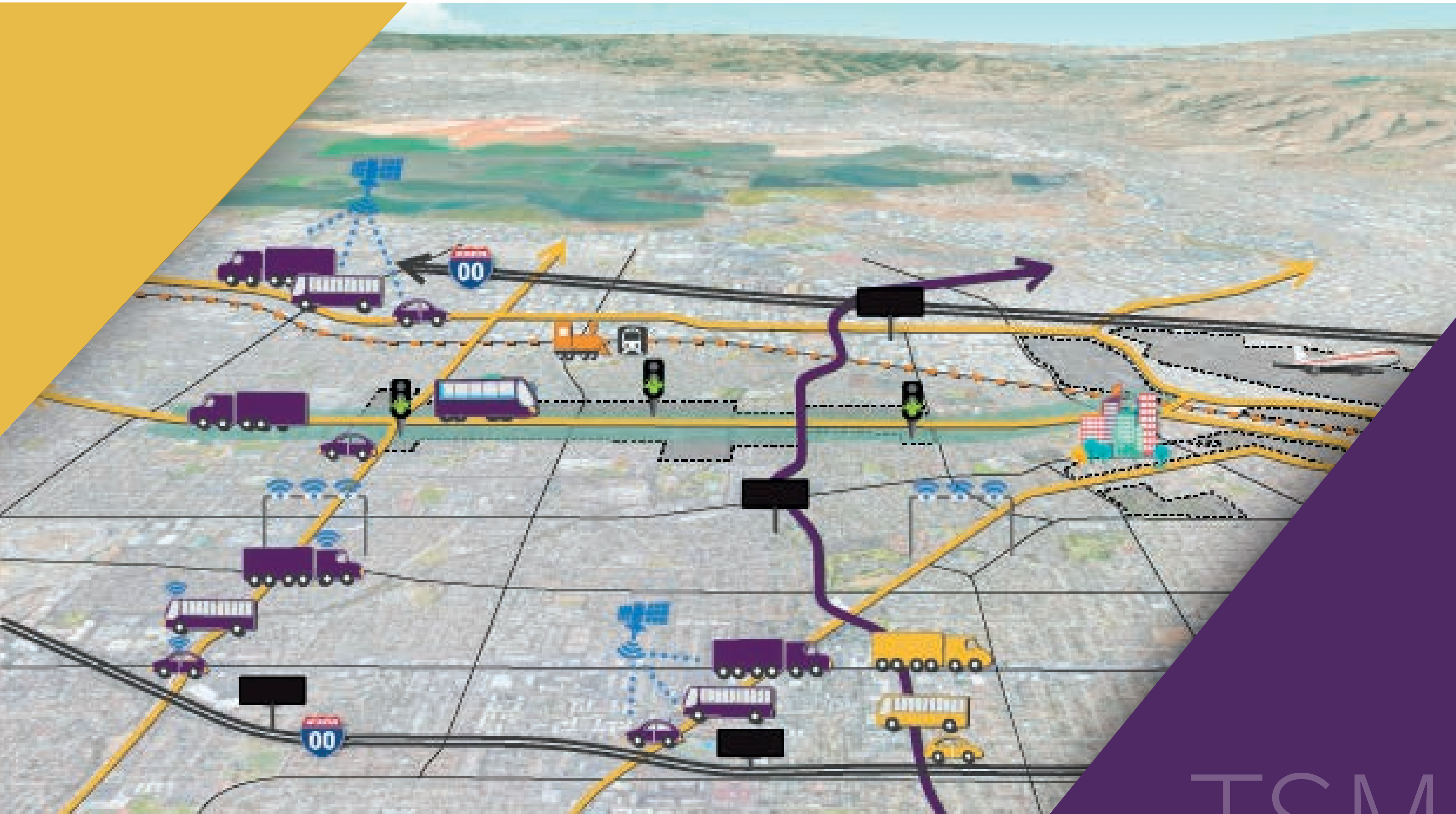
Model Transportation Systems Management and Operations

DEPLOYMENTS IN CORRIDORS AND SUBAREAS PRIMER



TSMO

U.S. Department of Transportation
Federal Highway Administration

Technical Report Documentation Page

1. Report No. FHWA-HOP-18-026	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Model Transportation Systems Management and Operations Deployments in Corridors and Subareas Primer		5. Report Date February 2018 6. Performing Organizations Code	
7. Authors Deena Platman, Renee Hurtado, Chris Muhs, Danella Whitt, Jim Peters, Jennifer Bachman, Jocelyn Bauer, Deepak Gopalakrishna, Michael Grant		8. Performing Organization Report No.	
9. Performing Organization Name and Address Leidos 11251 Roger Bacon Drive Reston, VA 20190 DKS Associates 720 SW Washington Street Suite 500 Portland, Oregon 97205 ICF 1725 Eye Street NW Washington, DC 20006		10. Work Unit No. (TRAIS) 11. Contract or Grant No. Contract No. DTFH61-12-D-00050	
12. Sponsoring Agency Name and Address Federal Highway Administration U.S. Department of Transportation 1200 New Jersey Avenue, SE Washington, DC 20590		13. Type of Report and Period Covered Primer, January 2016 – December 2017 14. Sponsoring Agency Code HOP	
15. Supplementary Notes Mr. Jim Hunt, Federal Highway Administration Government Task Manager			
16. Abstract This primer showcases six illustrative packages of transportation systems management and operations (TSMO) strategy deployments with varied geographic, social, and institutional contexts to serve as examples for advancing State, regional, and local plans and programs for TSMO. This document is intended to help planners, transportation engineers, and decisionmakers apply a comprehensive approach to the deployment of TSMO in corridors and subareas. This primer will enable planners and transportation engineers to think beyond deploying TSMO on a project-by-project basis to defining and advancing a "package" of project deployments, institutional advancements, and programs that can meet longer term strategic and operational objectives in a corridor or subarea.			
17. Key Words Transportation systems management and operations, planning for operations, corridor, subarea.		18. Distribution Statement No restrictions.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No of Pages 96	22. Price N/A

Form DOT F 1700.7 (8-72)

Table of Contents

List of Figures

List of Tables

List of Acronyms

ADM	active demand management
API	application programming interface
APM	active parking management
ATDM	active transportation and demand management
ATM	active traffic management
CAD	computer-aided dispatch
EOC	emergency operations center
DMS	dynamic message sign
DOT	department of transportation
FHWA	Federal Highway Administration
FRATIS	Freight Advanced Traveler Information System
HOV	high-occupancy vehicle
ICM	integrated corridor management
ITS	intelligent transportation systems
MPO	metropolitan planning organization
MUTCD	Manual on Uniform Traffic Control Devices
RWIS	road weather information system
SMART	specific, measurable, agreed-upon, realistic, and time-bound
SOP	standard operating procedure
TDM	transportation demand management
TIM	traffic incident management
TMC	traffic management center
TSMO	transportation systems management and operations
TSP	transit signal priority

1. Introduction

The purpose of this document is to showcase to State, metropolitan, and local planners, transportation engineers, and decisionmakers an effective and sustainable strategy, program, and package of project deployments for transportation systems management and operations (TSMO) for corridors or subareas. The document presents six illustrative packages of TSMO strategy deployments with varied geographic, social, and institutional contexts to serve as examples for advancing State, regional, and local plans and programs for TSMO. The concept behind this document is to help planners, transportation engineers, and decisionmakers apply a comprehensive approach to the deployment of TSMO in corridors and subareas. This primer will enable planners and transportation engineers to think beyond deploying TSMO on a project-by-project basis to defining and advancing a "package" of project deployments, institutional advancements, and programs that can meet longer term strategic and operational objectives in a corridor or subarea.

Transportation agencies, particularly at the State and regional levels, have increasingly sought to optimize the existing transportation system using TSMO strategies. These efforts have resulted in statewide and regional policies and programs. A largely untapped opportunity to further optimize the transportation system lies in applying an integrated approach to planning and deploying TSMO in corridors and subareas.

The target audience of this primer includes:

- Transportation planners.
- Traffic operations engineers.
- Transportation engineers and designers.
- Decisionmakers.

This introduction describes TSMO and its benefits, provides an overview of TSMO planning within corridors and subareas, and provides a guide for using this primer.

A **corridor** is a linear system of multi-modal facilities in which an existing roadway or transit facility will typically serve as the spine 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 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 scale, corridors may have different modal focuses, e.g., freight rail, high capacity passenger rail, limited access highway, and bus rapid transit.

A subarea encompasses a network of transportation facilities for a given geographic area. Subareas are generally defined as a portion of a region, such as a local municipality (city or county), a downtown or central business district, or a neighborhood. Planning for subareas typically addresses a broader planning context, which may include a wide array of topics, including transportation, land use, and urban design.

WHAT IS TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS AND WHY IS IT BENEFICIAL?

TSMO encompasses a broad set of strategies that 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 strategies are coordinated with related strategies and collaboration occurs among many stakeholders and modes.

TSMO strategies range from managing operational systems, like traffic signals, to managing travel demand, like traveler information.

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

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

TSMO strategies are supported by both institutional and technology-based activities. On the institutional side, TSMO is enabled by memoranda of agreement between agencies, operations policies and procedures, and shared resources (e.g., interoperable communications systems, centralized traffic signal operations, and closed circuit television video sharing). Technology enables real-time operations of the transportation system by controlling traffic flow, delivering pre-trip and en-route travel information, and delivering data for optimizing system efficiency.

TSMO strategies help transportation agencies address transportation issues in the near-term with lower cost solutions. TSMO strategies deliver a variety of benefits including:[1]

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 transit signal priority (TSP) reduces transit delay by 30 to 40 percent.

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

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.

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. Baltimore, Maryland's use of electronic toll collection reduced harmful emissions at toll plazas by 16 to 63 percent.

OVERVIEW OF TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS PLANNING WITHIN CORRIDORS AND SUBAREAS

This primer provides a set of six examples for how the TSMO planning process can be used to identify and deploy management and operations strategies that help address community needs and goals. It illustrates an integrated set of TSMO strategies across multiple program areas working together to achieve operations objectives within a corridor or subarea context. The objectives for this primer are to:

- Fill the gap in transportation planning to incorporate operational considerations alongside more traditional capacity improvements.
- Provide specific ideas about how to apply the planning for operations process to tangible examples.
- Support the high-level goals contained in national surface transportation legislation.

The TSMO planning process illustrated in this primer is founded on three themes that are consistent with noteworthy practices for successful deployment:

- Using a performance-based planning approach.
- Establishing a collaborative environment that cuts across agencies, jurisdictions, public-private sector roles, and travel modes.
- Connecting to overarching planning processes at the metropolitan and State levels.

This primer depicts the planning process and resulting strategy deployments within a variety of corridor and subarea contexts. The intent is to demonstrate how TSMO strategies can be applied across different geographic settings and address a wide variety of community needs and issues. Further, it shows how integrated sets of strategies can be deployed and operated in different contexts to achieve operational goals.

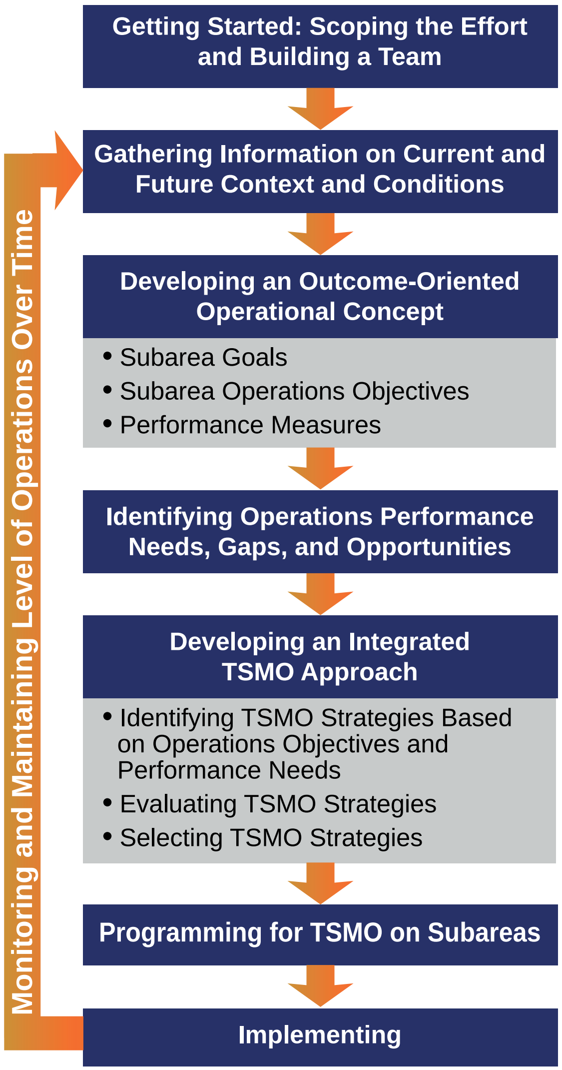
For in-depth guidance, see the *Planning for Transportation System Management and Operations within Corridors Desk Reference*[2] and the *Planning for Transportation System Management and Operations within Subareas Desk Reference*.[3]

HOW TO USE THIS PRIMER

Figure 1 shows the overarching approach to planning for TSMO within corridors or subareas. There is no one-size-fits-all approach to TSMO planning and implementation; however, proven practices and lessons learned can be applied. The primer uses six different examples to demonstrate the planning for TSMO approach. This section is a guide to help orient the primer user to the layout and use of the example deployments as they relate to the planning approach.

Gathering Information on Current and Future Context and Conditions

Each model corridor or subarea includes example background information on geographic extent (e.g., rural, suburban, urban); land use context (e.g., commercial, industrial); corridor transportation facilities (e.g., arterials, collectors); transportation modes (e.g., automobiles, transit, bicycles); existing institutional capabilities (i.e., degree of organizational readiness for deploying TSMO); and motivators driving the need to improve the corridor or subarea. While the examples focus on these aspects, practitioners should also take into consideration previous studies, reports, and plans; information on current system performance; anticipated future conditions and contexts; and stakeholder input.



TSMO=Transportation Systems Management and Operations

Figure 1. Diagram. Approach to planning for transportation systems management and operations within corridors or subareas.

2 Federal Highway Administration, *Planning for Transportation Systems Management and Operations within Corridors - A Desk Reference*, FHWA-HOP-16-037 (Washington, DC: September 2016). Available at: https://ops.fhwa.dot.gov/publications/fhwahop16037/index.htm.

3 Federal Highway Administration, *Planning for Transportation Systems Management and Operations within Subareas - A Desk Reference*, FHWA-HOP-16-074 (Washington, DC: October 2016). Available at: https://ops.fhwa.dot.gov/publications/fhwahop16074/index.htm.

Developing an Outcome-Oriented Operational Concept

Goals establish the desired end state of the plan. Operations objectives state the desired operational performance in each corridor or subarea. The goals and operations objectives are the link between the identified motivators and the set of TSMO strategies developed through a planning process. They are linked to quantitative or qualitative performance measures that document change over time.

A set of goals are defined that respond to the unique combination of motivators identified for each model corridor and subarea. Supporting each goal are one or more operations objectives. Individual operations objectives are written statements for desired performance. They are SMART statements—**s**pecific, **m**easurable, **a**greed upon, **r**ealistic, and **t**ime-bound—and have performance measures linked to them. The SMART operations objectives shown in this primer are for illustrative purposes only. Practitioners should take into consideration current system performance when developing specific corridor or subarea operations objectives and agree upon realistic targets for improvement. For more information on the objectives-driven, performance-based planning for operations approach, see the Federal Highway Administration's (FHWA) *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations – A Desk Reference.*[4]

Identifying Operations Performance Needs, Gaps, and Opportunities

Often a key step in understanding existing performance needs, gaps, and opportunities is to conduct a scenario planning exercise. Operational scenarios should be defined by corridor or subarea stakeholders and may include a normal or daily scenario, a traffic incident scenario, a planned event scenario, a weather-related, emergency or evacuation scenario, or a major work zone scenario. Although not implicitly described in this primer, guidance on scenario planning is provided in FHWA's *Advancing Transportation Systems Management and Operations Through Scenario Planning Primer.*[5]

Developing an Integrated TSMO Approach

A set of TSMO strategies that address the motivators, goals, and operational objectives are identified for each corridor and subarea. The strategies are generally organized into one or more of the eight TSMO program areas described later in this section. The selection of TSMO strategies based on goals and operations objectives forms the basis of an integrated management and operations approach. While this primer demonstrates an idealized complete TSMO system, it is important to acknowledge that a corridor or subarea may have some of the desired TSMO strategies in place today and the planning effort will augment these strategies with new devices, communications, or program activities. The primer intends to instill the practice of looking at the transportation system holistically to create a sustainable, integrated program of TSMO strategies within a corridor or subarea.

Evaluating the strategies to determine how well they meet defined operations objectives and whether they should be implemented all at once or phased in is an important part of determining the best set of TSMO strategies for the corridor or subarea. Common methods and

4 Federal Highway 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: April 2010). Available at: https://www.ops.fhwa.dot.gov/publications/fhwahop10027/index.htm.

5 Federal Highway Administration, *Advancing Transportation Systems Management and Operations Through Scenario Planning*, FHWA-HOP-16-016 (Washington DC: October 2015). Available at: https://www.ops.fhwa.dot.gov/publications/fhwahop16016/index.htm.

analysis tools used for evaluating TSMO strategies include travel demand models, sketch-planning tools, analytical/deterministic tools, simulation models, and hybrid approaches. FHWA's Organizing and Planning for Operations Analysis and Simulation Tools website provides resources.[6] Also, FHWA's *Active Traffic Management Feasibility and Screening Guide* provides examples for screening and evaluating active traffic management strategies.[7] A similar process may be used for other TSMO strategies.

There are more TSMO strategies than can be covered in this primer. The appendix includes a list of TSMO strategies and the right side of this page lists the FHWA operations program areas, which correspond to many of the TSMO strategy areas listed below.

Traffic Management and Operations. The application of management practices and operations strategies that promote the safe and efficient use of freeway and arterial roadway capacity to reduce congestion and increase safety. Examples of strategies that fall under this category include network surveillance, coordinated signal timing, adaptive signal timing, ramp metering, variable speed limits, and queue warning systems.

Road Weather Management. The use of strategies to minimize or eliminate the impacts of weather events such as rain, snow, high winds, or flooding on safe and reliable travel. Examples of strategies that fall under this category include the use of road weather information systems (RWIS) for weather responsive traffic management that are supported by variable speed limits, vehicle restrictions, and warning systems.

6 Federal Highway Administration, Analysis and Simulation Tools, https://www.ops.fhwa.dot.gov/plan4ops/focus_areas/analysis_p_measure/simulation_tools.htm.

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

FHWA Operations Program Areas

FHWA's Office of Operations web page provides a wealth of guidance online, including dedicated web pages for each program area: https://ops.fhwa.dot.gov/program_areas/programareas.htm.

Reducing Non-Recurring Congestion

- Traffic Incident Management
  - Planned Special Events Traffic Management
- Work Zone Management
- Road Weather Management

Reducing Recurring Congestion

- Active Transportation and Demand Management (ATDM)
- Arterial Management
- Congestion Pricing
- Corridor Traffic Management
- Freeway Management
- Travel Demand Management

Improving Day-to-Day Operations

- Business Process Frameworks for Transportation Systems Management and Operations
- Manual on Uniform Traffic Control Devices (MUTCD)
- Real Time Traveler Information
- Traffic Analysis Tools

Creating a Foundation for 21st Century Operations

- Organizing and Planning for Operations
- Performance Measurement
- Facilitating Integrated ITS Deployment

Improving Global Connectivity by Enhancing Freight Management and Operations

- Freight Analysis, Infrastructure, Technology and Operations
- Freight Professional Development
- Truck Size and Weight

Improving Mobility and Security through Better Emergency Management

- Emergency Transportation Operations

Work Zone Management. The practice of managing traffic impacts during construction to maximize traveler and worker safety, minimize traffic delay, maintain access for adjacent land uses, and support timely completion of construction. Examples of strategies that fall under this category include automated enforcement, queue warning, traveler information, and variable speed limits.

Planned Special Events Management. The practice of advanced planning and coordination to manage travel before, during, and after an event. Examples of strategies that fall under this category include real-time parking information, travel time information, and special signal timing plans.

Travel Demand Management. The policies and strategies aimed at enhancing travel opportunities and choices that make more efficient use of the transportation system. Examples of strategies that fall under this category include ridesharing systems, individualized marketing, and multimodal trip planning mobile device applications.

Public Transportation Management. The use of strategies to improve transit service operations and increase safety of riders and the traveling public. Examples of strategies that fall under this category include transit signal priority, electronic fare collection systems, transit surveillance, and blind spot detection systems for pedestrians and bicyclists.

Traveler Information. The use of strategies to deliver pre-trip and en-route information about travel options and conditions. Examples of strategies that fall under this category include dynamic message signs, wayfinding, and real-time transit arrival information.

Traffic Incident and Emergency Management. The practice of coordinating resources across partner agencies and the private sector to quickly detect, respond to, and clear traffic incidents; and to plan and coordinate response to man-made or natural events causing or threatening injury or loss of life, property damage, human suffering, or financial loss. Examples of strategies that fall under this category include dedicated incident response service patrols, computer-aided dispatch (CAD) integration, and TIM teams.

Each example corridor and subarea includes a decision-tree that graphically depicts how each strategy relates to the topic areas and the identified goals. The intent is demonstrate to the primer user how a set of TSMO strategies in a corridor or subarea helps achieve the desired goals and operational outcomes.

Programming and Implementing TSMO on Corridors and Subareas

Moving from the planning stage to programming and implementing TSMO typically requires improvements to existing institutional capabilities, which describe the degree of organizational readiness for deploying TSMO. Each model corridor or subarea provides examples for advancing business processes, systems and technology, performance measurement, culture, organization/workforce, and collaboration. Additional FHWA guidance for organizing for operations is described in *Creating an Effective Program to Advance Transportation System Management and Operations Primer*[8] and the related document entitled *Developing and Sustaining a Transportation Systems Management & Operations Mission for Your Organization: A Primer For Program Planning*.[9]

The final section of the primer, presents a collection of key factors for the implementation of TSMO strategies that can be applied across all six examples. Factors are grouped into the following three categories:

8 Federal Highway Administration, *Creating an Effective Program to Advance Transportation System Management and Operations Primer*, FHWA-HOP-12-003 (Washington DC: January 2012). Available at: https://www.ops.fhwa.dot.gov/publications/fhwahop12003/index.htm.

9 Federal Highway Administration. *Developing and Sustaining a Transportation Systems Management & Operations Mission for Your Organization: A Primer For Program Planning*, FHWA-HOP-17-017 (Washington, DC: September 2017). Available at: https://ops.fhwa.dot.gov/publications/fhwahop17017/index.htm.

- **Physical factors** include the characteristics necessary to design and build a TSMO system such as field devices, central systems, firmware/software, communications, and power connections.
- **Operational factors** are characteristics related to the processes and procedures needed for day-to-day operation such as agency roles and responsibilities, operating procedures, and performance measurement.
- **Institutional factors** include the characteristics related to the legal, organizational, and behavioral roles associated with operating and managing a transportation system. These include policies, regulations, intra- and inter-agency coordination, and public-private partnerships.

Guide to Model Corridors and Subareas

Table 1 provides a cross-reference of the model corridors and subareas to common motivators used in this primer. For practitioners looking for a place to dive in to this primer, this cross-reference allows you to find which motivator(s) exist in a corridor or subarea of interest in your community and identify which example may provide the most applicable ideas.

Table 1. Motivator cross-reference with model corridors and subareas.

Motivators	Corridor 1-Rural Interstate	Corridor 2-Small Urban Corridor	Corridor 3-Large Urban Corridor	Subarea 1-Neighborhood	Subarea 2-Urban Activity Center	Subarea 3-Urban Sub-Region
Adverse environmental issues (i.e., air or water quality).			✓			✓
Adverse weather (i.e., snow, ice, fog).	✓		✓			
High traffic volumes.			✓			✓
Variability in trip reliability.			✓		✓	✓
Capacity bottlenecks/limitations to capacity expansion.		✓	✓	✓	✓	✓
High prevalence of crashes.	✓	✓	✓		✓	✓
Other traffic incidents.		✓				
Construction impacts.	✓		✓			
Development pattern changes.						✓
Land use access issues.		✓		✓	✓	✓
Special event congestion.		✓	✓			✓
High reliance on single-occupancy vehicles.				✓		✓
Financial constraints and priorities.	✓		✓		✓	✓

2. Model Corridors

This section portrays three illustrative corridors based on fictional locations with unique geographic characteristics, motivators, and institutional capabilities that provide the backdrop for demonstrating how a package of transportation systems management and operations (TSMO) strategies can be planned and implemented to achieve a set of operations objectives.

MODEL CORRIDOR 1 – RURAL INTERSTATE

The backbone of Corridor 1 is a long stretch of rural interstate that passes through or near small cities, rural towns, and large unincorporated sections of rural counties, as depicted in Figure 2. Some sections of the interstate are paralleled by other principal arterials that connect nearby rural towns and rural lands to the interstate. Other principal arterials intersect the interstate to provide connections to far-off regions. Corridor 1 spans multiple regions that include a variety of State, county, and city agencies who manage the transportation system. The State department of transportation (DOT) maintains a statewide traffic operations program that oversees TSMO in the corridor.

The terrain is mountainous and the area experiences severe winter weather, including icy conditions and heavy snowfall. Some areas of the region are also prone to heavy fog or flooding during heavy rainfall events.

Due to the rural nature of the area, mode choice in Corridor 1 predominantly consists of automobile and truck freight travel, with limited transit service. The majority of the traffic is made up of through-trips on the interstate. The principal arterials and adjacent sections of interstate are used by automobiles to connect residents to employment, school, and retail and are used by truck freight for intermediate trip destinations within the corridor's small cities and rural towns.

The agencies managing and operating the transportation systems in Corridor 1 demonstrate the following institutional capabilities for implementing a TSMO program:

Business Processes – A multi-year TSMO plan and program exists at the statewide level. Targeted multi-jurisdictional business processes for Corridor 1 still need development.

Systems & Technology – Operator-driven TSMO deployments have been implemented in parts of the corridor including weather and work zone management practices.

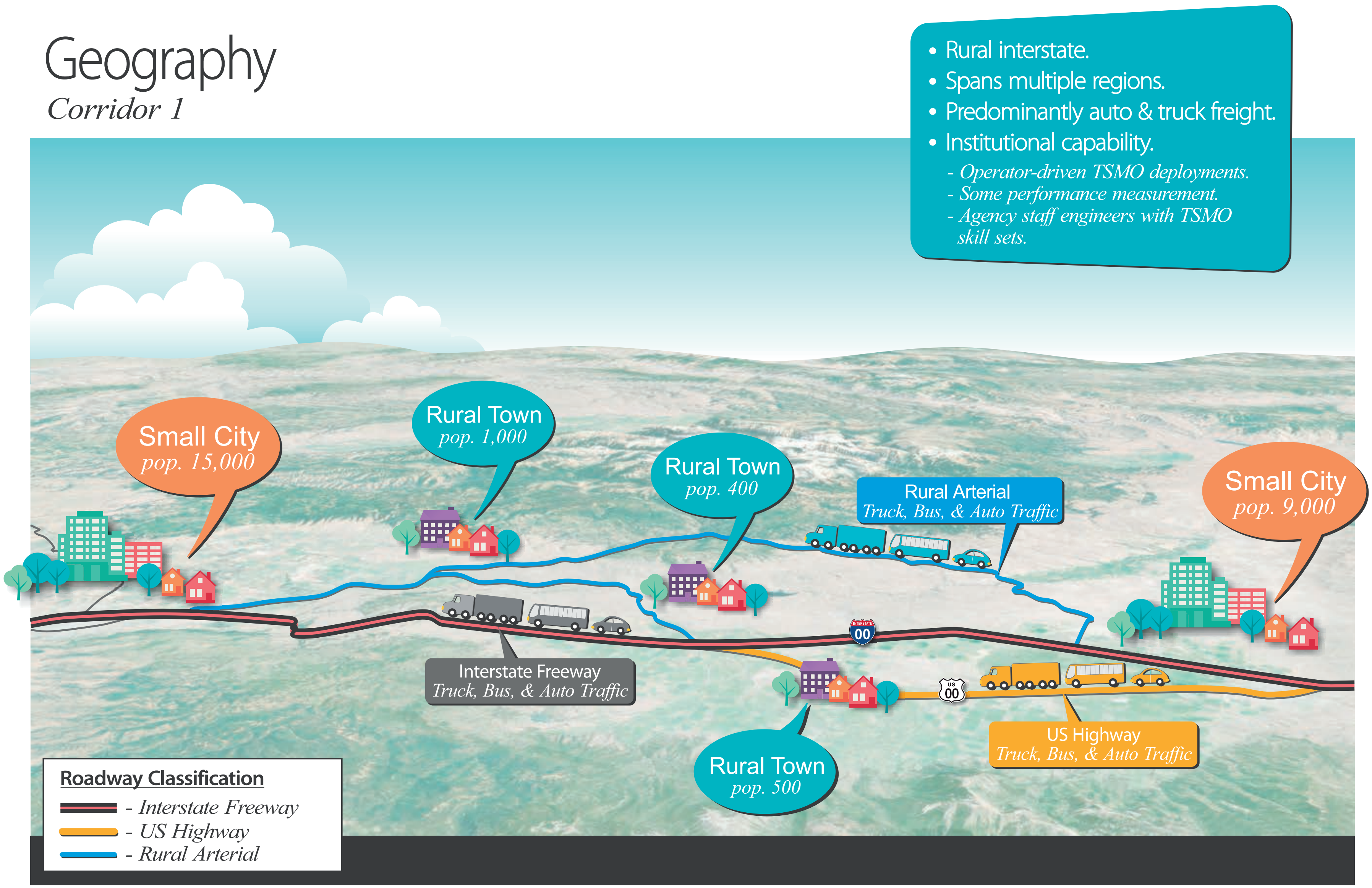
Performance Measurement – Some performance measurement of the system is regularly assessed but there is room for growth in this area.

Culture – Agencies within the corridor appreciate the value and role of TSMO.

Organization/Workforce – The State DOT staffs engineers with TSMO skill sets.

Collaboration – Informal collaboration occurs on a somewhat regular basis between the transportation and public safety agencies within the corridor.

Figure 2. Illustration. Corridor 1 geography.



The motivators driving the need to implement TSMO strategies in Corridor 1 include:

- **High prevalence of crashes.** Most of the crashes within Corridor 1 are run-off-the-road or rear-end collisions often caused by people driving too fast for the adverse weather conditions.
- **Adverse weather.** Corridor 1 experiences harsh winters. The interstate and principal arterials in the mountain pass in the western end of the corridor experience extensive periods of icy conditions and heavy snowfall. The central part of the corridor has heavy fog events, particularly from dusk to dawn. The eastern end of the corridor is prone to flooding during heavy rainfall events. These events sometimes result in full roadway closures.
- **Financial constraints and priorities.** Most resources are allocated to activities within Corridor 1, such as roadway maintenance, to address weather impacts or the use of maintenance crews to help public safety agencies with traffic incident management for the larger events that impact traffic (e.g., full road closures).
- **Construction impacts.** Frequent re-paving activities are needed to repair the roadways due to damage from the winter freeze/thaw cycles. Culvert and embankment repairs are also needed due to flood damage.

Figure 3 depicts the key motivators occurring in the corridor that stakeholders are keen to address with TSMO strategies.

Figure 3. Illustration. Corridor 1 motivators and goals.

Key stakeholders—including planners, engineers, operators, and maintenance crews from the State, county, and local transportation agencies and emergency responders—collaborate to build a set of SMART (**s**pecific, **m**easurable, **a**greed-upon, **r**ealistic, and **t**ime-bound) goals and operations objectives that address the identified motivators and provide guidance for the selection of a package of TSMO strategies. The four goals and supporting operations objectives include:

Goal 1: Reduce number and severity of crashes.

- Reduce severe and fatal crashes by 50 percent within 5 years.

Goal 2: Reduce non-recurring delay.

- Reduce the person hours of non-recurring delay associated with weather, incidents, and road work by 10 percent within 5 years.
- Decrease planning time for freight point-to-point travel times through Corridor 1 by 10 percent within 3 years.

Goal 3: Reduce traffic incident duration.

- Increase percentage of agencies that participate in a regional coordinated incident response team by 25 percent within 5 years.
- Reduce mean time for incident detection by 15 percent over 5 years.
- Reduce mean incident clearance time per incident by 15 percent over 5 years.

Goal 4: Improve construction coordination

- Increase the number of scheduled work zones on the rural interstate and parallel facilities that are identified in a shared, multi-agency database by 100 percent within 2 years.

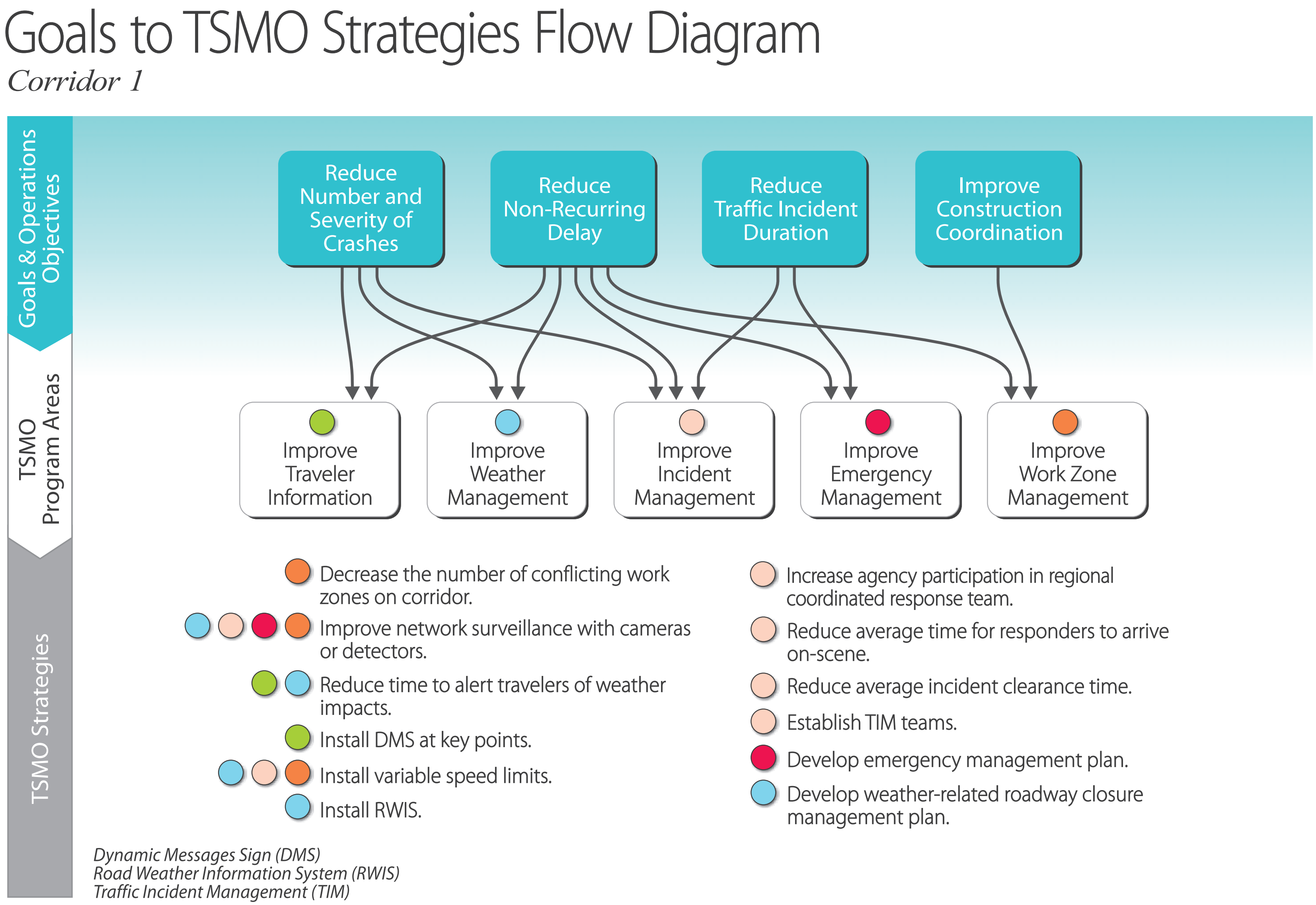
Figure 4 shows how the four corridor goals and operations objectives established by the stakeholders connect to a set of TSMO program areas and strategies that reflect the community's constraints, motivations, and values.

For this rural interstate corridor, the TSMO program areas that address crashes, non-recurring delay, traffic incidents, and construction include:

- Traveler information.
- Weather management.
- Incident management.
- Emergency management.
- Work zone management.

While these TSMO program areas have discrete focus on different elements of managing and operating the transportation system, Figure 4 demonstrates how each of the strategies selected for this model corridor support multiple program areas. The result is a comprehensive approach to corridor management.

Figure 4. Diagram. Links between Corridor 1 goals and transportation systems management and operations strategies.



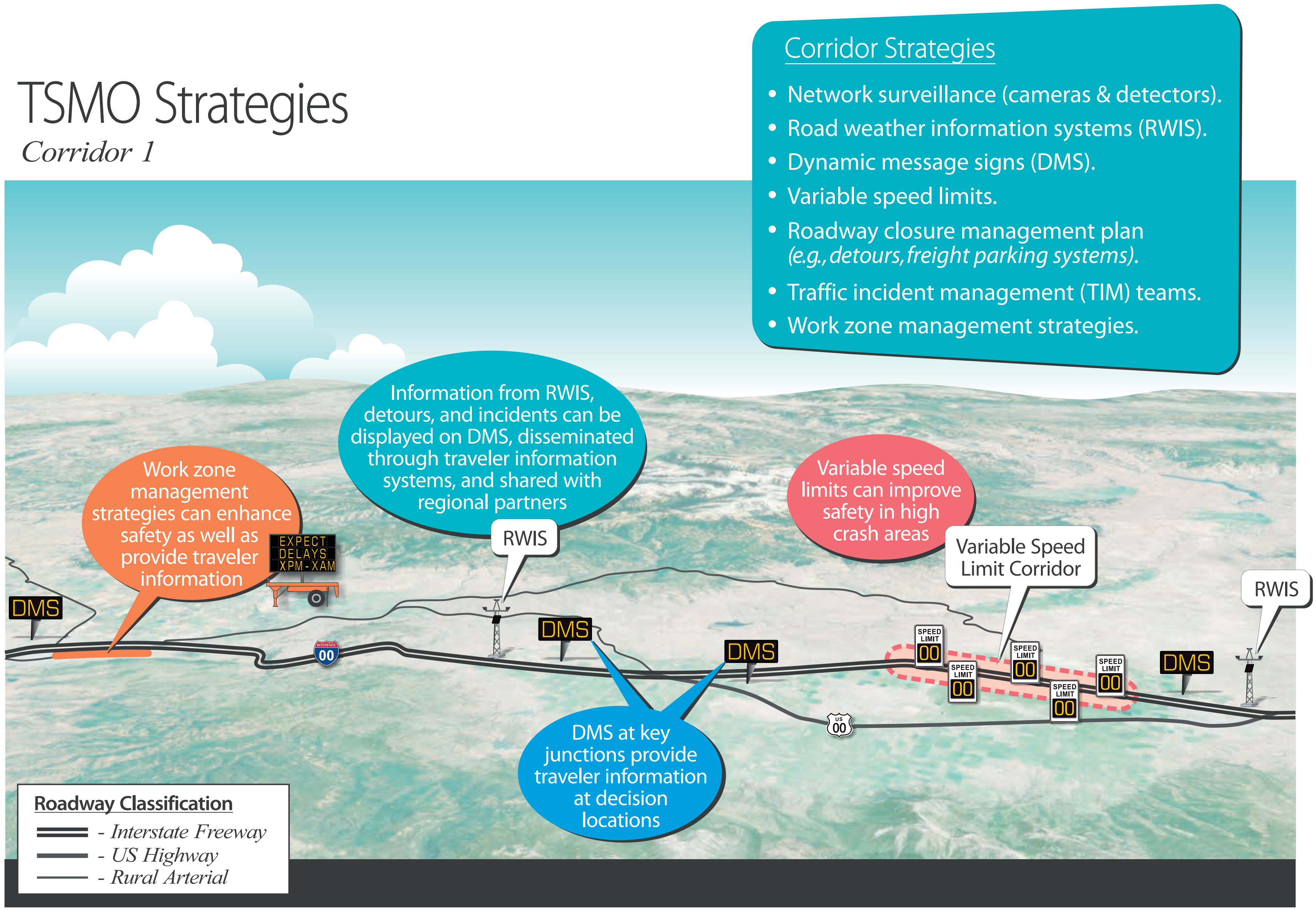
Corridor 1 stakeholders apply a scenario planning process that identified alternative operating conditions tied to the unique combination of motivators and goals for the corridor. Using this approach, stakeholders narrow down a broad array of potential TSMO strategies to a subset that are further screened for feasibility, potential benefits, and cost impacts. The strategies that best fit the Corridor 1 advance toward the implementation phase.

Figure 5 depicts the set of TSMO strategies selected by the corridor's stakeholders. This rural corridor has a base level of management elements in place, including a State-run traffic management center (TMC). The planning effort pulls together and augments these elements with new devices, communications, and activities to establish a focused TSMO approach to be advanced by the corridor's stakeholders.

The package of TSMO strategies included in Corridor 1 include:

- **Network surveillance.** The use of cameras and fixed and mobile detection throughout Corridor 1 allows system operators to monitor travel conditions and to detect and verify when travel is impacted by adverse weather, traffic incidents, or work zones. In turn, this allows quicker implementation of other strategies such as triggering a roadway closure management plan or turning on variable speed limits in high crash locations. Telematics on fleet vehicles can augment fixed detection by using mobile sensors to collect and transmit road conditions.
- **Road weather information systems (RWIS).** Deployment of full scale or low cost RWIS in key spots can help system operators detect adverse weather conditions such as fog and poor road surface conditions (e.g., icy, wet). This information enables use of variable speed limits, better dissemination of traveler information, and better allocation of resources (e.g., deicer application, snow plow assignment). Other road condition reporting systems using in-vehicle tablets on snow plows or agency fleets can also supplement fixed RWIS infrastructure.
- **Dynamic message signs (DMS).** Installation of DMS at key decision points along Corridor 1 allows travelers to make informed decisions, such as slowing down or taking an alternate route in response to adverse weather, traffic incidents, or work zones.
- **Creating traveler information interfaces for third parties.** Messages can be shared via a traveler information application programming interface (API) that makes agency travel data available to third party data providers. Since State DOTs are often the best source of road condition information in rural areas with limited private sector probe data coverage, the value of a third party interface is significant for low-volume rural areas
- **Variable speed limits.** The use of variable speed limits may reduce rear-end collisions in existing trouble spots. They may also control traffic flow through work zones.
- **Roadway closure management plan.** A plan can address roadway closures that occur during adverse weather. The plan may address detour feasibility for automobiles and freight (and associated traffic control devices), freight parking systems (so trucks are not stranded on the interstate), and agency roles and responsibilities. This plan may also be used to address full roadway closures caused by traffic incidents.
- **Traffic incident management (TIM) teams.** The use of TIM teams provides a framework for a coordinated regional response to the many run-off-the-road and rear-end collisions in the corridor. Regular meetings and debriefs help identify specific incident management strategies that are most beneficial for Corridor 1 (e.g., service patrols, quick clearance goals, towing agreements).

Figure 5. Illustration. Corridor 1 transportation systems management and operations strategies.



- **Work zone management strategies.** Numerous work zone strategies can help reduce non-recurring delay in Corridor 1, such as limiting the amount of work zones within the corridor (on the interstate and parallel routes) that occur at one time. Most TSMO strategies can be tailored to work zones. The Federal Highway Administration's (FHWA) *Work Zone Operations Best Practices Guidebook* (3rd edition) covers about 40 topics and numerous subtopics.[10]

To realize an integrated deployment of the TSMO strategies, Corridor 1 transportation agencies adjust their institutional capabilities under each of the following categories:

Business Processes

- Incorporate TSMO strategies into regional and agency long-range transportation plans. Coordinating the TSMO strategies with other regional or agency efforts helps align policies and goals and often helps develop project support and funding allocations.
- Develop life-cycle costs (total cost for procuring, installing, operating, and maintaining a system throughout its use) for TSMO strategies and incorporate these costs into regional and agency transportation programming.
- Use intelligent transportation system (ITS) standards for field devices and central systems to support interoperability between agencies and to support data sharing.
- Institute a schedule of preventative maintenance for field devices in the corridor.
- Develop maintenance agreements with some local agencies for the State DOT to maintain and operate ITS devices on county or city roadways such as cameras, detectors, or DMS that provide traveler information about conditions on the interstate.
- Develop an operations and maintenance manual to define procedures, roles, and responsibilities for new TSMO systems. For example, define what grip factor reading from an RWIS triggers the need for a maintenance crew to treat the roadway for icy conditions.

Systems and Technology

- Optimally locate field devices to minimize power and communications costs, provide maintenance accessibility, and to use devices to support multiple strategies (e.g., camera and detector locations that support variable speed limits, roadway closure management plan, traffic incident management, and work zone management).
- Provide center-to-field interfaces to allow all device data to feed into systems at the TMC.
- Automate procedures to the extent possible. For example, develop pre-set DMS messages for weather, incident management, work zone, road closure, and variable speed limit scenarios to support automated or faster decisionmaking for message posting.

Performance Measurement

- Establish data sharing policies and an archive structure to facilitate easy data access.

10 Federal Highway Administration, *Work Zone Best Practices Guidebook*, 3rd Edition, FHWA-HOP-13-012 (Washington DC: August 2013). Available at: https://ops.fhwa.dot.gov/wz/practices/best/bestpractices.htm.

- Share data with public and private partners to support traveler information. This allows the data to be used in a variety of formats (e.g., mobile device applications that show the camera images, maps with travel speeds based on the detector data, road weather conditions based on the RWIS data).
- Measure performance of all the systems periodically and compare the performance to the corridor's operations objectives. Adjust corridor strategies if needed. For example, if incident clearance time does not appear to be on track for a 15 percent reduction in 5 years, re-evaluate the TIM strategies in use and try other strategies that may support the objective.

Culture

- Link TSMO program activities with transportation agencies' strategic plans.
- Hold regular meetings to ensure on-going dialogue on integrated management activities across transportation and emergency response agencies.

Organization/Workforce

- Train staff on operating and maintaining new systems (e.g., variable speed limit system). Consider contracting out some maintenance responsibilities if more cost-effective for specialty items not needed often (e.g., fiber optic cable maintenance, in particular splicing and emergency restoration).
- Compile a database of personnel and resources across organizational units in each agency responsible for TSMO activities.

Collaboration

- Coordinate amongst Corridor 1 agencies on the development and implementation of a road closure plan.
- Participate in TIM teams by meeting regularly to conduct joint training, table top exercises, and major incident debriefs.

MODEL CORRIDOR 2 – SMALL URBAN CORRIDOR

The backbone of Corridor 2 is a section of interstate within a small urban area. The interstate is paralleled by a minor arterial to the north and by a stand-alone shared-use path to the south. These facilities provide access to the surrounding arterial and collector roadway network. The interstate provides automobile and freight connections for local traffic and for through traffic with interim destinations within the city. Figure 6 depicts the geography of Corridor 2.

The urban area is characterized by thriving commercial districts, historic neighborhoods, a regional hospital, a university, and a major fairground facility. Corridor 2 facilities and services are managed through a combination of the State DOT, city, and transit agencies. The State DOT maintains a statewide traffic operations program that oversees ITS in the corridor.

The terrain is flat and the weather is mild with limited weather-related travel impacts.

Travel in Corridor 2 includes a mix of automobile, truck freight, transit, bicycle, and pedestrian modes. Interstate trips combine automobiles and truck freight traveling through the urban area and making many local trips. Trips on the arterial network connect residents to employment, school, and retail activities, and connect visitors to special events at the fairground facilities. A local bus line that ties into the citywide bus system runs along the corridor's minor arterial. In addition to the shared-use path throughout the corridor, many of the arterial and collector roadways have on-street bicycle lanes and sidewalks.

The agencies managing and operating the transportation systems in Corridor 2 demonstrate the following institutional capabilities for implementing a TSMO program:

Business Processes – Regional TSMO planning and deployment processes are standardized system-wide and are well-documented.

Systems and Technology – Agencies use advanced technologies within the region but with a limited level of automation.

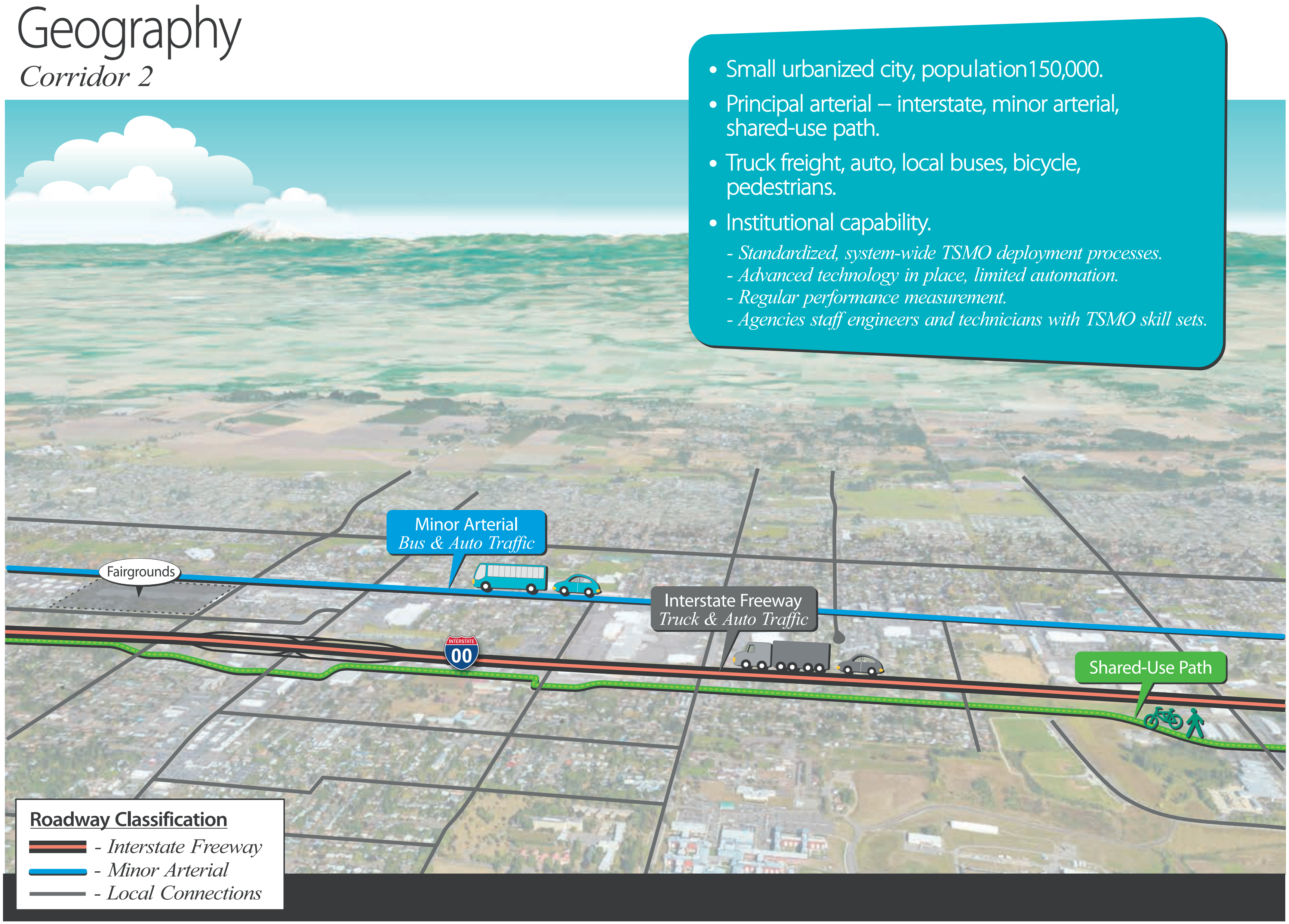
Performance Measurement – Agencies routinely identify desired outcomes and measure performance to improve strategy deployment and overall operations.

Culture – Agencies recognize TSMO as a core program that they regularly coordinate with other programs.

Organization/Workforce – Agencies within the corridor have in-house engineers and maintenance crews with TSMO skill sets.

Collaboration – Agencies collaborate on traffic management at a high level via regional stakeholder engagement.

Figure 6. Illustration. Corridor 2 geography.



The motivators driving the need to implement TSMO strategies in Corridor 2 include:

- **Capacity bottlenecks and limitations to capacity expansion**. Key bottleneck locations within the corridor include the interstate approaches to the interchange, the arterial approaches to the interchange, and the signalized intersections along the corridor's minor arterial. Limited right-of-way, including shoulders and built-out adjacent land limit the possibility of expanding capacity at the bottleneck locations.
- **High prevalence of crashes**. Many rear-end crashes occur on the interstate due to congestion at key interchanges. The arterials and collectors experience rear-end crashes at points where the road crosses shared-use paths, where there are also many bicycle and pedestrian reports of near-misses.
- **Other traffic incidents**. In addition to crashes, vehicles often stall out while sitting in congestion on the interstate. This blocks main lanes and further reduces capacity.
- **Special event congestion**. The annual state fair and periodic special events at the fairgrounds put a strain on the surrounding transportation network, causing queues on the arterials and interstate for arriving traffic and queues on the arterials for departing traffic. The congestion also causes delays to the corridor's bus line.

Figure 7 depicts the key motivators occurring in the corridor that stakeholders are keen to address with TSMO strategies.

Key stakeholders including planners, engineers, operators, and maintenance crews from the State and city transportation agencies, transit agency, and emergency responders collaborate to build a set of goals and SMART (specific, measurable, agreed-upon, realistic, and time-bound) operations objectives that address the identified motivators and provide guidance for the selection of a package of TSMO strategies. The five goals and supporting operations objectives include:

Goal 1: Reduce number of rear-end crashes.

- Reduce rear-end crashes by 20 percent within 5 years.

Goal 2: Manage travel demand.

- Increase mode share for transit, bicycles and pedestrians to 25 percent within 5 years.

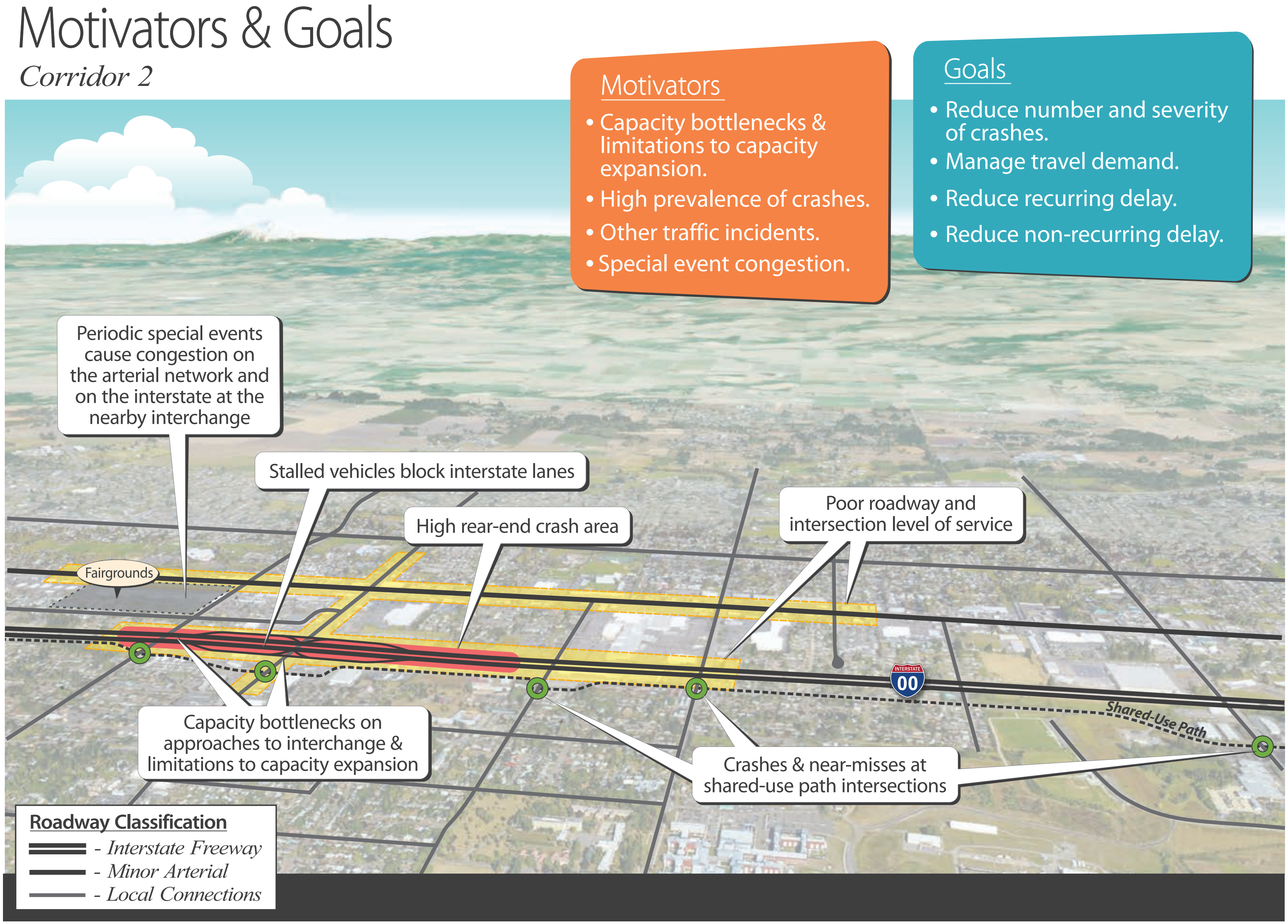
Goal 3: Reduce recurring delay.

- Decrease the seconds of control delay per vehicle on corridor arterial roads by 15 percent within 5 years.

Goal 4: Reduce non-recurring delay.

- Reduce the person hours of non-recurring delay associated with incidents and special events by 10 percent within 5 years.
- Reduce average travel time into and out of the fairgrounds by 10 percent within 5 years.
- Decrease freight point-to-point travel times through Corridor 2 by 10 minutes within 3 years.

Figure 7. Illustration. Corridor 2 motivators and goals.



Goal 5: Reduce traffic incident duration.

- Reduce mean time for needed responders to arrive on-scene after notification by 15 percent over 5 years.
- Reduce mean incident clearance time per incident by 15 percent over 5 years.

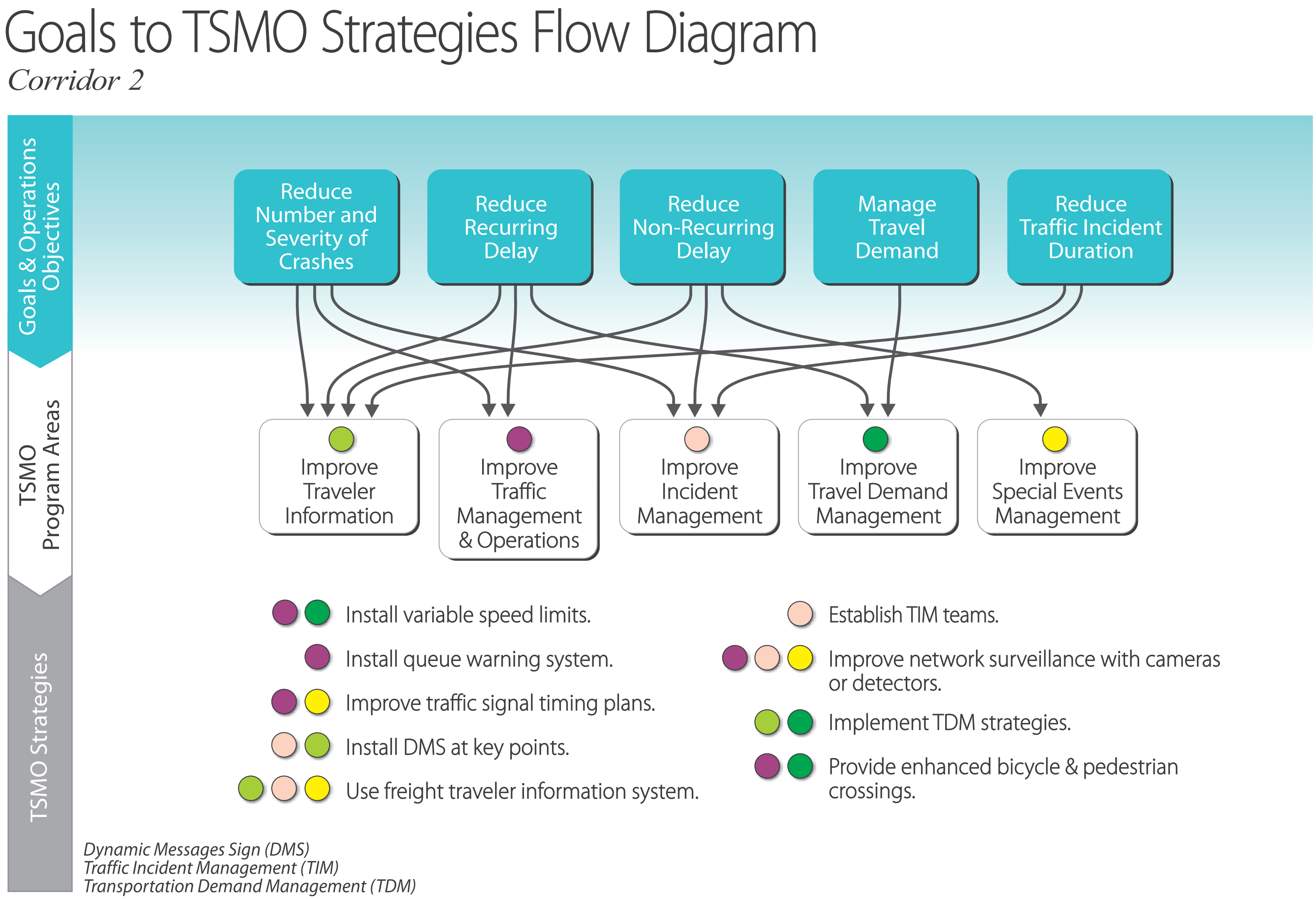
Figure 8 depicts how the five corridor goals and operations objectives established by the stakeholders connect to a set of TSMO program areas and strategies that reflect the metropolitan area's identified constraints, motivations, and values for the corridor.

For this small urban corridor, the TSMO program areas that address crashes, recurring and non-recurring delay, travel choices, and traffic incidents include:

- Traveler information.
- Traffic management and operations.
- Incident management.
- Travel demand management.
- Traffic incident reduction.

While these TSMO program areas have a discrete focus on different elements of managing and operating the transportation system, Figure 8 demonstrates how each of the strategies selected for this model corridor support multiple TSMO program areas. The result is a comprehensive approach to corridor management.

Figure 8. Diagram. Links between Corridor 2 goals and transportation systems management and operations strategies.



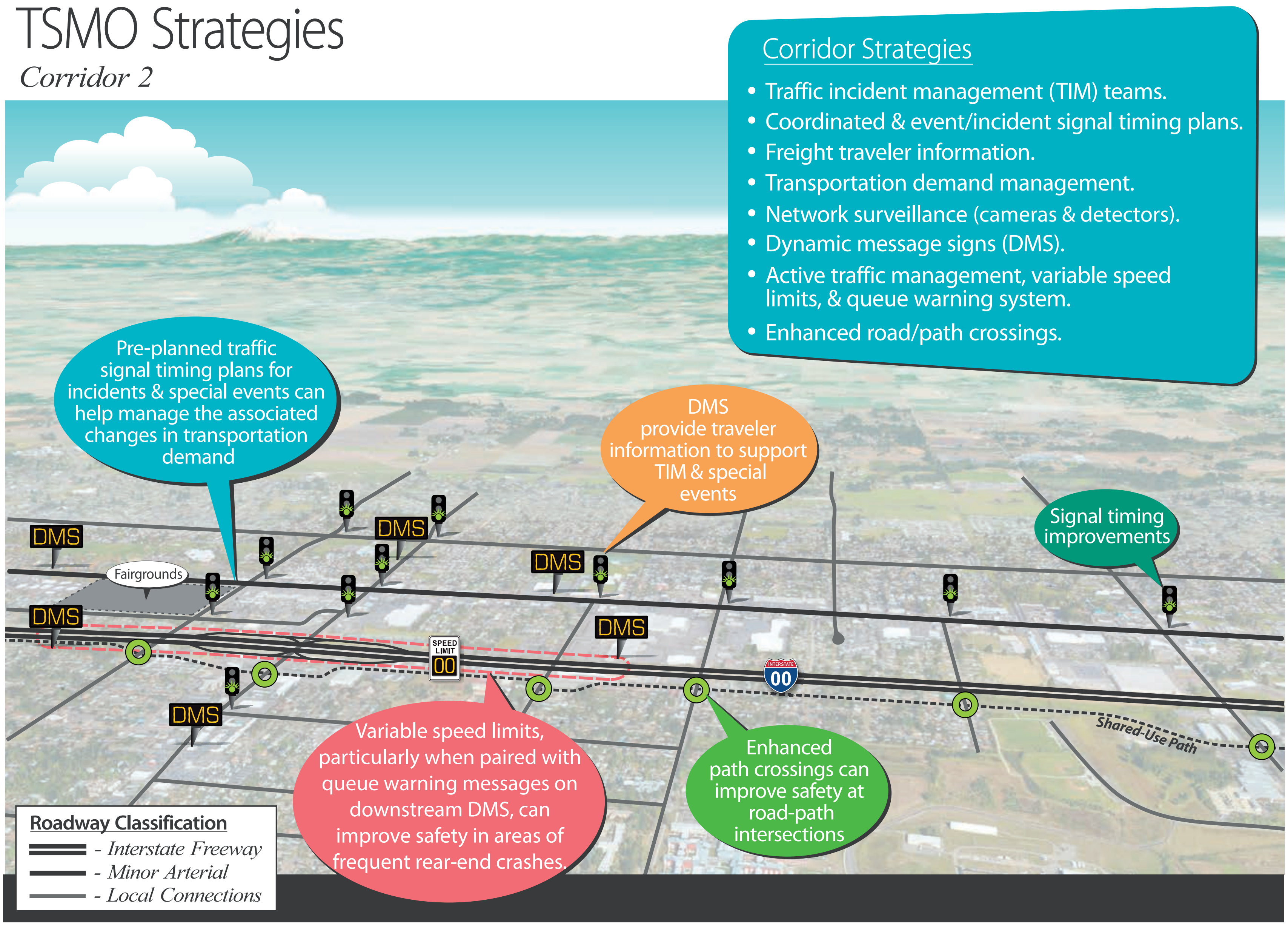
Corridor 2 stakeholders apply a scenario planning process that identified alternative operating conditions tied to the unique combination of motivators and goals for the corridor. Using this approach, stakeholders narrow down a broad array of potential TSMO strategies to a subset that are further screened for feasibility, potential benefits, and cost impacts. The strategies that best fit the Corridor 2 advance toward the implementation phase.

Figure 9 depicts the set of TSMO strategies selected by the corridor's stakeholders. This small urban area has a network of traffic signals connected to a central signal system, cameras and detectors on the interstate, cameras at some signalized intersections, detectors associated with each traffic signal, a State-run TMC, and a small workstation-based city-run TMC with limited hours of operation. The planning effort pulls together and augments these elements with new devices, communications, and activities to establish a focused TSMO approach to be advanced by the corridor's stakeholders.

The package of TSMO strategies selected for Corridor 2 include:

- **Traffic incident management teams.** The use of TIM teams provides a framework for a coordinated regional response to the many rear-end collisions and stalled vehicles in the corridor. Regular meetings and debriefs will help identify specific incident management strategies that are most beneficial for Corridor 2 (e.g., service patrols, quick clearance goals, towing agreements).
- **Coordinated signal timing plans**. Update coordinated signal timing plans on a routine basis to address changes in travel demand patterns. Develop pre-planned coordinated signal timing plans that can be activated for a variety of TIM and special event scenarios to handle the associated transportation demand.
- **Freight traveler information**. Use traveler information systems to help the freight industry plan routes and deliveries based on TIM events, planned special events, and weather restrictions. Provide truck parking information in partnership with the private sector.
- **Transportation demand management (TDM)**. Use TDM strategies (e.g., rideshare, reduced transit fares) to reduce commuter and special event trips to influence travel choice related to mode, time, location, or route.
- **Network surveillance.** The use of more cameras and fixed and mobile detection throughout Corridor 2 will allow system operators to monitor travel conditions and to detect and verify when travel is impacted by bottlenecks, traffic incidents, or special events. In turn, this allows quicker implementation of other strategies such as triggering a queue warning alert or turning on variable speed limits. Mobile observations from sensors on fleet vehicles and information provided by third-party data providers can augment fixed network detection.
- **Dynamic message signs.** Installation of DMS at key decision points along Corridor 2 allows travelers to make informed decisions, such as slowing down or taking an alternate route in response to traffic incidents or special events.
- **Creating traveler information interfaces for third parties.** Messages can be shared via a traveler information application programming interface (API) that makes agency travel data available to third party data providers. Information owned by public agencies such as construction, work zone locations, and road closures are particularly valuable to share in this context.

Figure 9. Illustration. Corridor 2 transportation systems management and operations strategies.



- **Active traffic management systems.** Active management of real-time traffic conditions can help reduce rear-end collisions and smooth traffic flow. For Corridor 2, this includes the use of variable speed limits and a queue warning system that may use DMS or in-vehicle messages to alert drivers they are approaching the end of a standing queue.
- **Enhanced safety at points where roads cross the shared-use path.** Provide enhanced visibility of bicycles and pedestrians at crossings with treatments such as pavement markings, push button-activated rectangular rapid flashing beacons, pedestrian hybrid beacons, or traffic signals.

To realize an integrated deployment of the TSMO strategies, Corridor 2 transportation agencies adjust their institutional capabilities under each of the following categories:

Business Processes

- Continue to incorporate TSMO strategies into agency and regional long-range transportation plans. Coordinating the TSMO strategies with other regional or agency efforts helps align policies and goals. It can also increase project support and funding allocations.
- Continue to develop life-cycle costs (total cost for procuring, installing, operating, and maintaining a system throughout its use) for TSMO strategies and incorporate these costs into regional and agency transportation programming.
- Use ITS standards for new field devices and central systems to support interoperability between agencies and to support data sharing.
- Institute a schedule of preventative maintenance for new field devices in the corridor.
- Develop maintenance agreements with city if needed for the DOT to maintain and operate ITS devices on city roadways such as cameras, detectors, or traffic signals.
- Develop standard operating procedures (SOP) to define procedures, roles, and responsibilities for new TSMO systems. The SOPs may be incorporated into existing operations and maintenance manuals (e.g., active traffic management (ATM) for the State DOT) or a new regional manual may need to be developed (e.g., regional TIM SOP Manual).
- Develop agreements, if needed, for the city or State DOT to operate the other agency's traffic signals if tied into the same coordinated timing system. Depending on staffing, the city may operate the signals during their standard business hours and the State DOT may operate them after hours if there is an unexpected system outage or change in travel demand due to a crash or special event.

Systems and Technology

- Optimally locate field devices to minimize power and communications costs, provide maintenance accessibility, and to use devices to support multiple strategies (e.g., camera and detector locations that support variable speed limits, queue warning system, and traffic incident management).
- Provide center-to-field interfaces to allow all device data to feed into systems at the State or city TMC. Update center-to-center interfaces as needed (e.g., allow both city and State to control pan-tilt-zoom cameras and set primary and secondary controls based on jurisdiction of camera location).
- Automate procedures to the extent possible. For example, develop incident lane closure and volume thresholds to determine when to activate a pre-planned signal timing plan.

Performance Measurement

- Update data sharing policies and archive structure to accommodate easy data access for new stakeholders (e.g., freight community for Freight Advanced Traveler Information System (FRATIS) strategies).
- Continue to share data with public and private partners to support traveler information. This allows the data to be used in a variety of formats (e.g., mobile device applications that show maps with travel speeds and variable posted speeds based on the detector data, special event travel conditions).
- Measure performance of all the systems periodically and compare the performance to the corridor's operations objectives. Adjust the corridor strategies if needed. For example, if average travel times into and out of the fairgrounds do not appear to be on track for a 10 percent reduction in 5 years, re-evaluate the event management strategies in use and try other strategies that may support the objective.

Culture

- Continue to link TSMO program activities with transportation agencies' strategic plans. Use service-related cost-effectiveness to compare the TSMO program to other transportation programs to justify the expansion of the TSMO program.
- Continue to hold regular meetings to ensure ongoing dialogue on integrated management activities across transportation and emergency response agencies. Include additional stakeholders as needed.

Organization/Workforce

- Train staff on operating and maintaining new systems (e.g., variable speed limit systems).
- Update database of personnel and resources across organizational units in each agency responsible for TSMO activities.
- Develop a TSMO management and organizational structure within key agencies (e.g., State DOT and city) equivalent to that of other major agency programs.

Collaboration

- Participate in TIM teams by meeting regularly to conduct joint training, tabletop exercises, and major incident debriefs.
- Develop a working group of transportation agencies and members of the freight community to develop the freight traveler information TSMO strategy. Meet on a routine basis to determine the effectiveness of the strategy and make updates as needed.
- Develop a fairgrounds special event working group that meets prior to and after the annual State fair and other major fairgrounds events. Stakeholders may include transportation agencies, the transit agency, law enforcement, the 911 center, special event promoters, venue management teams, parking facility operators, media, and property owners adjacent to and near the fairgrounds.

MODEL CORRIDOR 3 – LARGE URBAN CORRIDOR

Corridor 3 encompasses a set of closely spaced parallel transportation facilities: an interstate, a minor arterial, a commuter rail line, and a shared-use path. Parallel principal and minor arterials are located nearby. While the interstate carries auto and truck freight traffic through the region, Corridor 3 also provides local connections within a large urbanized metropolitan area. Figure 10 depicts the geography of Corridor 3.

The eastern section of the corridor includes key destinations: a regional employment hub, industrial center, a university campus, and an arena that holds events year-round. The remainder of the corridor includes densely populated residential areas interspersed with commercial land uses.

Transportation facilities are managed by a combination of State, county, cities, regional transit, and local transit agencies. A metropolitan planning organization (MPO) supports regional planning, programming, and collaboration. A regional TMC provides 24/7 management of the interstate and key arterials in the corridor.

The entire metropolitan area is prone to heavy snowfall during the winter, which can result in major delays on the transportation system.

The urbanized character of Corridor 3 supports a broad range of modes, including automobile, truck freight, transit, bicycle, and pedestrian trips. Interstate trips include a mix of automobiles and truck freight traveling through the area and making local trips. Arterial network trips connect to the major activity centers. A commuter rail line and a bus rapid transit line on the minor arterial provide key links within the corridor and connect to the region's transit backbone. In addition to the shared-use path that runs through the corridor, many of the streets have on-street bicycle lanes and sidewalks.

The agencies managing and operating the transportation systems in Corridor 3 demonstrate the following institutional capabilities for implementing a TSMO program:

Business Processes – Regional TSMO development and deployment processes are standardized system-wide but need more integration into other formal procedures of the agency.

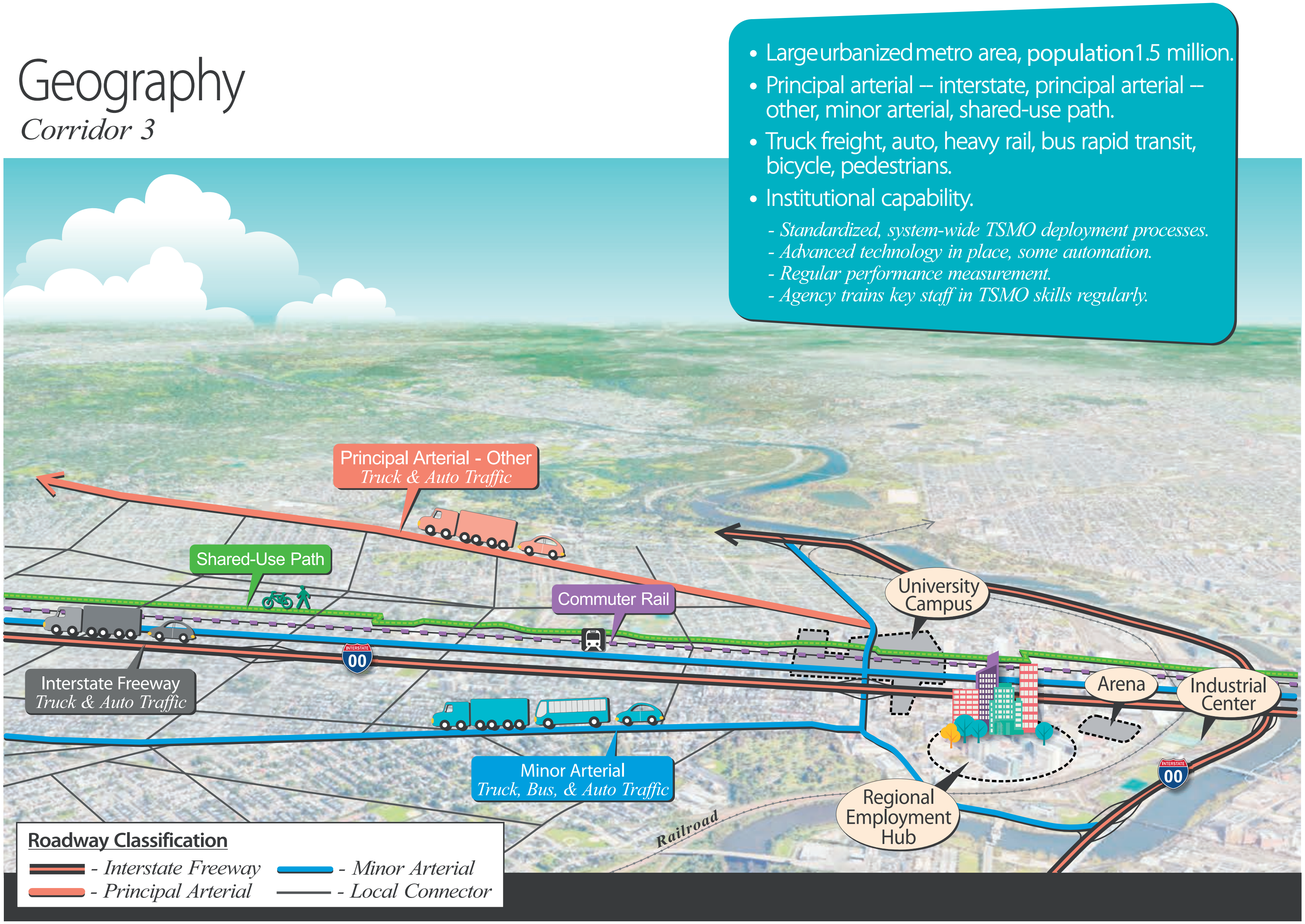
Systems and Technology – Within the region, many agencies use advanced technologies, some with advanced automation.

Performance Measurement – Agencies routinely identify desired outcomes and measure performance to improve strategy deployment and overall operations.

Culture – Agencies recognize TSMO as a core program and are working toward rationalizing it with other programs based on service-related cost-effectiveness.

Organization/Workforce – Agencies within the corridor have in-house engineers and maintenance crews with TSMO skill sets and share resources across agencies.

Figure 10. Illustration. Corridor 3 geography.



Collaboration – Agencies collaborate on TSMO via regional stakeholder engagement and are working towards negotiating region-wide roles and responsibilities.

The motivators driving the need to implement TSMO strategies in Corridor 3 include:

- **Adverse environmental issues**. Corridor 3 is located within a non-attainment area where air pollution levels persistently exceed standards for ozone, carbon monoxide, and particulate matter. The industrial centers on Corridor 3 contribute to the city's non-attainment status.
- **Adverse weather**. Snow and ice from winter storms often cause delays on Corridor 3 facilities and sometimes result in full facility shutdowns.
- **Capacity bottlenecks and limitations to capacity expansion**. Signalized intersections (including the interchanges) are the key bottleneck locations within the corridor. Limited right-of-way and built-out adjacent land limits the possibility of expanding capacity.
- **Construction impacts**. Frequent re-paving activities are needed to repair the roadways due to damage from the winter freeze/thaw cycles. Rail switches need to be replaced more frequently because of the winter freezes.
- **High prevalence of crashes**. Many rear-end crashes occur on the interstate due to standing queues. Many near-misses are reported at locations where the shared-use path crosses a roadway.
- **High traffic volumes**. The interstate and arterials carry high volumes of traffic throughout the day and are at or near capacity during peak periods. Commuter rail and bus rapid transit ridership is often at or near capacity during peak periods.
- **Special event congestion**. Year-round events at the arena impact the surrounding transportation network at varying times, including the weekday evening commute. This results in congestion on Corridor 3 roadways as well as surges in transit ridership that often exceed capacity.
- **Variability in trip reliability**. Average trip time varies widely from day to day. During the evening peak for example, trip time through Corridor 3 can be as short as 15 minutes and as long as 45 minutes.
- **Financial constraints and priorities**. Corridor 3 competes for funding with other regional programs and other similar corridors within the region. Many resources are also allocated to roadway maintenance related to the adverse winter weather.

Figure 11 depicts the key motivators occurring in the corridor that stakeholders are keen to address with TSMO strategies.

Figure 11. Illustration. Corridor 3 motivators and goals.

The MPO convened key corridor stakeholders including planners, engineers, operators, and maintenance crews from the State, county, local transportation agencies, and emergency responders to build a set of goals and SMART operations objectives that address the identified corridor motivators and provide guidance for the selection of a package of TSMO strategies. The seven goals and their supporting operations objectives include:

Goal 1: Reduce the number and severity of crashes.

- Reduce time to alert travelers of events (e.g., road weather, standing queues) by 15 percent within 5 years.

Goal 2: Reduce recurring delay.

- Decrease the seconds of control delay per vehicle on corridor arterial roads by 15 percent within 5 years.
- Reduce the daily hours of recurring congestion on the freeway and arterial corridors by 15 percent within 5 years.
- Reduce excess fuel consumed due to congestion by 25 percent within 5 years.

Goal 3: Reduce non-recurring delay.

- Reduce the person hours of non-recurring delay associated with weather, incidents, and road work by 10 percent within 5 years.
- Reduce average travel time into and out of the arena by 15 percent within 5 years.
- Decrease the percentage of special event attendees traveling to the event in single-occupancy vehicles by 25 percent within 5 years.
- Decrease average freight point-to-point travel times through Corridor 3 by 10 minutes within 3 years.
- Reduce the variability of travel time on Corridor 3 routes by 15 percent during peak and off-peak periods within 5 years.
- Improve average on-time performance for Corridor 3 transit routes by 15 percent within 5 years.

Goal 4: Reduce traffic incident duration.

- Reduce mean time for needed responders to arrive on-scene after notification by 15 percent over 5 years.
- Reduce mean incident clearance time per incident by 15 percent over 5 years.

Goal 5: Manage travel demand.

- Increase average pedestrian and bicyclist comfort level by 30 percent within 5 years.
- Increase the number of trips made by walking and bicycling by 15 percent over 5 years.
- Develop and provide travel option services to all Corridor 3 communities and stakeholder audiences within 5 years.

Goal 6: Improve construction coordination.

- Decrease the number of work zones on parallel routes or along Corridor 3 by 10 percent within 5 years.

Goal 7: Improve traveler information dissemination.

- Increase customer satisfaction ratings for timeliness, accuracy, and usefulness of traveler information in Corridor 3 by 50 percent within 5 years.

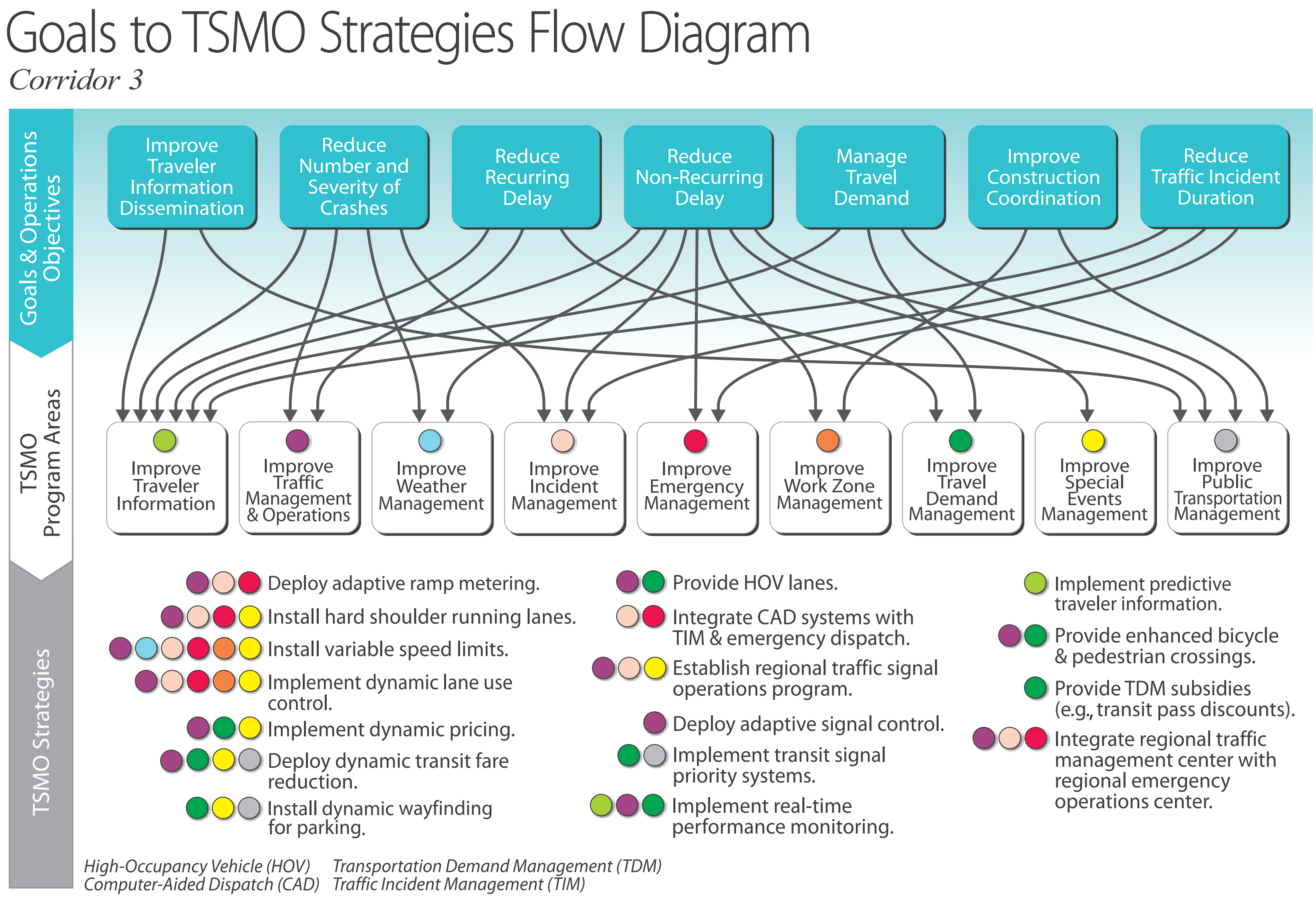
Figure 12 depicts how the seven corridor goals and operations objectives established by the stakeholders connect to a set of TSMO program areas and strategies that reflect the metropolitan area's identified constraints, motivations, and values for the corridor.

For this highly urban corridor, the TSMO program areas that address crashes, recurring and non-recurring delay, adverse weather conditions, traffic incidents, and frequent special events include:

- Traveler information.
- Traffic management and operations.
- Weather management.
- Incident management.
- Emergency management.
- Work zone management.
- Travel demand management.
- Special events management.
- Public transportation management.

While each of these TSMO program areas has a discrete focus on a different element of managing and operating the transportation system, Figure 12 demonstrates how each of the strategies selected for this model corridor support multiple TSMO program areas. The result is a comprehensive approach to corridor management.

Figure 12. Illustration. Links between Corridor 3 goals and transportation systems management and operations strategies.



Corridor 3 stakeholders apply a scenario planning process that identified alternative operating conditions tied to the unique combination of motivators and goals for the corridor. Using this approach, stakeholders narrow down a broad array of potential TSMO strategies to a subset that are further screened for feasibility, potential benefits, and cost impacts. The strategies that best fit Corridor 3 advance toward the implementation phase.

Figure 13 depicts the set of TSMO strategies selected by the corridor's stakeholders. The relative sophistication of transportation services in this corridor along with the high degree of institutional capability provide a solid foundation for implementing an advanced program of TSMO strategies. The planning effort pulls together and augments these elements with new devices, communications, and activities to establish a focused TSMO approach to be championed and implemented by the corridor's stakeholders.

Given the advanced state of TSMO activities in Corridor 3, the stakeholders recognize an opportunity to apply an integrated corridor management (ICM) approach to coordinate responses between multiple owners/operators of facilities and modes in the corridor. ICM can play an important role in managing incidents, planned special events, adverse weather, and work zones by establishing coordinated response protocols. Any combination of the Corridor 3 TSMO strategies can be used within an ICM process.

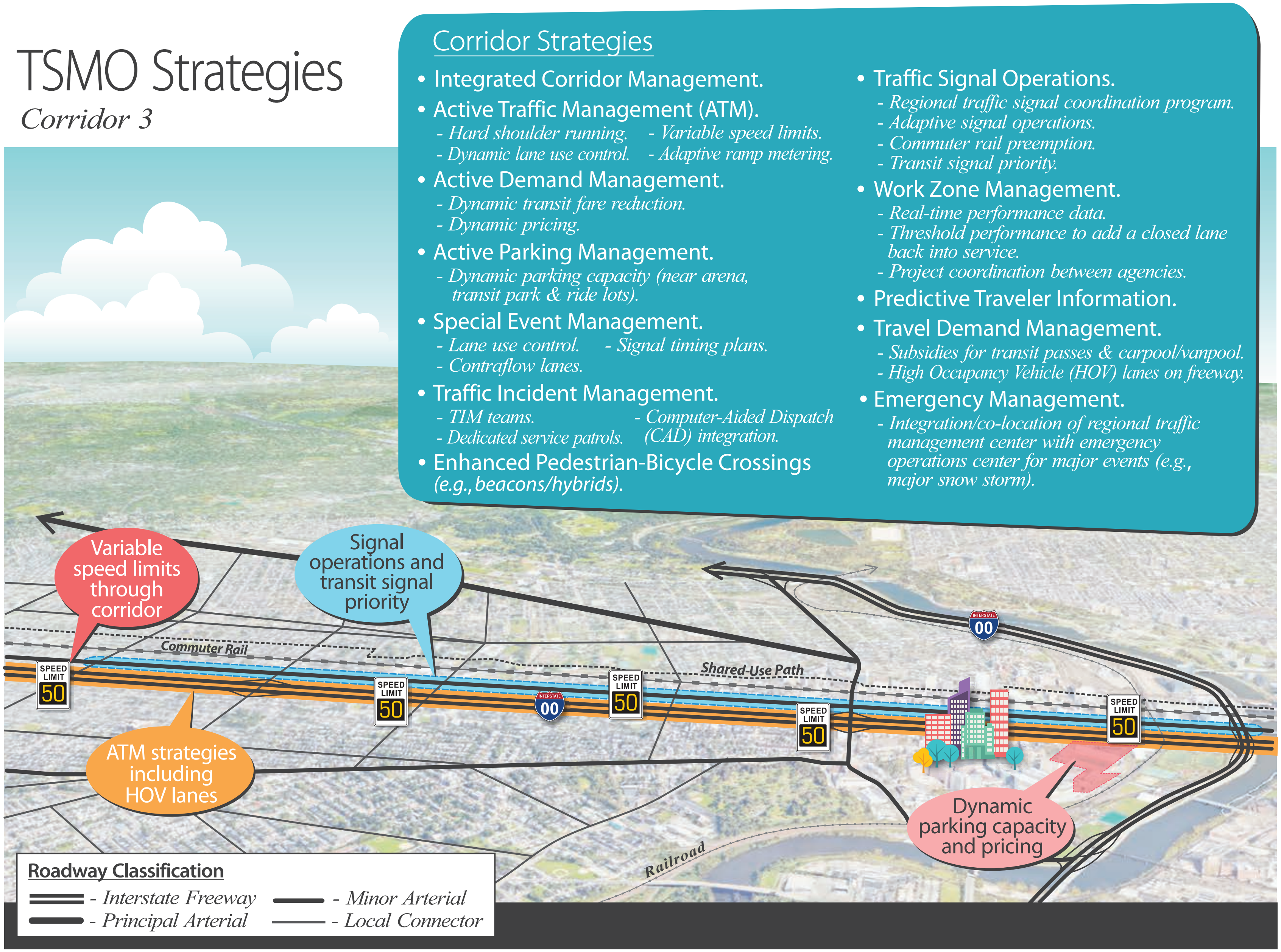
The package of TSMO strategies selected for Corridor 3 include:

- **Active traffic management.** Active management of real-time traffic conditions on congested mainlines can help reduce rear-end collisions and smooth traffic flow. For Corridor 3 this includes strategies such as adaptive ramp metering to control the flow of traffic entering the freeway, part-time shoulder use to add capacity on a temporary basis, variable speed limits to slow travel speeds approaching slow or standing queues, and dynamic lane use control to open and close lanes or to allow shoulder use.
- **Active demand management (ADM)**. Across the corridor, real-time information and technology can be used to actively manage demand by redistributing trips to less congested times of day or routes or to reduce overall vehicle trips by influencing mode choice. This can be done in Corridor 3 through dynamic pricing where roadway tolls dynamically change in response to congestion levels or through dynamic transit fare reduction that reduces the Corridor 3 transit fares as congestion increases on the interstate and arterials.
- **Active parking management (APM)**. Active management of parking facilities can help optimize the utilization of those facilities while influencing travel behavior at various stages of the trip-making process. In Corridor 3, dynamic parking contraflow wayfinding can provide parking space availability and location near the arena to minimize the time spent looking for parking. This can also be used for transit park-and-ride lots to encourage a shift in mode choice.
- **Special event management**. Apply coordinated operations strategies to inform the traveling public about travel conditions, monitor changing travel conditions, and manage travel demand associated with each planned special event. Strategies may include signal timing plans optimized for arena traffic demand, contraflow lanes or changeable lane assignment on roadways with a dominant travel direction during event ingress or egress, and any of the ATM, ADM, or APM strategies described for Corridor 3.

- **Traffic incident management**. With a high level of institutional capability, TIM teams and dedicated service patrols already provide TIM services on Corridor 3. The agencies can further optimize these practices with strategies such as computer-aided dispatch (CAD) integration between emergency management and transportation agencies or activating ICM, ATM, ADM, or APM strategies when traffic incidents occur.
- **Enhanced safety at locations where roads cross the shared-use path.** Provide enhanced visibility for bicycles and pedestrians at crossings with treatments such as pavement markings, push button-activated rectangular rapid flashing beacons, pedestrian hybrid beacons, or traffic signals.
- **Traffic signal operations.** Due to the many agencies that operate within the corridor and the metro area, a regional traffic signal coordination program can help seamlessly operate traffic signals across jurisdictional boundaries. Adaptive signal control may also be considered for densely populated urban areas where travel demand changes are not limited to morning and evening commutes. Commuter rail preemption and transit signal priority for the buses can help the transit routes maintain schedule performance and reduce transit trip variability.
- **Work zone management strategies.** Many of the Corridor 3 ATM and ADM strategies can be installed in advance of construction re-paving activities on the interstate to help with work zone management. Additionally, the use of real-time performance data can be used to actively monitor and update work zone traffic control, such as using threshold performance targets to determine when a closed lane should be added back into service. Close continued coordination between agencies can also help to schedule maintenance and construction activities in a way to minimize disruptions to travel within Corridor 3. For more information on influencing travel demand during the planning and operational phases of work zones, see FHWA's *Active Transportation and Demand Management (ATDM) Program Brief: ATDM and Work Zones*.[11]
- **Predictive traveler information**. Develop predictive algorithm applications to generate travel forecasts based on both archived and real-time data. Disseminate forecasted conditions to the traveling public.
- **Transportation demand management**. Use TDM strategies to reduce commute and special event trips to influence travel choice related to mode, time, location, or route. TDM strategies for Corridor 3 may include subsidies for transit passes and carpool/vanpool programs, high occupancy vehicle (HOV) lanes on the freeway, trip reduction programs (in partnership with employers, the university, and the arena), and many of the strategies (particularly ADM and APM) described in this section.
- **Emergency management**. To better manage major events such as heavy snow storms, integrate or co-locate the regional traffic management center with the regional emergency operations center. While regional emergency management plans have well-thought-out protocols and procedures, they do not always consider TSMO strategies that may be used to assist during a major event. For example, if a heavy snow storm has made many roads impassable in Corridor 3, dynamic lane control and part-time shoulder use may be used to increase freeway capacity once the interstate has been cleared of snow while the arterial roads and rail lines are still being cleared.

11 Federal Highway Administration, *Active Transportation and Demand Management (ATDM) Program Brief: ATDM and Work Zones*, FHWA-HOP-16-015 (Washington DC: May 2016). Available at: https://www.ops.fhwa.dot.gov/publications/fhwahop16015/index.htm.

Figure 13. Illustration. Corridor 3 transportation systems management and operations strategies.



To realize an integrated deployment of the TSMO strategies, Corridor 3 transportation agencies adjust their institutional capabilities under each of the following categories:

Business Processes

- Continue to incorporate TSMO strategies into regional and agency long-range transportation plans. Coordinating the TSMO strategies with other regional or agency efforts helps align policies and goals and often helps develop project support and funding allocations.
- Continue to develop life-cycle costs (total cost for procuring, installing, operating, and maintaining a system throughout its use) for TSMO strategies and incorporate these costs into regional and agency transportation programming.
- Use ITS standards for new field devices and central systems to support interoperability between agencies and to support data sharing.
- Institute a schedule of preventative maintenance for new field devices/systems in the corridor.
- Develop operations and maintenance agreements if needed for agencies to operate other agency's ITS devices or traffic signals. For example, a city may want the State DOT to post messages on arterial DMS about freeway conditions or pooled funding may allow for a regional transportation management center to provide after-hours operations for multiple agencies more cost-effectively than a single agency can for its jurisdiction.
- Develop SOPs to define procedures, roles, and responsibilities for new TSMO systems. The SOPs may be incorporated into existing operations and maintenance manuals (e.g., an existing agency manual or regional TIM manual) or a new regional manual may need to be developed (e.g., ICM SOP manual).

Systems and Technology

- Optimally locate field devices to minimize power and communications costs, provide maintenance accessibility, and to use devices to support multiple strategies (e.g., camera and detector locations that support as many TSMO strategies as possible).
- Provide center-to-field interfaces to allow all device data to feed into systems at a traffic management center. Update center-to-center interfaces as needed (e.g., allow city and State to operate traffic signals based on pre-defined SOPs).
- Automate procedures to the extent possible. For example, develop software (or software modules that integrate into existing advanced traffic management systems) that operates TSMO strategies based on pre-determined thresholds (e.g., change variable speed limits based on real-time 85th percentile travel speeds).
- While systems engineering is an important part of implementing any TSMO strategy, it is especially important for many of the more advanced TSMO strategies identified for Corridor 3 that require the most stakeholder collaboration and system automation.

Performance Measurement

- Update data sharing policies and archive structure to accommodate easy data access for new stakeholders (e.g., parking facility operators for APM).

- Continue to share data with public and private partners to support traveler information. This allows the data to be used in a variety of formats (e.g., mobile device applications that show real-time posted speeds, dynamic lane use control, dynamic pricing, and parking wayfinding).
- Develop a routine performance management process for continuing improvements in operating policies, procedures, systems, and deployments. This may include quarterly performance metrics prior to regional collaboration meetings to determine if adjustments are needed anywhere where TSMO strategies are falling short of reaching the corridor's operations objectives.

Culture

- Continue to link TSMO program activities with transportation agencies' strategic plans. Finalize service-related cost-effectiveness to compare the TSMO program to other transportation programs to justify the expansion of the TSMO program.
- Continue to hold regular meetings to ensure on-going dialogue on integrated management activities across transportation and emergency response agencies. Include additional stakeholders as needed.

Organization/Workforce

- Train staff on operating and maintaining new systems (e.g., dynamic lane control, dynamic pricing).
- Update database of personnel and resources across organizational units in each agency responsible for TSMO activities.
- Develop a TSMO management and organizational structure within key agencies (e.g., State DOT and city) equivalent to that of other major agency programs.

Collaboration

- Continue to hold regular (e.g., monthly) TSMO collaboration meetings with regional stakeholders.
- Develop working groups for TSMO strategies that require an expanded stakeholder set beyond the typical transportation and emergency response stakeholders and meet regularly (e.g., quarterly, prior to a planned event, post-event). For example, an active parking management working group may include private and public parking facility operators and transit agencies that operate park and ride lots. Some working groups could be scheduled to meet following a regularly scheduled regional TSMO meeting to optimize attendance.

3. Model Subareas

This section portrays three example subareas based on fictional locations with unique geographic characteristics, motivators, and institutional capabilities that provide the backdrop for demonstrating how a package of transportation systems management and operations (TSMO) strategies can be planned and implemented to achieve a set of operations objectives.

MODEL SUBAREA 1 – NEIGHBORHOOD

Subarea 1 is a neighborhood within a large metropolitan area with a predominantly cul-de-sac street pattern as depicted in Figure 14. The roadway network includes one principal arterial, several minor arterials and collectors, and one shared-use path for pedestrians and bicycles. The network provides access to mixed generation single-family residential areas, mixed-use residential/commercial areas (e.g., retail, local services, restaurants), primary and secondary schools, and several parks.

The city and local transit agency manage the transportation facilities and operations in Subarea 1. Transportation modes include automobiles, truck freight, local transit, bicycles, and pedestrians. On-street parking is provided throughout Subarea 1 to support the adjacent land uses. Truck freight includes a combination of large multi-axle and smaller six-tire vehicles making local deliveries throughout the community. Local transit includes local routes on the minor arterials and a frequent backbone bus route on the subarea's one principal arterial. Most of the roadways in Subarea 1 have sidewalks. Other than the shared-use path, bicycles typically travel in the automobile lanes or on the sidewalk.

The agencies managing and operating the transportation systems in Subarea 1 demonstrate the following institutional capabilities for implementing a TSMO program:

Business Processes – A multi-year TSMO plan and program exists at the regional level. Agencies are working towards targeted multi-jurisdictional business processes.

Systems and Technology – Operator-driven TSMO deployments have been implemented in parts of the subarea.

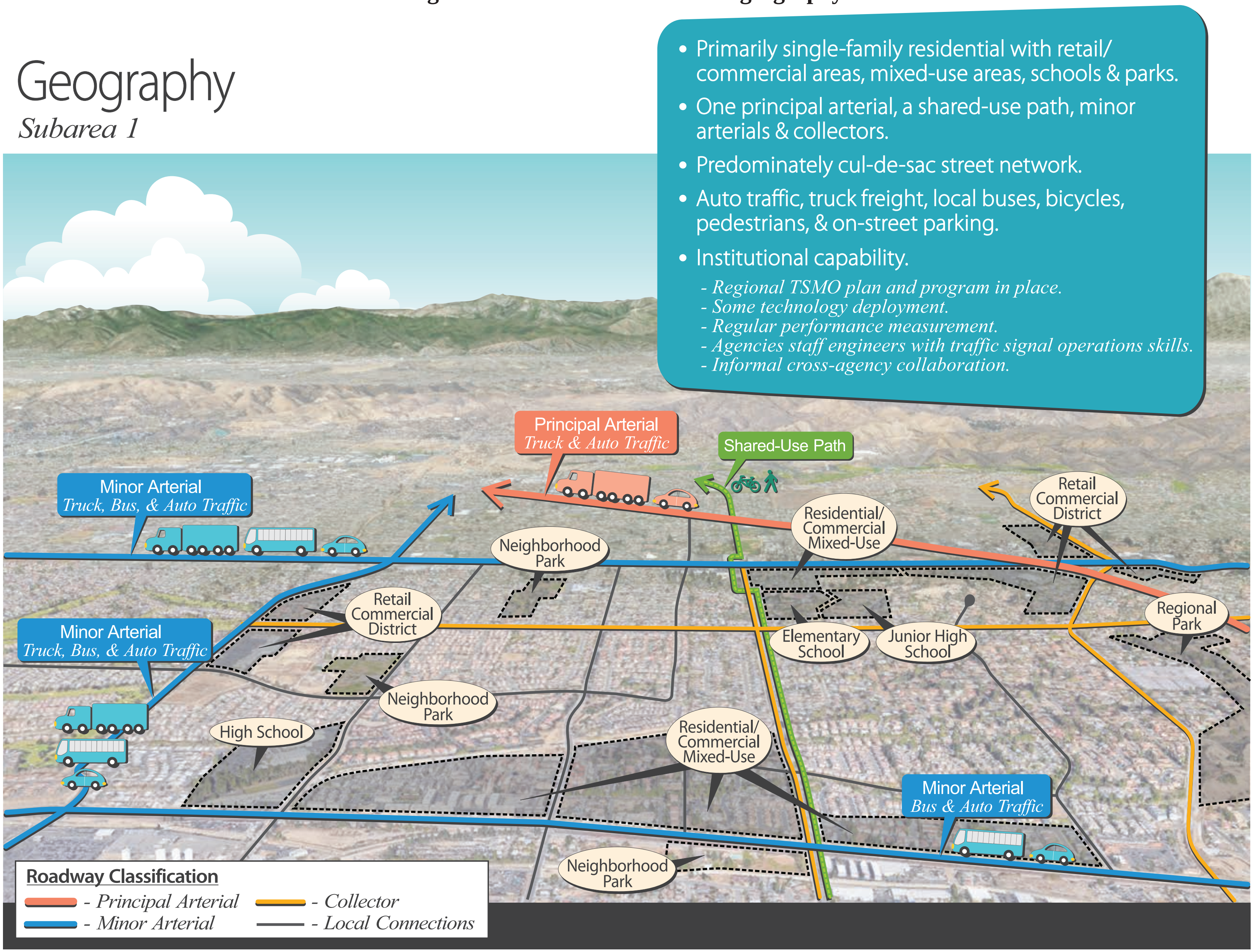
Performance Measurement – Some performance measurement of the system is regularly done but there is room for growth in this area.

Culture – Agencies within the subarea appreciate the value and role of TSMO.

Organization/Workforce – Agencies within the corridor, particularly the city, employ engineers with some TSMO skill sets, primarily those related to traffic signal operations.

Collaboration – Informal collaboration occurs on a somewhat regular basis between the transportation and public safety agencies within the subarea.

Figure 14. Illustration. Subarea 1 geography.



The motivators driving the need to implement TSMO strategies in Subarea 1 include:

- **Capacity bottlenecks**. The signalized intersections, particularly at locations where arterials or collectors intersect, are the key bottlenecks in Subarea 1. The intersection bottlenecks typically occur during the morning and evening peak commute periods and near the primary and secondary schools during morning arrival and afternoon dismissal. Roadway bottlenecks occur during school arrival and dismissal on the roadways adjacent to and near the schools. Roadway bottlenecks also occur in the evenings and on weekends adjacent to and near the commercial districts during the holiday shopping period from Thanksgiving to New Year's Day.
- **Limitations to capacity expansion**. The neighborhood has developed over many decades and land uses have been well established. This limits available right-of-way to expand capacity at bottleneck locations.
- **Land use access**. Few limitations have been placed on access to land uses within Subarea 1. Property frontages contain numerous driveways and arterial roadways have continuous two-way left turn lanes or traversable center lines, both of which can degrade safety and efficiency. Freight deliveries often block arterial travel lanes during peak periods.

Figure 15 depicts the key motivators occurring in the corridor that stakeholders are keen to address with TSMO strategies.

Key stakeholders—including transportation and land use planners, traffic engineers, and maintenance crews from the city and the transit agency—collaborate with the school district, park district, and business and neighborhood associations to establish a set of goals and SMART (**s**pecific, **m**easurable, **a**greed upon, **r**ealistic, and **t**ime-bound) operations objectives that address the identified motivators and provide guidance for the selection of a package of TSMO strategies. The two goals and supporting operations objectives include:

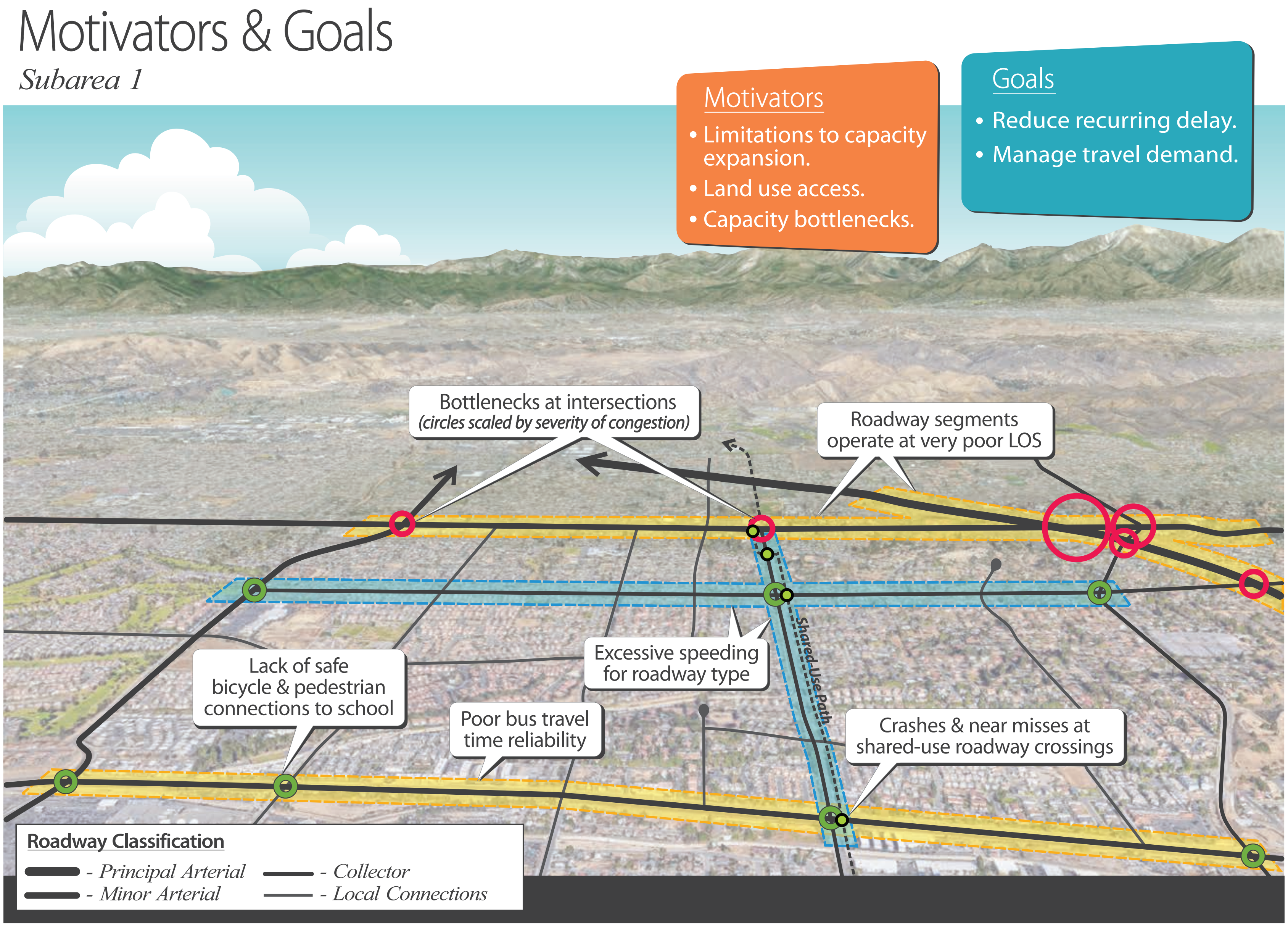
Goal 1: Reduce recurring delay.

- Decrease the seconds of control delay per vehicle on corridor arterial roads by 15 percent within 5 years.
- Reduce the daily hours of recurring congestion on the arterial corridors by 15 percent within 5 years.
- Improve average on-time performance for Subarea 1 transit routes by 15 percent within 5 years.

Goal 2: Manage travel demand.

- Increase average pedestrian and bicyclist comfort level by 30 percent within 5 years.
- Increase the number of trips made by walking and bicycling by 20 percent over 5 years.
- Increase transit mode share by 20 percent within 5 years.

Figure 15. Illustration. Subarea 1 motivators and goals.



- Develop and provide travel option services to all residents with children in primary and secondary schools within 5 years.

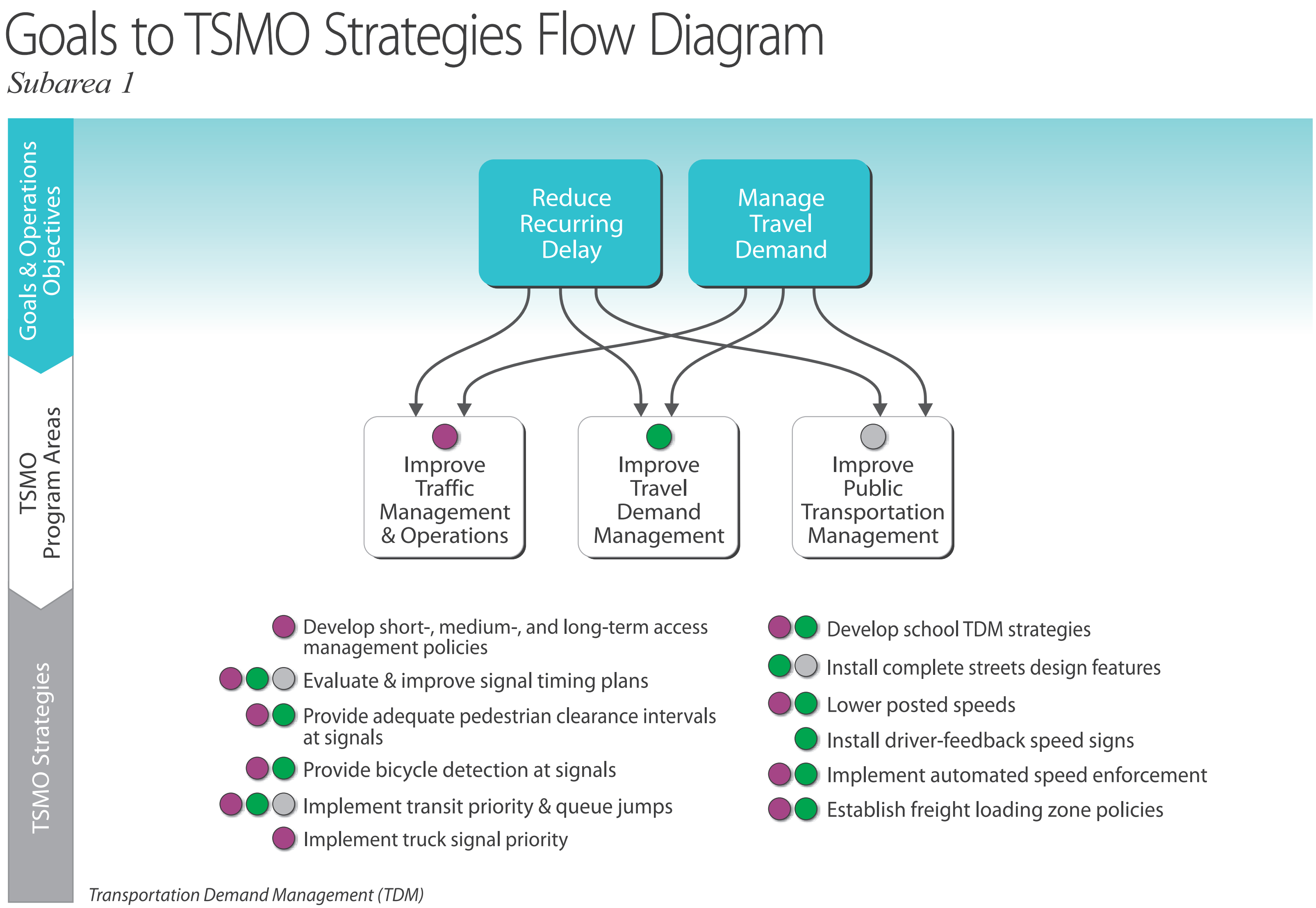
Figure 16 shows how the two subarea goals and operations objectives established by the stakeholders connect to a set of TSMO program areas and strategies that reflect the community's constraints, motivations, and values.

For this neighborhood, the TSMO program areas that address capacity bottlenecks and land use access include:

- Traffic management and operations.
- Travel demand management.
- Public transportation management.

While each of these TSMO program areas have a discrete focus on different elements of managing and operating the transportation system. Figure 16 demonstrates how each of the strategies selected for this model subarea support multiple program areas. The result is a comprehensive approach to neighborhood multimodal traffic management.

Figure 16. Diagram. Links between Subarea 1 goals and transportation systems management and operations strategies.



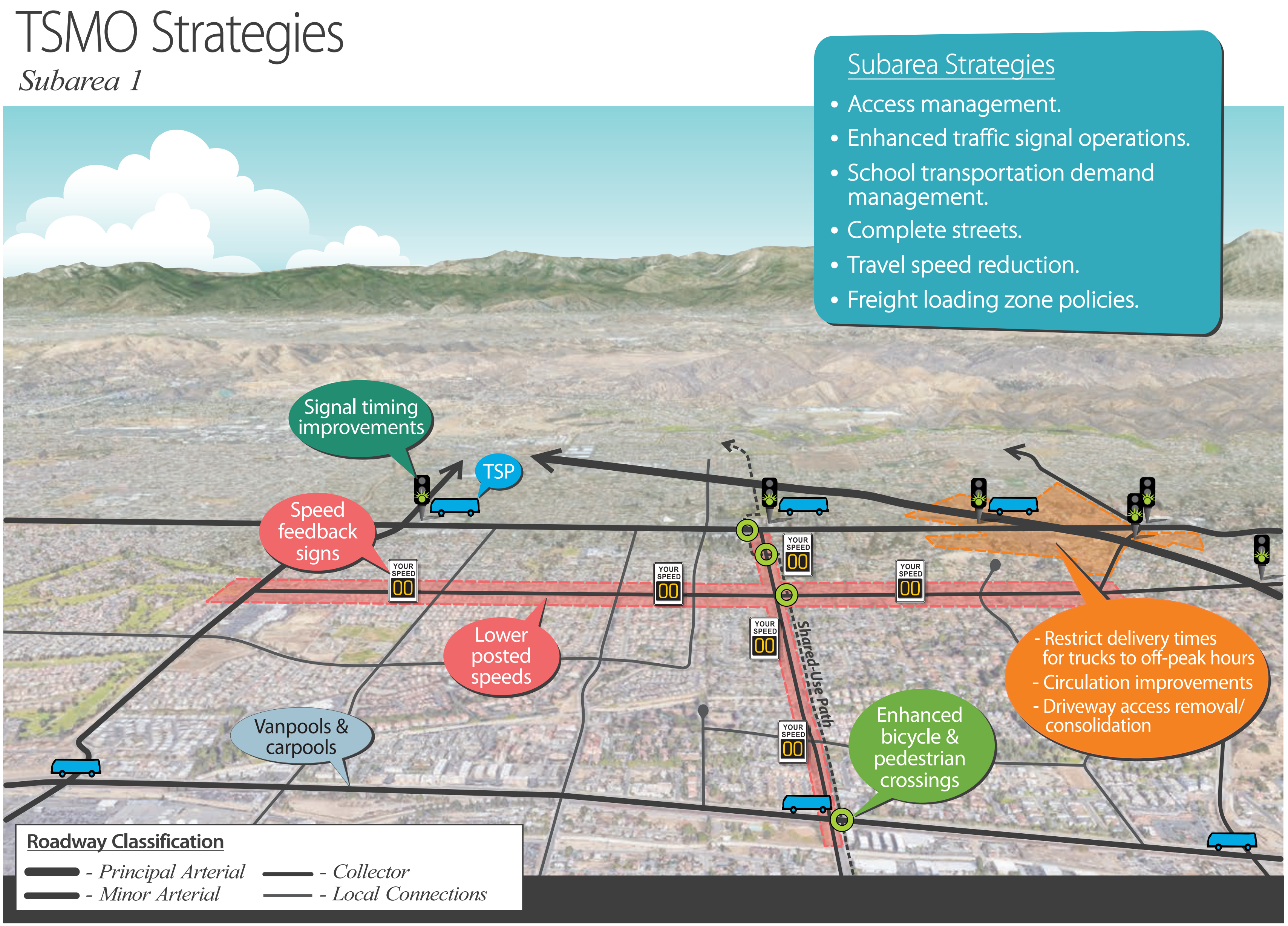
Subarea 1 stakeholders apply a scenario planning process that identifies alternative operating conditions tied to the unique combination of motivators and goals for the subarea. Using this approach, stakeholders narrow down a broad array of potential TSMO strategies to a subset that are further screened for feasibility, potential benefits, and cost impacts. The strategies that best fit Subarea 1 advance toward the implementation phase.

Figure 17 depicts the set of TSMO strategies selected by the Subarea 1 stakeholders. This neighborhood has a traffic signal system in place and the city has a traffic management workstation they use during regular business hours. The planning effort pulls together and augments these elements with new devices, communications, and activities to establish a focused TSMO approach to be advanced by the subarea's stakeholders.

The package of TSMO strategies selected for Subarea 1 include:

- **Access management.** Develop neighborhood policies and short-, medium-, and long-term strategies to manage land use access. These may include spacing standards, geometric standards, access removal or consolidation, curb-cut reductions, medians with well-placed openings, turn lanes, and circulation improvements (adjacent roadways and within private properties). Short-term strategies often target strategies that are amenable to current land and business owners whereas long-term strategies often target an ideal conceptual layout for if and when redevelopment occurs.
- **Enhanced traffic signal operations.** Signal timing can be fine-tuned to meet the travel demand needs of the neighborhood. This includes signal timing plans that favor a lower progression speed, more green time for approaches with reduced automobile travel lanes, turn pocket queue clearance, adequate pedestrian clearance intervals, bicycle detection, transit signal priority to support on-time transit performance, transit queue jumps, and truck traffic signal priority.
- **School transportation demand management (TDM).** Develop TDM strategies specific to each school such as staggered start and end times, evaluation of bus boundaries, walking school buses (e.g., adult-led group of children who walk from a nearby underutilized retail parking lot), and "school pool" (carpools and vanpools for school arrival and dismissal).
- **Complete streets.** Re-allocate existing right-of-way to support and encourage multiple modes. Strategies for Subarea 1 may include bus pull-outs, freight loading zones, comfortable bicycle and pedestrian facilities, and enhanced bicycle and pedestrian crossings (e.g., traffic signals, hybrid beacons, rapid rectangular flashing beacons, bicycle detection, bicycle boxes, multi-stage bicycle turns, and pedestrian scrambles).
- **Travel speed reduction.** Reducing travel speeds in neighborhoods supports access management and complete streets efforts. TSMO strategies to reduce travel speeds include lowering posted speed limits, driver-feedback speed advisory signs, automated speed enforcement, and signal timing plans that favor a lower progression speed. More traditional physical traffic calming strategies (e.g., roundabouts, curb bulb-outs) may also be used.

Figure 17. Illustration. Subarea 1 transportation systems management and operations strategies.



- **Freight management.** Develop and implement freight loading zone policies to reduce conflicts between freight and arterial roadway demands. Strategies may include suggested delivery times, designated freight loading zones (these may be curbside and shared with on-street parking with time-of-day/day-of-week restrictions), enforcement of loading zones, and truck routing analysis to update truck routes in Subarea 1.

To realize an integrated deployment of the TSMO strategies, Subarea 1 local transportation agencies adjust their institutional capabilities under each of the following categories:

Business Processes

- Incorporate TSMO strategies into regional and agency long-range transportation plans. Coordinating the TSMO strategies with other regional or agency efforts helps align policies and goals and often helps develop project support and funding allocations.
- Develop life-cycle costs (total cost for procuring, installing, operating, and maintaining a system throughout its use) for TSMO strategies and incorporate these costs into regional and agency transportation programming.
- Use intelligent transportation system (ITS) standards for field devices and central systems to support interoperability between agencies and data sharing.
- Institute a schedule of preventative maintenance for field devices in the corridor.
- Develop an operations and maintenance manual to define procedures, roles, and responsibilities for new TSMO systems. For example, define what parameters (e.g., bus behind schedule) will trigger traffic signal priority activation.

Systems and Technology

- Optimally locate field devices to minimize power and communications costs, provide maintenance accessibility, and to use devices to support multiple strategies (e.g., detector locations that collect data for traffic signal operations, school TDM efforts, and freight management).
- Provide center-to-field interfaces to allow all device data to feed into systems at the city's traffic management workstation.
- Automate procedures to the extent possible. For example, develop pre-set holiday signal timing plans to depict the typical travel demand from Thanksgiving through the New Year that can be implemented yearly with minimal updates.

Performance Measurement

- Establish data sharing policies and an archive structure to facilitate easy data access.
- Share data with public and private partners to support traveler information. This allows the data to be used in a variety of formats (e.g., mobile device applications that show freight parking availability, school travel options, and real-time queues at traffic signals or schools).
- Measure performance of all the systems periodically and compare the performance to the corridor's operations objectives. Adjust the corridor strategies if needed. For example, if walking and bicycling trips do not appear to be on track for a 20 percent increase within 5 years, re-evaluate the school TDM and complete street strategies in use and try other strategies that may support the objective.

Culture

- Link TSMO program activities with transportation agencies' strategic plans.
- Hold regular meetings to ensure on-going dialogue on integrated management activities across transportation and transit agencies.

Organization/Workforce

- Train staff on operating and maintaining new systems (e.g., driver-feedback speed advisory signs). Consider contracting out some maintenance responsibilities if it is more cost-effective for specialty items that are not needed often (e.g., fiber optic cable maintenance, in particular splicing and emergency restoration).
- Compile a database of personnel and resources across organizational units in each agency responsible for TSMO activities.

Collaboration

- Develop working groups for TSMO strategies that require an expanded stakeholder set beyond the typical transportation and emergency stakeholders and meet regularly (e.g., quarterly, prior to a planned event such as a new school year or the start of holiday shopping). For example, a school TDM working group may include the city, neighborhood schools, school bus operators, and neighborhood associations. A freight management working group may include the city, the freight community, the local chamber of commerce, and business owners/operators with freight needs.

MODEL SUBAREA 2 – URBAN ACTIVITY CENTER

Subarea 2 is an activity center within a large metropolitan area as shown in Figure 18. The roadway network is a conventional grid that includes principal arterials (including one interstate), minor arterials, collectors, local streets, and a shared-use path for bicycles and pedestrians. Many of the roadways provide for one-way travel.

Subarea 2 is both an employment destination and a shopping destination for locals and tourists. The network primarily provides access to commercial properties that include retail, restaurants, and office space and to multi-story mixed-use residential and commercial developments.

A combination of State, city, and transit agencies operate and maintain the transportation facilities. The State department of transportation (DOT) district office maintains a 24/7 traffic management center (TMC).

Transportation modes include automobiles, truck freight, streetcar, buses, bicycles, and pedestrians. On-street parking is provided throughout Subarea 2 to support access to the adjacent land uses. Shared mobility is present in the form of transportation network companies. Truck freight travels through the area using the interstate but also makes many delivery trips within Subarea 2, particularly to the commercial sites. The streetcar provides connections to the regional transit network and the local bus line circulates within Subarea 2. Wide sidewalks that accommodate higher volumes of pedestrian traffic are present throughout Subarea 2. Bicycle lanes are limited and primarily consist of the shared-use path.

The agencies managing and operating the transportation systems in Subarea 2 demonstrate the following institutional capabilities for implementing a TSMO program:

Business Processes – Regional TSMO programming, development, and deployment processes are standardized system-wide and are well-documented.

Systems and Technology – Agencies use advanced technologies within the region but with a limited level of automation.

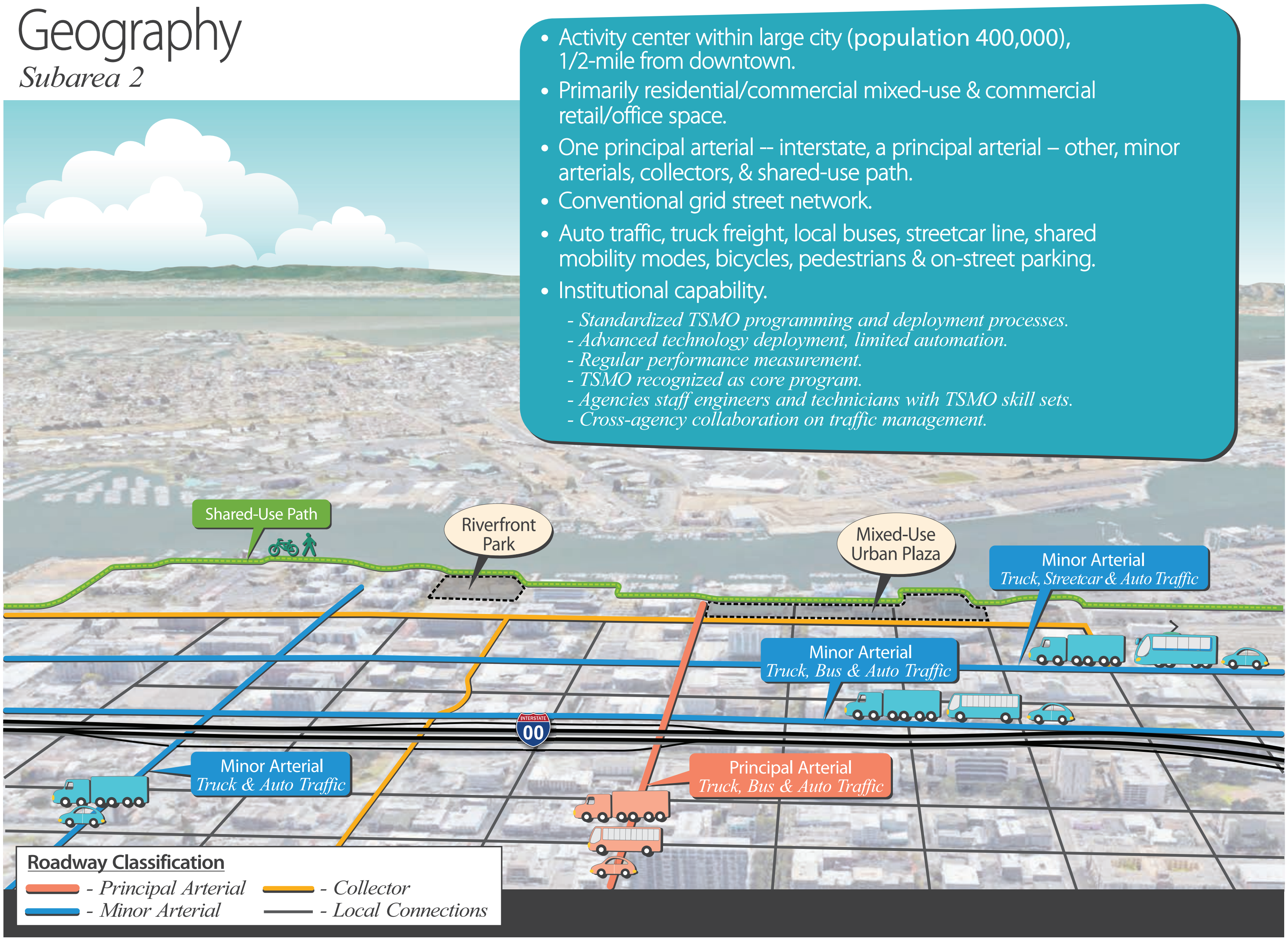
Performance Measurement – Agencies routinely identify desired outcomes and measure performance to improve strategy deployment and overall operations.

Culture – Agencies recognize TSMO as a core program that they regularly coordinate with other programs.

Organization/Workforce – Agencies within the corridor have in-house engineers and maintenance crews with TSMO skill sets.

Collaboration – Agencies collaborate on traffic management at a high level via regional stakeholder engagement and coordination.

Figure 18. Illustration. Subarea 2 geography.

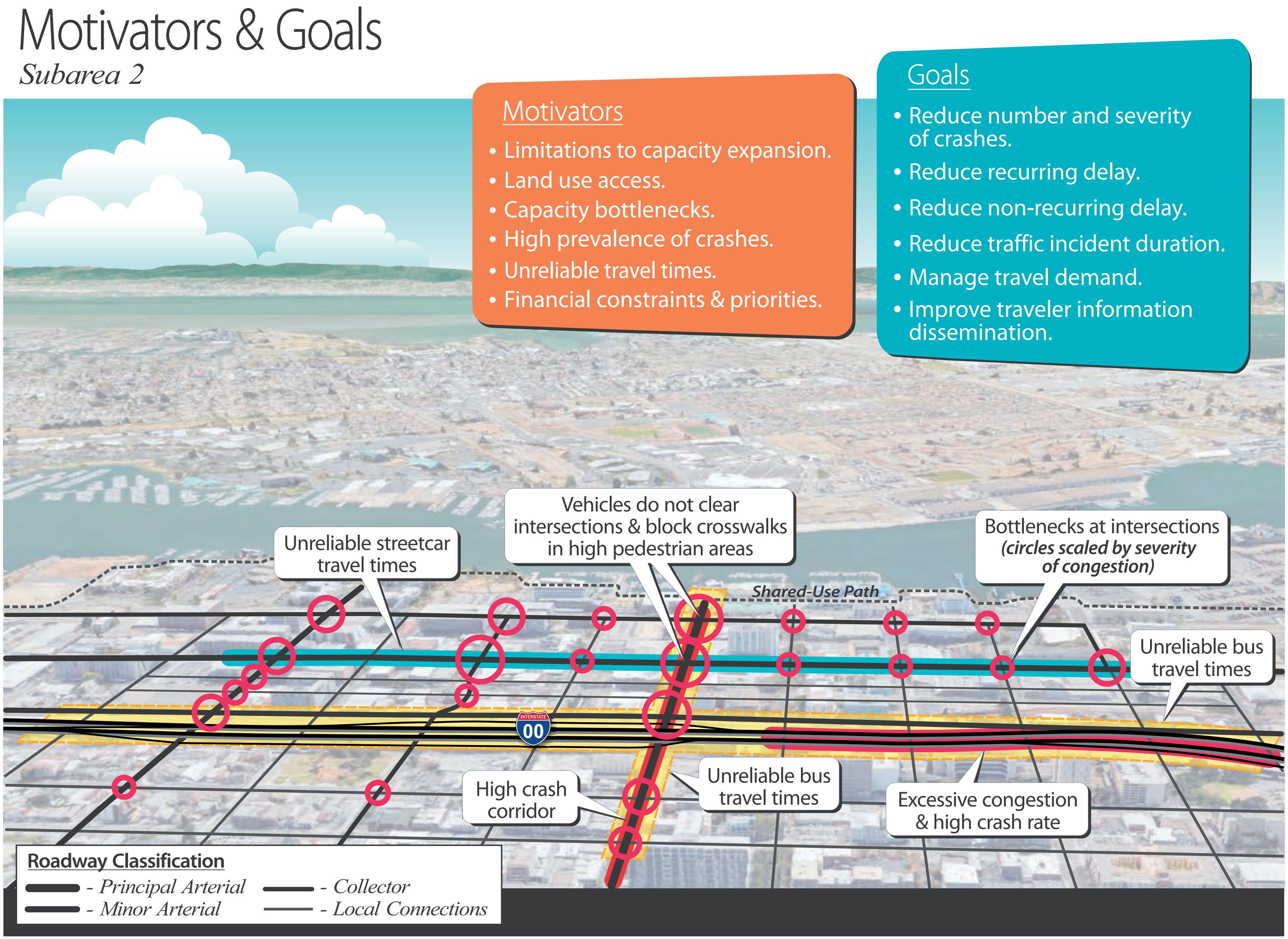


The motivators driving the need to implement TSMO strategies within Subarea 2:

- **Congestion and limitations to capacity expansion**. Subarea 2 is typically congested throughout the morning and evening peak periods and often on the weekends. Signalized intersections are the primary bottlenecks, often contributing to gridlock. The area is essentially built-out, which limits available right-of-way to expand capacity at bottleneck locations.
- **Land-use access**. Although Subarea 2 has ample parking (garages and some surface lots), automobiles and truck freight compete for on-street parking.
- **High prevalence of crashes**. A wide variety of crashes (involving vehicles, pedestrians, and bicycles) occur in Subarea 2 at intersections, driveways, and adjacent to on-street parking.
- **Variability in trip reliability**. Average trip time varies widely from day to day and can differ by as much as 35 minutes for the same time period.
- **Financial constraints and priorities**. Subarea 2 competes for funding with other regional programs and other similar activity centers within the region.

Figure 19 depicts the key motivators occurring in the corridor that stakeholders are keen to address with enhanced TSMO strategies.

Figure 19. Illustration. Subarea 2 motivators and goals.



Key stakeholders including transportation and land use planners, traffic engineers, and maintenance crews from the State, city, and transit agencies collaborate with the area business and neighborhood associations, emergency responders, transportation network companies, and bicycle and pedestrian advocacy groups to establish goals and SMART operations objectives that address the identified motivators and provide guidance for the selection of a package of TSMO strategies. The six goals and supporting operations objectives include:

Goal 1: Reduce number and severity of crashes.

- Reduce the crash rate by 50 percent within 5 years.

Goal 2: Reduce recurring delay.

- Decrease the seconds of control delay per vehicle on subarea roads by 15 percent within 5 years.
- Reduce the daily hours of recurring congestion on subarea roads by 20 percent within 5 years.

Goal 3: Reduce non-recurring delay.

- Reduce the variability of travel times by 15 percent during peak and off-peak periods within 5 years.
- Decrease average freight point-to-point travel times within Subarea 2 by 15 percent within 3 years.
- Improve average on-time performance for Subarea 2 transit routes by 15 percent within 5 years.

Goal 4: Reduce traffic incident duration.

- Reduce mean incident clearance time per incident by 15 percent over 5 years.

Goal 5: Manage travel demand.

- Develop and provide travel option services to all Subarea 2 stakeholder audiences within 5 years.

Goal 6: Improve traveler information dissemination.

- Increase customer satisfaction ratings for timeliness, accuracy, and usefulness of traveler information in Subarea 2 by 50 percent within 5 years.

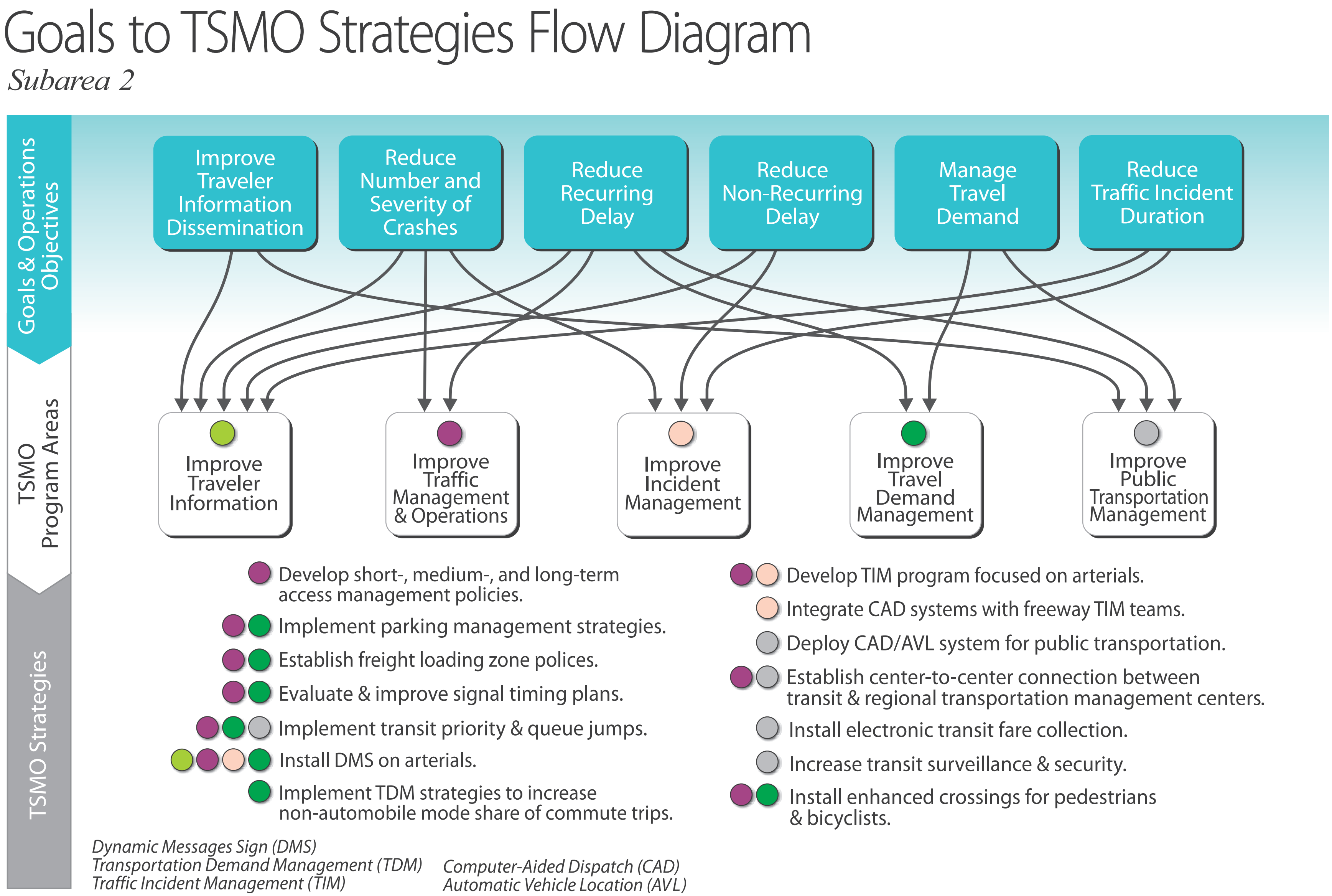
Figure 20 depicts how the six subarea goals and operations objectives established by the stakeholders connect to a set of TSMO program areas and strategies that reflect the identified constraints, motivations, and values for Subarea 2.

For this urban activity center, the TSMO program areas that address capacity bottlenecks and land use access include:

- Traveler information.
- Traffic management and operations.
- Traffic incident management.
- Travel demand management.
- Public transportation management.

While each of these TSMO program areas have a discrete focus on different elements of managing and operating the transportation system, Figure 20 demonstrates how each of the strategies selected for this model corridor support multiple program areas. The result is a comprehensive approach to multimodal transportation management.

Figure 20. Diagram. Links between Subarea 2 goals and transportation systems management and operations strategies.



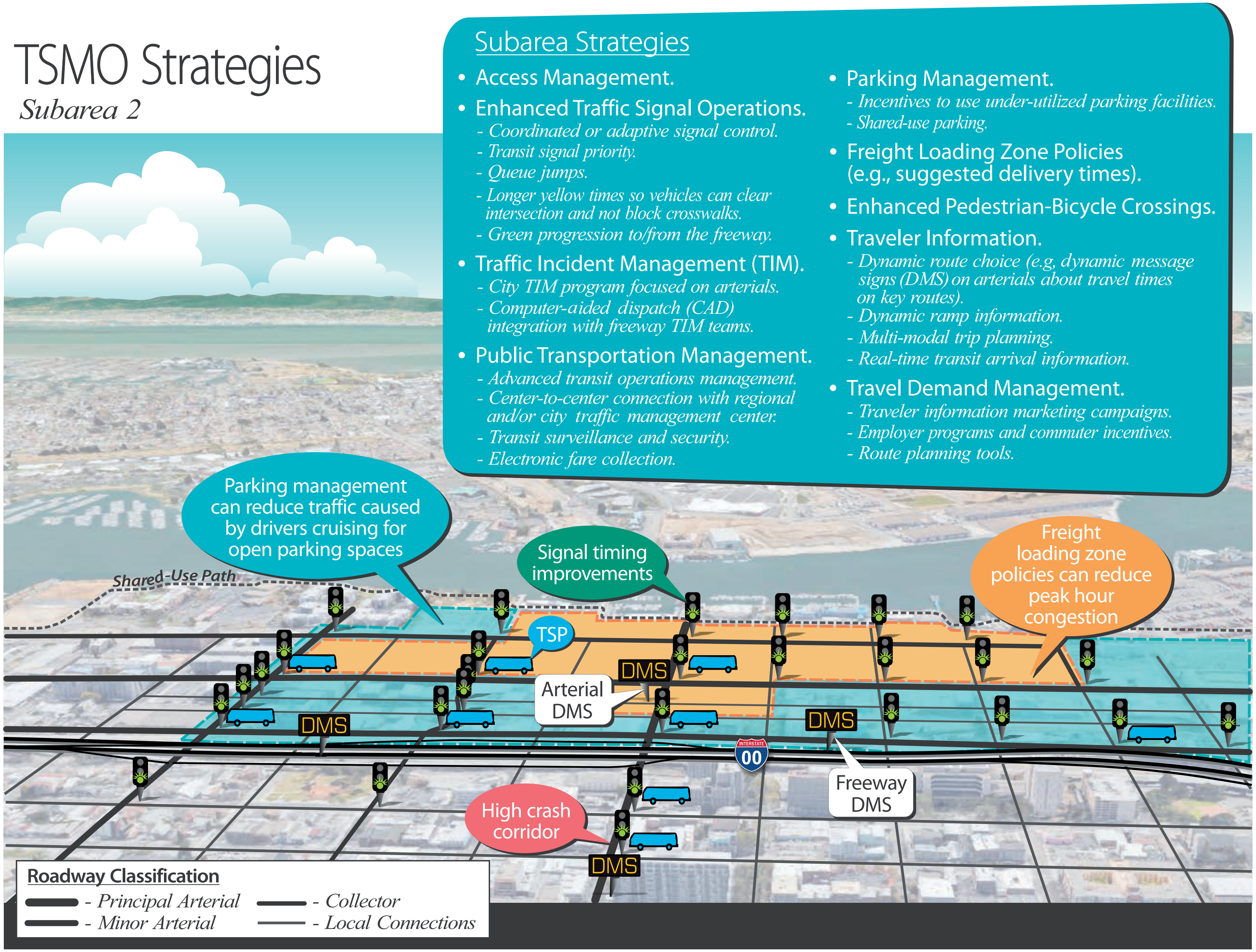
Subarea 2 stakeholders apply a scenario planning process that identifies alternative operating conditions tied to the unique combination of motivators and goals for the subarea. Using this approach, stakeholders narrow down a broad array of potential TSMO strategies to a subset that are further screened for feasibility, potential benefits, and cost impacts. The strategies that best fit Subarea 2 advance toward the implementation phase.

Figure 21 depicts the set of TSMO strategies selected by the subarea's stakeholders. The relative sophistication of transportation services in this subarea along with the high degree of institutional capability provide a solid foundation for implementing an advanced program of TSMO strategies. The planning effort pulls together and augments these elements with new devices, communications, and activities to establish a focused TSMO approach to be championed and implemented by the subarea's stakeholders.

The package of TSMO strategies for Subarea 2 include:

- **Access management.** Develop policies and strategies to manage land use access. Strategies for an activity center may include turn lanes, circulation improvements (public right-of-way and private properties), and parking and freight strategies described below.
- **Parking management.** To better manage on-street and off-street parking in Subarea 2, strategies may include shared-use parking, incentives to use under-utilized parking facilities, and electronic payment systems.
- **Freight management.** Develop and implement freight loading zone policies to reduce conflicts between freight and motor vehicle demands. Strategies may include suggested delivery times, designated freight loading zones (these may be curbside and shared with on-street parking with time-of-day/day-of-week restrictions), enforcement of loading zones, and electronic payment systems for freight parking.
- **Enhanced traffic signal operations.** Signal timing can be fine-tuned to meet the travel demand needs of the activity center. This includes signal timing plans that provide progression to and from the freeway, balance demand on the grid network, use coordinated or adaptive signal control, provide streetcar preemption or bus transit signal priority, accommodate transit queue jumps, and provide longer yellow times for vehicles to clear intersections and not block crosswalks.
- **Traffic incident management (TIM).** With existing institutional capability, TIM teams already focus on the region's freeways. Develop a city TIM program focused on arterials within Subarea 2 and integrate computer-aided dispatch (CAD) systems with freeway TIM teams.
- **Public transportation management.** Strategies may include advanced transit operations management (e.g., CAD/automated vehicle location (AVL) systems), center-to-center connection with the regional transportation management center, electronic fare collection, and transit surveillance and security.
- **Enhanced crossings for pedestrians and bicycles.** Improve visibility of pedestrians and bicycles at intersections and driveways using signing, pavement markings, and detection to activate signals or warning systems (e.g., electronic signs on driveway exits, particularly where sight distance is limited).

Figure 21. Illustration. Subarea 2 transportation systems management and operations strategies.



- **Traveler information**. Expand traveler information systems to include dynamic route choice (e.g., dynamic message signs (DMS) on arterials about travel times on key routes), dynamic on-ramp information, multimodal trip planning, real-time transit arrival information, real-time on- and off-street parking availability and making agency data available to third-party data providers in standardized format.
- **Transportation demand management**. Use TDM strategies to reduce commute trips. Subarea 2 strategies may include employer programs and commuter incentives, route planning tools, and traveler information marketing campaigns.

To realize an integrated deployment of the TSMO strategies, Subarea 2 transportation agencies adjust their institutional capabilities under each of the following categories:

Business Processes

- Continue to incorporate TSMO strategies into agency and regional long-range transportation plans. Coordinating TSMO strategies with other regional or agency efforts helps align policies and goals. It can also increase project support and funding allocations.
- Continue to develop life-cycle costs (total cost for procuring, installing, operating, and maintaining a system throughout its use) for TSMO strategies and incorporate these costs into regional and agency transportation programming.
- Use ITS standards for new field devices and central systems to support interoperability between agencies and to support data sharing.
- Institute a schedule of preventative maintenance for new field devices in the subarea.
- Develop maintenance agreements with city if needed for the State DOT to maintain and operate ITS devices on city roadways such as cameras, detectors, or traffic signals.
- Develop standard operating procedures (SOPs) to define procedures, roles, and responsibilities for new TSMO systems. The SOPs may be incorporated into existing operations and maintenance manuals (e.g., transit agency operations manual) or a new regional manual may need to be developed (e.g., regional traveler information SOP manual).
- Develop agreements, if needed, for the city or State DOT to operate the other agency's traffic signals if tied into the same coordinated timing system. Depending on staffing, the city may operate the signals during their standard business hours and the State DOT may operate them after hours if there is an unexpected system outage or change in travel demand due to a crash or special event.

Systems and Technology

- Optimally locate field devices to minimize power and communications costs, provide maintenance accessibility, and use devices to support multiple strategies (e.g., camera and detector locations that support TIM, TDM decisions, and freight management).
- Provide center-to-field interfaces to allow all device data to feed into systems at the State or city traffic management center. Update center-to-center interfaces as needed (e.g., allow both city and State to update messages on arterial DMS based on pre-defined SOPs).
- Automate procedures to the extent possible. For example, develop volume thresholds to determine what travel time messages to post to traveler information systems.

Performance Measurement

- Update data sharing policies and archive structure to accommodate easy data access for new stakeholders (e.g., freight community for freight loading zone strategies).
- Continue to share data with public and private partners to support traveler information. This allows the data to be used in a variety of formats (e.g., mobile device applications provide parking or freight loading wayfinding, neighborhood travel options, electronic parking, or transit payment).
- Measure performance of all the systems periodically and compare the performance to the subarea's operations objectives. Adjust the subarea strategies if needed. For example, if average freight point-to-point travel times within Subarea 2 do not appear to be on track for a 15 percent reduction within 3 years, re-evaluate the freight management strategies in use and try other strategies that may support the objective.

Culture

- Continue to link TSMO program activities with transportation agencies' strategic plans. Use service-related cost-effectiveness to compare TSMO program to other transportation programs to justify the expansion of the TSMO program.
- Continue to hold regular meetings to ensure on-going dialogue on integrated management activities across transportation and emergency response agencies. Include additional stakeholders as needed.

Organization/Workforce

- Train staff on operating and maintaining new systems (e.g., electronic payment systems).
- Update database of personnel and resources across organizational units in each agency responsible for TSMO activities.
- Develop a TSMO management and organizational structure within key agencies (e.g., State DOT and city) equivalent to that of other major agency programs.

Collaboration

- Continue to participate in TIM teams (emergency responders and State DOT) by meeting regularly to conduct joint training, tabletop exercises, and major incident debriefs. Expand participants to include arterial stakeholders such as the city, subarea businesses, and freight distribution centers.
- Develop working groups for TSMO strategies that require an expanded stakeholder set beyond the typical transportation and emergency stakeholders. For example, a parking management working group may include private and public parking facility operators and transit agencies that operate park and ride lots. Meet on a routine basis to determine the effectiveness of the strategies and make updates as needed.

MODEL SUBAREA 3 – URBAN SUB-REGION

Subarea 3 covers a large sub-region within a metropolitan area of approximately 200,000 people. The roadway network is a mix of conventional grid and curvilinear loops and includes multiple interstates, other principal arterials, minor arterials, collectors, and a regional shared-use path for bicycles and pedestrians as shown in Figure 22. Land use in Subarea 3 is predominantly residential interspersed with major activity centers, including a downtown mixed-use district, a regional retail district, industrial centers, an international airport, a large university campus, a theater district, and a regional park. The downtown and retail districts also include residential/commercial mixed use.

City, county, State, and transit agencies manage the transportation facilities in Subarea 3. A metropolitan planning organization (MPO) supports regional planning, programming, and collaboration. A consortium of regional transportation agencies support a 24/7 TMC.

Transportation modes include automobile, truck freight, heavy passenger and freight rail, light rail, streetcar, local buses, bicycles, pedestrians, and shared mobility services for cars and bicycles. On-street parking is prevalent throughout the subarea, but the activity centers also include off-street parking facilities. Truck and rail freight travel through the region but have a heavy presence in the industrial centers. Truck freight also makes local delivery trips. A passenger rail line connects the sub-region to neighboring cities. Light rail, streetcar, and bus routes provide transit connections across the region. Sidewalks are generally provided throughout the sub-region, and some on-street bicycle lanes are provided in addition to the regional shared-use path.

This subarea has a "Vision Zero" policy; the purpose of which is to achieve zero fatalities. The community has embraced and instituted strategies like greater enforcement, blanket speed limit reductions, driver education, and traffic calming.

The agencies managing and operating the transportation system in Subarea 3 demonstrate the following institutional capabilities for implementing a TSMO program:

Business Processes – TSMO development and deployment processes are standardized system-wide but need more integration of formal procedures across agencies.

Systems and Technology – Within the sub-region, agencies use advanced technologies, some with advanced automation.

Performance Measurement – Agencies routinely identify desired outcomes and measure performance to improve strategy deployment and overall operations.

Culture – Agencies recognize TSMO as a core program and are working toward making the case for it based on cost-effectiveness.

Organization/Workforce – Agencies within the corridor have in-house engineers and maintenance crews with TSMO skill sets or they share resources across agencies.

Collaboration – Agencies collaborate on TSMO via regional stakeholder engagement and are working towards negotiating region-wide roles and responsibilities.

Figure 22. Illustration. Subarea 3 geography.

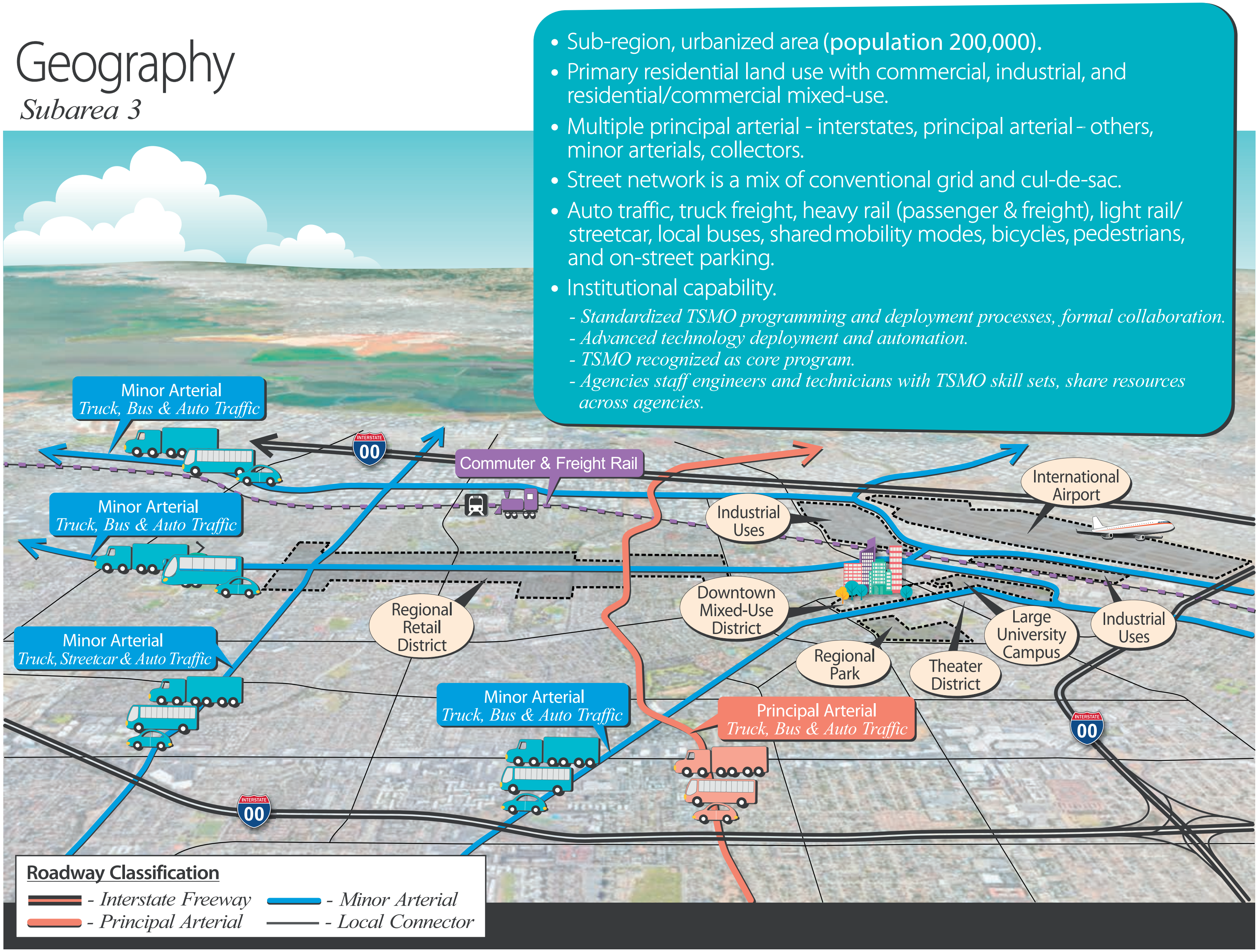


Figure 23 depicts the motivators driving the need to implement TSMO strategies in Subarea 3:

- **Adverse environmental issues**. Subarea 3 is located within a non-attainment area where air pollution levels persistently exceed standards for ozone and particulate pollution. The industrial centers in Subarea 3 contribute to the city's non-attainment.
- **Congestion and limitations to capacity expansion**. Congestion occurs throughout Subarea 3 during the morning and evening peak periods. Additional congestion occurs at some of the activity centers, including weekend congestion at the retail and downtown districts. Limited right-of-way is available to expand capacity at bottleneck locations.
- **Land-use access**. Automobile traffic competes for coveted on-street parking spots in the activity centers despite the availability of parking garages and surface lots.
- **Development pattern changes**. Development has occurred rapidly and the pattern has altered travel demand, particularly route choice and time of day, causing additional unplanned congestion.
- **High reliance on single-occupancy vehicles**. Transit options notwithstanding, residents in Subarea 3 rely heavily on single-occupancy vehicles for most trips, taxing roadway capacity, especially the routes into and out of the core downtown area.
- **High prevalence of crashes**. Many crashes occur throughout Subarea 3 including rear-end crashes on freeways and arterials due to standing queues; turning movement crashes at congested signalized intersections; and crashes adjacent to on-street parking spots.
- **Special event congestion**. The theater district holds events year-round that sometimes coincide with and add to the congestion of the weekday evening commute. Many events are held at the regional park that require roadway closures on the weekend.
- **Variability in trip reliability**. Average trip time varies widely from day to day (up to a 50 minute difference), not only during the peak periods but also on weekday afternoons and weekends.
- **Financial constraints and priorities**. Subarea 3 is located within a large MPO and competes for funding with other cities of similar and larger sizes with similar transportation issues.

Figure 23. Illustration. Subarea 3 motivators and goals.

Key stakeholders—including transportation and land-use planners, traffic engineers, and maintenance crews from the city, county, State transit agencies and metropolitan planning organization (MPO)—collaborate with the area business and neighborhood associations, key employers, freight haulers, emergency responders, transportation network companies, parking management companies, and bicycle and pedestrian advocacy groups to establish a set of goals and SMART operations objectives that address the identified motivators and provide guidance for advancing a package of TSMO strategies. The six goals and supporting operations objectives include:

Goal 1: Reduce number and severity of crashes.

- End traffic fatalities and severe injuries within 5 years.

Goal 2: Reduce recurring delay.

- Decrease the seconds of control delay per vehicle on corridor arterial roads by 15 percent within 5 years.
- Reduce the daily hours of recurring congestion on the freeway and arterial corridors by 15 percent within 5 years.
- Reduce excess fuel consumed due to congestion by 25 percent within 5 years.

Goal 3: Reduce non-recurring delay.

- Reduce the person hours of non-recurring delay associated with incidents by 10 percent within 5 years.
- Reduce average travel time into and out of the theater district by 15 percent within 5 years.
- Decrease the percent of special event attendees traveling to the event in single-occupancy vehicles by 25 percent within 5 years.
- Decrease average freight point-to-point travel times through Subarea 3 by 10 minutes within 3 years.
- Reduce the variability of travel time on Subarea 3 routes by 15 percent during peak and off-peak periods within 5 years.
- Improve average on-time performance for Subarea 3 transit routes by 15 percent within 5 years.

Goal 4: Reduce traffic incident duration.

- Reduce mean time for needed responders to arrive on-scene after notification by 15 percent over 5 years.
- Reduce mean incident clearance time per incident by 15 percent over 5 years.

Goal 5: Manage travel demand.

- Increase average pedestrian and bicyclist comfort level by 30 percent within 5 years.
- Decrease single-occupancy vehicle trips by 30 percent within 5 years.
- Develop and provide travel option services to all Subarea 3 communities and stakeholders within 5 years.

Goal 6: Improve traveler information dissemination.

- Increase customer satisfaction ratings for timeliness, accuracy, and usefulness of traveler information in Subarea 3 by 50 percent within 5 years.

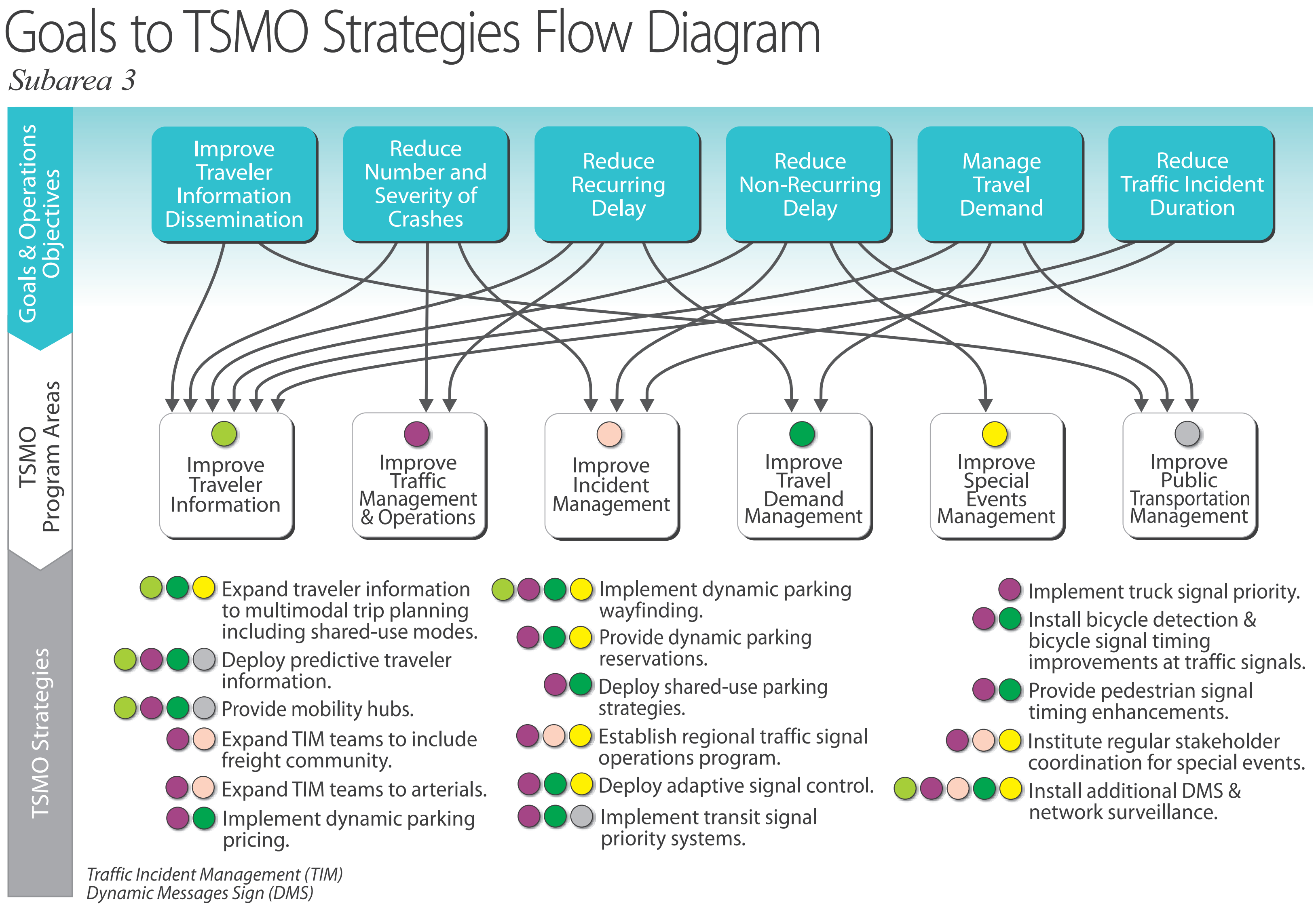
Figure 24 depicts how the six subarea goals and operations objectives established by the stakeholders connect to a set of TSMO program areas and strategies that reflect the identified constraints, motivations, and values for Subarea 3.

For this urban sub-region, the TSMO program areas that address local capacity bottlenecks and land-use access include:

- Traveler information.
- Traffic management and operations.
- Traffic incident management.
- Travel demand management.
- Special events management.
- Public transportation management.

While these TSMO program areas have discrete focus on different elements of managing and operating the transportation system, Figure 24 demonstrates how each of the strategies selected for this model subarea support multiple program areas. The result is a comprehensive approach to multimodal transportation management.

Figure 24. Diagram. Links between Subarea 3 goals and transportation systems management and operations strategies.



Subarea 3 stakeholders apply a scenario planning process that identifies alternative operating conditions tied to the unique combination of motivators and goals for the subarea. Using this approach, stakeholders narrow down a broad array of potential TSMO strategies to a subset that are further screened for feasibility, potential benefits, and cost impacts. The strategies that best fit Subarea 3 advance toward the implementation phase.

Figure 25 depicts the set of TSMO strategies selected by the subarea's stakeholders. The sophistication and maturity of transportation services in this subarea, along with a high degree of institutional capability, provide a solid foundation for implementing an advanced program of TSMO strategies. The planning effort pulls together and augments these elements with new devices, communications, and activities to establish a focused TSMO approach to be championed and implemented by the subarea's stakeholders.

Like Corridor 3, the stakeholders in Subarea 3 recognize an opportunity to apply an integrated corridor management (ICM) approach to coordinate responses between multiple owners/operators of facilities and modes in the subarea. ICM can play an important role in managing incidents, planned special events, adverse weather, and work zones by establishing coordinated response protocols. Any combination of the TSMO strategies identified for advancement in Subarea 3 can be used within an ICM process.

The package of TSMO strategies for Subarea 3 include:

- **Mobility hubs including options for shared mobility.** Shared use mobility is changing the way people travel, especially in large metropolitan areas. Strategies for Subarea 3 include mobility hubs that integrate modes at key transfer points such as activity centers or last-mile connections. A hub may include transit connections, transportation network company waiting/loading areas, shared-use parking, and a bicycle sharing station all in one location for easier transfers and a larger mode choice. See FHWA's *Shared Mobility: Current Practices and Guiding Principles* for more shared mobility ideas.[12]
- **Traffic signal operations.** Due to the many agencies that operate within the subarea, a regional traffic signal coordination program can help seamlessly operate traffic signals across jurisdictional boundaries. Adaptive signal control may also be considered where travel demand patterns fluctuate unpredictably. Light rail/streetcar preemption and transit signal priority for the buses can help the transit routes maintain schedule performance and reduce transit trip variability. Truck signal priority, or green light extension, can help keep truck freight and the traffic behind them moving on truck routes. Bicycle travel at signals can be enhanced with detection, separate phases, bicycle-specific passage time, bicycle boxes, and staged turn movements. Pedestrian travel at signals can be enhanced with countdown timers and phasing to reduce automobile-pedestrian conflicts.
- **Traffic incident management**. With a high level of institutional capability, TIM teams and dedicated service patrols already provide TIM services in Subarea 3. The agencies can further optimize these practices by expanding TIM teams to include the freight community, expanding TIM services to arterials, or adding strategies such as staged or dry run towing.

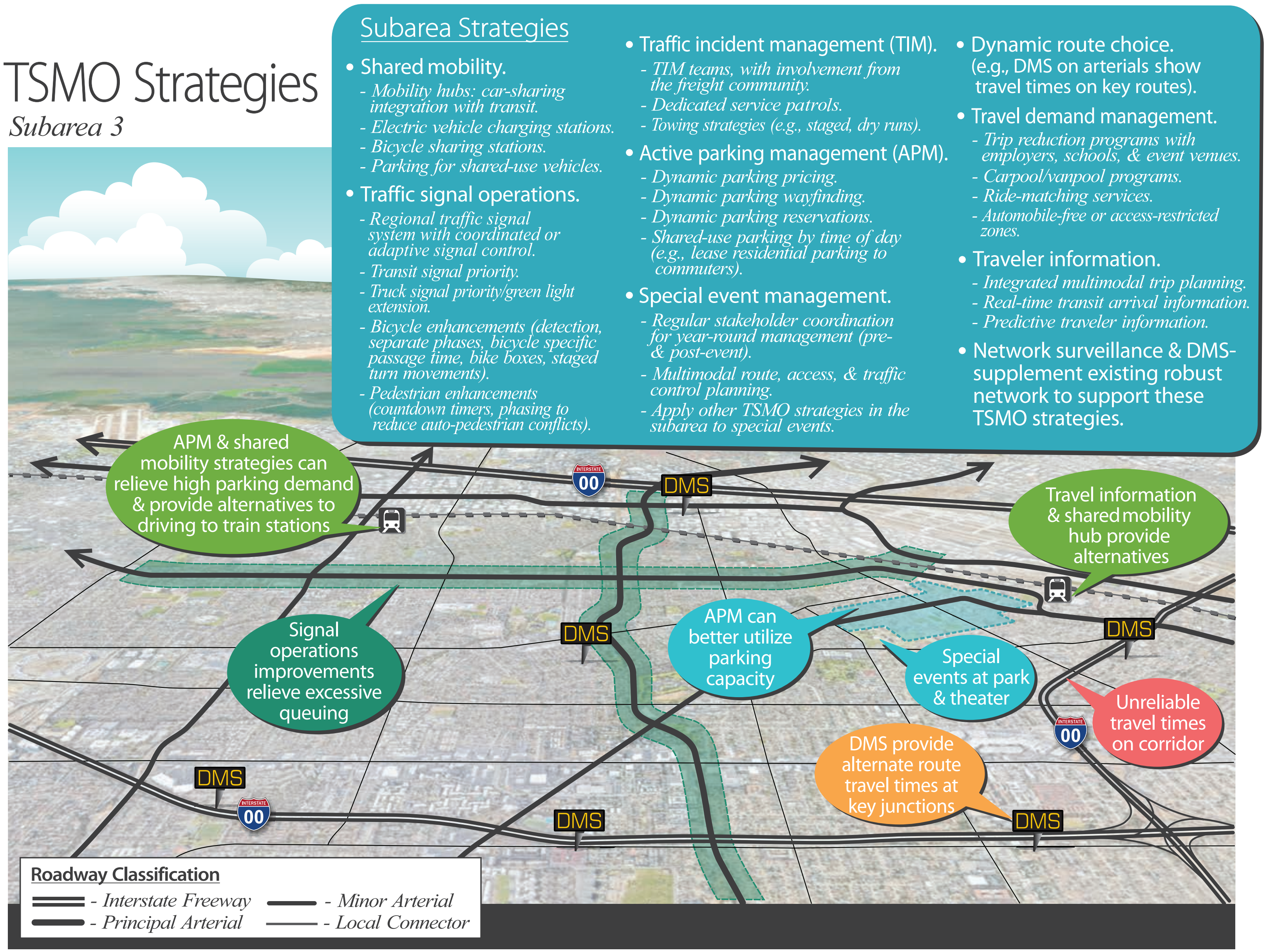
12 Federal Highway Administration, *Shared Mobility: Current Practices and Guiding Principles*, FHWA-HOP-16-022 (Washington DC: April 2016). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop16022/index.htm.

- **Active parking management (APM)**. Active management of parking facilities (on- and off-street) can help optimize the utilization of those facilities while influencing travel behavior at various stages along the trip making process. Several strategies may be considered for Subarea 3: dynamic parking pricing adjusts prices based on demand such as reduced prices at under-utilized facilities, dynamic parking wayfinding provides space availability by location, dynamic parking reservations allows users to reserve available parking spaces in advance, and shared-use parking uses time-of-day strategies such as leasing residential parking to commuters.
- **Dynamic route choice**. This active traffic management strategy provides alternate route information, including parallel transit options, based on real-time information about congestion along with a traveler's current route.
- **Special event management**. Apply coordinated operations strategies to inform the traveling public about travel conditions, monitor changing travel conditions, and manage travel demand associated with each planned special event. Regular stakeholder coordination, including pre- and post-event for larger events, is key for year-round management of events. Coordination should include planning for multi-modal routes, event access, and traffic control and address stakeholder roles and responsibilities. Subarea 3 uses many techniques today (e.g., police directing traffic at signalized intersections), but these could be automated or improved upon using other TSMO strategies described for this subarea, such as APM, enhanced signal timing operations, and traveler information.
- **Transportation demand management**. Use TDM strategies to reduce commute, retail, and special event trips to influence travel choice related to mode, time, location, or route. TDM strategies for Subarea 3 may include subsidies for transit passes and carpool/vanpool programs, trip reduction programs (in partnership with employers, the university, theater district, and special event operators), ride-matching services, automobile-free or access-restricted zones, and many of the strategies (particularly active demand management and APM) described in this section.
- **Traveler information**. Although Subarea 3 has a traveler information system in place, it primarily addresses the automobile and transit networks. Expand this system to include integrated multi-modal trip planning that considers public and private modes such as private bicycle sharing systems and transportation network companies. Develop predictive algorithm applications to generate travel forecasts based on both archived and real-time data. Disseminate forecasted conditions to the traveling public. Develop public-private partnerships for open data sharing and interoperability to support publicly or privately developed mobile device applications that help influence travel behavior. Common applications impacting transportation include mobility, vehicle connectivity, smart parking, and courier network services applications. See FHWA's *Smartphone Applications to Influence Travel Choices: Practices and Policies* for more background information and guiding principles for public agencies.[13]

13 Federal Highway Administration, Smartphone Applications to Influence Travel Choices: Practices and Policies, FHWA-HOP-023 (Washington DC: April 2016). Available at: http://www.ops.fhwa.dot.gov/publications/fhwahop16023/index.htm.

- **Network surveillance and dynamic message signs.** Subarea 3 already includes a healthy coverage of network surveillance (cameras and a variety of detectors) and DMS. However, additional deployments may be needed to support more advanced TSMO strategies or to measure system performance as it relates to the operations objectives. In the area, the use of probe data especially from third-party data providers may be particularly useful given the high penetration of such services in the area.
- **Active traffic management (ATM) and active demand management (ADM)**. These strategies described under the Corridor 3 scenario may also be applied within Subarea 3, particularly for the freeways.

Figure 25. Illustration. Subarea 3 transportation systems management and operations strategies.



To realize an integrated deployment of the TSMO strategies, Subarea 3 transportation agencies adjust their institutional capabilities under each of the following categories:

Business Processes

- Continue to incorporate TSMO strategies into regional and agency long-range transportation plans. Coordinating the TSMO strategies with other regional or agency efforts helps align policies and goals and often helps develop project support and funding allocations.
- Continue to develop life-cycle costs (total cost for procuring, installing, operating, and maintaining a system throughout its use) for TSMO strategies and incorporate these costs into regional and agency transportation programming.
- Use ITS standards for new field devices and central systems to support interoperability between agencies and to support data sharing.
- Institute a schedule of preventative maintenance for new field devices/systems in the corridor.
- Develop operations and maintenance agreements if needed for agencies to operate another agency's ITS devices or traffic signals. For example, cities or counties may want the State DOT to provide after-hours traffic signal operations because it is more cost-effective.
- Develop SOPs to define procedures, roles, and responsibilities for new TSMO systems. The SOPs may be incorporated into existing operations and maintenance manuals (e.g., existing agency manual or regional TIM manual) or a new regional manual may need to be developed (e.g., dynamic route choice SOP manual).

Systems and Technology

- Optimally locate field devices to minimize power and communications costs, provide maintenance accessibility, and to use devices to support multiple strategies (e.g., camera and detector locations that support as many TSMO strategies as possible).
- Provide center-to-field interfaces to allow all device data to feed into systems at a traffic management center. Update center-to-center interfaces as needed (e.g., allow a city, county, or State agency to update signal timings for multi-jurisdictional signal groupings based on pre-defined SOPs).
- Automate procedures to the extent possible. For example, develop software (or software modules that integrate into existing advanced traffic management systems) that operates TSMO strategies such as active parking management based on pre-determined thresholds (e.g., real-time parking occupancy and 85th percentile travel speeds on subarea roadways).
- While systems engineering is an important part of implementing any TSMO strategy, it is especially important for many of the more advanced TSMO strategies identified for Subarea 3 that require the most stakeholder collaboration and system automation.

Performance Measurement

- Update data sharing policies and archive structure to accommodate easy data access for new stakeholders (e.g., parking facility operators, freight community).

- Continue to share data with public and private partners to support traveler information. This allows the data to be used in a variety of formats (e.g., mobile device applications that show dynamic route choice, shared mobility options, parking wayfinding, and dynamic parking pricing).
- Develop a routine performance management process for continuing improvements in operating policies, procedures, systems, and deployments. This may include quarterly performance metrics prior to regional collaboration meetings to determine if adjustments are needed anywhere where TSMO strategies are falling short of reaching the subarea's operations objectives.

Culture

- Continue to link TSMO program activities with transportation agencies' strategic plans. Finalize service-related cost-effectiveness to compare the TSMO program to other transportation programs to rationalize expansion of the TSMO program.
- Continue to hold regular meetings to ensure ongoing dialogue on integrated management activities across transportation and emergency response agencies. Include additional stakeholders as needed.

Organization/Workforce

- Train staff on operating and maintaining new systems (e.g., dynamic route choice, active parking management).
- Update database of personnel and resources across organizational units in each agency responsible for TSMO activities.
- Develop a TSMO management and organizational structure within key agencies (e.g., State DOT, city, county) equivalent to that of other major agency programs.

Collaboration

- Continue to hold regular (e.g., monthly) TSMO collaboration meetings with regional stakeholders.
- Develop working groups for TSMO strategies that require an expanded stakeholder set beyond the typical transportation and emergency stakeholders and meet regularly (e.g., quarterly, prior to a planned event, post-event). For example, a shared mobility working group may include agencies and stakeholders who operate electric vehicle charging stations and bicycle sharing stations, transit agencies, parking facility operators, and transportation network companies. Some working groups could be scheduled to meet following a regularly scheduled regional TSMO meeting to maximize attendance.

4. Implementation Considerations

The previous section focused on describing illustrative examples for planning and deploying combinations of transportation systems management and operations (TSMO) strategies in a variety of contexts. This section presents a collection of considerations for the implementation of TSMO strategies to facilitate an integrated approach to deployment and operation of TSMO strategies. The intent is to highlight critical factors in the systems engineering process that emerge when designing and deploying TSMO projects. Many of these factors can be addressed in the planning and design phases of a project.

Travelers experience the transportation system as a single entity. However, the silos created around agencies, modal networks, and service providers can result in disconnected delivery of transportation services. The essence of TSMO depends on both the integrated and active delivery of the transportation network and services. Management of the transportation network and services must be coordinated between partners, and partners must cooperatively operate the transportation system to achieve a seamless traveler experience.

SYSTEMS ENGINEERING PROCESS

The systems engineering process is a key element in successful delivery and operation of TSMO strategies. In brief, systems engineering develops processes that account for interdisciplinary issues, needs, and requirements (e.g., customer needs, user needs, reliability, logistics, testing, maintenance) to design, manage, and realize successful systems over their life cycles.[14]

GUIDING PRINCIPLES

Some guiding principles to consider when implementing TSMO strategies:

- Establish a strategy team specifically for addressing implementation factors, especially for more complex TSMO strategies.
- When implementing a TSMO strategy for the first time, consider pilot or phased deployments.
- Strategies and policies evolve over time. Maintain enough flexibility to make adjustments later.
- Measure performance of strategies and adapt them as needed.

IMPLEMENTATION FACTORS

Implementation factors to consider when implementing TSMO strategies are grouped into three categories:

- Physical factors.
- Operations and maintenance factors.
- Institutional factors.

The following tables identify common factors and associated best practices.

14 Federal Highway Administration, *Systems Engineering for Intelligent Transportation Systems*. FHWA-HOP-07-069 (Washington, DC: January 2007). Available at: https://ops.fhwa.dot.gov/publications/seitsguide/index.htm.

Implementation Factors – Physical

Physical factors include the characteristics necessary to design and build a TSMO system such as field devices, central systems, firmware/software, communications, and power connections.

Table 2. Physical implementation factors.

Category	Effective Practice
Engineering design	
Field devices	▪ Ensure proper placement of sensors, signs, and other devices. ▪ Perform traffic analysis to inform where blind spots or problem areas exist. ▪ Address maintenance access issues (e.g., avoid the need to close travel lanes to service field devices).
Structures	▪ Leverage existing overcrossings and structures to reduce cost.
Right-of-way	▪ Ensure availability of right-of-way. ▪ Confirm agency ownership. ▪ Address utilities and design conflicts.
Power connections	▪ Coordinate with electrical utility to develop connections.
Communications	▪ Ensure networks are redundant and reliable.
Central systems	
User interfaces	▪ Design a system management interface. ▪ Make data available to the private sector in an industry standard format.
Compatibility	▪ Ensure system-to-system interface compatibility.
Firmware/software	▪ Ensure firmware/software budget includes procurement and development costs.
Interoperability	▪ Use applicable intelligent transportation systems (ITS) standards for field devices and central systems.
Commissioning & testing	▪ Bench test field devices and central system integration prior to deployment to verify that the system meets requirements. ▪ Bring installed devices online to verify that and the system operates correctly in the field environment. ▪ Conduct verification and validation testing.

Note: Other physical/design considerations can be found in Federal Highway Administration, *Designing for Transportation Management and Operations: A Primer*, FHWA-HOP-13-013 (Washington, DC: February 2013). Available at: https://ops.fhwa.dot.gov/publications/fhwahop13013/.

Implementation Factors – Operations and Maintenance

Operations and maintenance factors are characteristics related to the processes and procedures needed for day-to-day operation such as agency roles and responsibilities, operating procedures, and performance measurement.

Table 3. Operations and maintenance implementation factors.

Category	Effective Practice
Preventative maintenance	▪ Institute preventative maintenance including regular inspection, monitoring, and servicing of field devices. ▪ Regularly perform software and firmware updates.
Management	▪ Provide resources to staff personnel to manage and oversee operations, as TSMO strategies are often operationally intensive. ▪ Rely on partners, especially when their resources better align with TSMO strategies that are mutually beneficial (e.g., many State departments of transportation operate 24/7 and can help after hours). ▪ Identify stakeholder roles and responsibilities and work through potential conflicts of interest. ▪ Use decision-support systems developed in advance to facilitate a faster response when events occur in real time.
Notification/ Communications	▪ Establish contact lists and clear protocols for stakeholder notification of events and communications throughout the duration of the event.
Planning for failure	
Addressing failure	▪ Automate processes to notify operators and technicians of system failures. ▪ Train maintenance staff on how to resolve issues with new equipment.
Operation during failure	▪ Develop procedures and back-up plans in anticipation of system failures.
Prioritizing repair	▪ Implement a prioritization scheme for addressing issues, since resource limitations like staffing can extend down time.
System retirement & replacement	▪ Plan for end-of-life decommissioning and replacement of the system.

Implementation Factors – Institutional

Institutional factors include the characteristics related to the legal, organizational, and behavioral roles associated with operating and managing a transportation system. These include policies, regulations, intra- and inter-agency coordination, and public-private partnerships.[15]

Table 4. Institutional implementation factors.

Category	Effective Practice
Intra-agency coordination	■ Build and develop new working relationships with other departments (e.g., information technology maintenance, operations, planning, project development, public works, community development) and others that have a stake in transportation systems management and operations (TSMO) systems.
Inter-agency coordination	■ Establish agreements (e.g., memoranda of understanding, intergovernmental agreements) between agencies. ■ Consider full realm of public agency partners such as State departments of transportation, counties, cities, townships, metropolitan planning organizations, councils of government, transit service providers, and toll authorities. ■ Consider non-traditional partners (e.g., private sector information providers, communications network providers, chambers of commerce, neighborhood associations).
Outreach	■ Educate communities and education decisionmakers about TSMO strategies to get public acceptance.
Performance measurement	■ Leverage private sector data as appropriate.
Public-private partnerships	■ Develop procedures and back-up plans in anticipation of system failures.
Data policy	■ Establish data access policies. ■ Establish data quality policies including considering how to consider how to manage failure and poor data. ■ Create data storage and archiving infrastructure policies.
Costing	■ Use the life-cycle costing process to establish a total beginning to end cost for the TSMO strategy.

15 For more information, please see Federal Highway Administration, "Welcome to the Business Process Frameworks for Transportation Operations" web page at https://ops.fhwa.dot.gov/tsmoframeworktool/index.htm.

Table 4. Institutional implementation factors. (Continued)

Category	Effective Practice
Staff capability	■ Assign responsibility for maintenance; operations and maintenance staff may be reluctant to learn new technology. ■ Train staff so they understand systems. ■ Secure resources to manage systems, devices, and programming. ■ Cross-train staff to establish clear understanding of all roles and responsibilities.
Path dependencies	■ Address path dependencies regarding equipment compatibility.
Performance monitoring & evaluation	■ Collect quality "before" and "after" data for evaluation. ■ Evaluate and report out the effectiveness of the TSMO strategies.
Establish supporting regulations for strategies	■ May need to update rules and laws (e.g., variable speed limits, part-time shoulder use). ■ Create new rules if necessary.
Procurement	■ Do not low-bid software. ■ Look for opportunities to participate in another agency's procurement.

Appendix: Menu of Transportation Systems Management and Operations Strategies

This appendix includes a listing of transportation systems management and operations (TSMO) strategies grouped by Federal Highway Administration (FHWA) operations program area. This list is not exhaustive but includes many of the TSMO strategies most commonly used. Note, there is overlap between some of the strategies. Some program areas such as work zone management and planned special event management can use many of the TSMO strategies from other program areas for those specific applications. Each program area includes a web link where more information may be found about the strategies. The main website for the operations program areas is https://ops.fhwa.dot.gov/program_areas/programareas.htm.

Traffic Incident Management (TIM)
https://ops.fhwa.dot.gov/eto_tim_pse/about/tim.htm

- TIM teams.
- TIM training.
- Post-event after action debriefs.
- Incident detection, notification, and response.
- Roadway safety service patrols.
- Computer-aided dispatch (CAD) integration.
- Dispatch co-location.
- Emergency vehicle routing.
- Pre-planned detour/alternate routes.
- Incident traffic signal timing plans.
- Pre-established towing service agreements.
- Instant or staged towing.
- Towing recovery incentive program.
- Shared quick clearance goals.
- Supporting legislation (e.g., driver removal laws, authority removal laws, move over laws).

Planned Special Events Traffic Management
https://ops.fhwa.dot.gov/eto_tim_pse/about/pse.htm

- Pre- and post-event stakeholder coordination.
- Temporary traffic control.
- Network surveillance.
- Changeable lane assignment or contraflow lanes.
- Reversible lanes.
- Enhanced traffic signal operations for special events.
- Transit management.
- Parking management.

Work Zone Management
https://ops.fhwa.dot.gov/wz/index.asp

- Maintenance and construction activity coordination.
- Queue length detection.
- Mobile surveillance.
- Temporary ramp metering.
- Portable intelligent transportation system (ITS) technology for work zones.
- Dynamic speed control.
- Dynamic lane merge.
- Work zone ITS for traveler information.
- Work zone TIM.

- Active transportation and demand management (ATDM) for work zones.
- Dynamic warning systems (e.g., queues, congestion, over-dimension vehicles, work space intrusions).

Road Weather Management
https://ops.fhwa.dot.gov/weather/index.asp

- Road weather information systems.
- Winter roadway operations.
- Weather warning systems.

Active Transportation and Demand Management
https://ops.fhwa.dot.gov/atdm/index.htm

- Active demand management (ADM).
  - Dynamic ridesharing.
  - On-demand transit.
  - Dynamic transit fare reduction.
  - Dynamic pricing.
  - Dynamic route choice.
  - Dynamic truck restrictions.
  - Predictive traveler information.
- Active traffic management (ATM).
  - Dynamic lane use control.
  - Dynamic lane reversal.
  - Dynamic merge control.
  - Temporary shoulder running.
  - Dynamic speed limits.
  - Dynamic warning (e.g., queue, road weather conditions).
  - Adaptive ramp metering.
- Active parking management (APM).
  - Dynamically priced parking.
  - Dynamic parking reservations.
  - Dynamic parking wayfinding.
  - Dynamic parking capacity.
  - Dynamic overflow transit parking.

Arterial Management
https://ops.fhwa.dot.gov/arterial_mgmt/index.htm

- Traffic management center.
- Traffic network surveillance.
- Enhanced traffic signal operations (e.g., re-timing/optimization, adaptive detection, better detection).
- Emergency vehicle preemption.
- Transit traffic signal priority.
- Queue jump lanes at signalized intersections.
- Truck traffic signal priority.
- Bicycle and pedestrian operations and safety (e.g., crossing enhancements, bicycle detection, signal timing for bicycles and pedestrians).
- Access management.
- Complete streets.
- Improved traffic control schemes.
- Added capacity for critical movements.
- Travel speed reduction.
- Automated enforcement.
- Operations asset management.

Congestion Pricing
https://ops.fhwa.dot.gov/congestionpricing/index.htm

- Congestion pricing (e.g., variable pricing by lane, segment, time of day, or day of week).
- Managed lanes (e.g., high occupancy vehicle lanes, high occupancy toll lanes).

Corridor Traffic Management
https://ops.fhwa.dot.gov/program_areas/corridor_traffic_mgmt.htm

- Traffic management center.
- Traffic network surveillance.
- Safety applications (e.g., warnings about queues, geometry (such as curves or over height/over width), intersections, animals crossing).
- Access management.
- Bottleneck removal.
- High performance transit.

Integrated Corridor Management
http://www.its.dot.gov/research_archives/icms/index.htm.

Freeway Management
https//ops.fhwa.dot.gov/freewaymgmt/index.htm

- Traffic management center.
- Traffic network surveillance.
- Ramp metering.
- Ramp closures.
- Access management.
- Automated enforcement.

Travel Demand Management
https://ops.fhwa.dot.gov/tdm/index.htm

- Traveler information marketing campaigns.
- Route planning tools.
- Shared mobility (transportation services that are shared among users such as public transit, ridesharing, carsharing, ridesourcing, or bikesharing).
- Employer trip reduction programs and commuter incentives (e.g., subsidies for transit passes, carpool, vanpool).
- Gamification.
- Rideshare/ride-matching support.
- Telecommuting.
- Congestion pricing.
- Corridor investments to support mode transfers or trip ends.
- Automobile-free or access-restricted zones.
- School transportation demand management (e.g., staggered start/end times, bus boundaries, walking school buses, school pool).
- Mass communication.
- Individualized marketing.

Real-Time Traveler Information
https://ops.fhwa.dot.gov/travelinfo/index.htm

- Local/regional multimodal traveler information.
- Roadside traveler information dissemination (e.g., dynamic message signs, highway advisory radio).
- Predictive traveler information.
- Real-time transit arrival information.
- Real-time parking availability information.
- Multimodal trip planning and routing systems.
- Smartphone applications.
- Standardized data format for third-party data providers.

Freight Technology and Operations
https://ops.fhwa.dot.gov/freight/technology/index.htm

- Roadside truck electronic screening/clearance.
- Truck traffic signal priority.
- Freight Advanced Traveler Information System (FRATIS).
- Freight loading zone policies (e.g., delivery times, designated zones, electronic parking payment systems).

Emergency Transportation Operations
https://ops.fhwa.dot.gov/eto_tim_pse/index.htm

- Emergency operations center (EOC) and transportation management center integration.
- Emergency vehicle preemption.
- Roadway closure management plan.

Public Transportation Management

- Advanced transit operations management.
- Transit signal priority.
- Queue jump lanes at signalized intersections.
- Electronic fare collection and integration.
- Transit surveillance and security.
- Multimodal travel connections.

Parking Management

- Shared-use parking.
- Incentives to use under-utilized parking facilities.
- Electronic payment systems.

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

https://ops.fhwa.dot.gov
February 2018
FHWA-HOP-18-026

U.S. Department of Transportation
Federal Highway Administration