ODOT Transportation Systems Management & Operations Plan

Setting the Stage Brief

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OHIO DEPARTMENT OF TRANSPORTATION

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December 2016
Updated December 2017

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Transportation Systems Management & Operations

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Introduction

Historically, state departments of transportation (DOT), including Ohio DOT (ODOT), have focused efforts and resources primarily on construction and maintenance activities. Limited focus and resources have been placed on daily operational needs. The Federal Highway Administration (FHWA) has highlighted, through their Office of Operations, the Fixing America's Surface Transportation (FAST) Act, and Moving Ahead for Progress in the 21st Century (MAP-21) legislation, the need for state DOTs to strategize, implement, and evaluate the integration of systems management and operations into the agency. This requires an ongoing, iterative process that evaluates strengths, weaknesses, opportunities, and threats (SWOT) within the context of other agency plans and initiatives while taking into consideration relationships and interactions with stakeholders. As technology and demands on infrastructure change and funding and resources become more strained, ODOT must be positioned to meet these challenges and increase efficiency in the existing system through operational improvements.

To this end, ODOT developed a Transportation Systems Management and Operations (TSMO) Plan. ODOT's TSMO Plan will serve as a road map to guide the Department as it continues to integrate operations, asset management, and preservation into the organization. The TSMO Plan is the basis for statewide policy and process changes aimed at increasing the focus and execution of traffic operations to better meet future system needs.

During the TSMO Plan's development, the project team conducted research into current ODOT practices related to TSMO and national best practices that ODOT may want to consider.

This technical brief is divided into four areas:

1. ODOT TSMO efforts to date
2. Three nationally recognized innovative DOT plans: Colorado DOT, Iowa DOT, and Maryland DOT
3. National best practices related to ideas ODOT has discussed
4. Resource Catalog

ODOT TSMO Efforts to Date

Many transportation professionals who are unfamiliar with TSMO assume that it refers to a new concept that makes a distinct break from conventional transportation industry practices. In fact, many of the guiding principles and recommended practices that TSMO promotes are already in use at many DOTs, including ODOT.

Prior to current efforts to develop the Department's TSMO Plan, ODOT has supported many TSMO functions on a champion-led, ad hoc basis. Some functions are well developed and considered strengths as shown by the capability maturity model (CMM) results presented in the Goals and Objectives Brief. Other TSMO activities are less developed or newly undertaken functions.

ODOT Central Office Traffic Operations is responsible for deploying, monitoring, and maintaining sophisticated ITS devices and operations software, analyzing operations data and performance measures, managing partnerships with local jurisdictions and other agencies, and participating in national research programs as part of ODOT's current TSMO activities. The ODOT Districts lead TSMO efforts in work zone management, traffic incident management, and emergency operations and are also involved in data analysis, financial management, signing and pavement markings, highway lighting, and traffic signal systems management.

The TSMO Plan will align all of ODOT's current TSMO activities into a comprehensive program. New roles and responsibilities related to TSMO, changes in organizational structure, and an expanded emphasis on operations throughout the Department will be established through the TSMO Plan. However, the building blocks of a robust, industry-leading TSMO Program at ODOT are already firmly in place.

Table 1 includes a list of 26 current ODOT TSMO functions and their descriptions. The list confirms that while TSMO as a Department-wide program and policy is new, many key TSMO functions are already part of the day-to-day operations across ODOT's Districts and Central Office.

Table 1: ODOT Existing TSMO Functions

Existing TSMO Function	Description
Active Transportation and Demand Management	ODOT is planning to open its first Hard Shoulder Running corridor as part of a Statewide ATDM study. The pilot corridor will implement Variable Speed Limits and open the inside shoulder to live traffic during the 2 to 3 hours per day that traffic is normally congested. The corridor will be operated through the statewide TMC.
Asset Management	ODOT has over $21 billion worth of assets. For years, ODOT has been using asset management principles as the foundation for its data-driven approach to managing the transportation system, employing investment strategies that have steadily improved system conditions.
Connected and Autonomous Vehicles	Ohio is emerging as a leader in developing and testing connected and autonomous vehicle (CV/AV) technologies. ODOT has an internal CV/AV working group and is part of a CV/AV Pooled Fund Study (based at University of Virginia). ODOT is a partner with Smart Columbus and the US 33 Smart Mobility Corridor; other partners include Honda R&D Americas, the Transportation Research Center at East Liberty, and The Ohio State University's Center for Automotive Research, as well as local governments.
Data Analysis/Performance Measures/Critical Success Factors (CSF)	Traffic Operations publishes monthly Work Zone and FSP reports for internal use. TSMO-related CSFs include Snow & Ice Recovery Time, Travel Time Reliability Index (TTRI), Fatalities per Year (ODOT System), Serious Injuries per Year (ODOT System), and Crashes per Year (ODOT System).
Freeway Service Patrols (FSP)	The FSP's primary focus is detecting and responding to minor incidents. FSP teams are dispatched by the TMC, and patrol vehicles are equipped with onboard video links to the TMC. Patrol teams respond to approximately 5,000 incidents per month. A partnership with State Farm covers roughly 20 percent of overall program costs.
Unmanned Aircraft Systems and Ground Based Detect and Avoid (GBDAA)	GBDAA is a ground-based means of detecting airborne traffic and providing the necessary intelligence to unmanned aircraft systems to comply with Federal Aviation Administration "see and avoid" regulations. GBDAA provides the remote pilot-in-command with the detect and avoid capability needed to maintain safe separation from other aircraft while operating beyond-visual-line-of-sight and within the remote piloted aircraft operating area.
Highway Lighting	ODOT uses AASHTO-related warrants to provide a baseline for justifying lighting design needs. Traffic Academy Training is required of consultants prequalification. District System Lighting Plans are required as part of the Traffic Engineering Manual.
Highway Safety Program	ODOT is a leader in highway safety as an early adopter of the Highway Safety Manual and associated Safety Analyst software.
ITS Architecture/Systems Planning	Central Office lead development and updates to Statewide ITS Architecture. Districts are involved with developing regional ITS Architecture as a primary stakeholder.
Qualified Products/Purchasing and Contracts MOUs/Specs/Standards	ODOT has established business processes for adding items to the Qualified Products List/Traffic Authorized Products List.

Table 1, continued

Existing TSMO Function	Description
QuickClear and Emergency Operations	Ohio TIM is an ODOT-led multi-agency traffic incident management program that provides for the safety of responders and motorists and adds economic benefit by keeping traffic and commerce moving.
Ramp Meters	ODOT is responsible for maintaining and monitoring roughly 35 ramp meters on entrance-ramps along freeways in Columbus and Cincinnati. ODOT uses a traffic responsive plan for long corridors to minimize the level of congestion throughout the entire corridor. For areas with no vehicle radar detection, a time of day schedule is implemented during peak hours. ODOT uses software that displays the status of ramp meters and allows for remote control.
Research Programs and Pooled Fund Studies	ODOT participates in pooled fund studies, including the National Transportation Product Evaluation Program, the Transportation Pooled Fund Program and MAASTO Tiger Grant Truck Parking project, TMC and CV/AV pooled fund studies.
Signing and Pavement Marking	ODOT is responsible for signing and pavement marking on over 6,700 Interstate lane miles, over 8,000 miles of US Routes in unincorporated areas, and approximately 25,000 lane miles of State Routes in unincorporated areas. Central Office publishes the Ohio Manual of Uniform Traffic Control Devices which is in substantial conformance with the MUTCD published by FHWA. ODOT is working on installation of horizontal alignment warning signs, advisory speed plaques, and chevron and one-direction large arrow signs along all freeways, expressways, arterials, and collectors with more than 1,000 Average Daily Traffic (ADT). In 2016 ODOT's nationally renowned sign shop sold 73,600 signs totaling $1.8 million to Districts. It met 91 percent of maintenance orders within 17 days and all rush orders within five days.
SHRP2 - Organizing for Reliability	ODOT used Strategic Highway Research Program 2 funding to conduct a Scan Tour of other state DOTs. Findings were summarized in a report that describes staffing and organizational structure, operations programs, and performance measures of other state DOTs and provides benchmarks and best practices for ODOT to follow as it implements TSMO department-wide.
Snow and Ice Operations	ODOT uses over 1,600 plow trucks, 3,000 employees, and 650,000 tons of salt stored at 200 locations around the state for snow and ice removal. In total, snow and ice control can comprise 40-45% of the annual operating expense with approximately $50 million spent annually on labor, equipment, and materials.
Statewide ITS Device Maintenance	Approximately 1,221 sites with a total of roughly 3,000 devices (DMS, DDMS, Ramp Meters, Queue Warning Systems, HAR transmitters, HAR Beacons, vehicle detection stations, and CCTV) centrally maintained by a limited group of highly skilled staff.
Statewide Network Maintenance	Weather forecasting/RWIS uses real-time conditions to direct resources during winter weather, shifts local resources as needed during snow and ice operations or major traffic incidents, and uses low cost equipment to help make roadways more reliable. A route optimization project is taking a "no boundaries" look at ODOT maintenance and equipment to provide the most efficient customer service.

Table 1, continued

Existing TSMO Function	Description
Traffic and ITS Plan Review	Central Office provides plan review support to Districts.
Traffic Management Center	The Traffic Management Center (TMC) operates traffic management and traveler information systems on ODOT managed freeways. Dedicated operators monitor traffic in each major metropolitan area across the state. The TMC has a 24/7 facility for managing freeway traffic across the state located in Columbus at Central Office. The TMC also provides coordination for Traffic Incident Management activities.
Traffic Management Software and Applications	ODOT's Buckeye Traffic Management Software was developed in house and feeds into ODOT's public-facing OHGO app. The OHGO app has 31,000 unique users who have created 9,911 personal routes. OHGO.com has received over 8.3 million unique hits since October 2013. In addition, ODOT's 511 service has received 14,000 calls totaling 19,000 minutes. ODOT conducts regular cybersecurity security assessments and is working towards a separate network/firewall for Buckeye Traffic and specialized operations software. Location Finder helps motorists more accurately identify their location using ODOT's Linear Referencing System and mile markers. Internally focused mobile apps support various operations such as Work Zones.
Traffic Signal System Management	ODOT has dedicated funds for retiming activities, owns 1,460 signals, three central system software packages, and has multi-jurisdictional signal management strategies. ODOT has remote communications to approximately 55 percent of signals, with 125 Signal Systems statewide covering 696 individual traffic signals. ODOT also has a Signal Design Reference Packet and a signal electrician training program.
Traffic Signal Timing and Phasing Programs	Traffic Operations re-times over ten ODOT-maintained corridors annually. In 2014, the program saved $30 million in traffic delays and $2.5 million in crash reductions. This program is also extended to Locals, and ODOT has dedicated funding to assist Locals with the purchase of upgraded equipment to maximize the re-timing efforts.
Training	Traffic Academy Training for consultant prequalification covers a number of the above functions, including Traffic Safety Operations Engineering, Traffic Signals, Signing and Pavement Markings, Traffic and ITS Plan Reviews, Highway Lighting, and Work Zone Management.
TRIP Program	The nationally renowned Towing & Recovery Incentive Payment (TRIP) Program pays prequalified heavy-duty towing and recovery companies incentives for the quick clearance of large commercial vehicle incidents on selected, high-importance Ohio roadways.
Work Zone Management	ODOT uses several TSMO strategies in its work zones, including variable digital work zone speed limit signs, semi real-time crash reporting and performance measures, tools for assessing work zone delays, permitted lane closure map, and Maintenance and Traffic Alternative Analysis.

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Three Nationally Recognized Innovative TSMO Plans

Three plans recognized at the national level for being innovative were evaluated and recommendations have been developed related to practices that could benefit ODOT. The three documents evaluated are:

- Colorado DOT Transportation System Management & Operations Reorganization Report, 2013
- Iowa DOT TSMO Strategic and Program Plans, 2016
- Maryland Transportation Systems Management & Operations, Strategic Implementation Plan, 2016

Colorado DOT (CDOT) Transportation System Management & Operations Reorganization Report, 2013 (Figure 1)

Background

The CDOT Reorganization Report is often held up within the broader TSMO community as an example of how a DOT can organize to better address traffic operations. CDOT went through one of the most dramatic reorganizations of any state DOT to date to place a significant emphasis on TSMO. The sections below highlight the report findings.

CDOT recognized the need to realign and consolidate operations, due to a variety of factors including increased federal focus, limitations in funding, projected growth in population and traffic, greater demand on the transportation system, and rapid changes in technology.

Evolving Operations Culture within CDOT

CDOT created a variety of strategic business processes to start integrating TSMO throughout the organization:

- Management Commitment and Champions
- Measure the System
- Develop Priorities for Improving Operations
- Implement programs, dedicate funding, establish policies and procedures, and establish organization teams to achieve operations priorities
- Measure, monitor, and market the effects of the program

The recommendations from the report, many of which have been instituted, have thoroughly integrated TSMO across the organization:

Figure 1: CDOT TSMO Plan

- Provide a systematic and integrated approach to TSMO within CDOT, including an expanded system engineering analysis process whereby projects, initiatives, installations, and implementations require clearance and approval from the newly created Division of TSMO. Each project is evaluated for safety, operations, and ITS needs.
- Provide continued support to the Regions.
- Consolidate operations to provide integrated freeway and arterial operations as shown in **Figure 2**. A number of regional positions were pulled under the Division of TSMO. For example, regional ramp meter staff were assigned to the TSMO Division. The traffic operations staff for the Eisenhower Johnson Memorial and Hanging Lake Tunnels were moved to the TSMO Division. Also, several units within the TSMO Division were created including Corridor Management, Incident Management, and Event Management.
- Transportation Demand Management activities were pulled into the TSMO Division.
- The TSMO Division is responsible for supporting asset management needs within the context of broader Departmental initiatives.
- The TSMO Division is responsible for developing and maintaining operational performance measures in coordination with the Division of Transportation Development Performance Measures Branch.
- Hire an Innovation and Technology Manager to help improve productivity and efficiency throughout the new TSMO Division.

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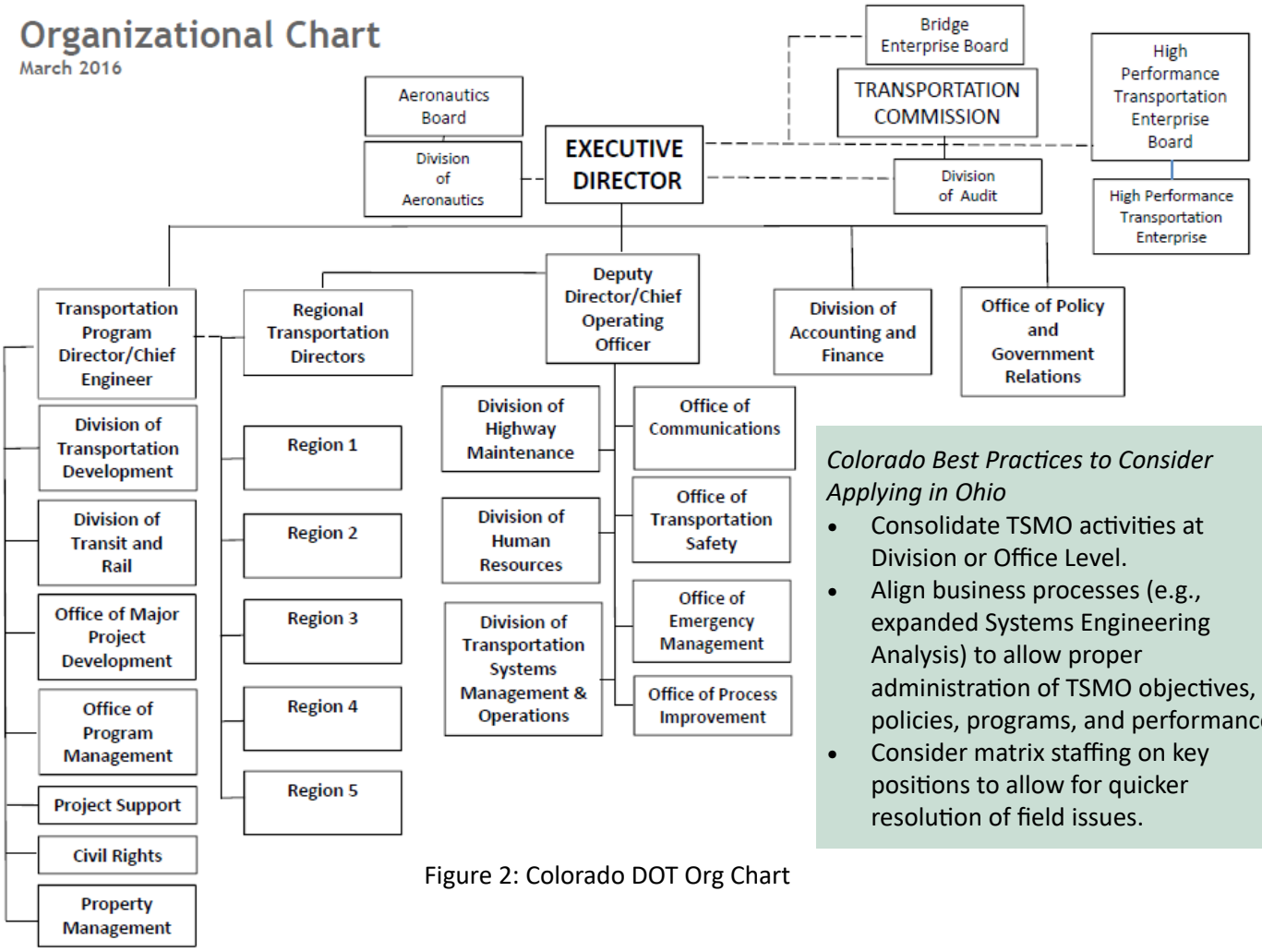

Colorado Best Practices to Consider Applying in Ohio

- Consolidate TSMO activities at Division or Office Level.
- Align business processes (e.g., expanded Systems Engineering Analysis) to allow proper administration of TSMO objectives, policies, programs, and performance.
- Consider matrix staffing on key positions to allow for quicker resolution of field issues.

Figure 2: Colorado DOT Org Chart

- An MOU was developed between the Chief Engineer and the Director of the TSMO Division to clarify roles, relationships, and responsibilities of various staff responsible for delivering TSMO objectives, policies, programs, and performance.
- There was an assessment completed to determine whether any maintenance staff would need to report to the TSMO Division through a matrix type organization.

Investment Commitments

CDOT made a number of strategic investment commitments to back up the proposed recommendations including:

- Engaging customers more frequently to understand their evolving needs and expectations.
- Leverage technology that has a high return on investment.
- Fill positions so TSMO Division is fully functional.
- Provide training to staff so they are prepared to deliver the objectives, policies, programs, and performance of the TSMO Division.
- Develop a dedicated budget to administer and effectively implement statewide operations.

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Iowa DOT TSMO Strategic and Program Plans, 2016 (Figure 3)

Background

Iowa and Maryland were based on the model TSMO Plan suggested in NCHRP Project Number 20-07/345, Program Planning and Development for TSMO in State Departments of Transportation. Several categories were assessed:

- Mission, Vision, Goals, Objectives, and Performance Measures
- Leadership and Organization (including Integration, Coordination, and Collaboration)
- Business Processes
- Resources (Financial, Human, Infrastructure, Technology)
- Packages of Services, Projects, and Activities with Related Policies and Guidelines

Iowa DOT leveraged resources made available through FHWA to support TSMO Implementation to develop its first TSMO Plan in 2015 and completed in early 2016. Due to the specific audiences, Iowa DOT's approach was to develop three levels of plans as shown in **Figure 4**. The Strategic Plan was geared towards decision makers and provided the Business Case for TSMO in Iowa. The Program Plan was geared towards middle management, who will likely be responsible for delivering the plan recommendations.

Eight Service Layers were identified as areas Iowa DOT wants to develop more detailed plans:

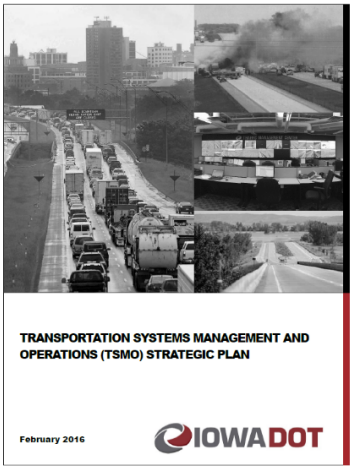

Figure 3: Iowa DOT TSMO Plan

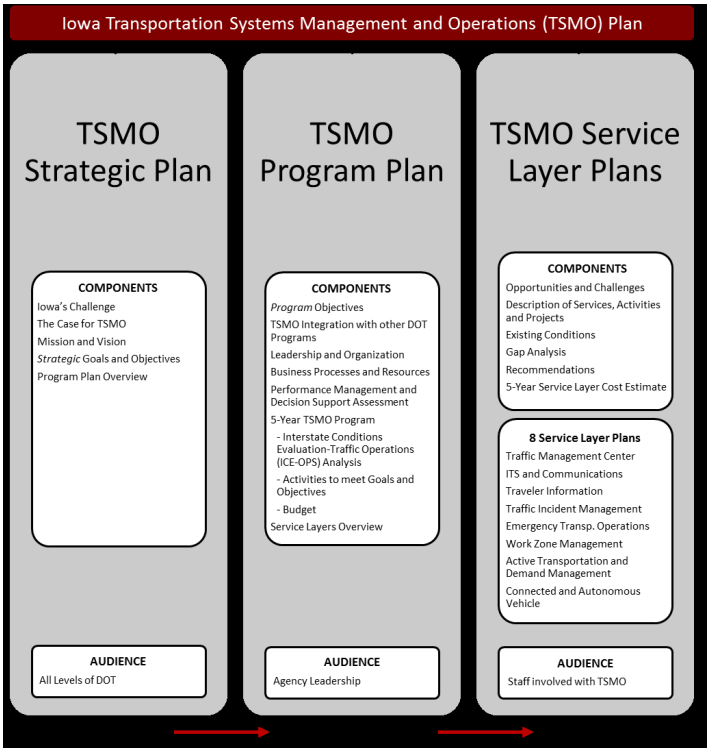

Figure 4: Iowa DOT TSMO Plan Structure

- Traffic Management Center
- ITS and Communications
- Traveler Information
- Traffic Incident Management
- Emergency Transportation Operations
- Work Zone Management
- Active Transportation and Demand Management
- Connected and Autonomous Vehicle

The ITS and Communications, Traffic Incident Management, and Travel Information Service Layers are in the process of being completed and anticipate completion in late Spring 2017.

Mission, Vision, Goals, Objectives, and Performance Measures

Mission: To get you there safely and reliably by proactively managing the transportation system.

Vision: Iowa's transportation system is safe, efficient, and reliable, supporting the state's environmental and economic health as a result of TSMO.

Goals, Objectives, and Performance Measures are shown in **Table 2** on the following page. Iowa DOT developed two focus groups to test the goals and objectives. One group was made up of highway operations partners including associations that represent law enforcement, fire, EMS,

Table 2: Iowa DOT Goals, Program Objectives and Performance Monitoring Sources

Goal	Program Objective	Monitoring Sources	TSMO Program	Associated Service Layers
Safety	Reduce the number of overall major crashes.	State crash records maintained by Traffic and Safety	X	
	Reduce the number of secondary crashes caused by traffic incidents.	Traffic Incident Response Measures		TIM
	Reduce the number of work zone related traffic incidents.	Work zone crash statistics maintained by the Office of Construction and Materials. Other related measures tracked in TCP Measures.		WZM
Reliability	Improve travel time reliability.	ICE-OPS uses the planning time index as a measure of reliability	X	
	Increase the resilience of the transportation system to floods, winter weather, and other extreme weather events.	Measures and monitoring needed		ETO
	Work with special event generators to actively manage traffic during large scale events that impact the highway network.	Measures and monitoring needed. ICE-OPS uses a measure to determine potential special event impacts.		TMC, ATDM
Efficiency	Improve level of service on major freight corridors.	Interstate Condition Evaluation (ICE) tracks major freight corridor bottlenecks. Real-time measures needed for TSMO.		ATDM
	Maximize use of existing roadway capacity	Incident related delay monitored in Traffic Incident Response Measures		TMC, ATDM
	Establish Network Level Priorities for managing traffic.	Hierarchy of operations important based on facility type defined in TSMO Program Plan		TMC, ATDM
	Respond to and clear traffic incidents as quickly as possible.	Incident related delay monitored in Traffic Incident Response Measures		TIM
	Minimize the environmental impacts of the transportation system.	Measures and monitoring needed	X	
Convenience	Provide timely, accurate and comprehensive information to customers.	TMC Activity Performance Measures monitor calls and notification distribution. Additional measures and monitoring needed to measure accuracy.		TI
	No unplanned road closures or restrictions due to conditions within Iowa DOT's control.	Incident related closures monitored in Traffic Incident Response Measures. Additional measures and monitoring needed to log unplanned road closures or restrictions.		TIM, WZM, ETO
	Provide high quality, machine ready data in open formats.	Measures currently logged in Traveler Information Measures		TI
	Accommodate bike, pedestrian, transit and commercial vehicle in TSMO.	Measures and monitoring needed		TMC, WZM
Coordination	Lead Statewide and Regional Traffic Incident Management Program activities.	Measures and monitoring needed		TIM
	Coordinate responses to large scale traffic incidents with adjacent states.	Measures and monitoring needed		TIM, ETO
	Provide staff knowledge and management resources to enable adaptation to rapidly changing technology.	Measures and monitoring needed		ATDM, CAV
Integration	Integrate TSMO into existing Iowa DOT Policies and Procedures.	Measures and monitoring needed	X	
	Develop standards-based systems, rooted in geospatial technologies, to improve performance management and decision support systems.	Measures and monitoring needed		TMC, ITS, ATDM, CAV
	Use integration and big data mining strategies to improve performance management and business intelligence.	Measures and monitoring needed	X	
	Implement integrated corridor management strategies to manage traffic across multiple jurisdictions.	Measures and monitoring needed		TMC, ITS, ATDM

towing, and contractors. The other focus group was made up of stakeholder groups that rely on well-operated highways such as AAA, trucking associations, chambers of commerce, and tourism groups.

Leadership and Organization (including Integration, Coordination, and Collaboration)

Nearly 20 detailed recommendations were provided to improve TSMO related Leadership and Organization based on best practices cited in NCHRP 20-7/345:

- Department-wide integration of TSMO concepts and principles.
- Development of an organizational unit(s) with lead responsibility for TSMO.
- Relative responsibilities of headquarters and region/ district offices.
- Responsibilities for TSMO deployment planning.
- Interaction with external stakeholders, expanding coordination and collaboration to enhance existing relationships and building new partnerships.

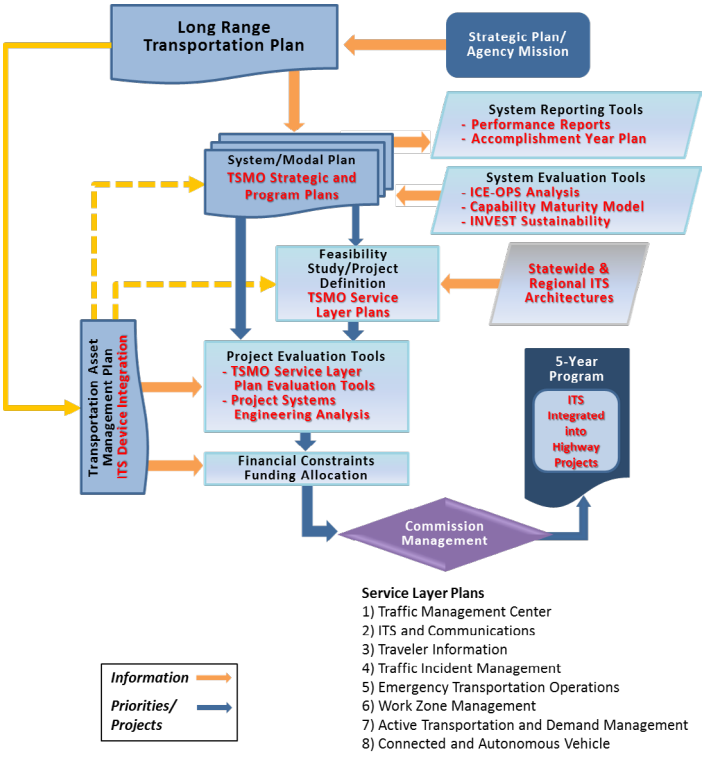

Figure 5: Integration of TSMO into overall transportation planning process

- Reducing organizational dependence on champions and sponsors.

A good example of one recommendation that has moved forward is the integration of TSMO into long range transportation planning activities. **Figure 5** highlights how TSMO activities have been superimposed on the Iowa Transportation planning process.

Business Processes

A number of business processes were suggested to be modified or enhanced to integrate TSMO into Departmental activities. One area that was being developed over the last three years is the Traffic Critical Projects (TCP) initiative. On an annual basis, Iowa DOT assesses all of its work zones for potential queuing and other operational issues. Based on a variety of criteria, the work zones forecast to create the most significant issues with several strategies employed include:

1. If a work zone is within a region that has an existing Traffic Incident Management (TIM) Plan, the plan is updated to reflect the work zone.
2. If outside area with a TIM Plan, a stand-alone TIM Plan is created.
3. Work zones expected to have long delays are equipped with Intelligent Work Zone (IWZ) monitoring to provide advance queue information to motorists.

Iowa DOT made several investments to make the TCP program work better including securing an on-call IWZ contractor to move equipment around the state as needed. The Department also modified its ATMS software so the IWZ equipment automatically shows up at the TMC as it is turned on and off. Lastly, Iowa works closely with Iowa State University to provide ongoing evaluation services.

Resources (Financial, Human, Infrastructure, Technology)

Similar to Ohio, planning for resources occurred on a very ad hoc basis and at best looked out two years. New processes have been established to synchronize traffic operations budgeting activities with the 5-Year Highway Improvement Plan. The longer-term approach allows the Department to better forecast when additional resources are needed,

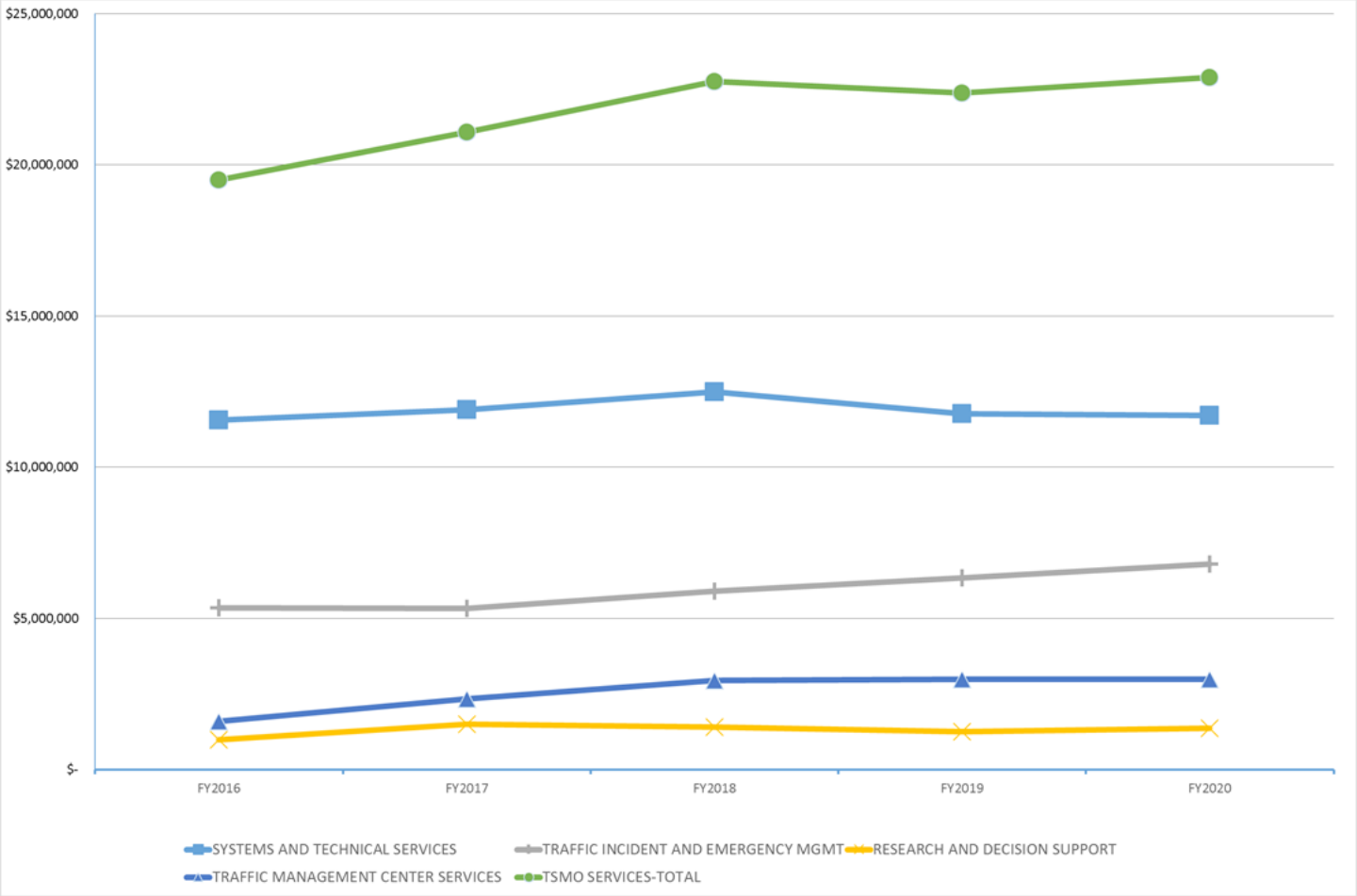

Figure 6: Iowa 5-Year cost for TSMO Services

whether it's related to the ITS portion of a large construction project, replacing high-cost ATMS software, or preparing for life cycle replacement of equipment that has exceeded its useful life. **Figure 6** highlights the five-year cost projection for TSMO services (there is another graphic for stand-alone ITS Projects and highway improvement projects with ITS).

Iowa also worked closely with Systems Planning to develop a tool that helps identify operationally sensitive roadway segments. It leveraged a recently completed tool that was used to help prioritize corridors throughout the state based on more traditional measures such as bridge condition, roughness index, etc. A number of operational measures were leveraged to develop a tool called ICE-OPS. The measures are as follows:

- All Bottleneck Occurrences per Mile (Weighting: 10 percent).
- Freight Bottleneck Occurrences per Mile (Weighting: 10 percent).
- Traffic Incident Frequency per Mile (Weighting: 15 percent).
- Crash Rate (Weighting: 15 percent).
- Planning Time Index (PTI) as a measure of reliability (Weighting: 10 percent).
- Event Center Buffer Index recognizes the impact to operations of special events (Weighting: 5 percent).
- Weather Sensitive Corridor Mileage based on ongoing winter research and flooding records (Weighting: 10 percent).
- Average Annual Daily Traffic (AADT) (Weighting: 20 percent).
- Interstate Condition Evaluation (ICE) Rating (Weighting: 5 percent).

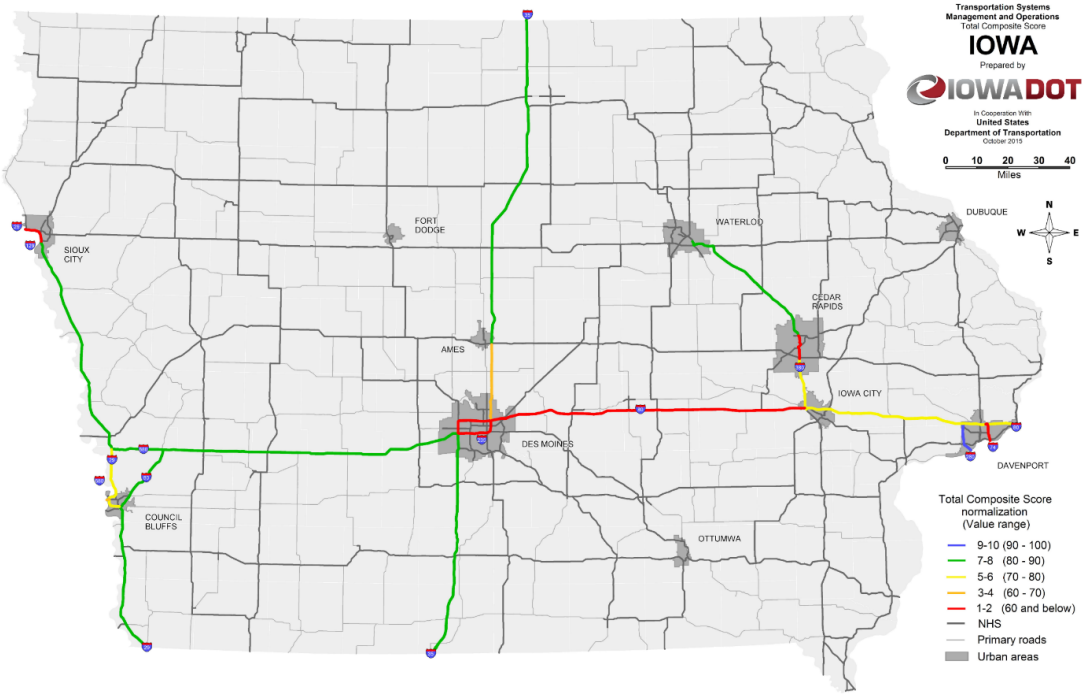

Figure 7: Iowa DOT ICE-OPS Analysis

After weighting the criteria and completing the GIS analysis, the map shown in **Figure 7** was created to assist in prioritizing future investments.

Packages of Services, Projects, and Activities with Related Policies and Guidelines

In addition to estimating TSMO services and project costs over a five-year period, the activities required to advance TSMO at Iowa DOT were also defined by a variety of categories:

- Staffing and Expertise.
- Budgeting, Accounting, Procurement and Contracting.
- Project Programming.
- Systems Engineering.
- Collaboration with External Partners.
- Programmatic and Administrative Support.
- Sustainability and Resiliency.
- Communications, Marketing, and Outreach.
- Data Management and Geographic Information Systems (GIS).
- Continuous Improvement.
- Research and Development.

Recent Implementation Activities

As Iowa DOT completed the initial TSMO Plan, the FHWA resource Center assisted in helping to plan two meetings. The first was an Executive Engagement Briefing where the DOT Director and FHWA Division office worked together to highlight the importance of the plan to other senior managers. The second meeting was called the TSMO Launch Workshop, an all-day event geared towards middle management where best practices were shared from around the country and break-out groups were allowed to provide initial comments on the direction of the Service Layer Plans. Task forces were also formed to look at how Iowa could start integrating TSMO into the culture of the organization.

Iowa Best Practices to Consider Applying in Ohio

- Establishment of a five-year program that includes Services, Projects, and Activities.
- Dedicate funding and resources to TSMO.
- Develop an Ohio operations analysis tool.
- Determine where the TSMO falls within the hierarchy of Departmental planning activities.
- Partner closely with universities to provide ongoing support for skills that aren't readily available in the Department (e.g., complex statistical analysis, data archiving, big data analysis, simulation, etc.)
- Integrate intelligent work zone equipment into the TMC and Buckeye Traffic.

Maryland Transportation Systems Management & Operations, Strategic Implementation Plan, 2016 (Figure 8)

Background

Maryland's definition of TSMO is an integrated approach to programmatic optimization of planning, operations, and maintenance in implementing new and existing multi-modal systems, services, and projects to preserve capacity and improve the security, safety, and reliability of our transportation system.

Mission, Vision, Goals, Objectives, and Performance Measures

Mission: To establish and maintain a TSMO Program and implement supporting projects within Maryland Department of Transportation State Highway Administration (MDOT/SHA) improving mobility and reliability for all people and goods through planned operations of transportation facilities.

Vision: Maximize mobility and reliable travel for people and goods within Maryland by efficient use of management and operations of transportation systems.

Goals and Objectives

Figure 9 on the following page highlights the Goals and Objectives developed as part of the Maryland TSMO Plan. Many of the objectives have specific dates associated with them. Another unique objective relates to setting a target of at least $1 billion user cost savings annually by effective congestion management and TSMO.

There were minimal details offered in the form of performance measures, other than one of the objectives which identified the need to develop a TSMO Program Performance Monitoring System. Several strategies and action items related to performance measures were highlighted throughout the Implementation Plan.

Figure 8: MDOT TSMO Plan

Leadership and Organization (including Integration, Coordination, and Collaboration)

Under the proposed reorganization, MDOT/SHA took a unique organizational approach to better accommodate TSMO as shown in **Figure 10** on the following page. A TSMO Executive Committee is chaired by the SHA Administrator. The Deputy Administrator, Office of Planning and Preliminary Engineering, and the Deputy Administrator, Operations are responsible for the TSMO Program Manager and the agency Offices working to achieve the strategic, programmatic, and institutional integration required to carry out the TSMO Program. The TSMO Program Manager provides overall support to the TSMO Executive Committee and has day-to-day responsibility for working with the Office Director TSMO representatives and the Deputy Administrators to carry out the TSMO Strategic Implementation Plan and the overall TSMO Program.

Business Processes

A number of business process improvements were recommended as strategies throughout the Implementation Plan:

- Identify and implement means of incorporating TSMO planning and evaluation methods into relevant agency policies.
- Determine current and future TSMO improvements and strategies that should be included in the planning

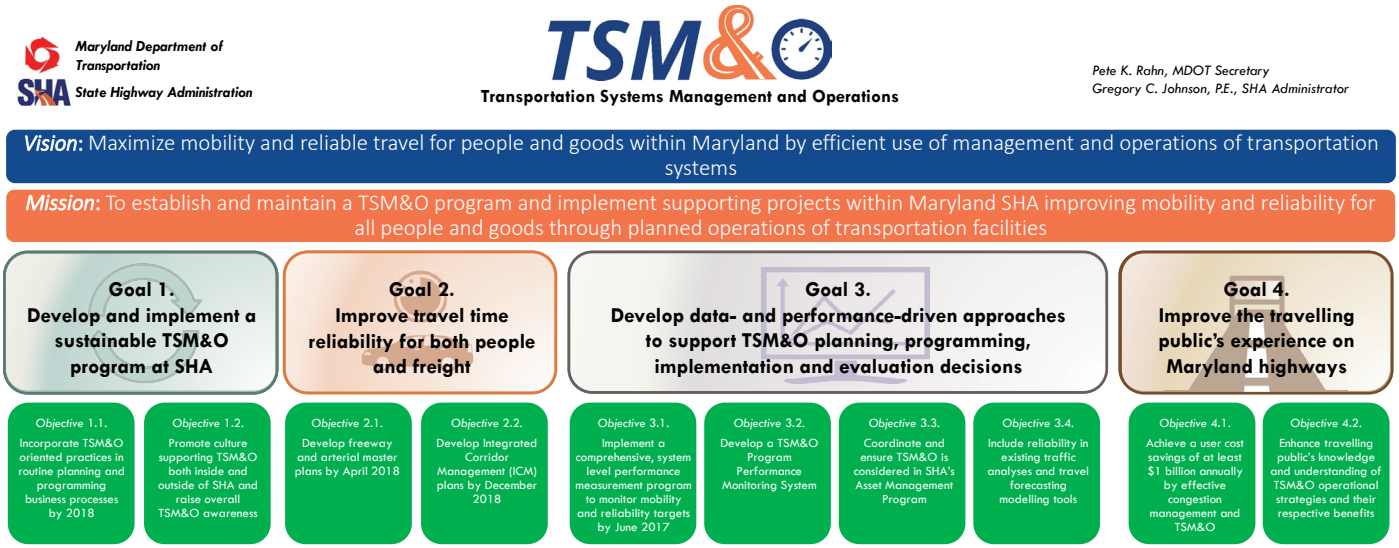

Figure 9: Maryland Goals and Objectives

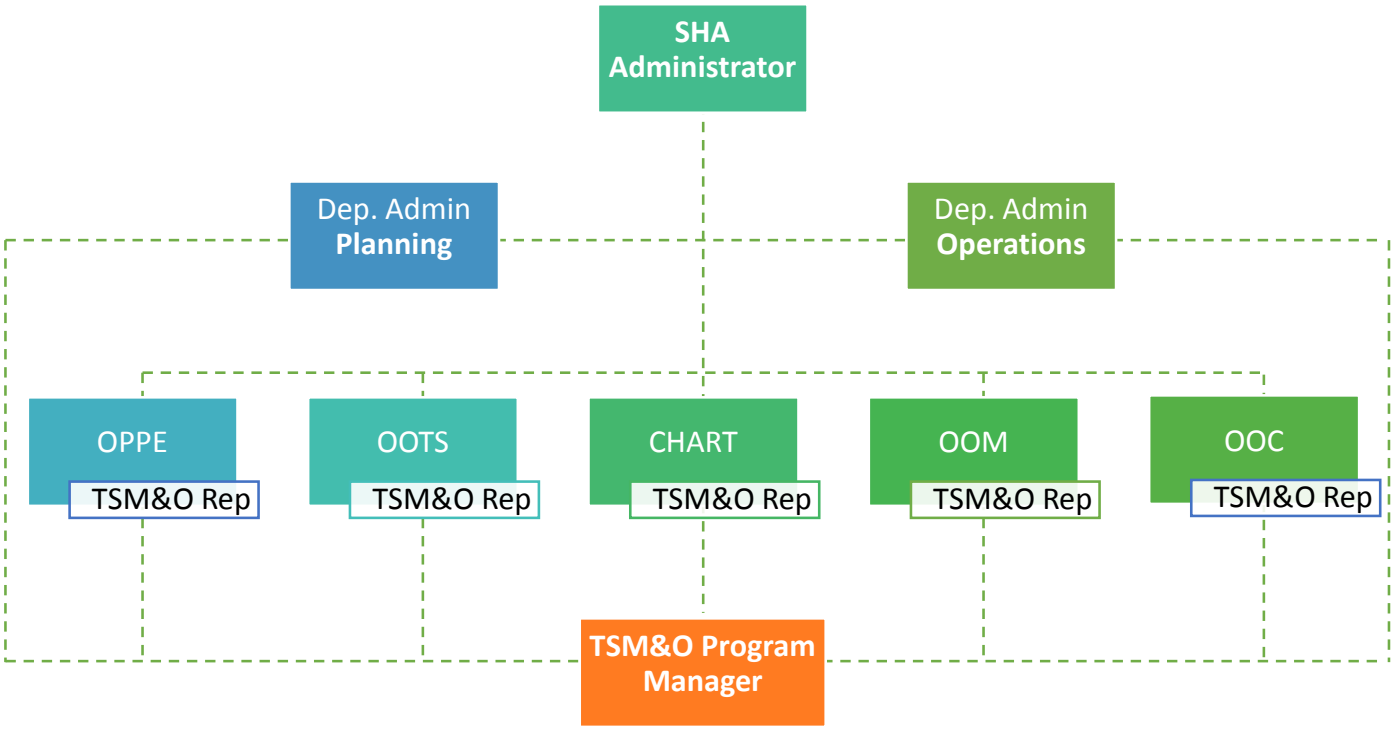

Figure 10: Proposed Maryland TSMO Organization

process and estimate their relative effectiveness in responding to the specific causes of recurring and non-recurring congestion.

- Develop modifications to the SHA Project Development Process (PDP) to accommodate TSMO.
- Develop a comprehensive ITS asset management process.
- Establish a framework for an institutionalized approach to support funding and deployment of operational improvements (including those targeting freight movement) on freeways and arterials.
- Develop modeling tools that effectively incorporate travel time reliability and can be used as a framework for evaluating trade-offs of TSMO operational strategies.

Resources (Financial, Human, Infrastructure, Technology)
For each strategy a sheet similar to **Figure 11** was developed highlighting:

- Responsible offices
- Resources needed
- Schedule
- Dependencies on other strategies
- Existing plans associated with strategy
- Action Items' Deliverables
- Anticipated Outcomes

Figure 11: Maryland TSMO Implementation Road-map Sample

Task Name	2016				2017				2018				2019			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Goal 1: Develop and Implement a sustainable TSM&O program at SHA																
Objective: 1.1. Incorporate TSM&O oriented practices in routine planning and programming business processes by 2018																
Strategy: 1.1.a .Identify and implement means of incorporating TSM&O planning and evaluation methods into relevant agency policies																
1.1a.I. Evaluate the inclusion of reliability in MDOT mission, vision, and strategic plans.																
1.1a.II. Develop a policy and procedure for TSM&O – Draft policy statement needs to address establishing TSM&O structure (office/functional area responsibilities). The procedure will include an institutional framework for TSM&O – including roles for steering and executive committees.																
1.1a.III. Incorporate planning for operations in all processes within SHA - Maryland Transportation Plan 2035 and SHA Business Plan																
1.1a.IV. Identify methods for evaluating capacity vs. TSM&O options considering: service issues, network scale, time to implement, incremental improvement options capital operating and maintenance costs, cost-effectiveness related to relevant performance measures																
Strategy: 1.1b. Determine current and future TSM&O improvements and strategies that should be included in the planning process and estimate their relative effectiveness in responding to the specific causes of recurring and non-recurring congestion																
1.1b.I. Identify strategies for implementing TSM&O improvements at various scales: area-wide, corridor, and facility-specific. These could include: Ramp Metering, Advanced Traffic Management, Work Zone Management, Arterial Management, Variable Speed Limits, Hard Shoulder Running, Managed Lanes, etc.																
1.1b.II. Document the SHA project programming process																
1.1b.III. Determine how to get projects in the range of $1 - $3M projects programmed, develop a systematic approach to including these types of projects in routine programming processes.																
1.1b.IV.Develop a process for benefit cost comparison of projects across the state (as opposed to current approach to comparing projects along the same facility)																

Packages of Services, Projects, and Activities with Related Policies and Guidelines

Maryland developed a road-map over the next four years that highlights the general order of activities to be performed as shown in **Figure 11** based on the action items developed for each strategy. **Figure 12** shows a sample profile sheet for one of Maryland's TSMO goals, similar to the one-page profile sheets in ODOT's TSMO Plan's Policy Action Brief.

Maryland Best Practices to Consider Applying in Ohio

- Establish matrix position(s) similar to TSMO Program Manager that has ability to cross organizational boundaries.
- Develop dependencies to highlight the order in which implementation activities need to be accomplished.
- Elevate TSMO responsibilities to the highest levels of the organization.
- While not explicit in the Implementation Plan, Maryland has been a leader in University partnerships. The relationship between MDOT/SHA and the CATT Laboratory at the University of Maryland, College Park is a model DOT/University partnership that transcends the traditional role of a research university and includes a variety of services that DOTs have traditionally had a difficult time hiring staff to perform (e.g., software development, advanced statistical analysis, data archiving, emerging technology evaluation, etc.)
- Develop modifications to the project development process (PDP) to accommodate TSMO.
- Comprehensive ITS asset management process.
- Develop modeling tools that effectively incorporate travel time reliability and can be used to provide a framework for evaluating trade-offs of various TSMO operational strategies.

National Best Practices Research

The project team researched national best practices related to programs and ideas discussed by ODOT during interviews, workshops, and TAC meetings. The following section provides a summary related to NCHRP guidance and other DOT and regional programs considered best practices. These were chosen because they have a direct relation to an ODOT objective or contain elements that ODOT is interested in exploring.

Figure 12: Sample Maryland TSMO Implementation Plan by Strategy

Summary of "Program Planning and Development for Transportation System Management and Operations (TSMO) in State Departments of Transportation", NCHRP Project Number 20-07/345

The research objective of Task 345 was to develop recommendations for the practice in TSMO Program planning on a strategic, program-level for state DOTs. Various resources ranging from literature reviews, scans of DOT websites, interviews with regional planning agencies/MPOs, and a two-day DOT senior manager workshop with regional and state agency representatives helped to develop recommendations. Based on the researchers' findings, detailed observations on the state of practice were compiled into five different categories:

1. Mission, Vision, Goals, Objectives, and Performance Measures
2. Leadership and Organization (including Integration, Coordination, and Collaboration)
3. Resources (Financial, Human, Infrastructure, Technology)
4. Business Processes
5. Services, Projects, and Activities

These five categories comprise the recommended framework for the development of TSMO Program planning. Below is a brief discussion on the researchers' observations and recommended framework for each of the five categories.

1. Mission, Vision, Goals, Objectives, and Performance Measures

Observations

Although there is not a significant shift towards system management and operations in the reviewed departmental mission/vision statements, some DOTs have adopted a few goals and objectives that focus on system management and operations. Most of the same DOTs have adopted TSMO-related performance measures. Additionally, there seems to be disconnect between department-level strategic planning and TSMO Program planning and development. Most TSMO efforts have focused internally on a DOT organizational vision, not a statewide vision that would be beneficial for all TSMO stakeholders.

Recommended Framework

TSMO Program Plans should be created to align with and support the vision, mission, goals, and core values of the DOT at the department level as well as for key units within the department. Management and Operations stakeholders and planners must work together to define a common vision for transportation system operations at the state, regional, and local level, develop operations objectives to guide the selection of Management and Operations strategies, and identify performance measures that will enable them to track progress toward their objectives.

2. Leadership and Organization

Observations

Much of the success of TSMO is attributed to particular champions or sponsors that were forward thinkers and able to overcome resistance to change. However, there are still many policymakers and organizational leaders that lack enthusiasm for TSMO efforts. Most feelings of apathy are related to skepticism about benefits, indifference, and a general sense that TSMO is a second-best approach to capital improvement projects.

In order to achieve effective coordination, DOTs must work to clarify the separate and shared responsibilities of "headquarters" and "regions/districts" to improve effectiveness of processes. Informal coordination and good working relationships built around personal contacts is not enough to ensure effective interaction between the two units. DOTs must work toward creating formal TSMO coordinating committees that include representatives from both headquarters and regional/district offices. In addition to internal coordination, coordination with external partners such as law enforcement and other public safety agencies is imperative to the success of TSMO.

Recommended Framework

TSMO Program Plans should ensure leadership and organizational responsibilities are well defined. Through the planning process, stakeholders should have the opportunity to be heard on issues such as development of responsibilities of headquarter and region/district offices; expanding coordination and collaboration to enhance existing relationships and building new partnerships; and department-wide integration of TSMO concepts and principles.

3. Resources (Financial, Human, Infrastructure, and Technology)

Observations

It is no secret that the strain on DOT budgets is reducing the number and size of major capital improvement projects. As a result, TSMO-related activities are forced to compete with other programs and priorities, and in some cases DOTs are forced to make cuts across-the-board. This may not only affect human resources, but the technology and infrastructure resources needed to carry out TSMO projects,

services, and activities as well. In order to help policy-level officials realize the higher benefit-cost ratio of TSMO proposals as compared to capital projects, more effort is needed to develop new tools for economic evaluation of alternatives.

Recommended Framework

During the program planning process, the available and needed resources to support all aspects of the TSMO Program should be evaluated and described in the TSMO Program Plan. In addition, the plan should also include strategies to improve the availability and effective use of all resources. It is likely that some of the "Resource" issues will overlap with "Business Process" issues. These areas of overlap require diligent intra-departmental coordination that involves interaction with DOT and state government offices.

4. Business Processes

Observations

"Planning" and "programming" were perhaps the two business processes discussed the most through the research process. More DOTs are working toward integrating TSMO into the ongoing long range transportation planning processes carried out by planning divisions. However, more effort to establish closer working relationships between "operations" and the "planning" divisions is needed in order for the integrated plans to influence budgets, allocation of other resources, and day-to-day decision making. "Budgeting and accounting" is another key business process that typically relies on informal arrangements for support from multiple line items rather than a predictable line item in the DOT budget. Unfortunately, current budgeting methods for TSMO are not conducive to effective decision making or financial planning. Although not an established TSMO business process, there is a need for "Communication, Marketing, and Outreach" to better educate policymakers, organizational leaders, and the public on the benefits of TSMO Program Plans.

Recommended Framework

TSMO Program Plans should follow a three step process to ensure TSMO success:

1. Identify the most important business processes for the success of the program plan.
2. Evaluate the existing processes.
3. Propose improvements to existing processes or completely new processes.

Examples of recommended processes in addition to those listed in the Observation section above include Procurement, System Engineering, Data Management, Collaborating with External Partners, and Adapting to Rapid Changes in Vehicle Technology, Traveler Information, and Systems Operations. Some of these business processes may already be used by departments, while others will be completely new processes to support TSMO.

5. Services, Projects, and Activities

Observations

Perhaps without a structured TSMO Program Plan, virtually every DOT has provided, implemented, and carried out TSMO services, projects, and activities. Although these unstructured efforts have been successful in improving transportation system management and operations, there is an opportunity for even more success.

Recommended Framework

As mentioned above, there is an opportunity for even greater TSMO success if DOTs can identify the package of services, projects, and activities that would be most effective in accomplishing the DOT's mission, vision, goals, and objectives, contribute to a measured performance, and are supported by effective leadership and organizational structures, effective business processes, and adequate resources. In addition, it is very important that Program Plans include policies and decision-making guidelines that will pave the way for subsequent TSMO deployment planning.

Summary of "Transportation Systems Management and Operations Program Planning – Experiences from the SHRP 2 Implementation Assistance Program," NCHRP Project Number 20-07/365

NCHRP 20-07/345, summarized in the section above, laid out the preliminary framework for TSMO Program planning. Many agencies have started down this path; transportation agencies must now formalize and document the activity as a TSMO Program Plan and advance the practice. The goals and objectives of NCHRP 20-07/365 included:

- Document lessons learned, challenges, and best practices in TSMO Program planning efforts to-date.
- Capture the progress of agencies that participated in the TSMO capability maturity model (CMM) workshops, supported by the second Strategic Highway Research Program (SHRP 2).
- Evaluate the TSMO Program planning framework previously developed by NCHRP 20-07/345 (summarized in previous section) to ensure it reflects best practices from agencies' real-world experiences.
- Validate and create a Unified TSMO Program Planning Framework that reflects agency experiences and incorporates research from this project.

Various forms of research resources were used to develop a Final Report that would provide TSMO professionals with the most up-to-date information in order to enhance the state of practice, resulting in measurable improvements in the nation's transportation systems. The research resources used include the following:

- The NCHRP 20-07/345 framework.
- Outputs and accompanying implementation plans from the CMM workshop.
- The national survey on TSMO Program Planning efforts.
- The NCHRP 20-07/365 workshop for panel members and agency representatives.

Regardless of a DOTs TSMO maturity, the Unified TSMO Program Planning Framework was developed to aid agencies to develop and implement TSMO Program Plans as efficiently and effectively as possible.

Existing TSMO Program Planning

The objective of this section is to understand two existing TSMO Program planning frameworks – the CMM and the framework developed in NCHRP 20-07/345. The TSMO Program planning framework developed in NCHRP 20-07/345 has already been summarized in the previous section so it will not be discussed below. Refer back to previous report sections for the summary.

TSMO CMM framework is an adaptation of the CMM concept from the IT industry that has been tailored to the transportation and TSMO communities to facilitate TSMO Program planning. The TSMO CMM framework is based on self-evaluation of the key processes and capabilities that transportation agencies need to achieve an effective TSMO Program. There are six key dimensions of the CMM framework that directly relate to improving TSMO Program effectiveness. These key dimensions include business processes, systems and technology, performance measurement, culture, organization and workforce, and collaboration. Within these key dimensions are four discrete levels of agency capabilities that range from ad hoc and unstructured activities and processes to more formalized, integrated programs. **Table 3** on the following page shows each of the four levels defined within the context of each of the six dimensions.

Agencies use the criteria in **Table 3** to evaluate their level of capability in each dimension during the CMM self-evaluation process. The dimension with the lowest level determines the agency's overall level of TSMO Program effectiveness. The greatest emphasis is placed on the lowest-rated dimension as it is generally the limiting factor that's constraining the agency's TSMO capabilities. Once self-evaluated, agencies are given the opportunity to identify relevant strategies for advancement through CMM workshops with expert facilitators or CMM materials available online through FHWA and NOCoE (National Operations Center of Excellence). The CMM framework is beneficial to agencies at any stage of TSMO Program development because it emphasizes the continuous and iterative nature of TSMO Program planning.

National Survey on TSMO Program Planning

The aim of the National Survey on TSMO Program Planning was to capture a wide range of experiences, lessons learned, and best practices from state DOTs and regional agencies at varying stages of TSMO maturity and program plan development. A total of 48 survey responses were collected over a six week period the survey was active. The responses represented 31 states and 8 regional agencies. The survey's "Yes Group" was comprised of 36 of the 48 responses that were from individuals working at agencies that were either implementing or developing TSMO Program Plans. The survey's "No Group" was comprised of 12 of the 48 responses that were from individuals working at agencies that currently are not working towards a TSMO Program Plan.

Table 3: Definition of the current levels of agency capability in each of six CMM dimensions

Capability Dimension	Level 1	Level 2	Level 3	Level 4
Business Processes	Processes related to TSMO activities are ad hoc and not integrated.	Multi-year statewide operations and management plan and program exist with deficiencies, evaluation, and strategies.	Programming, budgeting, and project development processes for TSMO standardized and documented.	Processes streamlined and subject to continuous improvement.
Systems and Technology	Ad hoc approaches outside systematic systems engineering.	Systems Engineering employed and consistently used for ConOps, architecture, and systems development.	Systems and technology standardized, documented and trained statewide, and new technology incorporated.	Systems and technology routinely upgraded and utilized to improve efficiency performance.
Performance Measurement	No regular performance measurement related to TSMO.	TSMO strategies measurement, largely via outputs, with limited after-action analyses.	Outcome measures identified and consistently used for TSMO strategies improvement.	Mission-related outputs/outcomes data routinely utilized for management, reported internally and externally, and archived.
Culture	Value of TSMO not widely understood beyond champions.	Agency wide appreciation of the value and role of TSMO.	TSMO accepted as formal core program.	Explicit agency commitment to TSMO as key strategy to achieve full range of mobility, safety, and sustainability objectives.
Organization and Staffing	Fragmented roles based on legacy organization and available skills.	Relationship among roles and units rationalized and core staff capacities identified.	Top-level management position and core staff for TSMO established in central office and districts.	Professionalization and certification of operations core capacity positions including performance incentives.
Collaboration	Relationships on informal, infrequent, and personal basis.	Regular collaboration at regional level.	Collaborative inter-agency adjustment of roles and responsibilities by formal agreements.	High level of operations coordination institutionalized among key public and private players.

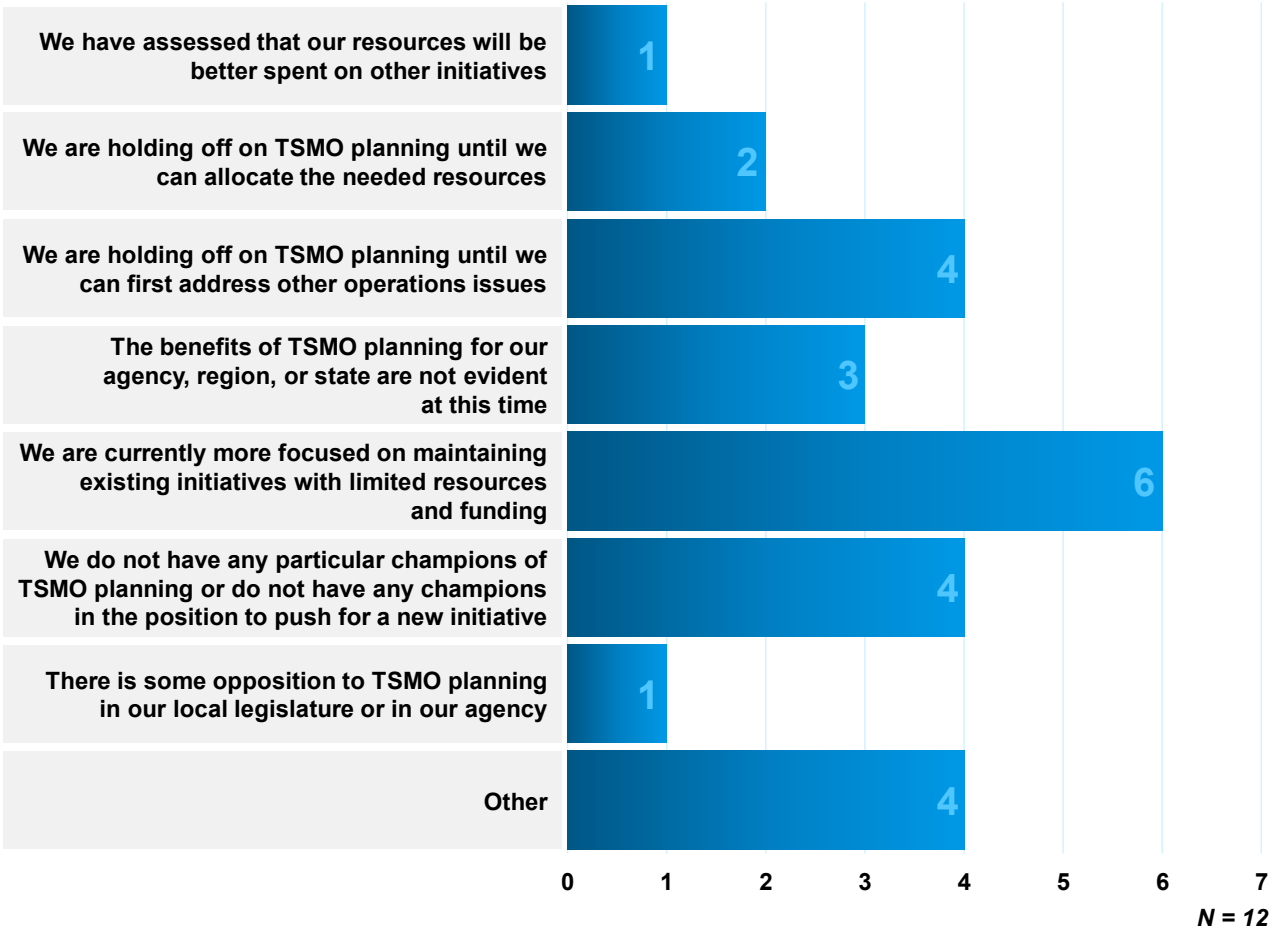

Figure 13: Reasons preventing agencies from working towards a TSMO Program Plan
(Source: NCHRP 20-07/365 project report)

One of the main objectives of the project's research was to follow-up with agencies that had received support and guidance on TSMO Program Planning through the SHRP 2 CMM workshops.

Survey respondents in the "No Group" were asked to identify why their agency was not currently working towards a TSMO Program Plan. Six out of the twelve respondents said their agency is currently more focused on maintaining existing initiatives with limited resources and funding. **Figure 13** shows the survey respondents' reasons preventing their agency from working towards a TSMO Program Plan.

Unified TSMO Program Planning Framework

The Unified TSMO Program Planning Framework is a result of a workshop held in February 2016 and is designed to be broad, synthesizing all project findings into a single, comprehensive reference for TSMO Program Planning. To demonstrate the concurrence and evolution between the initial NCHRP 20-07/345 framework, the draft consensus framework from the NCHRP 20-07/365 workshop, and the final Unified TSMO Program Planning Framework, **Table 4** on the following page lists the main components of each framework and indicates how the components of the earlier frameworks relate to the components of the Unified Framework.

As illustrated by **Table 4**, the final Unified TSMO Program Planning Framework is very closely aligned with both reference frameworks in sequence and content, and does not omit any elements from either source. The high level components of the Unified TSMO Program Planning Framework (listed in the third column of **Table 4**) are listed and described in detail in the first column of **Table 5** on the following page. The second column lists several key process steps that are expected to occur within each component of the framework followed by example program plan elements that may be found in the actual TSMO Program Plan in the third column. The Unified Framework is designed to be comprehensive and adaptive, with the expectation that agencies will tailor each aspect to best fit their individual needs.

As with previous TSMO frameworks, the latest experiences and lessons learned that helped develop the Unified Framework are from a wide range of agencies and staff across the country that are involved with TSMO and the development of their own Program Plans. To ensure the framework continues to remain a "living" document that reflects current and best practices, it will be crucial to take steps to ensure the framework is periodically revisited and updated as needed.

Table 4: Correspondence between components of the two earlier frameworks and the final Unified TSMO Program Planning Framework (source: NCHRP 20-07/365 project report)

NCHRP 20-07 (345) Framework[a]	**Draft Consensus Framework**[a]	**Unified TSMO Program Planning Framework**
Framework Coming into the Workshop	*Framework after Day 1 of the Workshop*	*Unified, Agreed-Upon Framework at the End of the Workshop*
• Mission, Vision, Goals, Objectives, and Performance Measures (A, B) • Leadership and Organization (C) • Business Processes (D) • Resources (Financial, Human, Infrastructure, Technology) (E) • Packages of Services, Projects, and Activities with Related Policies and Guidelines (F)	• Mission, Vision, Goals, and Objectives (A) • Performance Measures(B) • Staffing Resources (C, E) • Funding Resources (E) • Implementation of Services and Projects (F) • Roles and Responsibilities (G) • Evaluation and Reassessment (H)	• Mission, Vision, Goals, and Objectives • Performance Measurement • Leadership, Organization, and Staffing • Business Processes and Planning • Resource Positioning and Development • Services and Projects • Roles and Responsibilities • Evaluation and Reassessment

[a]Parentheses indicate which component from the Final Unified TSMO Program Planning Framework (A through H) corresponds to each components of the earlier frameworks.

Table 5: An overview of the Unified TSMO Program Planning Framework (source: NCHRP 20-07/365 project report)

Framework Component	Anticipated Process Steps *(not exhaustive)*	Sample TSMO Program Plan Elements
Foundational Prerequisites – Laying the groundwork to ensure the TSMO Program Plan development process is properly scoped and supported, including staff support, time and resource commitments, and leadership endorsement. This component involves identifying the core team and ensuring that a feasible management plan is in place to govern the rest of the framework and steps.	• Identify TSMO champion(s). • Get commitments from key staff and stakeholders (the full framework and process can be expected to take 1-2 years to fulfill). • Appoint staff or organizations for TSMO Program Plan development responsibility (typically led by operations divisions). • Establish TSMO Program Plan steering committee. • Secure the authority to make changes necessary for the successful design and implementation of the TSMO Program Plan.	N/A
A. Mission, Vision, Goals, and Objectives – Establishing the high level outcomes and setting expectations for the plan, to provide a common, clear direction for all of the components and steps that follow. This component ensures that all stakeholders and partners are like-minded in the understanding of what TSMO and the Program Plan will do, why it is necessary, and how it will benefit each entity.	• Achieve consensus on goals, objectives, scope, schedule, and budget. • Outreach to Agency Leadership, internal staff, and the public. • Outreach to decision-makers, stakeholders, and partners. • Update mission/vision to align with TSMO. • Define TSMO. • Define role of TSMO. Program Plan in context of other planning documents.	1. Consensus set of goals, objectives, and vision for TSMO. 2. Definition of TSMO (including scope and role, including in the context of other plans).

Table 5, continued

Framework Component	Anticipated Process Steps *(not exhaustive)*	Sample TSMO Program Plan Elements
B. Performance Measurement – Sets context for TSMO and the Program Plan, and gives greater definition to the high-level goal outcomes already established. This component provides tangible descriptions of the current state and goal state.	• Select performance measures and targets. • Assess existing conditions. • Identify performance reporting strategies. • Set priorities.	3. Presentation of performance targets and priorities. 4. Characterization of current conditions.
C. Leadership, Organization, and Staffing – Addresses foundational staff structure requirements necessary to support TSMO, thereby enabling the successful implementation of various operational and management strategies as they are adopted. This component ensures that technical and administrative support for TSMO is available at all levels of the organization.	• Outreach to Agency Leadership, internal staff. • Identify potential institutional improvements. • Identify and implement strategies to promote TSMO culture. • Develop staff retention strategies/ programs. • Define overall staffing plan and organization.	5. Description of career development plans for TSMO staff. 6. Description of staff organization and reporting structure. 7. Formal statement of endorsement from leadership.
D. Business Processes and Planning – Performs key integration of TSMO considerations into existing institutional processes, for systematic treatment according to well defined and documented procedures. Current shortcomings of agency processes regarding TSMO concepts are identified and addressed in this step.	• Integrate TSMO into planning processes. • Document agency TSMO practices and methods. • Develop or adjust business processes to include TSMO. • Identify procedural improvements for data-driven planning. • Integrate TSMO into maintenance planning.	8. Discussion of updates to planning processes (including programming, maintenance, project prioritization, etc.) to include TSMO and performance measures. 9. Documentation of agency practices for ensuring proper consideration of TSMO.

Table 5, continued

Framework Component	Anticipated Process Steps *(not exhaustive)*	Sample TSMO Program Plan Elements
E. Resource Positioning and Development – Defines the technical and financial resources available and required to support the high level general format and needs of TSMO services and projects, such as data systems, infrastructure, and funding sources. For any needs that are not yet met, this component quantifies the gaps between the present and future goal states, and develops implementable strategies to address them.	• Outreach to Agency Leadership, internal staff. • Develop data standards/ guidelines. • Conduct inventory and gap analysis of agency resources. • Identify and implement funding strategies. • Update and apply ITS architecture. • Identify required resources and investments. • Conduct inventory of data.	10. Description of current data resources, standards, and support systems. 11. Documentation of TSMO inventory. 12. Identification of resource gaps and needs. 13. Discussion of current, anticipated future, and potential future funding sources. 14. Presentation of updated ITS architecture to accommodate needs of TSMO.
F. Services and Projects – Develops a set of tangible initiatives and solutions in pursuit of the performance targets and goals/vision set earlier, subject to any inflexible practical constraints identified as part of previous framework components. Depending on the outcomes from this framework component, it may be necessary to revisit and update previous components to some degree.	• Outreach to stakeholders and partners. • Implement TSMO services/ projects. • Identify/prioritize strategies to implement TSMO improvements.	15. Describe services and projects to meet TSMO goals and objectives. 16. Map services and projects to resource needs (including funding), performance targets, and relevant staff (including roles). 17. Develop implementation plan (e.g., phases, initial steps, near-term goals) for services and projects.

Table 5, continued

Framework Component	Anticipated Process Steps *(not exhaustive)*	Sample TSMO Program Plan Elements
G. Roles and Responsibilities – Covers the required staff support elements of the services and projects from the previous component, including considerations of training, policies, and formal documentation. This component applies to staff both internally and at partner agencies/ organizations.	• Outreach to stakeholders, partners, and internal staff. • Define roles, responsibilities, and position requirements. • Develop Staff Training Strategies/ Programs. • Establish MOUs with partners regarding data sharing, resource sharing, incident management, etc.	18. Documentation or summaries of MOUs with partner agencies to support various services and projects. 19. Description of staff roles and responsibilities with respect to TSMO business processes, services, and projects. 20. Description of training program(s) for TSMO staff.
H. Evaluation and Reassessment – Ensures that the services and projects are effective at realizing progress toward the goals and targets established previously, and captures mechanisms and methods for ongoing monitoring and continual improvement of TSMO and the Program Plan.	• Assess existing conditions. • Collect post-performance metrics. • Conduct follow-up CMM workshop. • Outreach to decision-makers, stakeholders, partners, and public. • Establish reporting requirements and procedures.	21. Plan for ongoing performance measurement and reporting. 22. Discussion of schedule or trigger for next CMM evaluation. 23. Schedule and staff responsibilities for updating TSMO Program Plan.

Summary of Best Practices from Nationally Known Initiatives

From the development of TSMO Programs out of specific initiatives to the development of formal programs through institutionalization, TSMO Programs have evolved to link planning and operations in an effort to improve transportation decision-making and overall efficiency of transportation systems management. While programs are in varying stages of development and implementation, there are several states that have advanced beyond their peers and serve as guideposts for others. The following sections summarize best practices from nationally known initiatives.

Regional, Multi-Agency Traffic Signal Operations Management

Sustaining effective traffic signal coordination within and across jurisdictional boundaries has proven to be a daunting task for an increasing number of transportation agencies responsible for managing and operating traffic signal systems. There is an increasing number of agencies that are shifting to a more regional approach to managing and operating traffic signal systems. Regional traffic signal coordination provides substantial benefits to the road user by establishing consistent signal operations across a region, as well as making the typical reductions in travel time, stops, fuel consumption, emissions, and delays. Not only do the road users benefit from a regionalized approach, but so do the transportation agencies responsible for managing and operating traffic signals by pooling resources to provide ongoing staff training, development of signal timing plans, operations, and performance of maintenance activities. The subsequent paragraphs highlight the motivating factors, agency involvement, and measured benefits of several successful signal system programs.

Pennsylvania Department of Transportation (PennDOT) Green Light-Go

Made possible by Pennsylvania's transportation funding plan, Act 89, Green Light-Go establishes partnership agreements between municipalities and PennDOT through which municipalities request up to 50 percent funding for traffic-signal projects. The program is designed to improve safety and mobility by reducing congestion and improving efficiency of existing traffic signals on state and local highways. Grants can be used for upgrading traffic signals to LED technology and intelligent transportation applications, performing regional operations such as retiming, developing special event plans and monitoring traffic signals, as well as upgrading traffic signals to the latest technologies.

Under the Green Light-Go program, project corridors with fewer than 10,000 vehicles per day are managed by the municipality, and PennDOT manages any project with signals on corridors that have greater than 10,000 vehicles per day. In addition to facilitating improvements through the program, PennDOT is also using the program as an opportunity to complete a comprehensive traffic signal asset data collection project that assembles accurate data about traffic signals statewide. Not only does this effort improve the Green Light-Go program, but it also takes existing data from PennDOT, municipalities, contractors, and others to create one complete record. The data is compiled into the new electronic statewide Traffic Signal Asset Management System that is available to municipalities at no cost.

Georgia Department of Transportation (GDOT) Regional Traffic Operations Program (RTOP)

Georgia is a rapidly growing state, with more than half of its population living in the Atlanta region. There are more than 8,500 signalized intersections in Georgia, with the majority presently in the Atlanta metropolitan area. About half of the signalized intersection are on state routes. Signals are maintained by seven DOT districts, 54 county agencies, and 36 cities. This results in a mixture of standards and procedures.

While the Georgia Department of Transportation (GDOT) had made previous, significant, and statewide investments in upgrading traffic signal equipment and improved signal operations, GDOT recognized that ongoing, long-term investments must be made to overcome barriers to efficient operations. In GDOT's case, the barriers to optimal signal operations included routine maintenance of equipment, active management of signals, and cross-jurisdictional coordination. With determination to overcome these barriers and take signal operations to a new level of efficiency, GDOT established the Regional Traffic Operations Program (RTOP).

Transportation Systems Management & Operations

PID: 97927

RTOP's mission is to increase travel throughput by minimizing congestion and reducing delays along regional commuter corridors through improved signal operations and maintenance. Through RTOP, GDOT supplements local agency resources by providing personnel to evaluate the operations and maintenance of the signal system, develop and implement strategies for improvements, and to provide ongoing support focused on optimizing operations. GDOT recognized the desire of agencies to participate in the program at varying levels, as such two levels of participation were developed: GDOT lead and local lead. Further clarification of these two approaches is provided in **Table 6** on the following page.

Performance measures were created in order to define the effectiveness of the program. Performance measurements for RTOP generally fall into two categories: outcome and output measures. Outcome measures serve as an indicator of the progress the program makes towards meeting its mission of improving system throughput whereas output measures typically seek to measure individual actions or performance of one element of the system. In the first 16 months the program was operational, the following benefits were measured during the am and pm peak periods:

- Reduced number of stops by 5.9 percent
- Eliminated 1.4 million hours of delay
- Reduced total delay by 6.0 percent
- Saved 639,383 gallons of fuel

The success experienced with these results has led to the expansion of the program with increased funding.

Mid-America Regional Council (MARC)
Operation Green Light (OGL)

In March 1998, leaders of the Kansas City area issued a solicitation for proposals to develop a program that would improve traffic throughout the metro area. After several other local agencies expressed interest in participating in the process, the project scope was reformulated to take on a regional scope headed by MARC. The project became known as Operation Green Light (OGL). The purpose of OGL is to significantly reduce air pollution, stops, delays, driver frustration, and fuel consumption in the Kansas City area by optimizing the travel times, safety, and traffic flow along arterial corridors through safe and efficient traffic signal operations. There are a number of entities involved with OGL, including MARC, 20 area cities, the Kansas and Missouri Departments of Transportation, and FHWA.

The state and local governments that own traffic signals in the area are working together to make sure that the timing plans for the identified priority corridors (634 intersections) are coordinated for more efficient flow of traffic. Under normal traffic operating conditions, each member agency retains the responsibility of operating the traffic signals in its own jurisdiction. However, OGL provides weekday operations monitoring for system malfunctions and dispatches the appropriate agencies' personnel. Under incident conditions, MARC has the authority to implement special timing plans. However, MARC is required to notify each impacted agency immediately when these incident timing plans have been implemented. Although existing equipment is used wherever possible, some new communications equipment and software, and new signal controllers must be installed so the traffic signals on the system can communicate with each other and with a central operations center. This equipment and software help keep the traffic signals in sync with new timing plans.

After new timing plans have been implemented in a corridor, MARC performs an evaluation study of the effectiveness of the improvements on traffic flow and vehicle emissions. MARC also conducts a number of other analyses to measure changes in travel time, travel delays, number of stops, speed of travel, and fuel consumed during the corridors morning, noon, and evening peak hours. The results of the analyses are then summarized in a written report documenting the effects of the recently implemented traffic signal timing improvement. Through OGL, delays have been reduced up to 21 percent, fuel consumption reduced up to 18 percent, and harmful emissions reduced up to 15 percent.

Table 6: Agency Responsibilities (source: RTOP Concept of Operations)

Program Component	GDOT Lead		Local Lead	
	GDOT	Local	GDOT	Local
Corridor Signal Timing	X		X	
Timing Adjustments	X			X*
Maintenance	X			X
After Hours/Emergency Response		X		X
Detector, Communication, and Surveillance Repair	X		X	
Peak Hour Management and Monitoring	X			X
Major Repairs		X		X

Best Practices to Consider Applying in Ohio

- The performance measures in a region should directly relate to the region's long range transportation plan and be traceable back to the program's goals and objectives. In addition, a more aggressive approach in measuring a corridor's performance should be taken.
- The process of developing a comprehensive program begins with agencies conducting a comprehensive inventory of the capabilities and desires of all the agencies in the region.
- Agencies need to develop goals and objectives early in the program development process, with the understanding that some agencies may have short-term specific needs, deployments, or situations they want to address through the program.
- Each agency needs to define for itself what level of participation is best. Lead agencies need to be adaptable to meet the needs of local agencies.
- Agencies need to define a clear regional concept of operations, supported by standard operating procedures.

New Hampshire 5 Year Strategic Plan -TSMO

New Hampshire created a centralized TSMO Bureau in which there are two core programs: the ITS program and the TMC Operational program, with sub-programs underneath each. The Bureau manages ITS projects through their entire life cycle, meaning they manage funding, design, and construction of their ITS network, collect data, and report performance measurements and outputs. New Hampshire's TSMO structure allows them to oversee their technology and programs from start to finish. The ITS program handles maintenance and getting technology operating properly. After the technology has been accepted by the TSMO Bureau, it is handed over to the TMC where it is managed though their Advanced Traffic Management System. The TMC operator can then operate, monitor, and collect data from all the systems in use, with the key goals of providing effective traffic incident management and real time traveler information. Capital project prioritization and funding is established through the five-year strategic plan which provides general means and methods to focus on in the five-year period to fulfill the desired vision of the ITS program.

There is a three phase performance measurement reporting process that the TSMO Bureau follows. The first phase, named monthly activity measures, consists of monthly TMC operational statistics generated by the TMC operators and available on the public dashboard. The second and third phases, named public measures and corporate measures, consist of performance measures that management and program leaders want to see. The exchange of these reports with stakeholders and the public is important to the success of the ITS program because it ensures sound investments are being made in transportation technology.

Statewide Traffic Management Centers

A completely new Statewide Transportation Management Center (STMC) was built to bring New Jersey's main traffic management agencies- the New Jersey Turnpike Authority, New Jersey Department of Transportation, and State Police- together under one roof to support better monitoring, coordination, dispatch, and response. With an already extensive existing fiber optic network and a large web of cameras and electronic signs, feeding these assets into a

STMC would dramatically improve operations. Co-location affords simple and effective "region-wide" coordination of traffic incidents and emergencies in an inter-operable manner. Each of the agencies manages its own roadways from the STMC, but is supported by a technology base that shares information and video across agency boundaries. No longer reliant upon the phone to get or give information between agencies, dispatchers at the New Jersey STMC now get a clearer view of the situation using the video wall, can send emergency workers to the scene faster, update real time information on electronic signs, and inform the media in a more timely manner.

Since the occurrence of a significant but not catastrophic event in February 2007, the Pennsylvania Department of Transportation (PennDOT) and the Pennsylvania Emergency Management Agency (PEMA) have been working in a more cooperative way, sharing purpose but not operations. An opportunity to co-locate operations came about when the Commonwealth decided to build a new facility for PEMA's headquarters and the State Emergency Operations Center (SEOC). Once a cooperative Concept of Operations was developed, PennDOT committed to co-locate for daily operational assessment and collaboration. The functions of the STMC include statewide coordination of situational awareness, coordination between agencies, training of TMC personnel, QA/QC of traffic data, and analyses of traffic operations metrics. PEMA SEOC and the STMC share a video wall to monitor camera feeds, real time speed data, weather, and other emergency related information. The benefits of Pennsylvania's STMC include consistent and constant information sharing between PEMA watch officers and PennDOT STMC operators, clearer and more efficient chain of communications/command from District to Region to State, and a promotion of trust-building and a sense of unity of purpose and roles of agencies.

DOT – University Partnerships

State DOTs work together with University Transportation Programs to address critical research needs. State DOTs must deal with a wide range of technical, social, economic, and environmental issues to deliver top quality service to the traveling public. University-based transportation centers are better equipped to manage certain tasks, including big data mining and analysis, prototyping new applications and evaluating new technology. This synergistic relationship between DOTs and universities ensures the best available expertise is directed at our nation's transportation research and workforce development needs.

There are a number of DOT-University partnerships that exist, but the most successful programs promote a joint collaboration on determining research needs, conducting research, and implementing research results. Such examples of joint collaboration include the Center for Advanced Transportation Technology (CATT) Laboratory at the University of Maryland, the Urban Transportation Center (UTC) at the University of Illinois at Chicago, and the Wisconsin Traffic Operations and Safety (TOPS) Laboratory based at the University of Wisconsin-Madison.

Perhaps the most important practice these partnerships carry out is the collaboration among leaders within each organization working together to define, document, and communicate the partnership's shared mission, goals, strategies, structure, and operations. This initial groundwork paves the way to a partnership that is beneficial to both parties. In order to maintain such partnerships, both sides must practice effective, ongoing communication. While there is a formal framework for partnered activities, it is individual relationships that reflect a partnered approach, built on earned respect.

ODOT has conventional research partnerships with ten in-state universities. Extending these partnerships to include academic research staff on-site or embedded student research assistants at ODOT will elevate the caliber of cross-collaborative research in Ohio. It will also give ODOT the opportunity to train the next generation of transportation professionals who will lead the Department in years to come.

Resource Catalog

The Resource Catalog on the following pages serves as a clearinghouse for sources related to TSMO, including a number of foundational ODOT plans and documents. The Resource Catalog contains 60 sources, covering topics related to TSMO and ODOT, including but not limited to:

- ODOT's TSMO activities to date
- ODOT manuals, reports, plans, and studies
- TSMO Program Planning, development, and management
- TSMO and ODOT organizational structure and staffing
- State of the practice
- Performance measures
- Traffic Incident Management (TIM)
- Intelligent Transportation Systems (ITS)
- Traffic Management Centers (TMC)
- TSMO scenario planning
- TSMO gap analysis
- TSMO benefit/cost analysis
- TSMO and climate change

How to use the Resource Catalog
Resources are divided into five sources:

1. ODOT: 29
2. Federal (Federal Highway Administration): 11
3. Research-Oriented Sources (primarily American Association of State Highway Transportation Officials and Transportation Research Board): 9
4. Other DOTs: 8
5. Miscellaneous: 3

Sources are listed in **Table 7**. The first column shows the title of the document and a hyperlink to the document in PDF form. The second column summarizes the purpose and contents of the document. The third column explains how the document relates to TSMO and highlights topics of interest.

These documents may also be accessed on ODOT's TSMO Resource Catalog webpage: http://www.dot.state.oh.us/Divisions/Operations/Traffic/miscellaneous/Pages/TSMO.aspx

Table 7: Resource Catalog

Source	Summary	Relevance to TSMO
ODOT Sources		
2015 Annual Report and 2016-17 Business Plan	Summarizes ODOT's organizational structure, recent accomplishments, and funding allocations for FY2015 by project type and district.	• Critical Success Factors Dashboard breaks down goals by FY quarter and category. • Includes two goals for Operations: Travel Time Reliability Index and Snow and Ice Control.
Access Ohio 2040 Long Range Transportation Plan	ODOT's long range transportation plan. Includes a comprehensive inventory of transportation services and infrastructure, forecasts of transportation demand, asset condition and performance, and an analysis of the trends affecting transportation in Ohio.	• Some of the Goals and Objectives are related to TSMO in the categories of: — Safety — Mobility and Efficiency — Stewardship.
Business Case for a Dedicated Operations IT Office	Outlines role of IT in Traffic Operations' activities; proposes office responsibilities and positions for IT staff.	• IT support will be critical for Traffic Operations to successfully implement TSMO Programs.
Division of Operations Fiscal Year 2016 Business Plan	Outlines responsibilities, structure, and critical success factors for ODOT's Office of Traffic Operations.	• Operations is spearheading TSMO implementation at ODOT.
Excellence in Snow and Ice Control Award Nomination	Outlines ODOT's Snow and Ice operations for award consideration by the American Public Works Association.	• Snow and Ice Operations is one of the 20 existing ODOT TSMO Functions listed in **Table 1**.
Highway Safety Improvement Program 2015 Annual Report	Describes ODOT's efforts to achieve significant reduction in fatalities and serious injuries on all public roads.	• Data-driven program seeks to use ITS and ramp meters to reduce the high number of rear-end collisions caused by congestion and work zones.
ODOT RD&T Manual of Procedures	Defines policies and procedures for ODOT's research section. Provides guidance for ODOT employees, other agencies, and contractors conducting research on behalf of ODOT.	• Not immediately relevant to TSMO.

Table 7, continued

Source	Summary	Relevance to TSMO
ODOT's Planning Program Public Involvement Process	Describes ODOT's statewide planning products and processes and explains how partner agencies and the public can participate in shaping the state's transportation future.	• Guidance for introducing TSMO to the traveling public. • May provide guidance for internal ODOT branding and external stakeholder buy-in (e.g., MPOs).
Office of Traffic Operations IT Needs	Lists Traffic Operations' IT needs, including software development, database management, purchasing, and networking.	• IT support will be critical for Traffic Operations to successfully implement TSMO.
Office of Traffic Operations Staffing Analysis	Describes staffing shortages and resultant workloads for Traffic Operations staff. Includes comprehensive table of Traffic Operations duties.	• Traffic Operations will be unable to successfully implement TSMO without significant changes in staffing and resources.
Ohio Manual on Uniform Traffic Control Devices (MUTCD)	Establishes statewide standards for the design and use of traffic control devices on any street, highway, bikeway or private roads open to public travel in Ohio.	• Affects TSMO signal, ITS, and other operations. • Update frequently to maintain relevance regarding latest technologies and TSMO strategies.
Ohio Statewide Freight Study	Describes how Ohio's freight infrastructure is being utilized, plans and prioritizes future strategic investments in freight infrastructure, and guides future economic development to make the most efficient use of existing freight infrastructure.	• Proposes ITS solutions to freight bottlenecks, freight safety, efficiency, and operational challenges. • Could update freight (and auto) bottleneck information annually using probe speed data. • Could align truck parking information systems with freight commodity flow data.
Ohio TSMO Capability Maturity Self Assessment Workshop Memorandum	Identifies strengths and deficiencies in ODOT's TSMO operations and recommendations for improvement.	• Directly related to TSMO.
Pro Forma Budget	Provides ODOT's revenue and program use assumptions through multiple state fiscal years.	• A TSMO Program line item could be created (similar to the Safety Program).

Table 7, continued

Source	Summary	Relevance to TSMO
Program Resource Guide 2016	Navigational tool for ODOT's constituents. Overview of organizational structure, program manager contact information, and all infrastructure programs and initiatives.	• Document may need to be updated when ODOT implements TSMO department-wide. • Could include a TSMO Program that allows partner agencies to obtain funding for inter-operable traffic signal and surveillance systems to support integrated corridor management.
Project Development Process (PDP) Manual	Project management and transportation decision-making process that outlines project development from concept through completion.	• TSMO Check List will be included with respect to Scoping and Programming projects (Policy Action BP3).
SHRP2 Implementation Plan	Formalizes recommendations from CMIP memorandum into a plan for creating a model Operations program.	• Lays groundwork for Scan Tour and expanded TSMO Program at ODOT.
SHRP2 Scan Tour Documents	Summarize staffing and organizational structure, operations programs, and performance measures of other state DOTs.	• Provide best practices for ODOT to follow as it implements TSMO department-wide.
State Highway Access Management Manual	Establishes procedures and standards to protect the utility, function, capacity, and safety of the state highway system.	• Traffic control signal warrants and cross-jurisdictional agreements. • Access management plans to reduce congestion and preserve highway capacity.
Statewide Transportation Improvement Program (STIP)	Presents fiscally balanced, multimodal transportation program which includes both federally and state funded projects for SFY 2016-2019. Serves as the reference document required by the FHWA and FTA in approving the use of federal funds for transportation projects in Ohio.	• Section 7 describes TRAC program and efforts to reduce congestion. • Section 10 discusses CMAQ funding. • Some standalone signals, signal systems, and cameras are reflected as project line items in the STIP. • Could include line items for tracking TSMO projects in the future.

Table 7, continued

Source	Summary	Relevance to TSMO
Strategic Highway Safety Plan	Comprehensive statewide plan that identifies the greatest causes of serious injuries and deaths on Ohio roads. It establishes common goals, priorities, and strategies using data, identifies and tracks investments across organizations;, and helps Ohio leverage and maximize its resources to prevent injuries and save lives.	• The TSMO Plan could be aligned with SHSP data activities for accelerated TIM data collection (i.e. response time, response clearance, and secondary crashes). • Routinely connect TMC data with crash reports to improve After Action Reporting. • Consider including TIM Responder safety and Work Zone Management on future SHSP emphasis areas.
Strategic Transportation System (STS) Brochure[1]	Infographic and map summary of STS showcase projects and Access Ohio's transportation facts. STS Corridors were developed in order to help prioritize the state's most used and valuable aviation, bicycle, highway, maritime, rail, and transit corridors, and the connecting multimodal transportation facilities.	• Highlights multimodal projects and accomplishments that can potentially reduce congestion on Ohio's roads. • Could integrate TSMO-oriented measures such as: travel time reliability, weather sensitive segments, high traffic incident segments, and locations with frequent, large scale special events.
Traffic Engineering Manual	Assures uniformity in application of ODOT traffic engineering policies, guidelines, standards and practices.	• Sets standards and requirements for ITS, congestion mitigation, and signal operations • Describes Traffic Operations role in engineering and traffic control. • Update frequently to maintain relevance regarding latest technologies and TSMO strategies.
Traffic Incident Management (TIM) Plans	Overview of ODOT's TIM QuickClear program.	• TIM is an integral component of TSMO.
Transportation Alternatives Program 2016 Guidance	Describes funds for projects that advance non-motorized transportation facilities, historic transportation preservation, and environmental mitigation and vegetation management activities.	• Because TSMO focuses primarily on motorized traffic, this document is not immediately relevant.

1. See **Appendix A**.

Table 7, continued

Source	Summary	Relevance to TSMO
Transportation Asset Management Plan (TAMP)	Transportation asset management plays a critical role in the planning, development, preservation, and construction of Ohio's transportation system.	• While the Transportation Asset Management Plan takes care of what ODOT already has, the TSMO Plan will make the system work better, improve safety, and enhance capacity. • Policy Action BP2: Establish TSMO equipment (Signals/ITS) as a Tier 1 asset.
TransPort Ohio Statewide Freight Plan	Describes Ohio's freight assets, forecasts, opportunities, and trends. Outlines ODOT's freight goals, performance measures, specific recommendations, and proposes a Freight Investment Plan.	• Recommends completion of a TSMO Plan. • Recommends deploying a Truck Parking Information Management System (TPIMS). • Freight and Operations share CSFs: TTRI and snow and ice control.
UAS Center Flight Operations Manual	Formalizes flight operations procedures at the Ohio/Indiana Unmanned Aircraft Systems Center (UASC) and familiarizes ODOT employees and customers with the rules, regulations, and operating procedures governing flight operations at the UASC.	• As an emerging technology, UAS will be used to monitor, manage, and maintain ODOT's assets and operations, including TSMO-related functions, such as EM/TIM.
Unmanned Aircraft Systems Operations Within ODOT Right of Way	Procedures for consultants to follow when using unmanned aircraft systems (UAS) within ODOT Right of Way.	• As an emerging technology, UAS will be used to monitor, manage, and maintain ODOT's assets and operations, including TSMO-related functions, such as EM/TIM.
Federal Sources		
Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations	Designed to enable transportation planners to build plans that include operations objectives, performance measures, and strategies that are relevant to their region, reflect community's values and constraints, and move the region in a direction of improved mobility and safety.	• Defines TSMO. • Explains the utility of developing operations objectives and performance measures.

Table 7, continued

Source	Summary	Relevance to TSMO
Advancing Transportation Systems Management and Operations Through Scenario Planning	Informs transportation professionals on the potential use of scenario planning to enhance their TSMO planning and programming decisions.	• Directly related to TSMO.
Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance	Guidance on incorporating climate change into TSMO activities.	• Directly related to TSMO.
Creating an Effective Program to Advance Transportation System Management and Operations	Raises awareness of the opportunities for improving state and local TSMO activities.	• Directly related to TSMO.
Freeway Management and Operations Handbook	Overview of the institutional and technical issues associated with the planning, design, implementation, operation, and management of a freeway network.	• In-depth explanation of — Congestion — Performance measures — Managed lanes — TIM — TMCs
Operations Benefit/Cost Analysis Desk Reference	Guidance on suitable benefit/cost analyses for TSMO Programs to justify operational expenditures.	• Directly related to TSMO.
Planning For Transportation Systems Management And Operations Within Corridors: A Desk Reference	Guidance for transportation planners and operations staff to plan for and apply TSMO activities within corridors to achieve a more reliable, efficient, and livable outcome from their existing and planned transportation infrastructure.	• Focuses on TSMO issues such as mobility, reliability, and safety. • Provides a variety of tools to advance TSMO within corridors. • Multimodal perspective.
Recurring Traffic Bottlenecks: A Primer Focus on Low-Cost Operational Improvements	Explores the application of operational and low-cost "fixes" at spot-specific locations to relieve congestion.	• Discusses challenges and solutions to recurring congestion management. • Describes ITS tools to mitigate recurring congestion: ramp meters, hard shoulder running.
Traffic Incident Management Gap Analysis Primer	Guidance on how to establish a successful TIM program to manage non-recurring congestion.	• In-depth discussion of ITS tools and TMC's role in TIM.
Traffic Incident Management Handbook	Documents good practices, lessons learned, and necessary steps for implementing, improving, and expanding TIM program components.	• Explains how improved TIM efforts reduce congestion and ITS' role in TIM.

Table 7, continued

Source	Summary	Relevance to TSMO
Transportation Management Center Data Capture for Performance and Mobility Measures Guidebook	Technical guidance and recommended practices regarding concepts, methods, techniques, and procedures for collecting, analyzing, and archiving TMC operations data to develop measures of roadway and TMC performance.	• Discusses data collection tools. • Describes ITS infrastructure (cameras, ramp meters, dynamic message signs).
Research-Oriented Sources		
AASHTO Subcommittee on Transportation Systems Management & Operations (STSMO) 2015-2018 Strategic Plan	High-level overview of the state of the practice; summary of STSMO structure, activities, vision, mission, goals, and objectives.	• Directly related to TSMO.
AASHTO TSMO Guidance Documentation	Guide for agencies to self-evaluate TSMO capabilities; custom-tailored action plan for improving the performance-related effectiveness of TSMO activities.	• Directly related to TSMO.
Decision Support Systems for Transportation System Management and Operations (TSM&O)	Establishes data-rich decision processes to support TSMO objectives and activities in Florida DOT.	• Web-based tools • Performance measurements • Benefit-cost analysis • Signal timing • Impacts on congestion
NCHRP 20-07 TASK 365 - Transportation Systems Management and Operations Program Planning – Experiences from the SHRP 2 Implementation Assistance Program	Documents TSMO challenges and best practices and provides Unified TSMO Program Planning Framework based on regional and state agencies' experiences and lessons learned.	• Includes national survey results on TSMO Program Planning • Explains Capability Maturity Model to advance TSMO.
NCHRP Project Number 20-07/345 - Program Planning and Development for Transportation System Management and Operations (TSM&O) in State Departments of Transportation	Surveys the state of the practice in TSMO Program Planning and defines uniform framework to develop and administer plans for state, regional, and local networks.	• Strategic, program-level planning for state DOTs and state leadership, and support for TSMO planning at all levels.
SHRP2 Reliability Project L01 Guide to Integrating Business Processes to Improve Travel Time Reliability	Literature reviews, workshops, and case studies show how integrating operational and programmatic business processes can improve travel time reliability.	• Travel time reliability is a critical success factor goal for ODOT's Traffic Operations and an important component of TSMO.

Table 7, continued

Source	Summary	Relevance to TSMO
SHRP2 Reliability Project L06 Institutional Architectures to Improve Systems Operations and Management	Evaluation of state DOTs' current TSMO Program effectiveness with regards to technical/business processes and institutional/ organizational arrangements.	• Defines the TSMO Capability Maturity Model. • Provides self-evaluation based guidance.
SHRP2 Reliability Project L17 A Framework for Improving Travel Time Reliability	Assesses current state of research in the field and summarizes SHRP2 Reliability research focus area activities.	• Evaluates web-based Knowledge Transfer System for TSMO. • Branding and marketing strategies to communicate value of TSMO.

Temporary Losses of Highway Capacity and Impacts on Performance: Phase 2 Oak Ridge National Laboratory	Quantifies the extent of recurring and non-recurring congestion; one of the foundational reports used to create the National Sources of Congestion pie chart.	• Explores the various causes of congestion that TSMO seeks to alleviate, such as:
		  • Crashes
		  • Work zones
		  • Weather
		  • Signal timing

Other DOT Sources		
Colorado DOT Transportation System Management & Operations Reorganization Report	Recommendations for integrating TSMO into CDOT Operations.	• Examines current conditions within Operations. • Recommendations include staffing changes, division reorganization, asset management, and scope of responsibilities for CDOT's Division of TSMO.
Florida DOT TSMO Strategic Plan	High-level document describing Florida's transportation challenges, need for TSMO, and implementation steps across all FDOT divisions. Includes vision, mission, and policy statements for TSMO.	• Recommendations to implement TSMO at Central and District Offices within five years of plan publication.
Illinois DOT Human Capital Strategic Plan	Recommendations for internal recruitment, retention, and training, analysis of the Illinois transportation industry, and rationale for using Human Capital management at Illinois DOT.	• Workforce planning and development is a major component of TSMO.

Table 7, continued

Source	Summary	Relevance to TSMO
Iowa DOT TSMO Program Plan	Detailed document that describes five year TSMO strategic direction, program development direction, and specific strategies and actions.	• Except for additional staffing recommendations, TSMO Plan does not restructure IDOT. • TSMO functions are integrated into existing roles, including performance, asset, and risk management, workforce development, and customer service.
Iowa DOT TSMO Strategic Plan	High-level document describing Iowa's transportation challenges and need for TSMO. Outlines TSMO vision, mission, and strategic goals and objectives.	• Divides TSMO Plan into strategic, program, and service layer components. • Strategic goals and objectives include safety, reliability, efficiency, convenience, coordination, and integration.
New Hampshire DOT 5-Year Strategic Plan for Transportation Systems, Management & Operations (TSM&O)	Five year strategic plan with corridor approach for ITS implementation and integration into NHDOT.	• Outlines internal and external ITS objectives. • Focuses on TIM, traveler information, device deployment, maintenance, and using ITS to manage safe and efficient operations.
Wisconsin DOT Traffic Operations Infrastructure Plan	Long range plan for WisDOT's Bureau of Highway Operations, outlines operations infrastructure needs and opportunities, with technology recommendations and associated costs.	• Emphasizes ITS solutions (ramp control, travel warning systems, signal systems) for operational improvements. • Develops methodology to evaluate and compare operational projects with capital projects.
Utah Automated Traffic Signal Performance Measures	Public-facing database of real-time and a history of performance at UDOT-owned signalized intersections.	• Best practice in signal operations. • Could be replicated by ODOT.
Miscellaneous		
2016 Annual Report: Ohio Development Services Agency	Provides information about tourism's impact on Ohio economy.	• Well-maintained and operated roadways support commerce and economic growth.

Source	Summary	Relevance to TSMO
Columbus Smart City Application	Highlights elements of the City of Columbus's successful bid for the USDOT Smart Cities Competition.	• Smart City Program will rely heavily on ITS (smart corridors, real-time data, connected and driverless vehicles) to improve transit service, freight routing and delivery, and race/income equity. • City of Columbus could be a strong partner during ODOT's state-wide TSMO implementation.
Modernizing Ohio's Transportation System: Progress and Challenges in Providing a Safe, Efficient and Well-Maintained Transportation System	Describes ODOT's efforts to increase capital spending despite stagnant funds. Provides general statistics on Ohio travel trends.	• Information can be leveraged to help build ODOT's TSMO Business Case (Policy Action CU2).

Transportation Systems Management & Operations

PID: 97927

Appendix A: Strategic Transportation System Brochure

Transportation Systems Management & Operations

PID: 97927