Organizing for TSMO

Case Study 2: Systems and Technology – Utilizing ITS Architecture to Advance TSMO

July 2019

U.S. Department of Transportation

Federal Highway Administration

Notice

This document is disseminated under the sponsorship of the U.S Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document.

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

Quality Assurance Statement

The Federal Highway Administration (FHWA) provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. The FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-HOP-19-064	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Organizing for TSMO – Case Study 2: Systems and Technology – Utilizing ITS Architecture to Advance Transportation Systems Management and Operations		5. Report Date July 22, 2019 6. Performing Organization Code:
7. Author(s) Lacey Atkins, Olivia R. Brey, Austin Hoekstra, Charles R. Lattimer		8. Performing Organization Report No.
9. Performing Organization Name and Address Atkins North America, Inc. 482 South Keller Rd. Orlando, FL 32810		10. Work Unit No. 11. Contract or Grant No. DTFH6116D00048/0001
12. Sponsoring Agency Name and Address United States Department of Transportation Federal Highway Administration 1200 New Jersey Ave. SE Washington, DC 20590		13. Type of Report and Period 14. Sponsoring Agency Code HOP
15. Supplementary Notes Joseph Gregory (FHWA – HOTM)		

16. Abstract

Given the varying stages of TSMO adoption and advancement, the Federal Highway Administration identified the need for case studies to provide examples of common challenges and best practices for transportation agencies to learn from each other. This is one of 12 case studies developed to support organizing for TSMO. This case study focuses on how applying the systems and technology component of TSMO can improve operations and help reduce challenges faced by agencies. Four agencies with mature systems and technology programs within their TSMO programs were interviewed: Oregon Department of Transportation (ODOT), Georgia Department of Transportation (GDOT), Ohio Department of Transportation (OhioDOT), and Utah Department of Transportation (UDOT). Each agency provided information on how they managed systems and technology challenges, their lessons learned, and the next steps to continually improve these efforts

17. Key Words Capability Maturity Model, Transportation Systems Management and Operations, reliability, ITS, Architecture, Technology, Systems		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161. http://www.ntis.gov	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 32	22. Price

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

Table of Contents

EXECUTIVE SUMMARY 1
CHAPTER 1 – INTRODUCTION 3
Purpose of Case Studies 4
Identified Topics of Importance 4
Interviews 5
Description of Systems and Technology 5
CHAPTER 2 – BEST PRACTICE EXAMPLES 9
Oregon Department of Transportation (ODOT) 9
Georgia Department of Transportation (GDOT) 12
Ohio Department of Transportation (OhioDOT) 13
Utah Department of Transportation (UDOT) 14
CHAPTER 3 – SUMMARY 17
REFERENCES 19

List of Figures

Figure 1. Chart. Four Levels of Maturity 4
Figure 2: Diagram. Systems Engineering Model 6
Figure 3. Chart. Incorporating ITS 7
Figure 4. Photo. Intelligent Transportation Systems Field Maintenance 10
Figure 5: Chart. Systems Engineering and Architecture Compliance Checklist 11
Figure 6. Chart. Example QPL Products and Categories 12
Figure 7: Chart. TOAST Data Categories 14
Figure 8. Photo. UDOT's ATSPM Website 15

List of Tables

Table 1. Interview Participants and Agencies 20

List of Abbreviations and Acronyms

AASHTO .....American Association of State Highway and Transportation Officials
ATSPM .....Automated Traffic Signal Performance Measures
CMM..... Capability Maturity Model
FHWA.....Federal Highway Administration
GDOT .....Georgia Department of Transportation
ITS..... Intelligent Transportation Systems
MPO.....Metropolitan Planning Organization
ODOT .....Oregon Department of Transportation
OhioDOT .....Ohio Department of Transportation
OIT.....Office of Information Technology
PPP.....Public Private Partnership
QPL.....Qualified Product List
SEA.....Systems Engineering Analysis
SHRP2..... Strategic Highway Research Program 2
TRB.....Transportation Research Board
TSMO ..... Transportation Systems Management and Operations
UDOT .....Utah Department of Transportation

EXECUTIVE SUMMARY

Transportation systems management and operations (TSMO) provides tools for transportation managers to address safety, system performance, and reliability. TSMO is "an integrated set of strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and projects designed to preserve capacity and improve security, safety, and reliability of the transportation system.[1]" Through participation in the second Strategic Highway Research Program workshops, transportation agencies are working to better support TSMO programs. Deploying intelligent transportation systems (ITS), hiring internal information technology staff, and using performance measures for data-driven decisions are just a few examples of the many opportunities that a TSMO program can support.

Given the varying stages of TSMO adoption and advancement, the Federal Highway Administration identified the need for case studies to provide examples of common challenges and best practices for transportation agencies to learn from each other. This is one of 12 case studies developed to support organizing for TSMO. This case study focuses on how applying the systems and technology component of TSMO can improve operations and help reduce challenges faced by agencies, including:

- Standardizing systems engineering into the agency processes.
- Managing ITS and technology systems.
- Interoperability between differing systems.
- Implementing regional architectures.

Four agencies with mature systems and technology programs within their TSMO programs were interviewed: Oregon Department of Transportation (ODOT), Georgia Department of Transportation (GDOT), Ohio Department of Transportation (OhioDOT), and Utah Department of Transportation (UDOT). Each agency provided information on how they managed systems and technology challenges, their lessons learned, and the next steps to continually improve these efforts. Some of the best practices identified include:

- ODOT's staff management and planning efforts to implement a statewide ITS architecture.
- GDOT's development and implementation of a Qualified Product List.
- OhioDOT's alignment of information technology and ITS departments to streamline managing technology.
- UDOT's development of a statewide traffic signal system.

[1] Source: https://ops.fhwa.dot.gov/tsmo/index.htm

CHAPTER 1 – INTRODUCTION

Historically, transportation agencies have managed congestion primarily by funding major capital projects that focused on adding capacity to address physical constraints, such as bottlenecks. Operational improvements were typically an afterthought and considered after the new infrastructure was already added to the system. Given the changing transportation landscape that includes increased customer expectations, a better understanding of the sources of congestion, and constraints in resources, alternative approaches were needed. Transportation systems management and operations (TSMO) provides such an approach to overcome these challenges and address a broader range of congestion issues to improve overall system performance. With agencies needing to stretch transportation funding further and demand for reliable travel increasing, TSMO activities can help agencies maximize the use of available capacity and implement solutions with a high benefit-cost ratio. This approach supports agencies' abilities to address changing system demands and be flexible for a wide range of conditions.

Effective TSMO efforts require full integration within a transportation agency and should be supported by partner agencies. This can be achieved by identifying opportunities for improving processes, instituting data-driven decision-making, establishing proactive collaboration, and performing activities leading to development of performance optimization processes.

Through the second Strategic Highway Research Program (SHRP2), a national partnership between the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the Transportation Research Board, (TRB), a self-assessment framework was developed based on a model from the software industry. The SHRP2 program developed a framework for agencies to assess their critical processes and institutional arrangements through a capability maturity model (CMM). The CMM uses six dimensions of capability to allow agencies to self-assess their implementation of TSMO principles[1]:

1. Business processes – planning, programming, and budgeting.
2. Systems and technology – systems engineering, systems architecture standards, interoperability, and standardization.
3. Performance measurement – measures definition, data acquisition, and utilization.
4. Organization and workforce – programmatic status, organizational structure, staff development, recruitment, and retention.
5. Culture – technical understanding, leadership, outreach, and program authority.
6. Collaboration – relationships with public safety agencies, local governments, metropolitan planning organizations (MPO), and the private sector.

Within each capability dimension, there are four levels of maturity (performed, managed, integrated, and optimized), as shown in Figure 1. An agency uses the CMM self-assessment to

[1] FHWA, Office of Operations, "Organizing for Reliability – Capability Maturity Model Assessment and Implementation Plans Executive Summary," February 2017. https://ops.fhwa.dot.gov/docs/cmmexesum/sec1.htm

identify their level of maturity in each dimension, to determine their strengths and weaknesses, and to determine actions they can take to improve their capabilities.

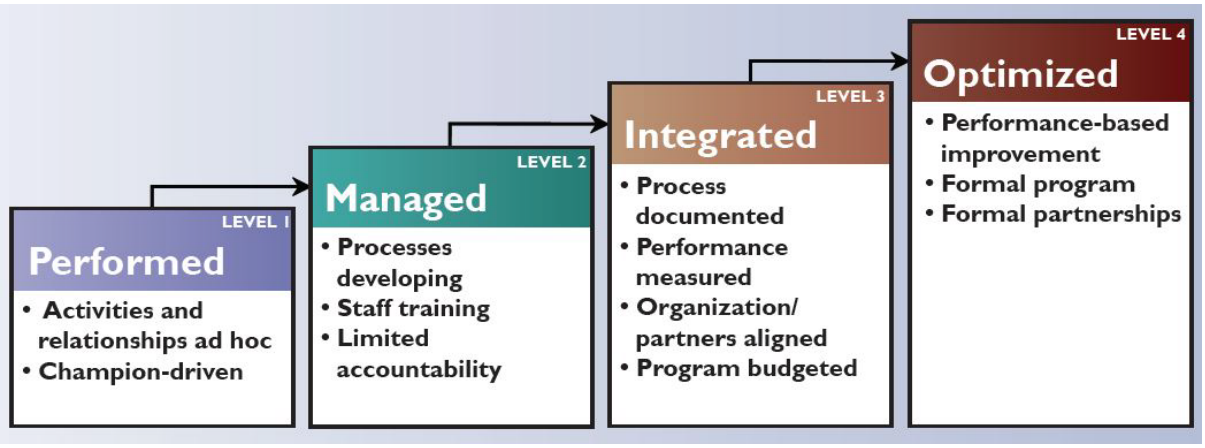

Figure 1. Chart. Four Levels of Maturity

Source: Creating an Effective Program to Advance Transportation System Management and Operations, FHWA Jan 2012

Purpose of Case Studies

In the first 10 years of implementation of the TSMO CMM, more than 50 States and regions used the tool to assess and improve their TSMO capabilities. With the many benefits experienced by these agencies, FHWA developed a series of case studies to showcase leading practices to assist other transportation professionals in advancing and mainstreaming TSMO into their agencies. The purposes of the case studies are to:

- Communicate the value of changing the culture and standard practices towards TSMO to stakeholders and decision-makers.
- Provide examples of best-practices and lessons learned by other State and local agencies during their adoption, implementation, and mainstreaming of TSMO.

These case studies support transportation agencies by showing a wide range of challenges, opportunities, and results to provide proof for the potential benefits of implementing TSMO. Each case study was identified to address challenges faced by TSMO professionals when implementing new or expanding existing practices in the agency and to provide lessons learned.

Identified Topics of Importance

The topic of systems and technology in TSMO is important because of the unique challenges associated with it, including collaborating among different departments and areas of expertise, planning and executing implementation, and managing systems and technology. The agencies highlighted for this case study addressed those challenges through consistent collaboration, integrated intelligent transportation systems (ITS) solutions, and employing data-driven decisions.

Interviews

Agencies were selected for each case study based on prior research indicating that the agency was excelling in particular TSMO capabilities. Care was taken to include a diversity of geographical locations and agency types (departments of transportation, cities, and MPOs) to develop case studies that other agencies could easily relate to and learn from. Interviews were conducted with selected agencies to collect information on the topic for each case study.

Description of Systems and Technology

The systems and technology component of TSMO includes:

- Systems engineering.
- Regional architectures.
- ITS procurement processes

Systems engineering, in relation to ITS, assesses the value and functionality of a high-technology project, service, or system from inception to end of life. It considers what the system requires operationally throughout its lifespan, results in better project cost and schedule adherence, and ensures that stakeholder needs are met.

FHWA realized the benefit of using a systems engineering analysis (SEA) on ITS projects and, since 2001, requires that a SEA be performed on all ITS projects funded through the Highway Trust Fund. Given the diversity in ITS projects, federal regulations require the SEA be on a scale commensurate with the project scope. As a result, this provides state and local agencies flexibility in the extent of how they conduct SEA.[2]

Key systems engineering principles include[3]:

- Agreements with all stakeholders on the purpose of the project and how success will be measured.
- Stakeholder involvement from local agencies, end users, and operational staff in all milestones of project planning and delivery.
- Solutions found through using the systems engineering process rather than jumping to solutions before accurately establishing the problem.
- Technology decisions based on the best solution for the problem; the best solution may not be immediately apparent.
- When necessary, breaking the problem down into smaller components and solving each one.
- Direct relationship of all actions to the tasks before and after during project development to ensure the final product can be traced back to the needs identified at the beginning.

There are many ways to conduct a SEA. One such method is the V model as shown in Figure 2.

[2] 23 CFR 940.11b
[3] Source: FHWA, Office of Operations, "Systems Engineering for Intelligent Transportation Systems, An Introduction for Transportation Professionals," January 2007. https://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf

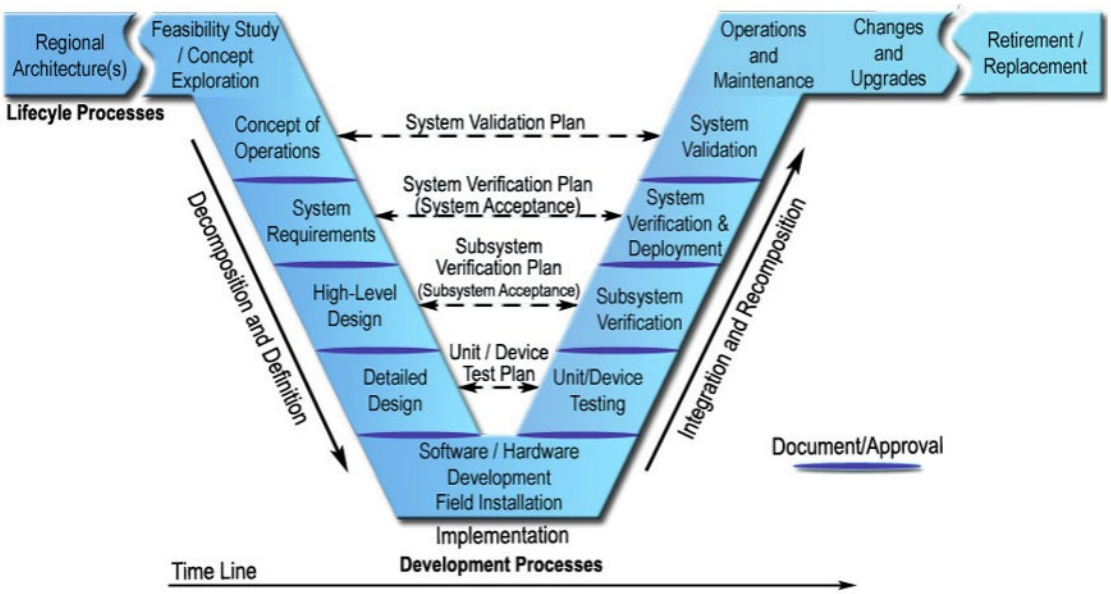

Figure 2: Diagram. Systems Engineering Model
Source: https://ops.fhwa.dot.gov/publications/seitsguide/section3.htm, FHWA, 2018

For more information on using a SEA during ITS project deployment, see the references at the end of this document.

Methods to incorporate ITS into transportation planning vary among agencies and regions. Ensuring processes are in place to consider ITS on all projects is a key component of TSMO planning. ITS enables agencies to holistically manage the transportation network, minimizing the need for additional capacity. Operational issues, such as congestion, require operational solutions. Establishing an operational plan for ITS that identifies challenges such as staffing, procurement processes, and funding allocation, is the first step to integrating ITS into the transportation planning process. Once operational constraints and solutions have been established, a regional ITS architecture should be developed.

A regional ITS architecture is a tool to assist with planning and implementing ITS needs. It promotes regional integration and interoperability of ITS components so that projects or services are deployed in an organized manner. The regional ITS architecture should define the needs and ITS solutions or selected ITS service packages for the region. Agencies can use the National ITS Architecture (now called the Architecture Reference for Cooperative and Intelligent Transportation[4] for assistance in developing their own regional plans. In addition to mobility and safety needs of the region, architectures should identify areas of ITS service gaps.

Finally, a project prioritization process or ITS Strategic Plan is established based on needs and opportunities identified during operational planning, ITS architecture development, benefit-cost ratios, and the SEA. Figure 3 shows elements used to incorporate ITS into programming.

[4] Architecture Reference for Cooperative and Intelligent Transportation, https://local.iteris.com/arc-it/

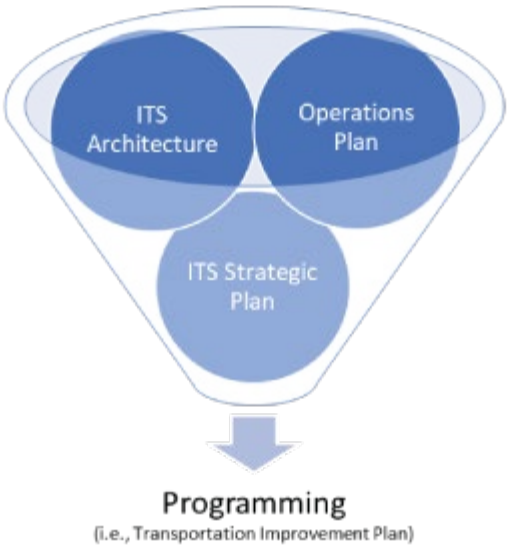

Figure 3. Chart. Incorporating ITS
Source: FHWA

CHAPTER 2 – BEST PRACTICE EXAMPLES

The Oregon Department of Transportation (ODOT), Georgia Department of Transportation (GDOT), Ohio Department of Transportation (OhioDOT), and the Utah Department of Transportation (UDOT) participated in previous second Strategic Highway Research Program (SHRP2) efforts. The capability maturity model (CMM) workshops with SHRP2 helped inform them about transportation systems management and operations (TSMO) and how it can apply to their agencies. This chapter highlights several successful initiatives each agency accomplished, specifically regarding systems and technology for TSMO.

Oregon Department of Transportation (ODOT)

ODOT supports the transportation needs of the State of Oregon through five regional offices. ODOT manages almost 74,000 miles of highways, streets, and roads, and over 8,000 bridges.

Enhancing Successful Technology Utilization and Deployment

Over the past few years, ODOT has developed a strong relationship with their internal information systems group, which has a proven systems engineering methodology. The information systems group is responsible for providing application development services, computer support, information security, governance, planning, and other information technology services. This relationship has established a strong foundation to implement ODOT's systems and technology programs, especially when TSMO was introduced. When completing the CMM assessment as part of the SHRP2 efforts, ODOT found that systems and technology was one of their strongest areas.

The agency has a statewide approach for operating and maintaining systems and technology. As such, ODOT needs a trained workforce to deploy their systems and software across the State for a broad range of uses that require tailoring the systems and software for urban and rural areas where needs vary. ODOT's intelligent transportation systems (ITS) maintenance group is responsible for ensuring ITS and signal devices are operational. This group is critical to success once projects and programs have been deployed or implemented. Figure 4 shows the workload of the ITS maintenance group.

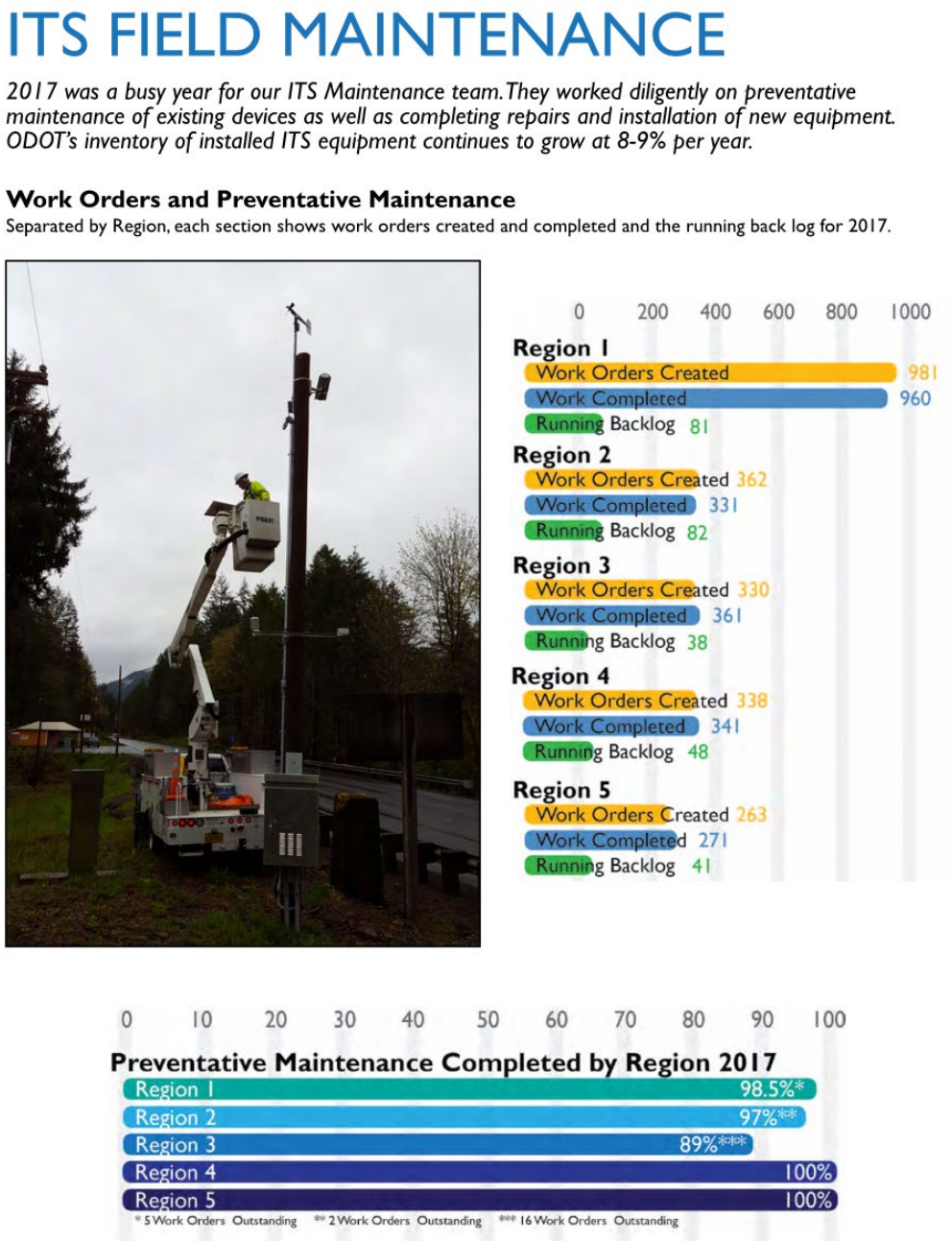

Figure 4. Photo. Intelligent Transportation Systems Field Maintenance
Source: 2017 Operations Program Annual Report, ODOT, 2017

ODOT attributes their success in systems and technology to the realization that ITS is a multi-discipline area. As such, their staffing includes a combination of information technology professionals, civil engineers, and electrical engineers. This mix of staff has proven to be effective at solving issues involving systems and technology, especially regarding software.

Planning and ITS

One of the goals identified after completion of the CMM assessment was to embed the ITS architecture and planning efforts within broader regional planning efforts. ODOT has a statewide ITS plan and statewide ITS architecture. ODOT has also worked with regional partners to develop regional ITS plans and regional ITS architectures but these plans have been disconnected from other regional planning efforts. As a result of the CMM assessment, ODOT is working to better integrate regional ITS and operations planning with the Region Transportation Plan update process.

ODOT has integrated systems engineering into its typical project delivery process. Systems engineering tasks have been integrated into their project schedule templates for operations projects. Project leaders now have a reminder to plan and think through systems engineering tasks in the early stages of a project so needs are preemptively identified and accounted for. Systems engineering deliverables, such as a concept of operations document, are prepared prior to the design acceptance stage in the project development process. This is the point early in the project where the full scope of the project is set. Having the desired system functions clearly specified early in the project ensures a good scope for the design and construction of the project and allows any required software development to proceed in parallel. This approach allows efficient delivery of projects, ensures that desired project outcomes are clearly understood, and provides good system documentation. ODOT noted that starting discussions about systems engineering early in a project has greatly impacted their ability to integrate the process into project development and delivery.

Another reason for ODOT's success is the process they established for scaling the systems engineering process to each project. For redundant projects, this process is minimal, but for a new project with new concepts, this process is a more in-depth effort. The purpose is to define new concepts and assess needs before the project begins. ODOT has a systems engineering and ITS architecture compliance checklist to efficiently identify which systems engineering tasks are needed for a project. An excerpt of this checklist is shown in Figure 5.

ITS Projects – Systems Engineering and Architecture Compliance (Rule 940) Checklist

SECTION 2 – Regional Architecture Assessment

2.1 PORTIONS OF REGIONAL ARCHITECTURE BEING IMPLEMENTED

- ☐ Archived Data Management
- ☐ Public Transportation
- ☐ Traveler Information
- ☐ Traffic Management
- ☐ Vehicle Safety
- ☐ Commercial Vehicle Operations
- ☐ Emergency Management
- ☐ Maintenance & Construction Management

Figure 5: Chart. Systems Engineering and Architecture Compliance Checklist
Source: ODOT

Georgia Department of Transportation (GDOT)

GDOT supports the transportation needs of the State of Georgia through seven districts. GDOT manages over 18,000 miles of interstates and highways, 5,000 miles of railroad track, 454 airports and heliports, and two marine ports.

Qualified Product List

After completing the CMM assessment as part of the SHRP2 efforts, GDOT created a Qualified Product List (QPL) containing all the ITS equipment approved for deployment on GDOT ITS projects. Vendors and manufacturers have their equipment tested and approved by GDOT for listing on the QPL. Contractors can pick any vendor or manufacturer for ITS equipment included on the QPL. Figure 6 shows part of the QPL for traffic signal and ITS equipment.

QP#	PRODUCT	CATEGORY
78	Traffic Signal Pull and Junction Boxes	Miscellaneous
79	Portable Arrow Boards	Traffic Control/Pavement Markings
80	Highway Sign Manufacturers	Traffic Control/Pavement Markings
81	Mineral Fillers	Asphalt
82	Portable Changeable Message Signs	Traffic Control/Pavement Markings
83	Center Mount Reflector Delineators	Miscellaneous

Figure 6. Chart. Example QPL Products and Categories
Source: http://www.dot.ga.gov/PS/Materials/QPL

Prior to the QPL, contractors for a project would submit products after reading the project specifications. GDOT would then have to review each product on a case-by-case basis to determine if it should be approved or denied for the project. This process delayed project construction and did not provide GDOT with sufficient time to review product compliance with specifications. GDOT's considerable number of simultaneous projects increased this challenge because the number of reviews became difficult to manage. The QPL eliminated this issue by significantly decreasing the amount of time the agency spends on product reviews.

One of the challenges associated with the QPL is keeping the list up to date. ITS technology is rapidly changing and improving and new products are released often. Part of the difficulty lies in trying to determine if a product requires retesting due to updates. This can become overwhelming if manufacturers release many updated products at once but fail to inform GDOT. This requires GDOT to actively monitor which products are no longer manufactured. Another

issue is when specifications are updated, there is a possibility that products no longer meet the new specification and must be retested.

Vendors and manufacturers realize the value of the QPL and will meet with GDOT to review specifications and share feedback. Making the process collaborative is mutually beneficial.

Ohio Department of Transportation (OhioDOT)

OhioDOT supports the transportation needs of the State of Ohio through 12 regional districts. OhioDOT manages over 49,000 lane-miles of interstates, highways, arterials, and collectors. Development of OhioDOT's TSMO program began in 2013 and is supported by the Traffic Management group of the Division of Operations.

ITS Maintenance and Operations

Historically, OhioDOT has centrally maintained ITS field devices with the exception of network routing and switching, which had been managed by the State Office of Information Technology (OIT). Through completion of CMM assessments as part of the SHRP2 efforts, one of the goals that OhioDOT established involved moving ITS network routing and switching from OIT to TSMO. This was beneficial for both groups. Operation and maintenance of ITS devices, including signals, did not align well with OIT's primary responsibilities. Following this shift, OhioDOT has seen improvements in service and reliability. Having an ITS network separate from the statewide information technology network provides an advantage because it is easier to manage and maintain. In addition, having all maintenance-related staff in the same group makes coordination and communication easier.

OIT is still involved with OhioDOT for information technology needs including data storage, management, and security. This is performed in cooperation with OhioDOT's TSMO unit through regular meetings.

OhioDOT experimented with allowing staff to utilize other non-engineering technical skills. By exploring other skills, employees can prove to OhioDOT that they are capable of handling different responsibilities and potentially finding a new role within the organization. An example of this was when an OhioDOT electrical engineer transitioned into an infrastructure specialist role while still performing electrical engineering tasks. This staff member is now the lead network engineer for the ITS network. Having flexible and capable staff has been instrumental to their TSMO successes.

Performance Measures in Planning

Additionally, OhioDOT has developed the Traffic Operations Assessment Systems Tool (TOAST) to help inform project planning by using available transportation data. Scores are calculated for routes with breaks at urban boundaries, interchange center points, and changes in roadway functional class. Scoring values range from 0-10 and performance percentages are calculated. Routes with lower percentages are identified as candidates to benefit from TSMO strategies. The data categories for OhioDOT's TOAST system are shown in Figure 7.

Figure 7: Chart. TOAST Data Categories
Source: FHWA

Having a clear strategic plan for systems engineering and ITS architecture for OhioDOT has enabled the agency to mature their capabilities in the systems and technology dimension. Communicating this ITS plan and engaging with the statewide audience ensures that the correct priorities are set and that the plan is successfully implemented.

Utah Department of Transportation (UDOT)

UDOT supports the transportation needs of the State of Utah through four regional offices. UDOT manages over 6,000 miles of interstates and State highways.

Modern Traffic Signal System

After completing the CMM assessment as part of SHRP2 efforts, UDOT prioritized signal upgrades in the State to support automated traffic signal performance measures (ATSPM) software that was developed in an effort led by the Indiana DOT with participation from FHWA, 11 State DOTs, and the City of Chicago. The ATSPM software allows better management and operation of the traffic signal system through visualization of high-resolution controller data. The software is open source and UDOT added more performance measures and customized the user interface in a way that fit their needs. The software has been shared with other agencies across the United States

Over 1,900 traffic signals were upgraded in Utah allowing UDOT to monitor and analyze the data of all signals in real-time, regardless of the owner, to make better and faster decisions. These decisions include responding to maintenance and operational issues as well as determining traffic trends. Because of these signal network upgrades, UDOT can monitor traffic across the State 24-hours a day, 365 days a year. In addition, UDOT created a website for the public to access traffic signal data, shown in Figure 8.

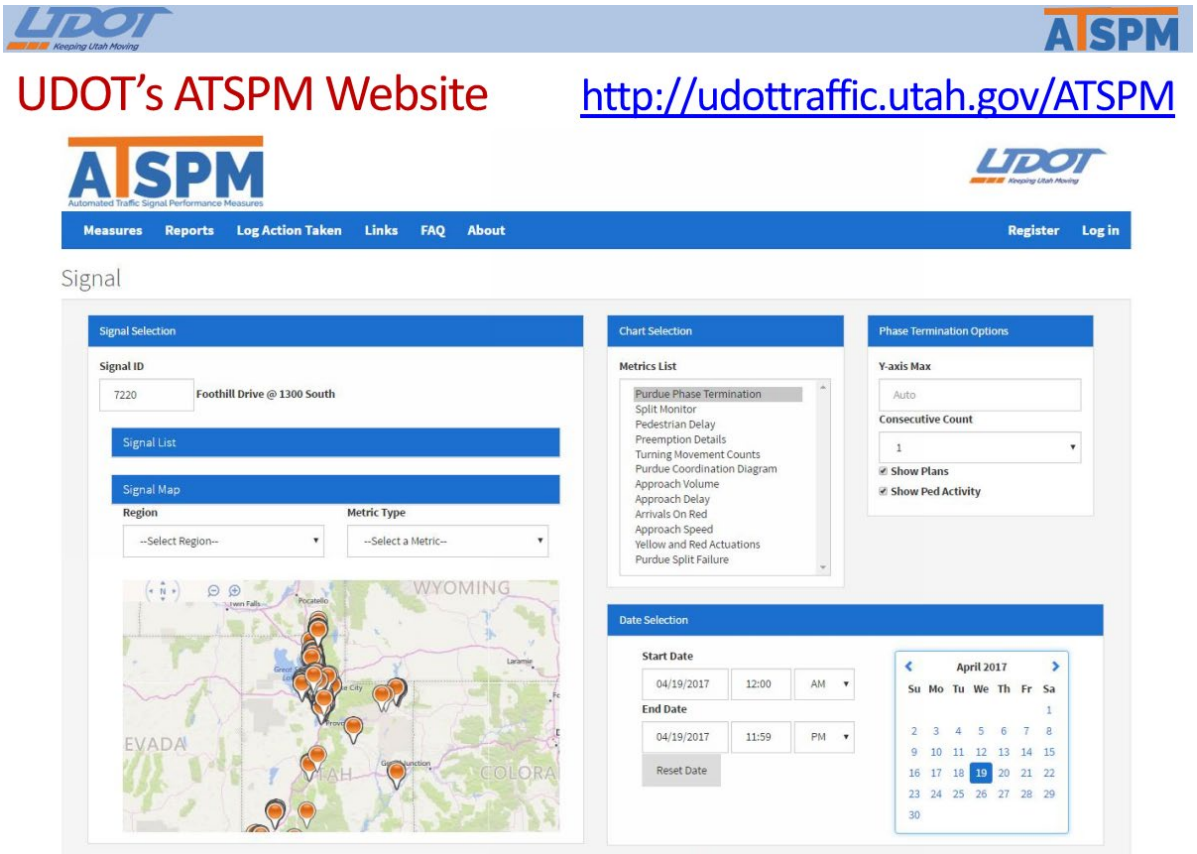

Figure 8. Photo. UDOT's ATSPM Website
Source: UDOT Automated Traffic Signal Performance Measures, UDOT, 2017

An enabling technology used by the signal system is a fiber optic network that connects all signals to UDOT. In the late 1990s during a major construction project near Salt Lake City, a decision was made to start laying fiber optic cable for the transportation system interconnect. Since this decision, installing either fiber optic cable or fiber optic conduit has become standard practice for large UDOT construction projects. Shortly after, UDOT hired a fiber manager who began to build public private partnerships (PPP) with private telecommunications companies. Through these PPPs, UDOT shared the costs of laying fiber and conduit with the companies based on an agreed upon trade value. This significantly reduced the cost of fiber construction for UDOT. These efforts contributed to growing the fiber optic network to over 2,000 miles in length, less than half of which were directly paid for by UDOT. Another key success to Utah's development is inclusion of all traffic signals on the same communication network, which enables UDOT to make important decisions on a large scale.

The traffic signal management plan is the overarching document that aligned these efforts. This plan, developed with FHWA, defines the mission statement, number of employees, budget, goals, and objectives for traffic signal operations and maintenance. In addition, the plan defined the goal of connecting all devices by fiber or radio statewide. This plan is valuable for providing a structured vision for the traffic signal program and how this program aligns with the overall goals and objectives of the agency.

CHAPTER 3 – SUMMARY

Each transportation agency has different approaches when addressing systems and technology. For some agencies, the emphasis is on optimizing departments and staff based on systems and technology needs. For other agencies, the emphasis is on the different types of technologies to be used. However, both of these areas must be emphasized to make the best use of systems and technology. Keeping up with the pace of technology is difficult but proper planning and efficient use of resources provides an environment that fosters advancement. All agencies interviewed for this case study had several key lessons learned that support the advancement of systems and technology in their TSMO programs:

- Having the right mix of disciplines, especially in an ITS department, is critical to creating and managing a robust ITS network. This area involves multiple skill sets to succeed. Selecting staff that meet these needs will ensure that the required areas of expertise are available to advance systems and technology.
- Combining appropriate departments or changing responsibilities can increase efficiencies for decision-making as well as align staff to contribute to a common goal. Modern systems and technology require planning and coordination among different areas of an agency.
- Managing and using technology the right way is critical to achieving TSMO goals. From increasing efficiency to gaining new insights from data, technology affects how agencies operate and can help realize large-scale changes that promote better use of transportation systems.

The benefits of using systems and technology to enhance the operation and efficiencies of transportation networks are proven. Examples include: mitigating arterial transportation challenges using automated traffic signal timing and performance measures; improving system reliability by deploying traffic management centers to monitor traffic flow; and enhancing safety in work zones by deploying traveler information systems, among others. The best practices identified in this case study can inform agency administration and leadership on the value of implementing systems and technology in day-to-day operations.

REFERENCES

Information for use in this case study was gathered from sources noted throughout the report together with the following web sites:

- FHWA's What is Transportation Systems Management and Operations (TSMO)?
  - https://ops.fhwa.dot.gov/tsmo
- AASHTO's TSMO Guidance
  - http://www.aashtotsmoguidance.org/
- FHWA's Organizing and Planning for Operations
  - https://ops.fhwa.dot.gov/plan4ops/
- FHWA's Organizing for Operations Resources
  - https://ops.fhwa.dot.gov/plan4ops/focus_areas/organizing_for_op.htm
- FHWA's Organizing for Reliability – Capability Maturity Model Assessment and Implementation Plans
  - https://ops.fhwa.dot.gov/docs/cmmexesum/sec1.htm
- FHWA's Creating an Effective Program to Advance Transportation Systems Management and Operations, Primer
  - https://ops.fhwa.dot.gov/publications/fhwahop12003/index.htm
- FHWA, Office of Operations, "Systems Engineering for Intelligent Transportation Systems, An Introduction for Transportation Professionals," January 2007
  - https://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf
- FHWA's Improving Transportation Systems Management and Operations – Capability Maturity Model Workshop White Paper – Systems and Technology
  - https://ops.fhwa.dot.gov/docs/cmmwhitepapers/systech/sec1.htm
- Additional SHRP2 Resources
  - https://www.fhwa.dot.gov/goshrp2/
- Oregon Department of Transportation
  - https://www.oregon.gov/odot/Pages/index.aspx
- Georgia Department of Transportation
  - http://www.dot.ga.gov/
- Ohio Department of Transportation
  - http://www.dot.state.oh.us/pages/home.aspx
- Utah Department of Transportation
  - https://www.udot.utah.gov/main/

Table 1. Interview Participants and Agencies

Agency	Oregon Department of Transportation (ODOT)	Georgia Department of Transportation (GDOT)	Ohio Department of Transportation (OhioDOT)	Utah Department of Transportation (UDOT)
Agency Representative Name:	Galen McGill	Mark Demidovich	Jason Yeray	Tyler Laing
Agency Representative Title:	Systems Operations and ITS Manager	Assistant State Traffic Engineer	Administrator	ITS Program Manager
Agency Representative Email:	Galen.e.mcgill@odot.state.or.us	mdemidovich@dot.ga.gov	Jason.Yeray@dot.ohio.gov	tlaing@utah.gov
Interview Date:	June 18, 2018	July 19, 2018	July 19, 2018	July 31, 2018

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

Office of Operations Web Site
https://ops.fhwa.dot.gov

July 2019
FHWA-HOP-19-064