deploying Operational Strategies for an example of this approach on page 2).

Life-Cycle Costing for Transportation Systems Management and Operations Projects

When evaluating TSMO strategies for a corridor, it is important to consider not just the initial investment required to deploy a strategy, but the costs incurred throughout the life of the strategy. Life-cycle costing is an approach for determining the true cost of a project – the total cost for acquiring, installing, configuring, operating, maintaining, and disposing of a system throughout the entity of its intended use. For TSMO strategies, costs associated with maintenance and day-to-day utilization (e.g., staff time, software) are particularly critical, because the ongoing costs of operations are typically critical to the effectiveness of the strategy.

Agencies typically do a good job estimating the cost of physical items associated with a strategy and the resources necessary to install them; however, over the life of a program, the costs to operate and maintain a system usually exceed the original investment. This can create challenges for agencies that did not prepare for the increased costs required to utilize such systems or it can lead to an unused investment. A system includes the people who are required to operate and manage it.

73 Metro, *Regional Transportation System Management and Operations Plan*, June 30, 2010. Available at: http://www.oregonmetro.gov/regional-transportation-system-management-and-operations-plan.

Depending on the agency and TSMO strategy, there are numerous facets of cost that can be included. In some agencies, years of research and development may be conducted before the initial roll-out of a system. The typical phases to be considered for life-cycle costing consist of:

- **Installation:** All costs associated with getting the system in place and ready for use, including purchasing, construction, configuration, process development, staffing, and other activities conducted prior to "Day One."
- **Operations:** Utilization of the system on a day-to-day basis.
- **Maintenance:** Preventive and corrective maintenance necessary to keep the system working in accordance with performance measures.
- **Technology Refresh:** Replacement of individual components of the system as they wear out or become obsolete.
- **Decommissioning:** Any costs associated with end of life.

The methodologies agencies use for estimating lifecycle costs for TSMO strategies vary greatly in detail and scope. Some agencies maintain detailed spreadsheets tracking cost components such as operations, maintenance and repair, and upgrades over the useful life of a specific strategy or device, factoring in whether and for how long any of these components are covered by the product warranty (e.g., whether repairs are covered by a product manufacturer for the first several years of deployment). Other agencies use more general cost estimates, such as the overall staffing costs for operating all ITS devices managed by the agency (e.g., transportation management center staffing costs). Still others only factor capital infrastructure costs into their lifecycle estimates.

Key considerations when estimating lifecycle costs for TSMO include:

- **Factor in All Costs** – When calculating lifecycle costs, it is important to factor in all of the costs required to operate and maintain a system. This includes labor and materials for day-to-day operations and repairs, as well as "hidden" costs, such as electricity and general facility costs for a TMC.
- **Split Preventive and Emergency Maintenance** – By tracking these two costs separately, agencies have found that preventive maintenance is more cost-effective and have been able to better incorporate it into their budgets rather than rely on costlier reactive repairs. This can also help an agency make a case for funding for upgrades before a system's end of life.
- **Conduct Benefit-Cost Analysis** – When it comes to operating and maintaining their systems, agencies often focus on "keeping things working" without considering what benefits their system is actually providing to the customer. By regularly conducting a benefit-cost analysis of the system, agencies will be able to adjust their budget to cover the lifecycle costs for those components of the system that provide the biggest "bang for the buck." This analysis can also be used to make a case to senior management and legislators for increased funding for TSMO.

- **Use Alternate Data Sources** – Even if an agency has not been internally tracking operations and maintenance costs long enough to use as historical data to generate lifecycle costs, they can rely on examples from peers or Federal resources to generate preliminary lifecycle estimates. They could also gather several representative cases (e.g., camera, sign, or traffic signal installation), and develop scenarios to estimate lifecycle costs based on internal knowledge.

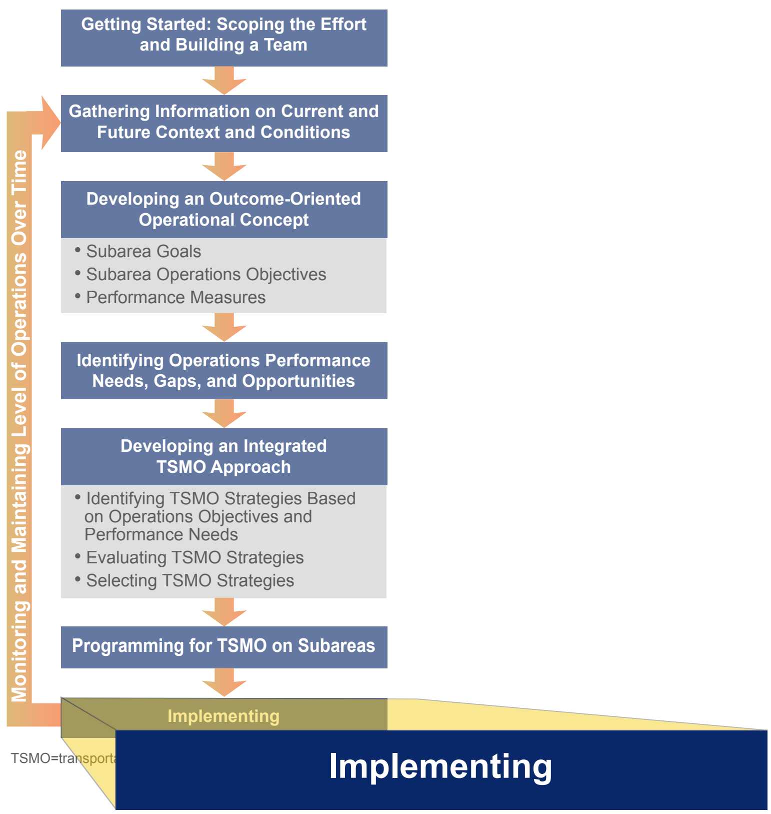
IMPLEMENTATION

There are several frameworks and methods to consider when preparing for the implementation of an integrated TSMO approach within a corridor (Figure 21). This section provides an overview of those frameworks and methods that can be critically important for successful implementation of TSMO within corridors.

Interagency Agreements

TSMO within corridors frequently requires close coordination to be successfully implemented among transportation and non-transportation agencies. Interagency agreements are used to facilitate needed collaboration across agencies for corridor operations activities such as traffic incident management, fiber sharing, special event management, traffic signal optimization, and joint purchasing.

Interagency agreements have become increasingly important as a collaborative transportation operating environment has emerged in the past decade. Individual agencies are increasingly collaborating with other agencies for a variety of reasons: transportation needs exceed resource levels, customer expectations for seamless travel across jurisdictions and modes, and advances in technology that have opened up opportunities and needs for the integration of systems that facilitate operations activities.



TSMO = transportation systems management and operations.

Figure 21. Diagram. The activity, "Implementing," of the approach for planning for transportation systems management and operations within corridors.

Within a single agency, there is an institutional structure for performing operations and allocating resources on an ongoing basis, but as agencies within a region increasingly seek ways to improve their effectiveness and efficiency through working together, they need a mechanism to formalize and codify those relationships to preserve and encourage the collaboration. Agreements provide a framework to facilitate and guide the collaboration. They are critical to enabling many of the partnerships that are now in existence and avoid fragmented operations. As resources become involved in the collaboration, agreements can be used to provide a legal means to protect the participating agencies and preserve the intent of the agreement. Interagency agreements are an important mechanism for allowing government agencies to combine services and resources, or just follow the same policy direction without giving up their autonomy. Interagency agreements serve a valuable purpose in that they formalize the complex coordination that needs to take place to develop and implement multi-agency projects that have different stakeholders and priorities.

There is not a standard naming convention or classification scheme for interagency agreements. Interagency agreements can be associated with three large groupings and refer to all types of agreements between government agencies. The first type of agreement is one that actually is not documented. The handshake agreement is a paperless agreement based on good faith. This may be appropriate for more informal collaborative efforts that do not require resource commitments from parties. The next two types of agreements are memoranda of understanding and intergovernmental agreements. The memorandum of understanding is generally less detailed and not legally binding, while the intergovernmental agreement is specific and binding for the signing parties.

As mentioned, general types of interagency agreements include:

- Handshake agreement.
    - Paperless agreement based on good faith.
- Memorandum of understanding.
    - Formal expression of intent by parties to engage in a specific course of action.
    - Defines roles and responsibilities.
    - Establishes common direction for achieving shared policy goals.
    - Documents area of mutual understanding.
    - Generally non-binding.
- Interagency or intergovernmental agreements.
    - Legal pact between two or more units of government.
    - Defines responsibility, function, and liability of each party.
    - Includes any financial or other resource obligations.
    - More detailed procedures for agreed upon activities.

The interagency agreement should serve as the vehicle for establishing an agreed upon course of action relating to TSMO. The agreement can be used to:

- Define the program or project objectives.

- Identify stakeholders.
- Address roles and responsibilities for each stakeholder.
- Establish guidelines for how agencies will work together.
- Identify timelines.
- Facilitate communication.
- Offer an opportunity to resolve any issues encountered during the life of the agreement.

Systems Engineering Process

Systems engineering is an organized approach intended to improve the success rate of system projects by reducing schedule and cost risks and ensuring that user needs and requirements are met. The approach can be applied to any of the TSMO strategies described in this Desk Reference. Systems engineering analysis is required for all ITS projects using Federal funds, per Title 23 Code of Federal Regulations 940.11. Although there are many ways to represent the systems engineering process, the winged "V" (or "Vee") model diagram shown in Figure 22 has been broadly adopted in the transportation industry.[74]

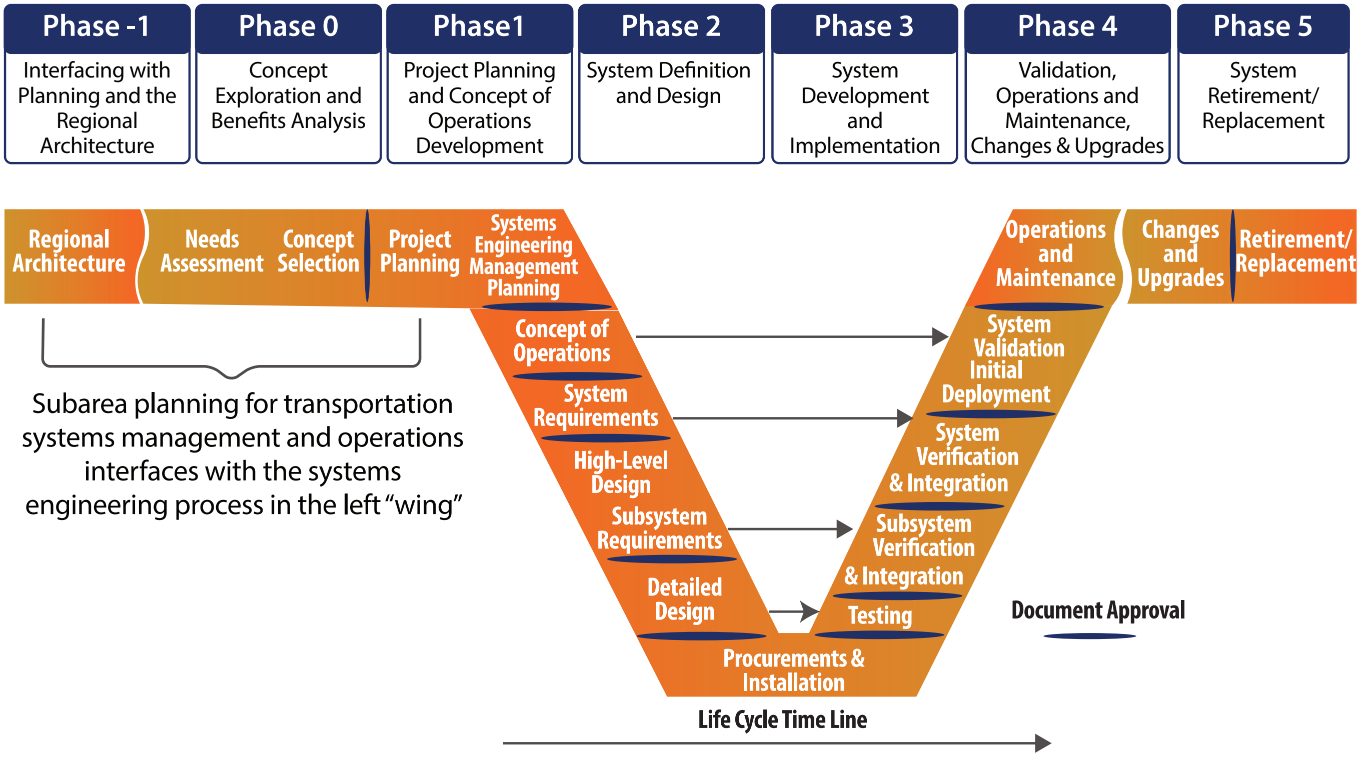


Figure 22. Graph. Corridor planning within the systems engineering "V" model.

Source: Federal Highway Administration and California Department of Transportation

74 For more information, see: Federal Highway Administration, *Systems Engineering for ITS: An Introduction for Transportation Professionals*, FHWA-HOP-07-069, 2007. Available at: http://www.ops.fhwa.dot.gov/publications/seitsguide/index.htm or Federal Highway Administration and California Department of Transportation, Systems Engineering Guidebook for ITS 3.0, 2009. Available at: http://www.fhwa.dot.gov/cadiv/segb/.

The left wing of the "V" process shows the regional ITS architecture, needs assessment, and concept exploration that support initial identification and planning for a project. Corridor planning interfaces and feeds into the systems engineering process primarily in the left wing. The regional ITS architecture can be used to inform corridor planning and a concept of operations, both of which are described below. The operations objectives and performance measures identified during the planning phases should be applied throughout the systems engineering process and validated once the project reaches the operations and maintenance phase in the right wing of the "V" diagram. This approach provides a systematic method to plan and design systems to achieve the desired operations objectives.

Regional Intelligent Transportation Systems Architecture

A regional ITS architecture is a framework for institutional and technical integration in a particular region. Over 300 regional ITS architectures have been developed; therefore, it is likely that one is available in any region or at the Statewide level as a tool to support the corridor planning process. Figure 23 shows how the regional ITS architecture can provide support in an objectives-driven, performance-based approach to planning for operations on a corridor.

The regional ITS architecture helps answer important questions, such as:[75]

- What existing or planned management and operations strategies may be available to help achieve the corridor operations objectives?
- What stakeholders and collaborative relationships can be leveraged as part of the corridor planning process?
- What data is available to monitor transportation system performance and track progress toward corridor operations objectives?

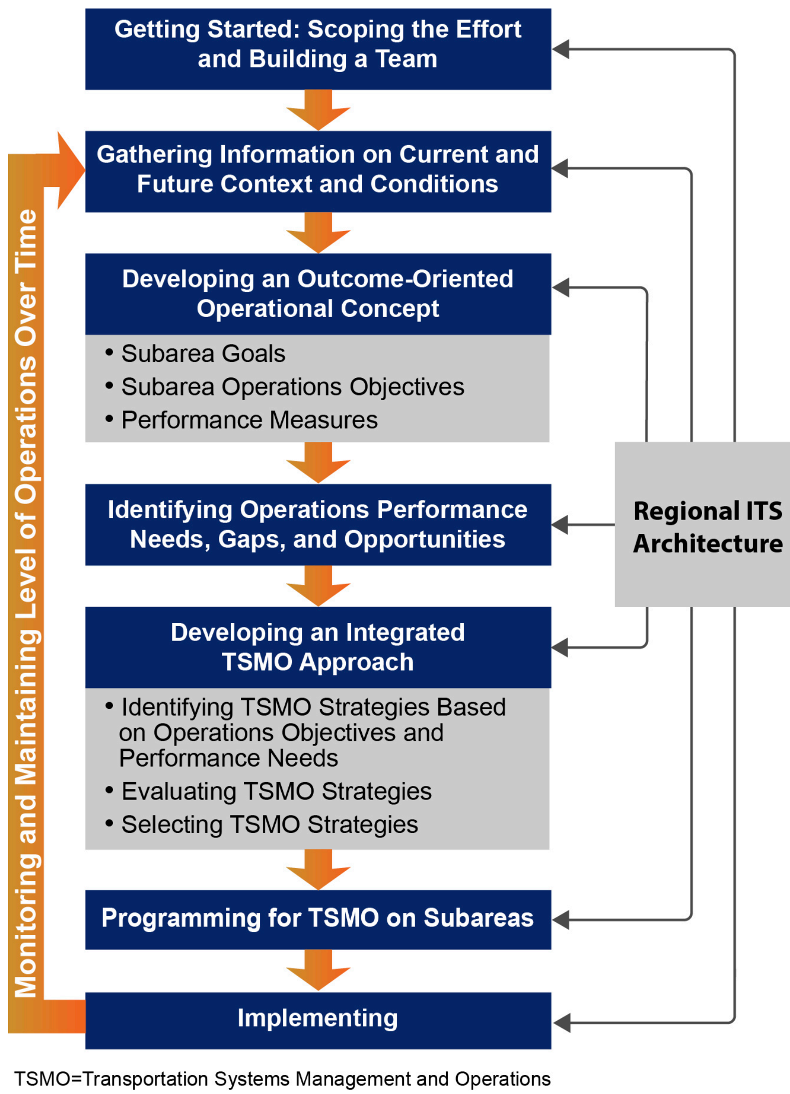


Figure 23. Diagram. Regional intelligent transportation systems architecture use in corridor planning.

75 For more information, see: Federal Highway Administration, *Applying a Regional ITS Architecture to Support Planning for Operations: A Primer*, FHWA-HOP-12-001 (Washington, DC: February 2012). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop12001/index.htm.

- What parts of the ITS architecture's operational concepts, functional requirements, or other contents can be used to support project development?

Concept of Operations

Another crucial step in the systems engineering process is the completion of a concept of operations. Once TSMO strategies have been recommended as part of the needs assessment and concept-selection phase of a corridor planning process, the recommended strategies should be carried forward into a concept of operations, which provides a stakeholder view of the system being developed in a non-technical manner with a focus on user needs, activity-based operations objectives, performance measures, roles and responsibilities, and institutional agreements. The concept of operations provides the basis for developing the systems requirements, which is the next step in the "V" diagram.

A successful concept of operations includes these key activities:[76]

- **Identify stakeholders** – This includes anyone involved in or impacted by the project, such as owners, operators, maintainers, users, etc. Stakeholder identification is described in Chapter 3 of this Desk Reference and often uses the regional ITS architecture as a starting point.
- **Develop a consensus on roles and responsibilities** – This is typically done by working through operational scenarios for the corridor, such as normal system operation (e.g., traffic signal operations) and various fault-and-failure scenarios (e.g., major incident and communications failure). This process also helps identify institutional agreements that may be needed to design and operate the project (e.g., agreement for one agency to implement signal timing adjustments to another agency's traffic signals on a multijurisdictional corridor).
- **Define stakeholder needs** – This captures a clear definition of stakeholder needs and differentiates between what is essential for system operations and wish-list items for "wants" and "nice-to-haves."
- **Define performance measures** – These measures should assess the effectiveness of the system in comparison to the operations objectives of the corridor. The performance measures provide the foundation for the system validation plan used in the systems engineering process.

The size of the concept of operations should be commensurate with the size and complexity of the TSMO strategies selected for the project corridor. A corridor with one or two simple TSMO strategies, particularly ones that expand on existing systems, may only require a document that is several pages. For example, the addition of TSP on an arterial corridor where TSP is already used by the transit agency within corridors in neighboring jurisdictions may require only a reference to other concepts of operations, but the concept of operations document will focus on the roles and responsibilities for the subject corridor. A larger, more complex corridor project, such as instituting integrated corridor management (ICM) on a freeway corridor, will require a much more extensive concept of operations document to capture numerous systems and stakeholders.

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76 For more information, see: Federal Highway Administration, *Systems Engineering for ITS: An Introduction for Transportation Professionals*, FHWA-HOP-07-069 (Washington, DC: January 2007). Available at: http://www.ops.fhwa.dot.gov/publications/seitsguide/index.htm.

Designing for Operations

The success of the corridor TSMO strategies to be implemented depends in large part on the design of the roadway or transit infrastructure. Examples of roadway design treatments that are important for improving the management and operation of the facility include:

- Median crossovers, which allow for incident responders to quickly access the opposite side of the road.
- Crash investigation sites, which reduce impacts associated with collecting incident information.
- Snow fences, which reduce blowing snow and drifts on the road.
- Emergency access between interchanges, which decreases response time to incidents.
- Bus turnouts, which ease arterial congestion.

Ideally, planning for TSMO within a corridor would occur in conjunction with the initial construction of the corridor's roads or rails so that TSMO strategies could be factored into the infrastructure design. For example, truck-only toll lanes or median breaks and crash investigation sites can be included as part of the road from the beginning. Even after the road or rail is initially built, TSMO planners and operators can take advantage of opportunities to influence design during reconstruction or maintenance projects. For example, laying fiber optic cable could be considered during reconstruction.

The effectiveness of TSMO strategies also relies on what type, how, and where the ITS and other equipment is deployed to support operations. These physical components that enable TSMO strategies include speed harmonization gantries, variable message signs, or traffic surveillance equipment. The current and future operational use of ITS equipment should help drive the design decisions. For example, the installation of variable message signs in locations prior to significant route or modal decision points for travelers or common incident areas supports relevant, actionable traveler information to the public.

The FHWA document, *Designing for Transportation Management and Operations: A Primer,* introduces the concept of designing for operations, describes tools and institutional approaches to assist transportation agencies in considering operations in their design procedures, and points out some specific design considerations for various operations strategies.[77] The tools and approaches to aid in designing for operations may include checklists for designers to reference operational considerations, formation of a technical advisement committee with operations expertise, or agency policies that instruct designers on how to incorporate operational elements within the project development process. These will benefit multiple practitioner groups, including planners, project designers, scoping engineers, maintenance and traffic managers, and contract development personnel. This primer can be consulted by corridor TSMO teams to learn more about how to integrate design elements that facilitate TSMO strategies within corridors into roadway design.

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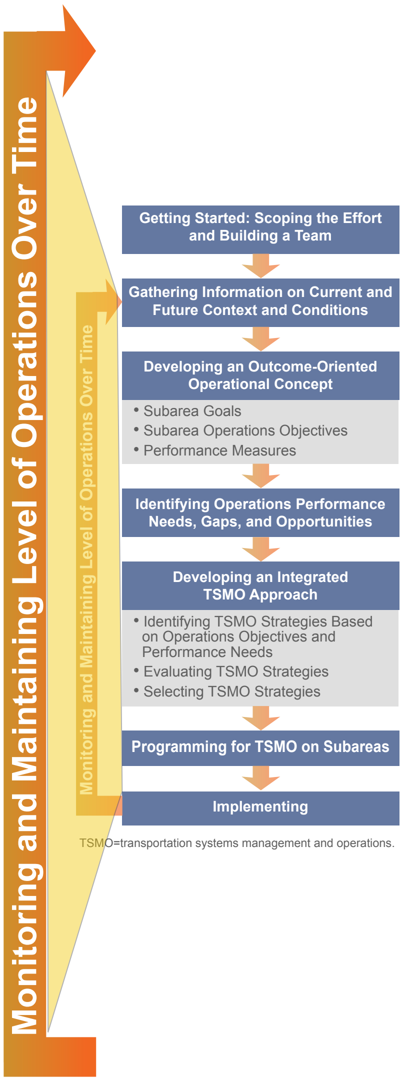
77 Federal Highway Administration, *Designing for Transportation Management and Operations: A Primer,* FHWA-HOP-13-013 (Washington, DC: February 2013). Available at: http://ops.fhwa.dot.gov/publications/fhwahop13013/index.htm.

Life-Cycle Planning – Monitoring and Maintaining Level of Operations Over Time

To fully realize the value of an objectives-driven, performance-based approach, it is necessary to assess how well the corridor strategies meet the objectives immediately after implementation and over the time the strategy is in use. The monitoring and evaluation feedback loop involves several elements (Figure 24):[78]

- **Evaluate the effectiveness of implemented strategies** – Develop a corridor evaluation plan during the planning or design process, and put the plan into action following implementation. Figure 25 provides an example evaluation plan with key steps during design, data collection and validation, data archiving and transformation, data analysis, and performance measure reporting. Some regions already have established performance measures and evaluation plans in place through the regional or metropolitan transportation plan, ITS or TSMO plan, congestion management process, or corridor planning process. These may be tailored to the corridor level.
- **Report corridor performance** – Inform decisionmakers and stakeholders about trends in corridor system performance. Highlight project benefits for any objectives that have been met or exceeded. For under-performing objectives, proceed to the next step.
- **Assess and refine operations objectives** – If measured corridor performance falls short of meeting a desired objective, consider refining the objective or contemplate alternate strategies that may meet the objective.

This process should be repeated on a regular cycle, perhaps in conjunction with other regional planning cycles, to identify any issues and address them to stop the degradation of corridor performance.



TSMO = transportation systems management and operations.

Figure 24. Diagram. The activity, "Monitoring and Maintaining Level of Operations over Time," of the approach for planning for transportation systems management and operations within corridors.

78 Federal Highway Administration, *Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach- A Guidebook,* FHWA-HOP-10-026 (Washington, DC: February 2010). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop10026/.

Step	Activities
Design	• Identify corridor performance measures (based on corridor objectives developed during the planning process) and associated data needs (often determined during the systems engineering process). • Determine the most appropriate technology to collect the required data. • Procure data sources and install field devices and communications as necessary.
Collect Data	• Collect data for corridor (to a central location if possible). • If needed, connect devices to central system. • If needed, upgrade central system data acquisition and storage capabilities. • Validate.
Validate	• Verify the accuracy of the data collected. • Correct mechanical data errors (e.g., failed detection). • Smooth the data to adjust for gaps in data. • Create methods to automatically flag data anomalies and failed detectors.
Archive and Transform	• Transform the data into a usable database. • Archive the data at the highest precision available. • Geocode the data so that it can be mapped easily. • Upload and save the databases to a local or regional data warehouse.
Analyze and Report	• Create standardized reports and visuals for performance measures. • Allow users to pull raw data where applicable. • Allow users to query the data by location, time period, and data resolution. • Allow data to be cross-referenced (e.g., linking speeds, weather conditions, collisions, or other factors to traffic conditions).

Figure 25. Diagram. Example process for automated corridor performance measurement.[80]

79 Adapted from Oregon Department of Transportation and Metro, Portland Multimodal Arterial Performance Management Implementation Guidance Document, February 2013. Available at: http://www.oregonmetro.gov/sites/default/files/Arterial_Measures_Guide.pdf.

CHAPTER 5. TOOLBOX FOR EFFECTIVE TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS PLANNING

There are a variety of tools that can support transportation systems management and operations (TSMO) planning on a corridor, and many of them have already been discussed prior to this chapter, including analytical tools and simulation models, the regional intelligent transportation system (ITS) architecture, and archived operations data. (Note: The word "tools" is used in this chapter in the broadest sense – anything that can be used to support and enhance TSMO planning on a corridor.) This chapter offers readers a "toolbox" of analysis tools and planning techniques that can be applied when planning for TSMO within corridors. For several of the tools described, there is at least one additional Federal Highway Administration (FHWA) guide that can give readers a much greater understanding of how the tool may be applied. This chapter begins with two planning techniques and then moves into short reference sheet-style descriptions of common types of analysis tools. Following the reference sheets are overviews of several specific applications that planners and operators can use to directly address analysis needs while planning for TSMO within corridors.

SCENARIO PLANNING FOR TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS WITHIN CORRIDORS

Scenario planning is an important enhancement to planning for TSMO within a corridor. It can be used to incorporate the consideration of factors that are difficult to predict, such as evolving technology, climate change, shifting traveler behavior, financial uncertainty, failing infrastructure, natural and man-made events, and other unknowns into planning and programming decisions. Scenario planning supports the exploration and consideration of different future conditions along a corridor.

Scenario planning is an approach to strategic planning that uses alternate narratives of plausible futures (or future states) to play out decisions in an effort to make more informed choices and create plans for the future. It engages participants in considering the "what ifs" of tomorrow, whether those are desirable or undesirable outcomes. The simple task of imagining a different future can help to challenge the status quo and encourage creative thinking, which ultimately can lead to the development of more thoughtful and resilient plans. Scenarios are developed to enable participants to test out possible decisions, analyze their impacts given the conditions in each scenario, and come to agreement on a preferred course of action.

Scenario planning follows many of the same planning activities as described in Chapter 3, beginning with scoping the effort, examining current conditions and trends, and then identifying goals and objectives. In scenario planning, the leaders and stakeholders would then develop multiple scenarios or descriptions of possible futures, identify the strategies needed to realize each of the scenarios, and then analyze the impacts of each scenario against reaching their objectives. The scenario planning approach to TSMO is shown in Figure 26.

Source: Federal Highway Administration, Advancing Transportation Systems Management and Operations Through Scenario Planning, FHWA-16-016 (Washington, DC: 2016). Available at: http://ops.fhwa.dot.gov/publications/fhwahop16016/index.htm.

Figure 26. Diagram. Phases of scenario planning for transportation systems management and operations.

As an example of scenario planning for TSMO within a corridor, the planning team could be looking to achieve the following goal and objectives for a 40-mile corridor from a rural area to a very large metropolitan area:

- Goal: Provide efficient and reliable travel along the I-21 corridor.
- Operations Objectives:
    - Efficiency: Reduce the per-capita hours of delay along the I-21 corridor by X percent by 2024.
    - Reliability: Reduce the average planning time index for the I-21 corridor by X points by 2024.

The I-21 corridor stakeholders must then create scenarios based on prioritizing modal options or prioritizing route and time of day travel options. The first scenario would be created in response to the question: "What does efficient and reliable travel along the I-21 corridor look like if one emphasizes and encourages the use of multiple modes?" The second scenario would be a response to the question: "What does efficient and reliable travel along the I-21 corridor look like if one emphasizes and prioritizes the use of route and time-of-day travel options?" Assuming the scenarios are written from the perspective of two commuters, the TSMO strategies that would achieve each of the futures provided in the scenarios would be identified and evaluated to see what impact they would have on the operations objectives. During the final step of the scenario planning process, the results of the evaluation would be presented to the stakeholders, who would provide extensive feedback on both the scenarios as well as the predicted impacts on the measures and goals of interest. Stakeholders would then select or combine elements of each scenario together to create a preferred scenario that encompasses a comprehensive vision for the future operations of the corridor.

This is only one example of the many ways scenario planning can be applied to planning for TSMO within corridors. Generally, there are three types of scenario planning that reflect the different conditions and purposes for which scenario planning may be used. For example, scenario planning for TSMO within a corridor may be used to identify the most effective package of TSMO strategies given an expected change in conditions on the corridor (trend-based type). Alternatively, scenario planning may be used to build consensus on operations objectives by examining multiple desired future conditions and the strategies needed to support those conditions (normative type). Finally, scenario planning can be used to examine different scenarios in response to uncontrollable or unknown future conditions (e.g., to better understand the impacts of global trade changes, extreme weather, etc.). The purpose of this is to guide stakeholders in identifying policies, plans, and strategies that can work best under all extreme conditions (exploratory type).

Additional information on how to use scenario planning to advance TSMO can be found in the FHWA's *Advancing Transportation Systems Management and Operations Through Scenario Planning*.[80]

80 Federal Highway Administration, *Advancing Transportation Systems Management and Operations Through Scenario Planning*, FHWA-16-016 (Washington, DC: 2016). Available at: http://ops.fhwa.dot.gov/publications/fhwahop16016/index.htm.

USE OF ARCHIVED OPERATIONS DATA

Archived operations data is a critical tool in an objectives-driven, performance-based planning approach to TSMO within corridors. Archived operations data is information that is collected and stored in support of day-to-day efforts to monitor and manage the transportation system. Archived operations data can include traffic, transit, bike, pedestrian, construction, and weather information that is usually collected in real time by ITS infrastructure, such as in-pavement inductive loop detectors, radar detectors, remote traffic microwave sensors, Bluetooth, and EZPass or other unique identification tag readers. It also includes incident or event information entered into electronic logs by transportation or public safety personnel. Transportation planners at the State, metropolitan, and local level are finding that, with archived operations data, they are able to do more, be more accurate, and solve more problems than ever before—relying less on assumptions and modeled data, and making more effective, less costly decisions.

There are several advantages to having archived operations data available:

- Provides a more accurate picture of system performance.
- Opens up new types of analyses to support the planning process.
- Enables more advanced modeling.

The following are examples of significant uses for archived operations data in planning for TSMO within corridors:

- **Monitoring and evaluating system performance in support of identifying performance issues/needs, project prioritization, and reporting.** Archived travel time data forms the basis for computing a wide variety of congestion, reliability, and freight performance measures.
- **Setting performance targets.** Archived data provides information on past trends that are useful in establishing targets.
- **Evaluation of completed projects.** A key component of performance-based planning is the ability to conduct evaluations of completed projects and to use the results to make more informed investment decisions in the future.
- **Trip-based mobility monitoring and accessibility.** Although archived origin-destination travel time data is just becoming available, it is expected to become more prevalent as technology evolves. Origin-destination data makes it possible to monitor the performance of trips taken by travelers.

The FHWA has produced a desk reference (*Use of Archived Operations Data in Planning*) on applying archived operations data to planning aimed toward TSMO planners and their planning partners. This desk reference raises planners' awareness of the opportunities afforded through archived operations data and provides guidance on how to take advantage of that data to expand and improve planning practices.[81] It also identifies new and innovative applications for this data in planning. The desk reference is intended to help planners and their operations data partners overcome the barriers to obtaining and using data.

81 Federal Highway Administration, *Use of Archived Operations Data in Planning*, FHWA-HOP-16-017 (Washington, DC: 2016). Available Summer 2016 at: http://ops.fhwa.dot.gov/publications/fhwahop16016/index.htm.

ANALYSIS TOOLS AVAILABLE FOR TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS PLANNING WITHIN CORRIDORS

Following are the reference sheets for several types of analysis tools that can be applied for TSMO planning within corridors. The types of analysis tools covered are travel demand models, sketch planning tools, analytic/deterministic tools, simulation tools, and dynamic traffic assignment (DTA) methods.

Travel Demand Models

Description	Travel demand models are widely used to compare or screen alternatives by using origin-destination patterns, demand-to-capacity ratios, differences in percent volumes, and rough estimates of travel times. These models consider land use, demographics, mode choice, and the transportation system (roadway and transit).
Examples	• Types of models: ◦ Three-step models (no mode choice). ◦ Four-step models. ◦ Activity-based models. ◦ Mesoscale models Software: Cube, Emme, and TransCAD.
Planning for Operations Uses for Corridors	• Supply data (e.g., travel forecast inputs) to sketch-planning tools, simulation models, and post-processors that can analyze corridor operations strategies. • Use traffic origin-destination patterns or volumes for input into corridor simulation models. • Provide changes in peak-hour turning volumes at major corridor intersections and freeway ramp volumes through refined (subarea) travel demand models. • Extract tables with origin-destination for trips in a focus area as required input for microscopic corridor simulation models. • Screen and evaluate corridor strategies. • Assess mode choice and travel pattern/volume impacts. • Capture linked trips (e.g., home-to-work-to-shopping-to-home), smart growth, walk/bike trips for parcel-level models, and more accurate origin-destination estimates for use as inputs to simulation models.
Advantages	• Validates models available for most metropolitan areas. • Evaluates corridor impacts. • Is consistent with current planning practices. • Is capable of estimating mode choice and travel pattern change reductions. due to transit and smart growth.
Challenges	• Limited ability to analyze operational strategies. • High initial costs. • Typical travel day does not capture incident, weather, work zones, and special event conditions.

Sketch Planning Tools

Description	Sketch-planning tools provide quick order-of-magnitude estimates with minimal input data (e.g., traffic volumes and speeds) in support of preliminary screening assessments. These tools are appropriate early in the planning process when prioritizing large numbers of projects or strategies for more detailed evaluation. Tools are often spreadsheets or simple databases that are based on built-in assumptions of impacts and benefits for various strategies. Data from sketch-planning tools, such as Florida ITS Evaluation Tool (FITSEVAL), can be integrated with travel demand model data to provide analysis of operational strategies.
Examples	• Tool for Operations Benefit CostAnalysis (TOPS-BC). • ITS Benefit/Cost Database. • California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C). • Florida ITS Evaluation Tool (FITSEVAL). • QuickZone (work zone analysis tool). • Results from other corridor before-and-after studies.
Planning for Operations Uses for Corridors	• Evaluate policy-based and corridor TSMO strategies. • Screen a large number of potential TSMO strategies and obtain a general idea of whether a strategy is worth investigating further. • Generate expected impacts of TSMO projects that can be compared with other potential investments, such as traditional roadway capacity improvements.
Advantages	• Low cost. • Fast analysis times. • Uses readily accessible data. • View of the "big picture." • Some tools expressly for evaluating policy-based or corridor strategies. • May be integrated with travel demand model.
Challenges	• Limited in scope, robustness, and presentation capabilities. • Results constrained by quality of input data and built-in assumptions of impacts. • Not always transferable between agencies.

Analytical/Deterministic Tools

Description	Most analytical/deterministic tools implement the procedures of the Highway Capacity Manual. The following summarize the Highway Capacity Manual procedures: • **Closed-form:** A practitioner inputs data and parameters and, after a sequence of analytical steps, the Highway Capacity Manual procedures produce a single answer. • **Macroscopic:** Input and output deal with average performance during a 15-minute or a 1-hour analytical period. • **Deterministic:** Any given set of inputs will always yield the same answer • **Static:** Predict average operating conditions over a fixed time period and do not deal with transitions in operations from one system state to another. Analytical/deterministic tools quickly predict capacity, density, speed, delay, and queuing on a variety of transportation facilities.
Examples	• Highway Capacity Software (HCS). • Traffix.
Planning for Operations Uses for Corridors	• Analyze the performance of isolated or small-scale transportation facilities. • Examine impacts under different demand conditions. • Assess a range of traffic control strategies (e.g., uncontrolled, stop-controlled, signalized).
Advantages	• Predicts impacts for isolated or small-scale transportation facilities. • Is widely accepted. • Provides repeatable results.
Challenges	• Limited ability to assess many TSMO strategies. • Limited ability to analyze broader corridor network or system effects. • Limited output of performance measures.

Simulation Tools

Description	Simulation tools use a variety of formulas and algorithms to simulate travel behavior to analyze operations of traffic and transit to conduct needs assessments, alternatives analysis, environmental impact studies, and operations planning. These tools may be deterministic or incorporate stochastic sampling or perturbation. Simulation tools can be classified as: • **Macroscopic**: Simulates average flow, speed, and density on a segment-by-segment basis. • **Mesoscopic:** Simulates individual vehicles based on average segment speed and density. • **Microscopic:** Simulates detailed movement of individual vehicles throughout the network.
Examples	• **Macroscopic:** PASSER, TSIS-CORSIM (includes TRANSYT-7F), and VISTA. • **Mesoscopic:** DYNASMART-P, DynusT, DynaMIT, TransModeler, TRANSIMS, Aimsun, and Dynameq. • **Microscopic:** TSIS-CORSIM, Paramics, VISSIM, TransModeler, and Aimsun.
Planning for Operations Uses for Corridors	• Evaluate a range of improvements and strategies at corridor levels. • Conduct sensitivity testing to reflect variability in traffic demands or incident severity. • Refine project scope and design. • Support environmental assessment.
Advantages	• Simulates operations strategies to varying degrees. • Offers extensive and comprehensive model outputs. • Incorporates traffic variations as observed in the field. • Provides dynamic analysis of incidents and real-time diversion patterns when coupled with dynamic traffic assignment (DTA). • Analyzes complex conditions and multimodal interaction. • Offers visual presentation opportunities.
Challenges	• Expertise needed to develop and apply models. • Demanding data and computing requirements. • Resource requirements may limit network size and number of analysis scenarios. • Calibration may be time consuming. • Extensive outputs may require development of separate post processing tools. • Static network assignment.

Dynamic Traffic Assignment

Description	DTA is a simulation tool that assigns vehicles to paths based on traffic conditions instead of pre-defined routes using origin-destination data and link path travel time equilibrium. Simulated vehicles can adapt to prevailing conditions, change start times, choose alternative routes, or change modes. DTA often involves a combination of model types representing multi-resolution modeling. The following are requirements for DTA: • Travel demand model (highly recommended). • Data for development and calibration. • Origin-destination estimation technique. • Transportation modeling software with DTA capabilities. • Appropriate transportation modeling skill.
Examples	• DYNASMART-P. • DynusT. • DynaMIT. • Dynameq.
Planning for Operations Uses for Corridors	• Simulate the impact of incidents/events. • Evaluate operational strategies that are likely to induce a temporal or spatial pattern shift of traffic. • Estimate travel behavior from various demand/supply changes and interactions. • Conduct analyses involving incidents, construction work zones, active transportation and demand management (ATDM) strategies, integrated corridor management (ICM) strategies, managed lanes, congestion pricing, etc.
Advantages	• More realism in estimating traveler response and therefore operations. • Wider range of strategies can be more accurately tested.
Challenges	• Is resource intensive. • Requires skill sets of both travel demand modeling and simulation modeling.

Work Zone Traffic Analysis Tools

Work zone management is essential element to a comprehensive approach to managing travel within corridors because of the frequent maintenance and major rehabilitation projects that are required as the infrastructure continues to age. Work zone traffic analysis enables agencies to evaluate the mobility and safety impacts of a transportation construction, maintenance, or rehabilitation project and make more informed decisions regarding when and how the projects should take place. There are a variety of work zone modeling and simulation tools to support work zone traffic analyses ranging from the simple to complex.

Work zone traffic analysis can assist in three primary types of decisions:[82]

- **Scheduling decisions** – When the work zone activity should occur in terms of time of day, days of the week, or time of year and when the project phases should occur.
- **Application decisions** – How the construction or maintenance should be done, such as what technique can be used to minimize mobility and safety impacts.
- **Transportation management plan decisions** – How traffic will be managed during a work zone including traveler information, temporary traffic control devices, and other strategies.

The traffic analysis tools to support work zones include tools in several of the analysis tool categories previously mentioned including sketch-planning tools, travel demand models, and microscopic simulation models. Many tools that were not specifically designed to support work zone traffic analysis can be used in that capacity, but there also are many tools that have been built to address the specific needs of work zone related analysis. The FHWA Office of Operations Work Zone Management Program maintains a list of many of the available tools on its website.[83] Two of the more common tools for work zone traffic analysis are QuickZone and the Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS).

QuickZone is a tool that compares the traffic impacts for work zone mitigation strategies and estimates the costs, traffic delays, and potential backups associated with these impacts. QuickZone assists State and local traffic, construction, operations, and planning staff, and construction contractors to accomplish the following:

- Quantify delay along corridors due to capacity reductions in work zones.
- Examine the impacts of alternative project phasing plans on delay.
- Support tradeoff analyses between construction costs and delay costs.
- Identify the impacts of construction staging by location, time of day, and time of year.
- Evaluate travel demand management strategies.
- Help build incentives for completing work.
- Support impact analysis efforts encouraged by the Work Zone Safety and Mobility Rule.[84]

82 Federal Highway Administration, Traffic Analysis Toolbox Volume XII: Work Zone Traffic Analysis – Applications and Decision Framework, FHWA-HOP-12-009 (Washington, DC: 2012). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop12009/index.htm.

83 Federal Highway Administration, Work Zone and Traffic Analysis Tools Web page. Available at: http://www.ops.fhwa.dot.gov/Wz/traffic_analysis/tools.htm.

84 Federal Highway Administration, QuickZone Web page. Available at: http://www.ops.fhwa.dot.gov/wz/traffic_analysis/quickzone/index.htm.

The Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS) is a tool that allows users to conduct an integrated analysis of project alternatives including pavement design, construction logistics, and traffic operations options. It helps State departments of transportation (DOTs) and contractors make effective scheduling decisions that minimize traffic delay, extend the service life of pavement, and reduce agency costs.[85]

Application to Planning for Transportation Systems Management and Operations within Corridors

Work zone traffic analysis tools help planners and operators reduce the impacts of transportation infrastructure projects within a corridor. Specifically, these tools help transportation agencies in:

- Allocating resources more effectively before and during a road or bridge construction, maintenance, or rehabilitation project.
- Improving the management and schedule coordination of multiple projects within a corridor or on parallel corridors so as to minimize overall impacts.
- Developing methods to monitor and mitigate work zone impacts during construction.
- Conducting performance assessment pre- and post-construction that leads to improved work zone policies, procedures, and practices in the future.

Tool for Operations Benefit CostAnalysis

The Tool for Operations Benefit CostAnalysis (TOPS-BC) offers a means to determine whether investment in a given TSMO strategy is justifiable in comparison to investment in a traditional capital infrastructure project. The tool was created by the FHWA as a sketch-planning benefit-cost analysis tool to support preliminary screening and initial prioritization of TSMO strategies. The TOPS-BC tool has four key functions:

- Allows users to look up the expected range of TSMO strategy impacts based on a database of observed impacts in other areas.
- Offers guidance and a selection tool for users to identify appropriate benefit-cost methods and tools based on the input needs of their analysis.
- Supports the ability to estimate life-cycle costs of a wide range of TSMO strategies.
- Enables users to estimate benefits using a spreadsheet-based sketch-planning approach and the comparison with estimated strategy costs.

As a sketch-planning tool, TOPS-BC allows users to quickly understand typical benefits for a range of TSMO strategies and then estimate the benefit-cost ratios for each of those TSMO strategies. The tool also provides a suggested list of analysis tools whose use depends on user selected criteria, such as the level of confidence required, which TSMO strategies are being investigated, key measures of effectiveness, and a few other filters.

The TOPS B-C tool is built on a Microsoft Excel platform and can be downloaded from the FHWA's Planning for Operations website at: http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm. TOPS-BC is a companion resource to the FHWA's Operations Benefit/Cost Desk Reference.

85 Federal Highway Administration, Work Zone and Traffic Analysis Tools Web page. Available at: http://www.ops.fhwa.dot.gov/Wz/traffic_analysis/tools.htm.

Application to Planning for Transportation Systems Management and Operations within Corridors

TOPS B-C is a useful tool for analyzing TSMO strategies identified in corridor planning. The strategies included in TOPS B-C are commonly applied in corridors. Table 5 lists those TSMO strategies included in the TOPS-BC tool and indicates whether typical impacts or benefits are provided for the strategy, as well as the availability of more detailed calculation tools for costs and benefits.

Table 5. Strategies included in the Tool for Operations Benefit-Cost Analysis.

TSMO Category	TSMO Strategy	Typical Impacts	Cost	Benefit
Traveler Information	Dynamic message signs.	Yes	Yes	Yes
	Highway advisory radio.	Yes	Yes	Yes
	Pre-trip traveler information.	Yes	Yes	Yes
	Other traveler information strategies.	Yes	No	No
Traffic Signal Coordination Systems	Preset timing.	Yes	Yes	Yes
	Traffic actuated.	Yes	Yes	Yes
	Central control.	Yes	Yes	Yes
	Transit signal priority.	Yes	Yes	No
	Emergency signal priority.	Yes	No	No
Ramp Metering Systems	Central control.	Yes	Yes	Yes
	Traffic actuated.	Yes	Yes	Yes
	Preset timing.	Yes	Yes	Yes
Other Freeway Systems	Traffic incident management.	Yes	Yes	Yes
Advanced Traffic Demand Management	Speed harmonization.	No	Yes	Yes
	Employer-based traveler demand management.	No	Yes	No
	Hard shoulder running.	Yes	Yes	Yes
	High-occupancy toll lanes.	Yes	Yes	Yes
	Road weather management.	Yes	Yes	Yes
	Work zone.	Yes	Yes	Yes
	Advanced public transit systems.	Yes	No	No
	Congestion pricing.	Yes	No	No
Supporting Strategies	Traffic management center.	No	Yes	No
	Loop detection.	No	Yes	No
	Closed circuit television cameras.	No	Yes	No

TSMO = transportation systems management and operations.

Samples of Use

As noted above, the tool exists as a Microsoft Excel spreadsheet with several tabs and color coded cells that clearly identify where the user needs to provide information but also allows the user to modify the spreadsheet as needed.

TOPS-BC calculates an annualized cost for each strategy that incorporates the useful life of the equipment, the replacement cost, and the annual operations and maintenance cost. The net present value of implementing the strategy also is provided, and while default values for the discount rate and time horizon are provided, the user can change those values.

The cost components for each TSMO strategy are broken down into two categories: the one-time costs to create the backbone structure for the strategy, such as software and system integration; and the incremental cost of each additional installation, such as additional loops, weather stations, and dynamic message signs. Default costs are included in the spreadsheet for all of the cost components. The user simply needs to enter the number of infrastructure deployments and the number of incremental deployments.

The annual benefits calculated by TOPS-BC focus on travel time savings for both recurring and non-recurring congestion, energy/fuel savings, and savings due to reduced crashes. A tab marked "Parameters" includes all of the assumptions used to calculate the benefits, such as:

- Cost of fuel.
- Fuel economy of autos and trucks.
- Cost of hourly travel for autos and trucks.
- Typical percent of trucks on the facility.
- Cost of crashes by severity.
- Typical emissions.
- Typical crash rates by facilities.
- Speed-flow relationships.
- Typical incident delay factors.

If local information is known, in particular the percentage of trucks on the facility and crash rates on the facility by severity, those can be modified to provide a more accurate assessment of benefits. However, if local factors are not known, the default values make the tool ready to use for an approximation of the benefit for the desired TSMO countermeasure.

As with the cost component, each strategy has its own tab to calculate benefits. Again, color-coded cells are used to help the user identify where input is required. A basic benefit analysis requires minimal input from the users. For example, to calculate the benefits for dynamic message signs, the user is required to provide three pieces of information:

- Length of the analysis period.
- Type of traveler information (three options are provided on a pull-down menu).
- Traffic volume passing the sign location(s) during the period of analysis.

There are additional categories where default values are provided, or the user can override those values when location-specific information is known. For example, the ramp meter benefits assessment assumes a freeway free flow speed of 55 miles per hour and a ramp free flow speed of 35 miles per hour. Both of those values can be overridden if local data is known.

In addition to the benefit tabs for each strategy, the tool contains a generic link-based analysis tab that can be used to enter benefits related to a TSMO strategy not specifically identified. The TOPS-BC tool also includes a summary tab that allows the user to select some or all of the strategies for a total benefit-cost summary.

Advantages

The following are advantages of the TOPS B-C tool:

- The tool provides information that can be used in conjunction with benefit-cost analyses for capital infrastructure, which can be useful when comparing TSMO and capital infrastructure projects.
- It is customizable; therefore, if better data is available, the user can easily modify the spreadsheet with project-specific costs or add components.

Challenge from Training

- The right-of-way acquisition is an important component that is not captured in the cost-estimating tool.[86]
- The strategies are treated independently. Synergies or countervailing effects among strategies are not captured
- Due to limited performance results for some strategies, the user often needs to come into the tools with expected impacts from more sophisticated models or real-world data
- Analyses are facility based. Network or system effects are not directly accounted for.

The Traffic Incident Management Benefit-Cost Tool

Traffic incident management (TIM) strategies are critical components of TSMO. These strategies deal with safety and mobility issues resulting from traffic incidents on the roadways and support quick incident response, thereby shortening incident duration and controlling traffic delays around the occurrence scene. Because resources and funding are oftentimes limited for State DOTs and local transportation agencies, it is essential to investigate benefits and costs for potential and existing TIM strategies to avoid potentially expensive or ineffective approaches.

Various types of TIM strategies have been implemented world-wide. Some of the most cost effective and commonly used TIM strategies include:

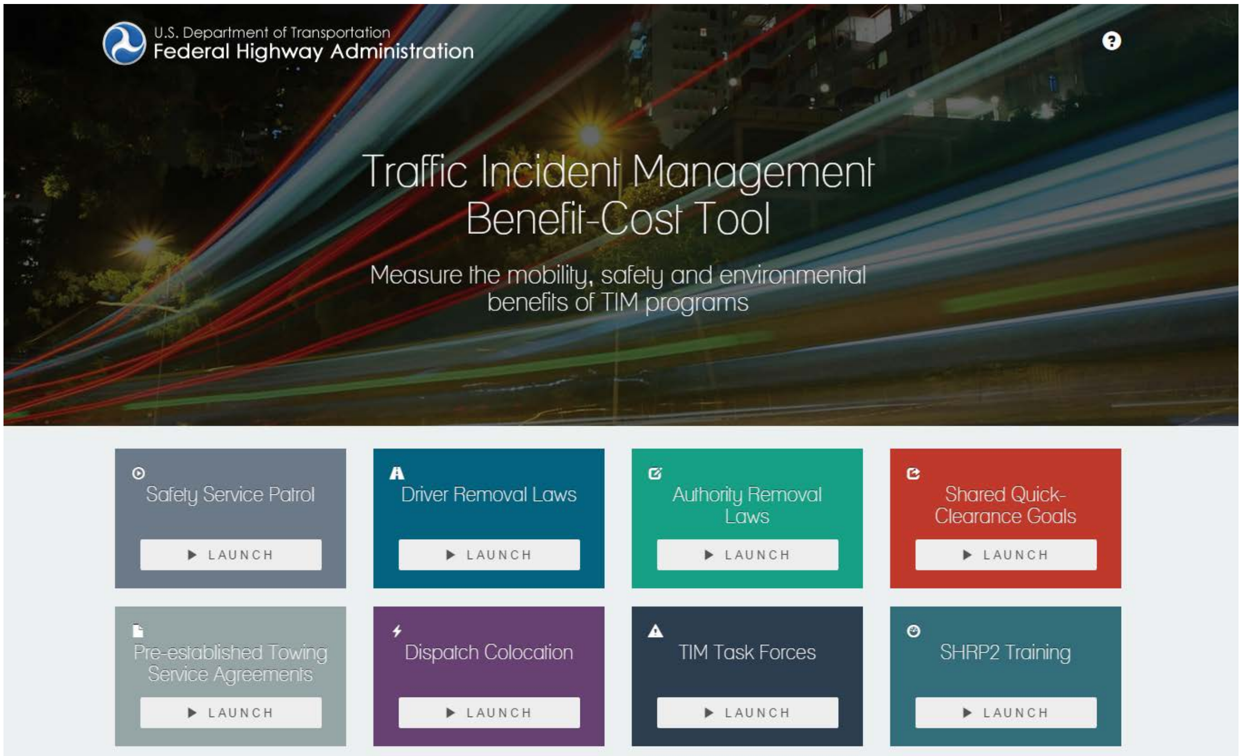
- Safety service patrols.
- Driver removal laws.
- Authority removal laws.

86 For more information and access to the TOPS BC tool, refer to the FHWA's TOPS- BC web page at: http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm.

- Shared quick-clearance goals.
- Pre-established towing service agreements.
- Dispatch collocation.
- TIM task forces.
- Strategic Highway Research Program 2 (SHRP2) training.

The Traffic Incident Management Benefit-Cost Analysis (TIM-BC) Tool is a web-based tool with a standardized methodology that can be universally employed in benefit-cost ratio estimations for different TIM programs.[87] Standardization benefits the evaluations by creating consistency and, therefore, greater confidence in the validity of the results. With access to the approach in the form of a user-friendly, less data-intensive tool, TIM programs and taxpayers alike can benefit from cost-effective evaluations.

TIM-BC features different sub-tools for the eight different TIM strategies described above, and users are able to input their own parameters based on their local experiences and engineering judgment. The tool also provides default values for these parameters to facilitate quick TIM-BC evaluation, particularly for areas where targeted TIM strategies have not been implemented and no relevant data is available. A screenshot of the main navigation page is shown in Figure 27.



Source: Federal Highway Administration, Traffic Incident Management Benefit-Cost (TIM-BC) Tool.

Figure 27. Screenshot. Traffic Incident Management Benefit-Cost Tool navigation page with panels linking to all eight sub-tools.

87 Federal Highway Administration, Office of Operations Research and Development, Software – Traffic Incident Management Benefit-Cost (TIM-BC) Tool. Available at: http://www.fhwa.dot.gov/software/research/operations/timbc/.

Application to Planning for Transportation Systems Management and Operations within Corridors

The TIM-BC tool includes the capability to estimate travel delay, fuel consumption, emissions, and secondary incidents. The data and equations encompassed in the database are derived directly from well-designed simulation experiments, which consider different incident information (i.e., number of lanes, lane blockage, duration, and location) under different traffic conditions. The computations employ a hybrid statistical-simulation methodology in which parameters from regression analysis are combined with results from simulation runs to improve the fit of the regression model.

A key user interface of one sub-tool, the Safety Service Patrol (SSP) benefit-cost tab (for evaluating a safety service patrol) is shown in Figure 28. Other than basic SSP program information, such as location, number of vehicles, and staff for back-end program cost calculation, the user has the flexibility to input information on roadway geometry, the SSP program, traffic, weather, and incidents. The tool also can automatically generate an evaluation report that is professionally designed for effective presentation of evaluation results.

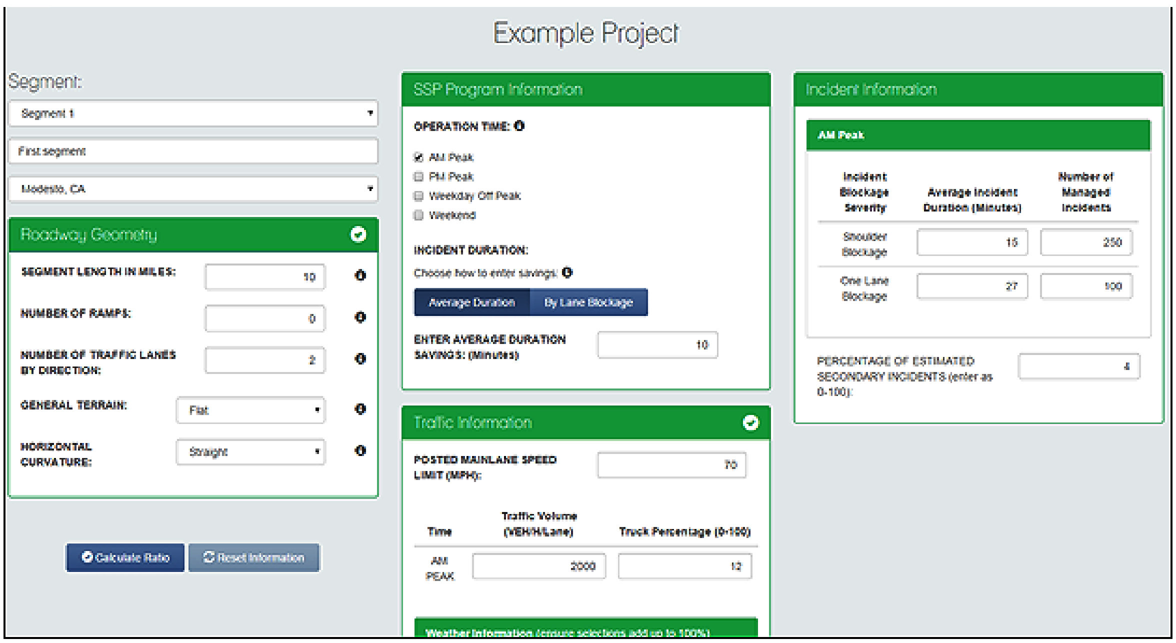


Figure 28. Screenshot. Key user interface for the Safety Service Patrol Benefit-Cost sub-tool.

Source:Federal Highway Administration, Traffic Incident Management Benefit-Cost (TIM-BC) Tool.

Samples of Use

A recent case study on the I-95 Corridor Coalition in New York was conducted to explain the TIM-BC tool application. This study was performed on the I-287 segment that was approximately 10 miles long, beginning at the junction with I-95 and continuing west to the Tappan Zee Bridge in New York.[88] This stretch of roadway has four lanes in each direction and 14 ramps, with level terrain and straight horizontal curvature. The speed limit is 65 miles per hour, and the traffic volumes are 1,800 and 1,200 vehicles per hour with a truck percentage of 7.8 percent. During the 6-month evaluation period, there were 659 incidents on the segment.

88 Miller-Hooks, E., TariVerdi, M. and Zhang, X. 2012. S*tandardizing and Simplifying Safety Service Patrol Benefit-Cost Ratio Estimation, Report to the I-95 Corridor Coalition*.

In addition to SSP program evaluation, two other potential TIM programs, driver removal laws and dispatch collocation, also are evaluated and compared with SSP. The annual program cost of SSP is calculated by the tool based on user input information on number of patrol vehicles, driver's hourly wage, working hours, fuel price, and other costs. Users are required to give an overall estimate of the annual costs of the other two programs, and a conservative value of 5,000 dollars for this segment is assumed for both programs.

As shown in Table 6, SSP is the most cost-effective strategy, with a benefit-cost ratio of 18.43, while the other two strategies have relatively lower, but still significant ratios of more than 3.0. The results indicate that all three investments are cost effective and should be considered for the segment. Further, with adequate funding for TIM programs, it is recommended that SSP should be considered initially. The program costs for the driver removal laws and dispatch collocation are assumed to be conservative. If their costs, particularly the institutional components, are reduced by five times, these two strategies will be comparable with the SSP.

Table 6. Evaluation results of three traffic incident management strategies.

Benefit Type	Performance Measure	Safety Service Patrol	Driver Removal Law	Dispatch Collocation
Total Program Savings	Travel Delay of Passenger Vehicles	52,343.64 vehicle hours	302.09 vehicle hours	256.07 vehicle hours
	Travel Delay of Trucks	1,326.12 vehicle hours	5.88 vehicle hours	7.21 vehicle hours
	Fuel Consumption of Passenger Vehicles	-36.96 gallons	62.45 gallons	143.46 gallons
	Secondary Incidents	5.09	0.03	0.03
	Annual Costs	$161,280	$5,000	$5,000
Emissions Reductions	Hydrocarbon (HC)	-0.0023 metric tons	0.0039 metric tons	0.0089 metric tons
	Carbon Monoxide (CO)	-0.0171 metric tons	0.0288 metric tons	0.0663 metric tons
	Nitrogen Oxide (NOx)	-0.0011 metric tons	0.0019 metric tons	0.0044 metric tons
	Carbon Dioxide (CO2)	-0.3683 metric tons	0.6224 metric tons	1.4299 metric tons
	Sulfur Oxide (SOx)	-0.0059 grams	0.01 grams	0.023 grams
Benefit-Cost Ratio	N/A	18.43	3.50	3.10

Note that there are negative benefits of fuel consumption and emissions for the SSP in the case study, and this result is expected through the development process. From various test cases, it was observed that the fuel savings output in relatively high-volume, high-speed scenarios was negative. That is, for these scenarios, a decrease in incident duration resulted in an increase in fuel consumption over the base case. These results are reasonable given that some incidents may have the effect of slowing down fast-moving traffic to more fuel-efficient speeds. The choice to consider these negative values as costs represents a conservative approach and further reflects the fact that some congestion lowers fuel consumption despite increases in travel delays.

Advantages

The following are a few key advantages of the developed TIM-BC tool:

- The tool uses a standardized methodology that can be universally and equitably employed in benefit-cost ratio estimation for different TIM programs, which is essential to creating consistency and, therefore, greater confidence in the validity of the results.
- The tool assesses a range of eight different TIM strategies, offering practitioners greater flexibility in deploying and evaluating TIM strategies.
- The methodology also is incorporated into a user-friendly and less data-intensive web-based TIM tool to facilitate the cost-effective TIM evaluation by State DOTs.

Challenges

While the new TIM-BC tool offers the possibility of evaluating a wider range of TIM programs, there are still areas for future studies. For example, it should be noted that the results for different TIM strategies are not additive. This is because the benefits of different TIM strategies may not be independent of each other. Future studies should consider the potential interactions between these strategies, and corresponding modules should be incorporated for better evaluation. Also, the evaluation of more strategies can be potentially added as next steps, and this is particularly important when more effective TIM strategies are developed in the future. Further, under the environment of TSMO, the tool is limited to evaluating TIM strategies only, and its level consistency with evaluation results from other TSMO tools is yet to be investigated. Future studies should consider how to integrate the TIM-BC tool with other general TSMO evaluation tools to better support TSMO programs.

The Strategic Highway Research Program 2 Tools – Incorporating Travel Time Reliability in Operations and Planning Models

The approach for modeling and estimating travel time reliability employed by researchers through the SHRP2 supplements existing simulation models with two components: a scenario manager, and a vehicle trajectory processor.[89] The simulation models that are compatible with the two tools have to be particle-based, including microscopic (AimSun, VISSIM, and Paramics) and mesoscopic models (DynaSmart, DynasT, and MATSim), but not macroscopic models (TransCAD and Cube), because macroscopic models cannot generate vehicle trajectories.

The Scenario Manager is a preprocessor to prepare input scenarios for the traffic simulation models. It captures exogenous sources of travel time variation, such as external events, traffic control and management strategies, and travel demand-side factors. Recognizing the importance of the scenario definition and the complexity of identifying relevant exogenous sources, the Scenario Manager provides the ability to construct scenarios that entail any mutually consistent

89 Transportation Research Board, Strategic Highway Research Program, Report S2-L04-RW-2: *Incorporating Reliability Performance Measures into Operations and Planning Modeling Tools: Application Guidelines* (Washington, DC: 2014). Available at: http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-L04-RW-2.pdf.

combinations of external events. It captures parameters that define external sources of unreliability (e.g., special events, inclement weather, and work zones) and enables users either to specify scenarios with particular historical significance or policy interest, or to generate them randomly given the underlying stochastic processes of the associated events.

The scenario input files generated by the Scenario Manager are then fed to the traffic simulation model. The model generates vehicle trajectory files for each of the scenarios.

The Vehicle Trajectory Processor then extracts reliability-related measures from the vehicle trajectory outputs. It produces and helps visualize reliability performance measures (e.g., travel time distributions and indicators) from observed or simulated trajectories. Observed trajectories may be obtained directly through measurement (e.g., Global Positioning System-equipped probe vehicles), thus enabling validation of travel time reliability metrics generated on the basis of output.

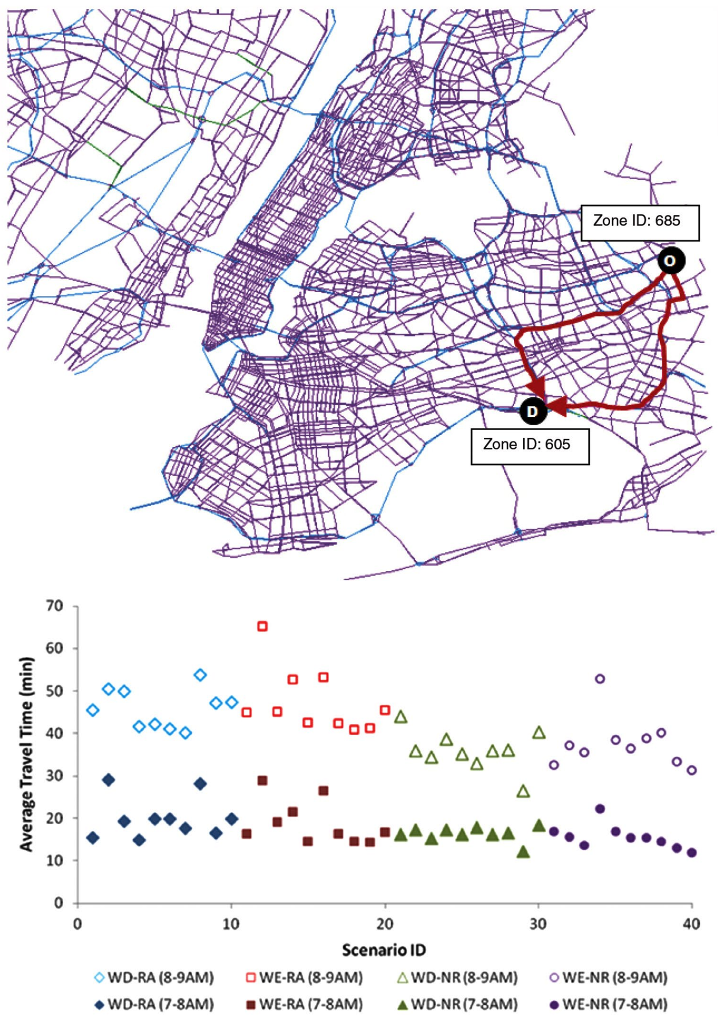
The two tools are not stand-alone applications; instead, they work as a preprocessor and a postprocessor of mesoscopic and microscopic simulation models for travel time reliability analysis on the network level, origin-destination level, path level, and segment/link level. The tools are available from the Transportation Research Board SHRP2 project website: http://www.trb.org/Main/Blurbs/170717.aspx.

Application to Planning for Transportation Systems Management and Operations withinCorridors

The proposed tools can be used to evaluate TSMO benefits within corridors as long as the simulation models have been established with the corresponding TSMO strategy. Depending on the TSMO strategy, an appropriate simulation model needs to be selected. Factors to consider include the scale of analysis (e.g., regional, corridor, or intersection/segment level), and whether travel demand in terms of intensity, departure time, or mode choice needs to be considered.

Samples of Use

Two case studies have been conducted to demonstrate how the tool set can be applied: one in mesoscopic (DYNASMART-P), and one in microscopic (AimSun).



Source: *SHRP 2 Report S2-LO4-RR-1: Incorporating Reliability Performance Measures into Operations and Planning Modeling Tools*, Figure 8.7 and Figure 8.8, p. 103. Copyright, National Academy of Sciences, Washington, D.C., 2014. Reproduced with permission of the Transportation Research Board.

Figure 29. Graphic. Origin-destination-level travel time in different weather scenarios.

Mesoscopic Case Study

This case study examines the effect of inclement weather on travel time reliability for weekday and weekend traffic. Specifically, reliability performance measures for the following four scenario cases were obtained: Weekdays under Rain (WD-RA), Weekends under Rain (WE-RA), Weekdays under No Rain (WD-NR), and Weekends under No Rain (WE-NR). The rain scenarios are based on historical observations. Weather data collected on May 3, 2010, at the Automated Surface Observing System weather station located at the LaGuardia Airport are used. Incident properties are characterized using parametric models. For frequency, a Poisson distribution is used to model the number of incidents for a given time period. To capture the dependency between weather and incident frequency, weather conditional incident rates are used.

Figure 29 illustrates an example of the results using the New York City DYNASMART-P network. TSMO concepts, such as managed lanes, road weather management, traveler information system, traffic signal coordination, and transit signal priority (TSP), can be applied on this network, and travel time can be evaluated for both the before and after cases.

Microscopic Case Study

The objective of the microsimulation tests was to determine a range of reliability measures that is characteristic of the study area for weekday and weekend traffic. The weekday and weekend scenarios were subjected to incident and demand variation events that are typical of the study area (East Manhattan). The micro-model covers an area that includes 178 lane kilometers and 217 signalized intersections. A total of 147 centroids were connected to the network to generate origin–destination trips, including 44 gate and 103 internal centroids.

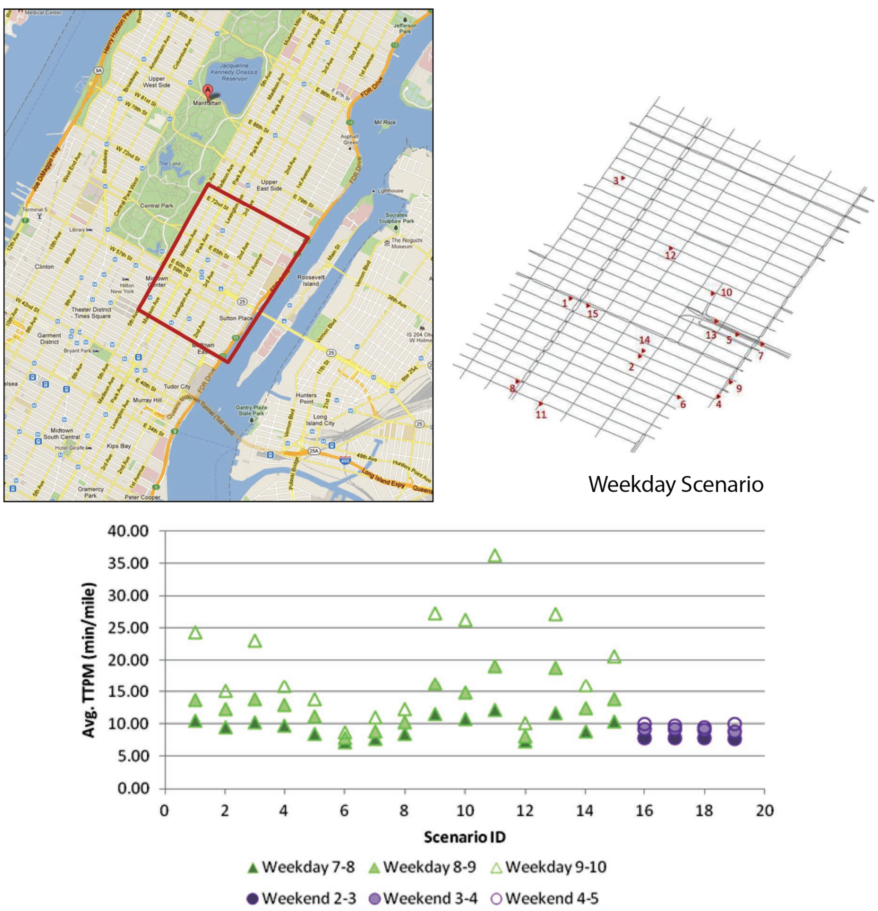


Figure 30. Graphic. Network-level travel time in different incident scenarios.

Source: *SHRP 2 Report S2-LO4-RR-1: Incorporating Reliability Performance Measures into Operations and Planning Modeling Tools*, Figure 9.1 and Figure 9.2, p. 115 and Figure 9.3, p. 116. Copyright, National Academy of Sciences, Washington, D.C., 2014. Reproduced with permission of the Transportation Research Board.

The same methodology that was used to generate scenarios for the mesoscopic model using the Scenario Manager was applied for the microscopic model. The scenarios relevant for the microsimulation study area were then selected based on incidents that were located within the boundaries. Fifteen of the generated weekday scenarios and four of the weekend scenarios contained incidents within the microsimulation study area. Two base models were constructed representing peak a.m. weekday and weekend conditions. The weekday a.m. peak period model consisted of a total demand of around 155,000 vehicles over a 5-hour period from 6 a.m. to 11 a.m. The weekend peak period model consisted of a total demand of around 80,000 vehicles over a period of 3 hours from 2 p.m. to 5 p.m. The results are in formats very similar to those of the mesoscopic model (i.e., average, standard deviation, 80th percentile, Buffer Index, and Skew Index of the travel time of the regional, origin-destination, path, and link levels).

This example can be used to evaluate TSMO concepts, such as incident management, special event management, ridesharing and demand management, and traveler information systems.

Advantages

- The tools promote greater appreciation and recognition of the entire distribution of travel time rather than simply mean values.
- The tools overcome the limitations of a conventional single-run framework to incorporate important reliability-related phenomena, such as non-recurrent congestion due to a traffic incident, special event, or extreme weather condition.
- The tools are robust in that they can be integrated with different simulation models instead of requiring extensive software development to include the travel time reliability measurement function.
- Adopting scenario-based approaches to project evaluations is the primary, default approach for conducting such evaluations.

Challenges

- Mainstream traffic simulation tools focus on the supply side. It is still a challenge to incorporate travel-time reliability into the demand side (e.g., activity scheduling and departure time). Agent-based models are becoming more and more important as they ensure a full consistency of daily activity patterns at the individual level.
- The post-processing nature of the tool set makes it difficult to incorporate reliability measures in such a way that they could be effectively generated within the network simulation procedure and, thus, affect the route choice embedded in it.

CHAPTER 6. TAKING ACTION

While transportation systems management and operations (TSMO) at the corridor level can be advanced in many ways, and can involve coordination among operating agencies to major planning studies, it does not have to be daunting to proceed. The scope of the effort can be scaled to the needs and challenges of the corridor and can be integrated into ongoing operational coordination efforts and planning studies.

The checklist below summarizes the key points presented in this Desk Reference and can be used to guide the process for developing a TSMO plan for a corridor.

❑ Scoping the Effort and Building a Team.

The team working on a corridor planning study or operations plan should encompass many different agencies and partners who, together, operate services and influence operations in the corridor. The team may include multiple jurisdictions (State, county, city, other municipality), as well as a range of different agencies and service providers, which may include regional transit providers, local bus services, State departments of transportation (DOTs), toll authorities, port authorities, vanpool operators, transportation management associations, or others. In addition, it is valuable to involve planners, traffic engineers, transit operators, law enforcement, and other organizations that play a key role in the corridor. Getting the agencies together is often a critical component of success in gaining an early understanding of who operates in the corridor, what their opportunities are for enhancing operations, and ways to work together to optimize system performance.

Transportation planning in a corridor should build off of broader planning efforts for TSMO, as well as operations programs and strategies at a regional and State-level. Regardless of the size of the corridor, planning for corridor operations should recognize and build upon existing programs that can benefit the corridor.

Develop a clear definition of the corridor where TSMO strategies are to be introduced. While an effort to advance TSMO can focus on one facility, a corridor should be looked upon as more than an individual facility and should consider the interconnected nature of travel across facilities in a travel-shed to maximize the effectiveness of the selected TSMO strategies. Components of a corridor may include a freeway; major arterials; local road networks; transit rail and bus services; and transportation services, including rideshare programs and parking facilities.

Think carefully about the boundaries and definition of a corridor to assess and develop solutions comprehensively. Defining a corridor often begins with a review of data on travel patterns (including origin-destination data) and connecting networks and choices available to travelers, which are informed by public perceptions.

❑ Gathering Information on Current and Future Contexts and Conditions.

Compile information on the transportation assets, capabilities, and resources that exist within the corridor. Document existing intelligent transportation system (ITS) equipment, real-time traffic and bus monitoring, park and ride facilities, traffic signal timing plans, and other technologies and facilities relating to corridor operations, because operational improvements can build upon these assets. In addition, identify regional resources (e.g., highway and transit traveler information systems, ridesharing programs, and regional incident management programs).

❑ Developing an Outcome-Oriented Operational Concept – Goals, Objectives, and Performance Measures.

This may be the most important step in the process because it establishes how the corridor is expected to perform once TSMO strategies are implemented and operated on a day-to-day basis. Operations objectives are developed through interactions with partners and stakeholders who help define the intended objectives and performance outcomes for the corridor. These objectives can be further refined through a study process, but the initial identification of objectives is critical for setting the context for developing and evaluating corridor TSMO strategies. Objectives can be expressed in the form of an objectives tree that shows how higher-level objectives are reached by first achieving lower level objectives that support them.

❑ Identifying Operations Performance Needs, Gaps, and Opportunities.

Gather and analyze data for performance measures to identify existing gaps between desired outcomes (objectives) and current conditions, as well as potential opportunities for improvement. Define scenarios or conduct a scenario planning exercise as a basis for understanding current performance gaps and potential opportunities. By defining scenarios, participants in the corridor can identify existing gaps, performance needs, and opportunities for improvements. In many cases, performance data is available that clearly demonstrate where problems exist and need attention, which leads to understanding where investments are needed and what efforts should be prioritized in the planning process.

❑ Developing an Integrated TSMO Approach.

Consider TSMO strategies working together in the context of the corridor as opposed to selecting and implementing strategies in isolation. Planning for an integrated set of strategies allows planners and operators to leverage synergies between strategies. Build on the assessment of potential strategies using available analysis tools so that the corridor plan involves a set of promising strategies that achieve the operations objectives for the corridor. Given the wide array of potential strategies to consider, include those that focus on highway/traffic operations, transit operations, demand management, and capacity. Selecting strategies for a corridor involves both quantitative and qualitative assessments of what would work best to fit within the specific context of the corridor.

The Federal Highway Administration (FHWA) document *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations* provides a guide for assembling a range of complementary TMSO strategies that, together, provide wide-ranging benefits to corridor management and operations. This document, along with other FHWA references and guides, addresses the range of needs for improving corridor performance.

❑ Putting it All Together: Efficiency, Reliability, Travel Options, Non-Recurring Delay, Arterial Management, Freeway Management, and Transit Operations and Management.

The Federal Highway Administration (FHWA) document *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations* provides a guide for assembling a range of complementary TMSO strategies that, together, provide wide-ranging benefits to corridor management and operations. This document, along with other FHWA references and guides, addresses the range of needs for improving corridor performance.

❑ Programming for TSMO.

Identify and understand the various sources of funding for TSMO strategies in the corridor, and prioritize TSMO projects based on funding availability and potential benefits. Use an incremental investment approach that gains benefits from early implementation while maintaining a strategic view of fully implemented solutions in the corridor.

❑ Implementing, Monitoring, and Maintaining Level of Operations over Time.

Apply well-tested systems engineering processes to ensure that system requirements are properly specified and achieved in systems design and deployment and that the corridor plan includes consideration for life-cycle management and operation.

U.S. Department of Transportation
Federal Highway Administration
Office of Operations
1200 New Jersey Avenue, SE
Washington, DC 20590

www.ops.fhwa.dot.gov
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