

ORGANIZING FOR RELIABILITY – CAPABILITY MATURITY MODEL ASSESSMENT AND IMPLEMENTATION PLANS

Executive Summary



U.S. Department of Transportation
Federal Highway Administration

May 2015

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Introduction

The Second Strategic Highway Research Program (SHRP 2) L06 research determined that agencies with the most effective transportation systems management and operations (TSM&O) activities were differentiated not by budgets or technical skills alone, but by the existence of critical processes and institutional arrangements tailored to the unique features of TSM&O applications. The significance of this finding has been validated in 40 State and regional self-assessment workshops using the Capability Maturity Model (CMM) process. This report summarizes the general background, process, and outcomes of the CMM self-assessment workshop program.

Section 1 describes the basic SHRP 2 research identifying the key dimensions of capability needed to support effective TSM&O, the CMM framework structured around these dimensions, and the criteria for capability self-assessment in each. It describes the SHRP 2 and Federal Highway Administration (FHWA) sponsored workshops to date – their structure, process, and participants – and identifies the host State Department of Transportation (DOT) and regional entities.

Section 2 presents the general findings on TSM&O state-of-the-practice based on 40 workshops and subsequent implementation plans developed at 23 of those sites.

Section 3 presents a separate discussion for each of the six dimensions including:

- Key findings for the major elements of the subject dimension;
- Key synergies with other dimensions; and
- State DOT/Regional implementation plan priorities for the subject dimension.

Section 4 uses the common implementation plan priorities for the six dimensions as the basis for determination of a set of potential national activities needed both to disseminate best practice and to support development of certain new business and technical methods and processes. Important roles are seen for FHWA, the American Association of State Highway and Transportation Officials (AASHTO), and the National Operations Center of Excellence (NOCoe).

An appendix contains a comprehensive list of implementation plan priorities as indicated in the 23 workshops.

1.0 State DOT and Regional Capability Maturity Self-Assessment Program: General Background

Many State DOTs and regions have recognized the importance of more effective TSM&O to improving customer service and system performance. TSM&O is an integrated program to optimize the performance of existing multimodal infrastructure through implementation of specific systems, services, and projects designed to preserve capacity and improve the security, safety, and reliability of the transportation system.

1.1 SHRP 2 Research on Reliability and the TSM&O Capability Maturity Model

SHRP 2 included a Reliability Focus Area that produced research and products on many important data, analytic, and design issues, as well as process and applications improvements. In addition, the SHRP 2 Reliability Focus Area included a project to identify the institutional characteristics of the agencies with the more effective TSM&O activities.¹ This research determined that agencies with the most effective TSM&O activities were differentiated not by budgets or technical skills alone, but by the existence of critical processes and institutional arrangements tailored to the unique features of TSM&O applications. These processes and institutional arrangements are organized into six dimensions: business processes; systems and technology; performance measurement; agency culture; organization and staffing; and collaboration.

Using these critical dimensions, the research project adapted concepts from the CMM process – widely used in the Information Technology industry – to create a self-assessment framework designed to help transportation agencies identify their current strengths, weaknesses, and related actions needed to improve their capabilities for effective TSM&O – in effect, a roadmap for “getting better at getting better.”

A detailed version of the CMM framework was further developed into a web-based self-assessment tool: *AASHTO Guide to Transportation Systems Management and Operations*.² The framework has been used in the National Operations Academy™ and the Regional Operations Forum programs, as well as by FHWA in specific applications.³

The TSM&O CMM framework was adapted for use in the facilitated one-day self-assessment workshop process for State DOTs and regions. As part of the SHRP 2 research project, the process was validated in five State and regional workshops in 2010 and 2011. Following validation, FHWA sponsored 11 additional workshops from 2011 through 2013.

¹ *Institutional Architectures to Improve Systems Operations and Management*, SHRP 2 L06, 2012.

² National Cooperative Highway Research Program Project 03-94 (2011).

³ National Operations Academy™: <http://www.operationsacademy.org/index.html>; and Regional Operations Forums: <http://www.transportationops.org/resources/regional-operations-forums>.

1.2 CMM Workshop Program

Based on this experience, FHWA expanded the workshop concept through its SHRP 2 Implementation Assistance Program by adding a pre-workshop senior leadership meeting and post-workshop implementation plan development based on the priority actions established in the self-assessment process. In 2013, FHWA and AASHTO solicited State DOTs and regional agencies and selected 27 host entities to implement this full process. Three of these 27 previously had conducted a self-assessment workshop and were selected to develop an implementation plan.

In total, 40 TSM&O CMM workshops have been conducted through December 2014 as shown in Figure 1.1.

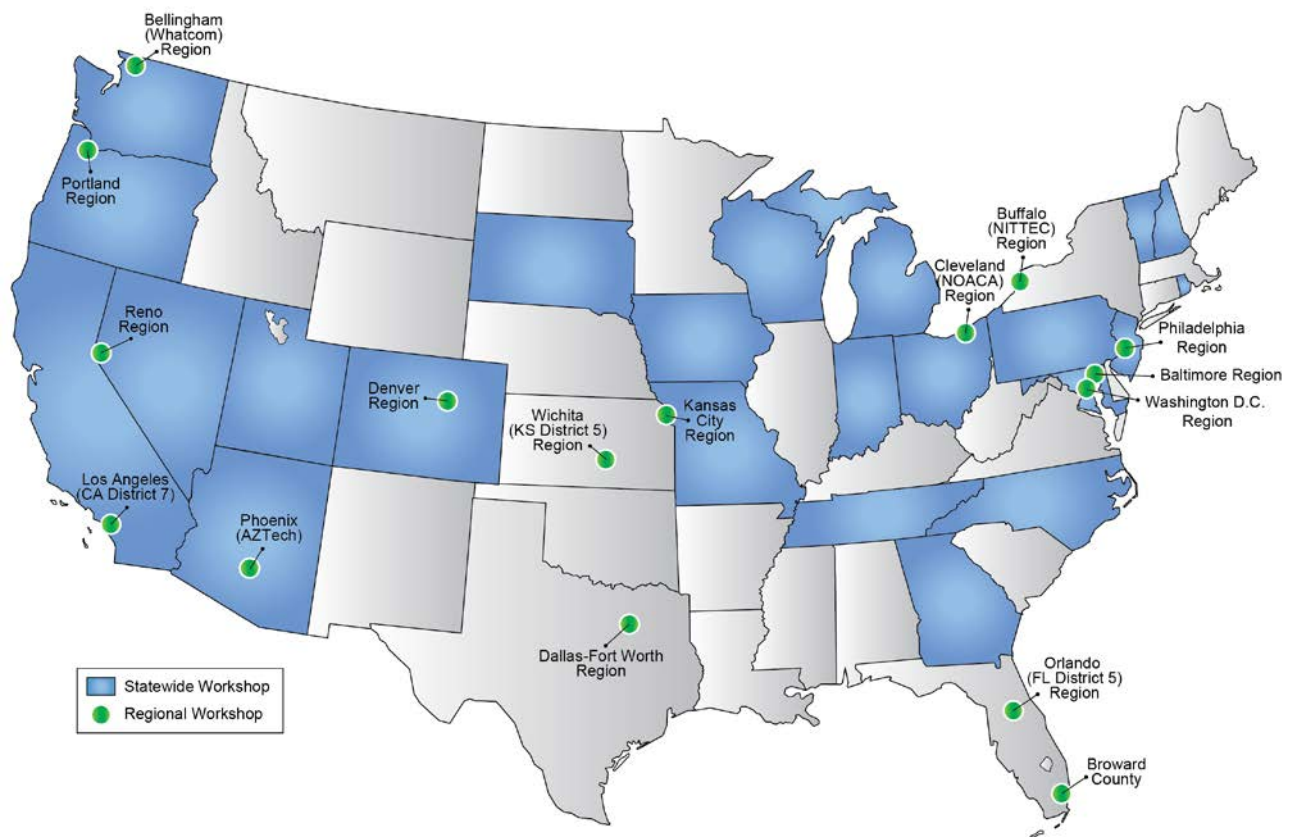


Figure 1.1 Map. Self-Assessment CMM Workshop Locations

(Source: Cambridge Systematics, Inc.)

This report synthesizes findings, as of December 2014, from 23 of the sites selected by FHWA and AASHTO in 2013 as part of the SHRP 2 Implementation Assistance Program. These 23, listed in Table 1.1, included consultant workshop development and facilitation. Twenty of these sites, indicated in bold, also received consultant assistance for creation of their implementation plans. Of the 23 workshops, 19 were hosted by State DOTs, of which 17 were

statewide in focus. Six workshops had a regional focus (indicated in italics), of which two were hosted by State DOT districts and four were hosted by regional entities, including metropolitan planning organizations (MPOs).⁴

**Table 1.1 Self-Assessment CMM Workshop Locations Analyzed
in this Final Report**

Arizona	<i>NOACA (Cleveland, Ohio)</i>
California	Ohio
Colorado	Oregon
<i>Florida District 5 (Orlando)</i>	Pennsylvania
Georgia	Rhode Island
Iowa	South Dakota
<i>Kansas District 5 (Wichita)</i>	Tennessee
Maryland	Utah
New Jersey	<i>Washington, D.C.</i>
Michigan	Washington State
Missouri	<i>Whatcom (Whatcom County, Washington)</i>
<i>NITTEC (Buffalo, New York)</i>	

1.3 The CMM Self-Assessment Workshop Objectives and Stakeholders

The CMM workshops are intended to improve the effectiveness of TSM&O applications and activities by assisting staff and management who are central players in statewide and regional TSM&O agencies. The workshop framework provides a structured focus on the six dimensions of capability, together with a facilitated self-assessment process in which participants evaluate their current activities and arrangements according to criteria from the CMM framework defining levels of capability. The current challenges and problems identified by workshop participants are used to identify actions needed to improve capability and are subsequently embodied in an implementation plan to improve the effectiveness of TSM&O.

Given the self-assessment focus, workshop participation includes agency middle management: the unit managers and key technical staff with day-to-day oversight of TSM&O-related activities. Senior management are involved in a pre-workshop briefing, referred to as the Senior Leadership meeting, and their approval of the implementation plans are required as a

⁴ The three sites not bolded in Table 1.1 completed an implementation plan without consultant assistance, along with four other sites (out of 27) not listed in the table for which no consultant assistance was supplied for a workshop or an implementation plan.

precondition of Federal financial assistance. Workshops are limited to 20 to 25 participants selected by the host agency to represent the most important players at central office and district/regional units, as well as their partners in the delivery of TSM&O, including public safety agencies, MPOs, local governments, and the private sector.

1.4 The Capability Maturity Self-Assessment Framework

The CMM self-assessment framework is structured in terms of six dimensions of capability. Three dimensions are process oriented:

1. **Business Processes**, including planning, programming, and budgeting (resources);
2. **Systems and Technology**, including use of systems engineering, systems architecture standards, interoperability, and standardization; and
3. **Performance Measurement**, including measures definition, data acquisition, and utilization.

Three dimensions are institutional:

1. **Culture**, including technical understanding, leadership, outreach, and program legal authority;
2. **Organization and Staffing**, including programmatic status, organizational structure, staff development, and recruitment and retention; and
3. **Collaboration**, including relationships with public safety agencies, local governments, MPOs, and the private sector.

For each of these six dimensions, the self-assessment utilizes four criteria-based “levels” of capability maturity that indicate the direction of managed changes required to improve TSM&O effectiveness:

- **Level 1 – “Performed.”** Activities and relationships largely ad hoc, informal, and champion driven, substantially outside the mainstream of other DOT activities.
- **Level 2 – “Managed.”** Basic strategy applications understood; key processes support requirements identified and key technology and core capacities under development, but limited internal accountability and uneven alignment with external partners.
- **Level 3 – “Integrated.”** Standardized strategy applications implemented in priority contexts and managed for performance; TSM&O technical and business processes developed, documented, and integrated into DOT; partnerships aligned.
- **Level 4 – “Optimizing.”** TSM&O as full, sustainable core DOT program priority, established on the basis of continuous improvement with top-level management status and formal partnerships.

Table 1.2 illustrates the basic CMM self-assessment framework of dimensions and levels of capability.

Table 1.2 The CMM Self-Assessment Framework

Dimensions	Capability Level Criteria			
	Level 1 Performed	Level 2 Managed	Level 3 Integrated	Level 4 Optimizing
Business Processes (Planning and Programming)	Each jurisdiction doing its own thing according to individual priorities and capabilities	Consensus regional approach developed regarding TSM&O goals, deficiencies, B/C, networks, strategies and common priorities	Regional program integrated into jurisdictions' overall multimodal transportation plans with related staged program	TSM&O integrated into jurisdictions' multi-sectoral plans and programs, based on formal continuing planning processes
Systems and Technology	Ad hoc approaches to system implementation without consideration of systems engineering and appropriate procurement processes	Regional ConOps and architectures developed and documented with costs included; appropriate procurement process employed	Systems and technology standardized and integrated on a regional basis (including arterial focus) with other related processes and training as appropriate	Architectures and technology routinely upgraded to improve performance; systems integration/ interoperability maintained on continuing basis
Performance Measurement	Some outputs measured and reported by some jurisdictions	Output data used directly for after-action debriefings and improvements; data easily available and dashboarded	Outcome measures identified (networks, modes, impacts) and routinely utilized for objective-based program improvements	Performance measures reported internally for utilization and externally for accountability and program justification
Culture	Individual staff member champions promote TSM&O, varying among jurisdictions	Jurisdictions' senior management understands TSM&O business case and educates decision makers/public	Jurisdictions' mission identifies TSM&O and benefits with formal program and achieves wide public visibility/understanding	Customer mobility service commitment accountability accepted as formal, top level core program of all jurisdictions
Organization/Staffing	TSM&O added on to units within existing structure and staffing – dependent on technical champions	TSM&O-specific organizational concept developed within/ among jurisdictions with core capacity needs identified, collaboration takes place	TSM&O Managers have direct report to top management; Job specs, certification and training for core positions	TSM&O senior managers at equivalent level with other jurisdiction services and staff professionalized
Collaboration	Relationships ad hoc and personal (public-public, public-private)	Objectives, strategies, and performance measures aligned among major players (transportation and public safety agencies (PSAs)) with after-action debriefing	Rationalization/sharing/ formalization of responsibilities among key players through co-training, formal agreements, and incentives	High level of TSM&O coordination among owner/operators (State, local, private)

Levels cannot be skipped as an agency improves its capability since each level builds on the technical and/or organizational readiness of the previous level. The dimension at the lowest level of capability is usually the principal constraint to improvement in program effectiveness and therefore the highest priority focus for capability improvement.

1.5 The CMM Workshop Process

The full CMM self-assessment workshop sequence conducted for the 23 agencies summarized in this report consists of four steps. The first step involves pre-workshop preparation by the facilitators to review key documents provided by the State or region documenting current TSM&O initiatives and activities, programs, and priorities in the host area. Facilitators review items such as ITS strategic plans, concepts of operations, long-range transportation plans, agency organization charts, and other relevant plans and documents. A pre-workshop conference call with the lead and/or core team from the host State or region also helps to identify current issues and challenges.

The second step is a senior leadership meeting held a day in advance of the workshop at which senior agency leaders are briefed to explain the process and its value and to obtain their perspectives on important issues.

The third step is the facilitated self-assessment workshop involving the essential TSM&O-related managers from State DOTs and their partners. This workshop starts with a facilitated self-identification of current strengths and weaknesses in each dimension and a consensus determination regarding their current levels of capability. These assessments serve as the basis for participants' identification of the actions needed to improve to the next level of capability in each dimension and the priorities on which to focus.

The fourth step consists of implementation plan development. Based on workshop results, the facilitators suggest work program tasks for the priority dimensions, starting with those at the lowest level of capability. The host agency then produces a detailed implementation work program to improve capabilities in these priority dimensions and makes adjustments to the recommendations as they see fit. Upon FHWA and host agency management approval, the implementation plan is eligible for both financial and technical resource support from FHWA and AASHTO under the SHRP 2 Implementation Assistance Program. The support includes training, workshops, peer exchanges, technical assistance, collaboration activities, and additional progress assessments and meetings.

The CMM concept including the dimensions and levels utilized in the TSM&O program level assessments presented in this report have also been adopted by FHWA for utilization in developing application-specific self-assessment tools and activities.

2.0 Summary of All Capability Dimensions

Table 2.1 and Figure 2.1 presents the range of self-assessment levels by CMM dimension and capability level for the 23 workshop locations with implementation plans analyzed in this report.

Table 2.1 Workshop Self-Assessment Levels Distribution by Dimension (23 Workshops)

Dimension	Capability Self-Assessment			
	Level 1 Performed	Level 2 Managed	Level 3 Integrated	Level 4 Optimizing
Business Processes	11	10	2	0
Systems and Technology	7	12	3	1
Performance Measurement	9	11	3	0
Culture	8	11	4	0
Organization and Staffing	8	9	6	0
Collaboration	4	12	6	1

Note: Workshop self-assessment scores were often augmented with a “plus” or “minus” or given as a fraction (e.g., 1.5). For the purpose of the exhibit, “pluses” and “minuses” were ignored and all fractions were rounded to a whole number (with one-halves rounded down).

Self-assessment “scoring” is subjective and specific to each site. The result represents the consensus of workshop participants – agency staff and their partners. The distribution of assessment levels shown in Table 2.1 and Figure 2.1 suggest certain general conclusions:

- Most locations assessed themselves at the “performed” or “managed” level (often somewhere in between) for most dimensions. This suggests that key issues for those dimensions are increasingly well-understood and consideration is being given to improvement actions. However, only a few agencies indicated reaching the level of “integrated” for any given dimension, even fewer rated themselves at that level in more than one dimension, and only two locations rated themselves as “optimizing” in a specific dimension.
- Collaboration and Systems and Technology are the strongest dimensions: for Collaboration, this appears to reflect the impact of recent FHWA incident management training and other collaboration outreach; for Systems and Technology, this is based on the accumulated experience with technology deployment over the past 10-15 years. Performance Management and Business Processes (reflecting planning and programming) exhibited a different pattern: most agencies were aware of the need for improvement in these areas in response both to Federal policy and their own internal needs – and are beginning to evolve approaches to meet those needs.

- There is often a significant gap between best practice and average practice among sites within any given dimension. Even within individual States, progress in improving capabilities across the six dimensions is uneven. In many cases, however, there is visible change and strong staff leaders that are fully aware of best practice and are working within their agencies to establish the essential capabilities.
- While the aggregate assessment distributions among several dimensions were similar, this result masks very different distributions within individual agencies; that is, strengths and weakness differed among agencies responding to varying conditions.

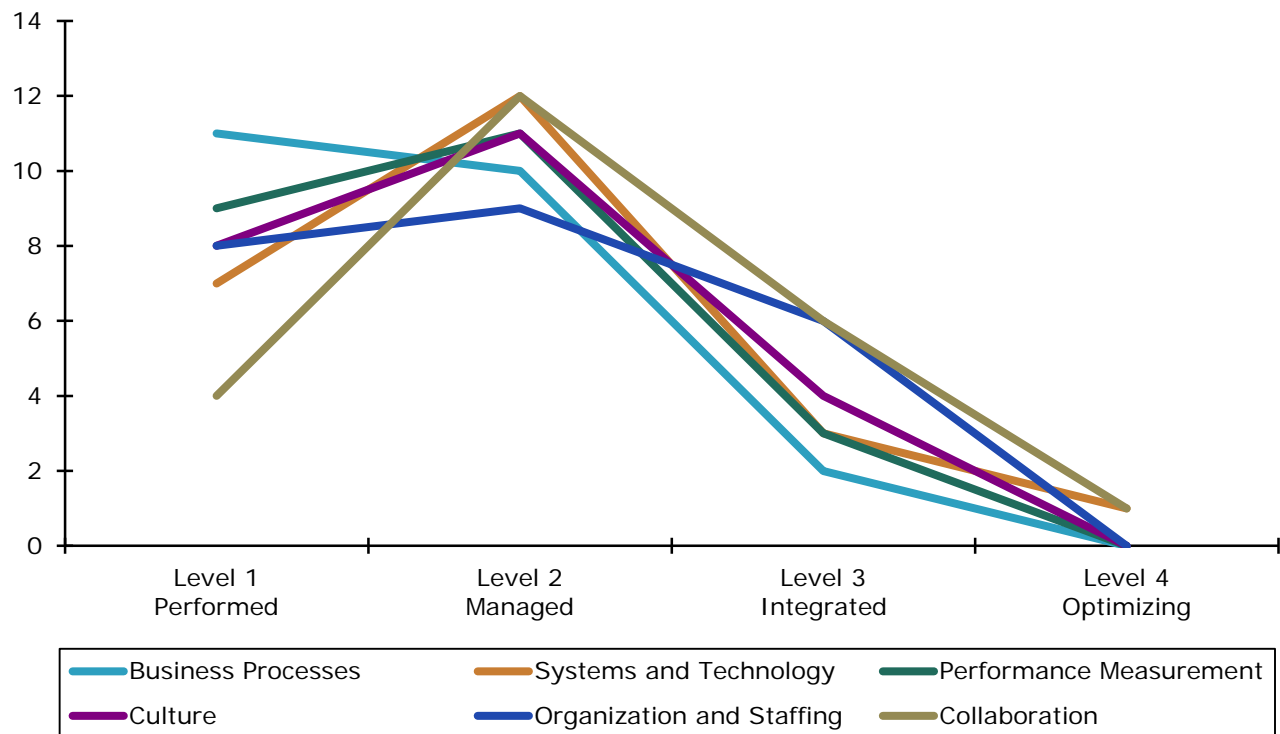


Figure 2.1 Graph. Distribution of Self-Assessments (23 Workshops)

(Source: Cambridge Systematics, Inc. and Parsons Brinckerhoff.)

It should be noted that the self-assessment scores cannot be used for cross-site comparisons, as some sites were “tougher” self-graders than others. However, within any given workshop location, the scores for each dimension appear to reflect the relative level of capability among the dimensions.

2.1 Synergies among Dimensions of Capability

One of the most important findings of the SHRP 2 research, clearly validated in the workshops, was the apparent interdependence among process and institutional dimensions, as suggested in Figure 2.2.

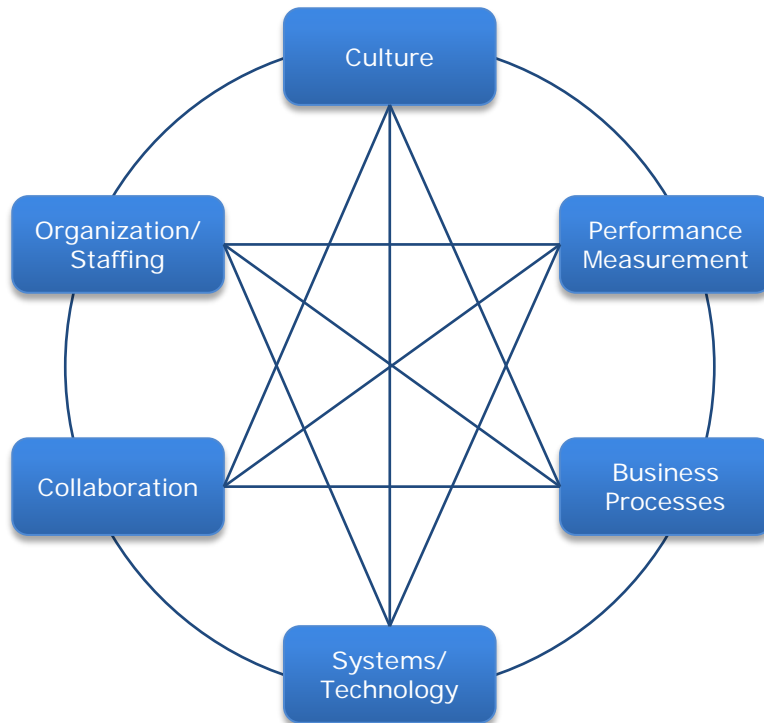


Figure 2.2 Graph. Synergy among Dimensions of Capability

(Source: Cambridge Systematics, Inc. and Parsons Brinckerhoff.)

The dimensions of capability appear to be highly interdependent, such that it is difficult to improve a current level of capability in one dimension without simultaneously improving other dimensions that support it. This is reflected by the narrow spread in capabilities found among all workshops. As examples, workshop participants noted that strategic planning is hampered by lack of performance data; business processes were hampered by lack of staff capabilities; and reorganization was impossible without top management buy-in to the culture of TSM&O.

The wide variety of improvement actions identified by workshop participants across the six dimensions – including plans, processes, agreements, business cases, and organizational and staffing recommendations – reflect that each has a mutually reinforcing effect on overall capability. This synergy among the dimensions appears to represent a major management challenge to agencies desiring to improve TSM&O effectiveness, as it indicates that the required actions are likely to involve several agency units, including several necessarily involving top management.

3.0 Summary of Capabilities by Dimension

In the following sections, the state of the practice for each of the six dimensions of TSM&O capability is discussed, including general observations, highlights for the key elements within each dimension, key synergisms and TSM&O implementation plan priorities.

3.1 Business Processes Dimension

3.1.1 State of the Practice Findings

Key findings from the workshops for the Business Process dimension are summarized below in terms of key elements of capability.

General

There are very few statewide TSM&O-specific plans that go beyond ITS and an equally limited number of MPOs with a TSM&O-related plan or budget element. TSM&O planning and budgeting have been largely limited to specific projects or initiatives. In addition, TSM&O as a program has very limited visibility in statewide and MPO comprehensive plans and programs – although valuable guidance is available. Planning initiatives are discouraged by lack of sustainable funding and lack of program status. TSM&O funding is rarely over 2-3 percent of agency total on a multiyear basis. However, newly emerging multijurisdictional applications and new technology applications (integrated corridors, active traffic management, connected vehicles) appear to highlight the need for a systematic planning approach. Consensus indicates that a start-up TSM&O “program plan” is needed with several components, including the basic business case and strategies for dealing with all the CMM dimensions as well as system investment strategies. Workshop participants noted lack of relevant methodologies and the lack of technical capacities.

TSM&O Planning Process

- **Plateauing.** Many of the state TSM&O activities have “plateaued.” They have completed implementation of conventional freeway management applications and now realize that expanding beyond these conventional applications requires new planning and programming, especially for strategies that involve greater involvement with other stakeholders.
- **Types of current TSM&O-related planning efforts.** Very few states have incorporated TSM&O as a distinct category of expenditure in their agency comprehensive plans and programs. However, some states have produced separate “plans” for specific applications such as incident management and Integrated Corridor Management.
- **Need for a “TSM&O Program Plan.”** A TSM&O-specific plan is not required either by Federal regulations or as a matter of standard agency procedure. However, there was widespread support for a specific start-up TSM&O Program Plan, including the business

case, performance measures, concepts of operations, procedures/protocols, and organizational, staffing and collaboration needs – as well applications priorities.

- **TSM&O element in statewide planning.** TSM&O has not achieved the status of a formal “program” within the statewide planning process, either as an investment category or as an alternative to certain capacity improvements. However, a few MPOs have distinct TSM&O plan elements and have included them in their metropolitan plans.
- **Key capabilities and methodologies needed – pilot approach.** Agency TSM&O staff lack both a planning background and relevant planning tools and methods. At the same time agency planning staff lack a TSM&O background. In several workshops, Strategic Highway Safety Plans were identified as a relevant model. Several agencies are using corridor programs as the template for the development of needed approaches.

Programming/Budgeting

- **TSM&O programming and budgeting.** Most TSM&O funding for specific projects is ad hoc and intermittent. Funding is inhibited by TSM&O’s lack of program status and agency resource constraints and thereby leads to fragmented implementation, difficulty addressing lifecycle costs, and vulnerability (elimination from programs when cost reductions are necessary).
- **Level of investment.** Few State DOT managers know what resources are being invested in TSM&O or how current investments might relate to more cost-effective use of scarce DOT resources. The absence of a plan-based TSM&O program and related multiyear budget reduces the ability of TSM&O to compete for these resources.

Project Development/Procurement

- **Accommodating the project development process.** TSM&O projects have special requirements (systems engineering, concepts of operations, types of procurement, systems integration/deployment needs, and special contracting requirements) that make them difficult to accommodate in the conventional project development process. Procurement of advanced technology systems is presenting a special challenge.

3.1.2 Metropolitan/Regional Planning Organization Roles

Workshop locations did not include any of the few regions that have prepared TSM&O-related plans. However, the larger workshop MPOs conduct a Congestion Management Process, and several have allocated Congestion Mitigation and Air Quality Improvement (CMAQ) funds under their control for signal upgrades and coordination, and sponsored/managed incident management training for their local transportation and public safety members.

3.1.3 Synergism

TSM&O Business Processes are especially dependent on capabilities in other dimensions: on systems engineering to identify concepts of operations required for planning and programming; on organization and staffing for relationships between planning and TSM&O staff; and, on performance measurement for the setting of objectives and progress measurement. All these relationships are often collaborative in nature.

3.1.4 State DOT and Regional Implementation Plan Priorities

The leading participant-suggested implementation plan priorities in Business Processes focus on developing and communicating a regional/statewide “TSM&O Program Plan” and integrating TSM&O into statewide long-range plans and transportation improvement programs. See the appendix for the complete list of suggested implementation plan priority actions for the Business Processes dimension.

3.2 Systems and Technology Dimension

3.2.1 State of the Practice Findings

Key findings from the workshops for the Systems and Technology dimension are summarized below in terms of key elements of capability.

General

Systems development is consistently well-understood. Statewide and/or regional ITS architectures or concepts of operations usually exist (typically following FHWA guidance), although they are often more than a few years old and need updating or better documentation. New applications involving arterial operations and Integrated Corridor Management require new architectures and concepts; keeping up-to-date with rapidly advancing technologies is a challenge. Many states rely on private consultants to supply this expertise. Separate State departments of Information Technology (IT) are seen as a significant barrier to efficient procurement of new systems with low bid constraints and inappropriate State standards. Interoperability is often a problem with regard to both data and voice communications, with cost a major barrier to improvements in the latter. This is especially a concern in multijurisdictional environments.

Regional Architectures

- **Regional and statewide ITS architecture documents and use.** All workshop states have some kind of an ITS architecture (either statewide or regional) consistent with Federal standards and the National ITS Architecture, although they were often acknowledged as needing updating. However, the use of the architecture for project planning or procurement varied widely. The importance of concepts of operations was also widely

understood for its importance in identifying appropriate roles and relationships for each TSM&O application.

Project Systems Engineering/Testing and Validation

- **Improve awareness and training.** The systems engineering process was generally employed by State DOTs and MPOs for ITS projects, following the guidance provided in the National Architecture program and requirements of using the systems engineering process, in place since 1998. However staff turnover results in significant training gaps regarding exposure to FHWA training opportunities. State DOT rotational training programs typically do not include a slot for ITS or TSM&O assignments. With staff turnover and/or expansion, and with new technologies entering Transportation Management Centers (TMC), lack of staff capabilities was noted as a serious challenge. Some of these challenges are being met by an increased level of outsourcing of technical responsibilities to the private sector, especially within TMCs.
- **Procurement challenges.** Oftentimes States noted that purchasing ITS hardware is often subject to State IT procurement procedures, which often were felt to be inappropriate to the special characteristics of ITS infrastructure and systems and software – as well as being lengthy, bureaucratic, and unresponsive to technology lifecycles. In addition, standard State procurement approaches (low bid, security issues) were noted as not aligning with specific ITS or TSM&O requirements. Where ITS infrastructure was embedded in other construction projects, the cost pressures and lack of staff influence also were noted as challenges to advancing ITS procurements.
- **Keeping pace.** Workshop participants identified the challenge of keeping pace with rapidly evolving technology and the difficulties this creates, such as obsolescence of deployed equipment, outdated specifications, legacy equipment incompatibility with newer equipment, incompatibility with deployed software, and maintenance capabilities. There were also a wide range of issues associated with keeping up with maintenance of equipment, including learning to maintain new technology while maintaining older deployed technology when vendors move on to newer and more advanced equipment.

Standards/Interoperability

- **Interoperability.** Many State DOTs have made interoperability of systems a priority for both field and central system hardware and software operations. There is a reluctance to upgrade large legacy systems when they are incompatible with newer equipment. Interoperability is often a special issue for systems maintained by various agencies within a region, such as voice and data communications between a DOT and public safety agency or transit agency's computer-aided dispatch system.
- **Standards.** Workshop participants are aware of the necessity of updating standards regularly to stay on the forefront of quickly evolving technologies, with interoperability as the motivating goal. Reorienting standards away from technical specifics to functional requirements has allowed for an improved ability to keep pace with technology, and open

standards has allowed for more flexibility in procurements. Participants noted the challenge of accessing resources, guidance, and peer interaction to maintain their knowledge of evolving standards.

- **Documentation.** Concepts of operations and project architecture documentation were not consistently produced, except for larger, complex projects or where Federal funding requirements necessitated preparing them. In many cases, existing material lacks important information components such as cost elements, performance requirements, and evaluation. Ad hoc approaches to system implementation, with limited documentation, were oftentimes still employed, thereby holding back the success of agencies' programs.
- **Approved vendor product lists.** Agencies find that having qualified (pre-certified) product lists facilitates purchasing ITS elements and can reduce the time needed to acquire products. The challenge of having (and continually maintaining and updating) specifications for field equipment was cited in several workshops.
- **Arterial systems experience.** Most State DOTs have considerable experience with freeway management systems. State involvement with arterial operations is more varied. Some State DOT traffic engineering units are administratively separate from freeway management. An increased focus on arterial operations and integrated corridors are creating new systems integration challenges within TMCs, with a focus on developing plans and institutionalizing TSM&O freeway and arterial applications and performance guidelines.

3.2.2 Synergism

Central to the Systems and Technology dimension are Business Processes and planning documents such as the statewide architecture and concepts of operations associated with technology projects. Links to the Organization and Staffing dimension were identified due to the need for additional systems engineering and other technical training. Collaboration has strong linkages, with the need for coordination with many stakeholders a core element in the systems engineering process.

3.2.3 State DOT and Regional Implementation Plan Priorities

The leading participant-suggested action included in TSM&O implementation plans for Systems and Technology related to the need to work with State IT agencies regarding the special technical requirements of ITS – including appropriate standards, specifications, procurement processes, vendor lists, and general streamlining of approaches – possibly through forming joint working groups. In addition, most workshop participants recognized the need to update and document their existing systems architectures – and to take a more formal systems engineering approach to new TSM&O applications with multijurisdictional and/or new technology challenges. See the appendix for the complete list of suggested implementation plan priority actions for the Systems and Technology dimension.

3.3 Performance Measurement Dimension

3.3.1 State of the Practice Findings

Key findings from the workshops for the Performance Measurement dimension are summarized below in terms of key elements of capability.

General

Most agencies are conscious of the need to measure operational performance and aware of impending MAP-21 requirements. Many agencies have defined measures, but are struggling with accessing relevant data and creating appropriate analytics. Existing measures are largely output oriented. There is little development of customer-focused outcome measures and agency staff noted lack of guidance and examples. There is limited accountability for operational performance beyond visible agency performance in major incidents/weather events, and few agencies use measures to manage improvements. Participants noted that private sector data and the potential of connected vehicle systems were important new sources of “big data” and increasing awareness of these relationships must be part of an ongoing dialogue.

Measures Definition

- **Policy visibility of performance.** Most States are conscious of the impending requirements of MAP-21, and performance measures are much discussed in professional circles. All workshop locations were at least in the stage of producing operations performance measures and most had started to compile them, with the vast majority being related to Transportation Incident Management (TIM), probably because of the availability of data from incident management logs and the focus on TIM programs and strategies that is emerging across the country.
- **Performance measure definition.** Lack of consensus over performance measure definitions where multiple agencies are involved – such as incident management – is sometimes problematic. State DOTs and public safety agencies may hold themselves to different standards regarding the stages in incident management and this can be a special problem for State DOTs that are dependent on law enforcement Computer Aided Dispatch (CAD) data.
- **Input, output, and outcome measures.** A few agencies have defined outcome as well as output measures, but the need for guidance and standardization of outcome was cited by several agencies. Creating outcome measures is impeded by limitations on the availability and integration of multisource data. At least two agencies identified the need to track assets (“input” performance measures) in addition to outputs and outcomes. A few agencies noted a disconnect between operations units and planning units in terms of performance measures, i.e., different measures are used.

- **Resources for performance measurement.** Obtaining funding for performance measurement is a challenge for some agencies although several have established an agency-wide unit in response to the performance measurement requirements of MAP-21 that is considering adding TSM&O measures.

Data Acquisition

- **Existing in-house data availability.** Data availability varies. Some TSM&O units collect and “own” TIM data while others are dependent on emergency responder CAD systems. Freeway detector data also are widely available and used by some agencies to create congestion statistics. Work zones are usually overseen by other units which often have their own processes.
- **Outsourcing.** Private vendor vehicle probe data are becoming more widely available, not only to meet MAP-21 requirements but also to fill in gaps where detectors do not exist.

Measures Utilization

- **Internal utilization.** Incident management and snow and ice control – with high visibility – are the two areas where performance data are used for operational management. Many States collect and report basic incident data, and some conduct after-action review of incidents that are supported by the data. However, only a few make routine use of the data to modify incident management programs. Traveler information program performance (e.g., web site hits and variable message sign messages posted) also was noted by several areas. Agencies also are struggling to decipher how to use performance measures in the decisionmaking process regarding problem identification and resource allocation.
- **External reporting.** Production of periodic performance reports was the most common use of performance measures – largely output data on external (web site) dashboards. Incident characteristics were by far the most frequent subject of performance reports. Travel time (congestion) reports and service patrol feedback were far less common.
- **Management accountability.** Accountability for TSM&O program performance is in the early stages. Several States have incident clearance targets but conduct reviews only when the target (often 90 minutes) is exceeded. There were no instances described in workshops where State DOT units were subject to performance reviews in this regard.
- **Comprehensive performance management program.** No agency has achieved a fully integrated performance measurement system that links inputs, outputs, outcomes, and targets into a formal TSM&O performance management process. Agency staff are aware of the importance of outcome measures to making the business case for TSM&O to decision makers and the public, but they have made very limited progress in considering the data and analytics related to outcome measures such as travel time, reliability, and safety.

- **Outsourcing of outcome measures.** Private sector probe data is seen by many States as a way of obtaining useful performance analyses. It appears that the need for progress in this area has inhibited staff from making the business case for TSM&O benefits on either a standalone or alternative investment basis. Several States are in the early stages of identifying outcome measures and acquiring probe data to support them. State DOTs with extensive toll operations are capitalizing on tags as probes. A number of States and regions recognize the need to focus on Performance Measurement for arterial operations, although data availability is an obstacle.
- **Use of performance measures in business case materials.** Only a few agencies have prepared a TSM&O strategic plan that identifies TSM&O goals and objectives and establishes performance measures that track progress towards them. Several agencies cited a need for guidance on conducting before/after evaluations of operations projects and cited the lack of guidance documents of any kind.

3.3.2 Synergism

Performance Measurement is especially interactive with the Business Processes and Collaboration dimensions. The Business Processes dimension should be used to define the Performance Measurement framework. This should be an ongoing process, not a single undertaking or a one-way link. Performance Measurement itself should evolve along with the other dimensions as more is learned about what types of measurement are needed. The Collaboration dimension is significant in that Performance Measurement needs to be consistent across departments and agencies. Collaboration is important to Performance Measurement in that it can “break down silos” of related but uncoordinated activities.

3.3.3 State DOT and Regional Implementation Plan Priorities

The leading participant-suggested implementation plan priorities in Performance Measurement focus on: creating a comprehensive performance measurement system (definitions and measures, related data and analytics targets); promoting operations in traditional planning and programming processes; and, using this material to create a communication strategy for describing the benefits of TSM&O to upper management and the public. See the appendix for the complete list of suggested implementation plan priority actions for the Performance Measurement dimension.

3.4 Culture Dimension

3.4.1 State of the Practice Findings

Key findings from the workshops for the Culture dimension are summarized below in terms of key elements of capability.

General

The legacy culture of State DOTs is civil engineering with a capital project orientation. While most agencies have accepted the notion that it is not possible to “build our way out of congestion,” the business case for TSM&O is not completely understood, although a few agencies have begun to incorporate operational objectives into their formal policy. This same situation was reported at the metropolitan level. TSM&O is just beginning to be considered for formal “program” status with its own line item budget and top level representation in executive leadership. Lack of this status appears to reduce the presence of TSM&O in the resource allocation process. Generally, time demands associated with other priorities have limited executive leadership interest/visibility in TSM&O – with a few notable examples that have spurred significant program improvement. However, new technology is raising the profile of operations as well as public expectations.

Technical Understanding and Business Case

- **Legacy culture.** The primary orientation of most State DOTs remains the delivery of capital projects that dominate agency policy, program, and public communications. While some individual TSM&O strategies are well understood by non-TSM&O staff and management, the concept of TSM&O as a multi-activity, coordinated “program” is just beginning to evolve in most agencies.
- **Making the TSM&O business case and external reinforcement.** It is increasingly recognized that it is not possible to “build our way out of congestion,” highlighting the business case for the unique payoffs from highly cost-effective TSM&O solutions and new technology. This case has often been demonstrated by the significant TSM&O needs required to respond to agency challenges involving major events both planned and unplanned (e.g., large-scale crashes or weather crises). National activities by FHWA, SHRP 2, and AASHTO have also increased the visibility of TSM&O. Broad understanding of the business case appears to be a key precondition to securing a clear role for TSM&O within a State DOT’s program.

Leadership/Champions

- **Top management and middle management champions.** By and large, TSM&O lacks formal State DOT “program” status. With a few exceptions, top management has not provided substantial visibility for TSM&O. As a result, the momentum of TSM&O programs substantially depends on middle management “champions,” who are committed to improving TSM&O and who exercise persuasion and “intra-preneurship” within their agencies.

Outreach – Internal and External

- **Internal outreach.** Non-TSM&O State DOT staff with some level of involvement in specific TSM&O strategies (e.g., maintenance and safety staff who respond to incidents and weather outcomes) have an understanding of TSM&O. Staff with less day-to-day contact,

such as design, planning, and project development staff who have major programming influence, are less likely to include TSM&O considerations in their activities.

- **External outreach.** Continuous and targeted outreach among partners and stakeholders appears essential, especially to MPOs and local government leaders (who are largely focused on capital projects of interest to their constituencies) and even with public safety agency partners, reminding them of the business case related to maximizing mobility as part of their mission through agreements, co-training, and other collaborative activities.

Policy/Program Status/Authorities

- **TSM&O in agency policy.** TSM&O is rarely a separate first-level division equivalent to project development and maintenance. This status detracts from the ability for TSM&O to compete for management, staff, and financial resources. It also limits organizational accountability for systems' operational performance.
- **Legal authorities.** Most States have obtained the necessary statutory authority for such measures as Quick Clearance, Move It, and emergency access use of shoulders. But given public safety agencies' incident command authority, State DOTs must aggressively collaborate to promote the importance of mobility through Memoranda of Understanding (MOU) and co-training with their partners.
- **Funding constraints.** TSM&O is rarely supported by a dedicated multiyear budget determined as part of a top-level resource allocation. Funding is ad hoc and unpredictable. Some States even have legal constraints on the use of State funds for TSM&O activities. While information on level of investment in TSM&O is not typically compiled or available, workshop material suggest 1-3 percent of total agency budget is typical.
- **Roles of public vs. private sector.** Staffing limitations and the need for special technical expertise associated with new technology have led to a substantial level of outsourcing to consultant organizations or contracted staff, especially for planning, systems engineering, data acquisition/analytics, TMC staffing, and device maintenance. The reliance on outsourcing stimulated workshop discussion on the broader issue of what "core" functions and capabilities should be retained in-house.

3.4.2 Synergism

TSM&O Culture is closely related to and synergistic with other dimensions of capability, especially Performance Measurement required to support a "culture of performance." The Culture dimension is interdependent with Collaboration because its success is dependent on interagency cooperation. For the agency as a whole, changes in the dimension of Organization and Staffing often are needed to support an operational culture.

3.4.3 State DOT and Regional Implementation Plan Priorities

Most States included some aspect of Culture in their implementation plans. The two highest priorities were preparing a TSM&O business case, together with a campaign to increase its level of awareness, understanding and support, both internally and externally. See the appendix for the complete list of suggested implementation plan priority actions for the Culture dimension.

3.5 Organization and Staffing Dimension

3.5.1 State of the Practice Findings

Key findings from the workshops for the Organization and Staffing dimension are summarized below in terms of key elements of capability.

General

TSM&O activity managers are typically two to three levels down in headquarters and in regions, often stovepiped into distinct engineering and operations units, and typically report to senior managers who have multiple programmatic responsibilities. Program initiatives are therefore heavily dependent on middle management champions, rather than formal organization. A few states are establishing more consolidated organizational structures with clear lines of authority/reporting but vary widely in how functions are allocated between headquarters and district offices. TSM&O staffs are very small and trained on-the-job, as formal training opportunities are not generally available (FHWA National Traffic Incident Management Responder Training is a notable exception). Some core technical capacities are difficult to recruit and retain, which appears to be leading to increased outsourcing of more technical functions to private entities.

Program Status

- **TSM&O organized as a program.** In State DOTs, TSM&O typically has not yet been accorded formal program status equivalent to legacy programs: construction, project development, maintenance, or safety. This subsidiary status is reflected in agency organizational structure at both the headquarters and district/regional level as well as in agency policy, planning, and budgeting. While TSM&O ultimately needs to be integrated into a wide range of agency activities, the consensus from most workshops has been that given its early stage of maturity, TSM&O should be established as a program with a separate and more visible identity.

Organizational Structure

- **TSM&O in the DOT hierarchy.** At the headquarters level, the highest level of TSM&O program management is typically at a branch level three to four levels down from top leadership and part of one of the conventional legacy programs. A similar situation exists at the district and regional level, where TSM&O activity managers typically report to the

district managers of operations or maintenance. Workshop participants noted that this subsidiary status limits the representation of TSM&O in overall agency staffing and budgeting considerations.

- **Centralization/decentralization.** Most TSM&O applications are real-time and delivered with or by TMCs at the regional level reporting to district management, while TSM&O program development and administrative functions are typically handled in headquarters. As a result (especially in larger states) local operations managers report some communications problems and confusion in chain of command related to TSM&O program development and operations.
- **Siloing and responsibility versus authority.** In many State DOTs, TSM&O duties are often siloed between engineering/project development units and system operations/management units (including TMCs), thereby separating systems and technology improvement from real-time systems management, with no single senior manager with full time responsibility for all aspects.
- **Reorganization.** In several states, pressures for agency-wide efficiency combined with increasing understanding of TSM&O synergies have led to considerable consolidation of TSM&O-related units and clarified reporting relationships, although stopping short of creating a new top-level division.

Staff Development

- **Staffing levels.** The overwhelming reality in most State DOTs is staff hiring freezes or even reductions in force. Workshop participants indicated that staffing constraints undercut ability and initiative for expanding and/or improving TSM&O programs because they require additional staff resources.
- **Champion dependency.** TSM&O activities are typically reliant on a small, dedicated, hard-working staff, often energized by one or more highly committed individuals who are able to overcome lack of formal authority or dedicated resources through knowledge of the agency, strong personal relationships and personal persuasiveness. However, such informal leadership is fragile and subject to retirements or reassignments that can significantly undercut the momentum and priority of TSM&O initiatives.
- **Core capacities, mentoring, and succession.** Most of the TSM&O staff has come from other parts of the agency, especially from traffic engineering, maintenance, or safety. Few staff members have significant systems engineering, information systems, or performance management backgrounds – or capabilities relevant to newer applications such as connected vehicles. Workshop discussion reflected an increasing recognition of the need for specialized technical and managerial staff capacities to sustain an effective TSM&O program, including improving relevant knowledge, skills, and abilities (KSAs). In addition, there is rarely a formal approach to mentoring or succession planning. There were several instances where departure of key staff left holes in agency capacity.

- **Training.** Formal in-house training with a TSM&O focus is limited, supplied largely through FHWA-based programs that have provided important onsite training. Related association activities have also provided some training. Many of the relevant KSAs are acquired via on-the-job training. While most State DOTs offer support for technical training and coursework, this opportunity has limited impact due to the lack of training curricula or university courses specifically focused on TSM&O.
- **Outsourcing.** The lack of specialized staff capacity and slot limitations encourage the outsourcing of activities that require special technical expertise, such as planning, systems engineering, data management, and device maintenance, to private technology and service suppliers, especially where the need for expertise is episodic. Most workshop States outsource two or more activities and several outsource five or six – sometimes managed by different units within the agency. Uniform performance management of outsourced activities is becoming a challenge.

Recruitment and Retention

- **Recruitment and retention.** Most State DOT TSM&O staff comes from within the agencies, transferring from other units. The hiring processes, internal staff job preferences, relative compensation and union constraints appear to discourage external hires. Hiring staff with background in key technical specialties is especially difficult. At the same time, some States report retention challenges as younger staff (Millennials) value career flexibility and varied opportunities over long-term institutional career commitments, especially if they have obtained levels of technical skills of value in the private sector.
- **Career attractiveness.** With very few exceptions, TSM&O is not seen as part of the traditional career track to senior DOT management, where senior roles historically have been rooted in engineering and planning and district or division management. Furthermore, TSM&O brings with it a lifestyle at odds with the 9-to-5 office culture – including 24x7 availability, rapid response, improvising solutions, and working extensively with outside collaborators, all without any special recognition in grade level or compensation. State DOTs report entry level staff with relevant technical backgrounds often use department employment as a stepping stone to more lucrative and mobile career options, especially in the private sector.

3.5.2 Synergism

The Organization and Staffing dimension is synergistic with other dimensions of capability. The agency Culture dimension is extremely influential in terms of top management support for organization and staffing improvements and the need for external Collaboration. At the same time, the process dimensions (Systems and Technology, Business Processes, and Performance Measurement) are all dependent on both efficient organizational structure and staff capabilities.

3.5.3 State DOT and Regional Implementation Plan Priorities

Most States included some aspect of Organization and Staffing in their implementation plans to improve agency capability. The two highest priorities were organizational consolidation of related units and the creation of TSM&O staffing plans, potentially including identification of core staff capacities, position descriptions, and succession plans. Several agencies had undertaken some degree of recent reorganization. See the appendix for the complete list of suggested implementation plan priority actions for the Organization and Staffing dimension.

3.6 Collaboration Dimension

3.6.1 State of the Practice Findings

Key findings from the workshops for the Collaboration dimension are summarized below in terms of key elements of capability.

General

Agencies recognize the criticality of external collaboration to several TSM&O strategies. Some formal MOUs with other public sector agencies have been negotiated, especially for TIM, but interagency collaboration is still substantially informal and based on personal relationships, which are sensitive to staff turnover. Key challenges in collaboration include the definitions of common performance objectives and relative capacity and resources of partner entities. Co-training is beginning to have a positive effect. Outsourcing to private entities is becoming increasingly used for the more technical functions.

Public Safety Agency Collaboration

- **Leading from behind.** In some cases, State DOTs find themselves needing to take the initiative in raising awareness among their application delivery partners (especially with public safety agencies) about the mobility aspects of incident response and through promoting cooperative activities such as MOUs, co-training, and after-event debriefings.
- **Building collaboration habits from major events and more complex applications.** The experience in coping with significant crashes, major weather emergencies, and planned special events, where extensive collaboration is essential to public safety, often spotlights issues that need to be addressed in routine procedures and organizational changes. A focus on Integrated Corridor Management and greater emphasis on public agency performance measurement is spurring a greater focus on interagency collaboration.
- **Challenges with smaller local governments and rural areas.** Multijurisdictional regions with many local agencies (sometimes including limited operating hours and volunteer staff) present special challenges to establishing interoperability, common procedures, real-time coordination, and co-training.

- **Championing.** Collaborative activities such as interagency teams are often informal and based on individual TSM&O staff member “champions” for “outreach” and regular person-to-person reinforcement. This type of collaboration is, however, vulnerable to staff turnover.
- **Formal agreements and resource sharing.** Stimulated by the FHWA-sponsored National Traffic Incident Management Responder Training, more than one-half of the States indicated that they have formal MOUs with public safety agencies. These are often reinforced by collocation and innovative funding arrangements such as incentive payments.
- **Cooperative use of performance measurement and data.** Collaboration between State DOTs and their public safety partners on performance measure definition, analytics, and their routine use was largely absent. In most workshop locations, after-action debriefings were confined to major incidents, and secondary incidents were rarely addressed.

Metropolitan Planning Organization/Regional Transportation Planning Agency/Local Government Collaboration

- **Collaborative planning and operations.** In a few instances, MPOs have taken the initiative by creating a TSM&O regional plan and program, often building on their Congestion Management Process and using technical committees as a method for coordination and collaboration. Operational collaboration is increasing in two specific application areas: contracting to MPOs for arterial signal improvements and maintenance; and Integrated Corridor Management programs.

Public-Private Partnerships

- **Outsourcing.** State DOTs are outsourcing an increasing number of the more “technical” TSM&O functions, including systems planning and engineering, TMC staffing, ITS device maintenance, traveler information program development, and project delivery. Expansion of outsourcing is introducing its own set of management challenges and opportunities related to procurement, contract management, standardization, performance-based oversight, and use of incentives.

3.6.2 Synergism

TSM&O Collaboration is especially dependent on capabilities in the Culture dimension for supporting institutionalization of interagency working relationships. The Collaboration dimension itself is critical to other TSM&O dimensions requiring both internal and external close working relationships with Systems and Technology and Business Processes.

3.6.3 State DOT and Regional Implementation Plan Priorities

The leading participant-suggested implementation plan priorities in Collaboration focused on establishing a forum and/or formal agreements to support better interagency relationships especially in incident management, including greater focus on reliability performance measurement. See the appendix for the complete list of suggested implementation plan priority actions for the Collaboration dimension.

4.0 National Activities to Support Improving TSM&O Capabilities

The areas for improvement and related implementation plan actions identified in common by many State DOTs and their partners suggest an agenda of needs for research, guidance, and training at the national level. Consistent with the capability dimensions, this agenda is focused on process and institutional improvements that are not substantially addressed by existing support materials already created by peer states or by AASHTO, FHWA, or other entities. The activities include both identification and dissemination of best practice (peer-to-peer exchanges, webinars, guidelines, and lessons learned) and support for the evolution of certain new business and technical methods and processes. Important roles are seen for FHWA, AASHTO, and the National Operations Center of Excellence. Table 4.1 through Table 4.6 present the key recommendations organized by dimension.

Table 4.1 Suggested National Activities to Support Improvements in Business Processes

Activity	Business Processes Element	Sponsor(s)	Comments
Conduct webinar on TSM&O program planning as defined in this report and drawing on participants in NCHRP 20-07/345	<ul style="list-style-type: none"> • TSM&O Planning Process • Programming/Budgeting 	National Operations Center of Excellence (NOCoE) TRB Regional Transportation Systems Management and Operations (AHB10) (RTSMO)	Definition of “program planning” as in this report. See Strategic Highway Safety Plan as useful precedent
Develop guidance and best practice examples related to TSM&O program planning, including example plans	<ul style="list-style-type: none"> • TSM&O Planning Process • Programming/Budgeting 	FHWA NOCoE	Definition of “program planning” as in this report. Highlight DOT and MPO best practices
Compile lessons learned from ICM planning and programming to date	<ul style="list-style-type: none"> • TSM&O Planning Process • Programming/Budgeting • Project Development/Procurement 	FHWA NOCoE	Would be extracted from interviews of State DOT and regional staff

Activity	Business Processes Element	Sponsor(s)	Comments
Develop resources and collect examples of TSM&O business cases	<ul style="list-style-type: none"> • TSM&O Planning Process • Programming/Budgeting • Project Development/Procurement 	FHWA AASHTO NOCoE	Build on material already included in the NOCoE web site and incorporate case studies and B/C material from ITS Joint Program Office and FHWA web sites
Apply FHWA INVEST model for operations and maintenance sustainability assessment	<ul style="list-style-type: none"> • TSM&O Planning Process • Programming/Budgeting 	FHWA NOCoE	INVEST provides a life-cycle cost model
Identify, collect, and circulate best practices on integrated TSM&O in standard DOT project development processes. Establish a group of peers that could provide lessons learned to other States/regions	<ul style="list-style-type: none"> • Project Development/Procurement 	FHWA AASHTO NOCoE	Primer or synthesis of best practices; include non-TSM&O perspectives to show depth of collaboration and process change

Table 4.2 Suggested National Activities to Support Improvements in Systems and Technology

Activity	Systems and Technology Element	Sponsor(s)	Comments
Compile examples of best practices for the use of Statewide and Regional Architectures	<ul style="list-style-type: none"> • Regional Architecture 	ITS Joint Program Office (JPO) (official web site), National Highway Institute (NHI), Professional Capacity Building (PCB), Consortium for ITS Training and Education (CITE) Courses	T3 Webinars or list-serves could broadcast and raise awareness of available current resources

Activity	Systems and Technology Element	Sponsor(s)	Comments
Develop basic webinar module focused on ITS procurement processes	<ul style="list-style-type: none"> • Regional Architecture • Project systems engineering/testing and validation 	NOCoE	Requires modest technical study using CMM Workshop materials and limited peer interviews and collecting information sources
Compile resources related to training regarding the systems engineering process	<ul style="list-style-type: none"> • Project systems engineering/testing and validation 	JPO, NHI, PCB	Compile comprehensive list of available training resources and raise awareness of availability
Strengthen NOCoE Knowledge Transfer Database regarding Systems and Technology	<ul style="list-style-type: none"> • Standardization 	NOCoE	Systems and Technology are search items
Compile resources related to training regarding the standards implementation (testing and training)	<ul style="list-style-type: none"> • Standards 	JPO, NHI, PCB	Compile comprehensive list of available training resources and raise awareness of availability
Develop a clearinghouse of standard specifications for frequently procured TSM&O technology	<ul style="list-style-type: none"> • Standardization 	NOCoE	
Compile best practices and strategies for ITS device maintenance, ITS maintenance programs, and keeping pace with rapidly changing lifecycle considerations	<ul style="list-style-type: none"> • Overall 	FHWA Institute of Transportation Engineers (ITE) AASHTO	This would update existing resources to include new requirements for effective TSM&O technology asset management and address options such as contracting/outsourcing for maintenance, performance requirements for newer technologies, training for in-house maintenance staff, and using updated lifecycle information for newer technologies to inform maintenance budget/program needs

Table 4.3 Suggested National Activities to Support Improvements in Performance Measurement

Activity	Performance Measurement Element	Sponsor(s)	Comments
Create checklist for developing a TSM&O Performance Management Plan	<ul style="list-style-type: none"> Measure definition 	FHWA	Assimilate current best examples; produced a template/prototype document
Develop standardized definitions for a wide range of TSM&O performance measures covering TIM, work zones, weather, and signalized arterials	<ul style="list-style-type: none"> Measure definition 	FHWA OPMM #12 and #17; possible AASHTO or ASTM if formal standards are to be produced	Some efforts currently underway (e.g., NUG) but do not cover all relevant measures, just a common core; more guidance is needed especially in coordination of both outcome measures (e.g., MPOs, MAP-21 measures) and output measures (e.g., emergency responders)
Develop standardized procedures for conducting TSM&O evaluations	<ul style="list-style-type: none"> Measure utilization 	FHWA OPMM #14	Some guidance developed in SHRP 2 L17 but needs further methodology work and case studies
Develop guidance on TSM&O performance target setting	<ul style="list-style-type: none"> Measure utilization 	FHWA OPMM #4	Coordinate with target setting procedures in other functional areas; explore analytical methods available and how to conduct consensus exercises
Document best practices for communicating TSM&O performance	<ul style="list-style-type: none"> Measure utilization 	FHWA OPMM #13	Needs to move beyond what “best” agencies are doing and adapt methods from other sectors
Develop guide to TSM&O data acquisition, management, and analysis methods	<ul style="list-style-type: none"> Data acquisition 	NCHRP or FHWA	Include requirements for a prototype system; incorporate standardized procedures noted above; identify alternative strategies for data acquisition especially from other agencies or units, including best practice case studies
Conduct Peer-to-Peer Exchange on TSM&O Performance Measurement	<ul style="list-style-type: none"> Measure definition, data acquisition, and measure utilization 	FHWA	Formal program with a set number of annual exchanges

Activity	Performance Measurement Element	Sponsor(s)	Comments
Document best practices in using TSM&O performance measures in investment decisionmaking	<ul style="list-style-type: none"> Measure utilization 	NCHRP or Pooled Fund	Conduct scan for best practices and enhance as necessary; feed results into field test
Conduct field test of TSM&O performance measures in decisionmaking	<ul style="list-style-type: none"> Measure utilization 	FHWA	Follow-on to above study; fund an agency to design and implement a model procedure for fully utilizing TSM&O performance measures for decisionmaking; include both long-range and short-range activities; include development of a comprehensive and linked PM program: inputs, outputs, outcomes, and targets

OPMM Operations Performance Measures and Management (OPMM) Program Road Map.

NUG National Unified Goal.

Table 4.4 Suggested National Activities to Support Improvements in Culture

Activity	Culture Element	Sponsor(s)	Comments
Develop resources and collect examples of TSM&O business cases	<ul style="list-style-type: none"> Technical Understanding and Business Case Outreach – Internal and External 	FHWA, AASHTO, NOCoE	Build on material already included in the NOCoE web site and incorporate case studies and B/C material from ITS Joint Program Office and FHWA web sites
Support appropriate level of national consistency in “branding” TSM&O as key transportation agency function	<ul style="list-style-type: none"> Technical Understanding and Business Case Outreach – Internal and External 	FHWA, AASHTO, NOCoE	Ensure that external communications from both to the public use common language and most effective examples
Establish regular forum for State DOT leadership (chief engineers, district engineers) to discuss TSM&O-related issues and provide a group of peers for potential peer exchanges	<ul style="list-style-type: none"> Leadership/ Champions 	FHWA, AASHTO, NOCoE	No TSM&O forum for agency leadership exists (top management is not often involved in any peer-to-peer discussion in AASHTO, Regional Operations Forums, etc.)

Activity	Culture Element	Sponsor(s)	Comments
Identify and communicate payoffs from new forms of public-private partnerships, including towing and recovery incentives and travel data	<ul style="list-style-type: none"> Policy/Program Status/Authorities 	FHWA, AASHTO, NOCoE	Many DOTs remain unaware of the dramatic payoffs from these types of arrangements
Identify and communicate the impact of operations and technology focus continuity across TSM&O and connected vehicles (CV)	<ul style="list-style-type: none"> Technical Understanding and Business Case Outreach – Internal and External 	FHWA, AASHTO, NOCoE, TRB, transportation associations	Public interest in CV can be used as a “hook” to support TSM&O by noting the baseline TSM&O functions that support various CV applications

Table 4.5 Suggested National Activities to Support Improvements in Organization and Staffing

Activity	Organization and Staffing Element	Sponsor(s)	Comments
Compile examples of reorganizations, including organization charts, functions, and underlying policies as examples for other States and use for technology transfer	<ul style="list-style-type: none"> Program Status Organizational Structure 	Operations Academy™, NOCoE	Material could be circulated among interested peer States
Develop basic webinar and/or training module focused on organization and staffing	<ul style="list-style-type: none"> Organizational Structure 	FHWA/ITS PCB Program, CITE	Requires modest technical study using CMM workshop materials and limited peer interviews
Develop a TSM&O organization and staffing gap analysis tool for agencies to compare current operations with those needed to fulfill all desired functions	<ul style="list-style-type: none"> Organizational Structure 	FHWA, AASHTO, NCHRP	Existing model is FHWA's Traffic Signal Operations and Maintenance Staffing Guidelines
Establish electronic dialogue among DOT TSM&O managers for general peer-to-peer discussion of organization, staffing, and other management issues	<ul style="list-style-type: none"> Organizational Structure 	Operations Academy™, NOCoE	Dialogue would have to be structured and managed

Activity	Organization and Staffing Element	Sponsor(s)	Comments
Strengthen NOCoE Knowledge Transfer System database (as created for SHRP 2 L17)	<ul style="list-style-type: none"> Organizational Structure 	NOCoE	Organization and staffing are existing search items; further material could be added
Poll State DOT senior TSM&O managers on key staff capacities needed and unmet; compare identified needs with training and educational opportunities and consider remediation actions to fill gaps	<ul style="list-style-type: none"> Staff Development 	AASHTO and/or FHWA via peer-to-peer interchange or polling	No State has systematically identified core capacities; Use emerging TSM&O applications as guide to specific technical staffing needs (ATM, ICM, CV, arterial operations)
Develop a suite of core competencies with lists of helpful training, experiences, and resources for TSM&O managers	<ul style="list-style-type: none"> Staff Development 	AASHTO and/or FHWA via peer-to-peer interchange or polling, NOCoE	Alternative or complementary to the above
Review critical training deficiencies across all levels of TSM&O employees and sponsor permanent classes to address these deficiencies (for example, CITE or NHI courses)	<ul style="list-style-type: none"> Staff Development 	FHWA/ITS PCB Program, CITE	May extend beyond organization and staffing or be conducted in conjunction with other dimensions
Adjust curricula of National Operations Academy™ and Regional Operations Forums (ROF) to include material supporting managers' needs to improve processes and organization	<ul style="list-style-type: none"> Staff Development 	Operations Academy™, ROFs	Specific tasks developed in workshop implementation plans constitute a starting point
Identify State DOT functions typically outsourced and associated agency rationales	<ul style="list-style-type: none"> Staff Development 	AASHTO, ITE, ITS-A	Workshop experience shows substantial outsourcing of ITS-related functions in many states
Investigate existing State DOT experience regarding TSM&O as a career option, including education and training, conditions of employment, and career track options	<ul style="list-style-type: none"> Staff Development Recruitment and Retention 	FHWA, AASHTO, NCHRP	Increasingly technical staff positions are hard to compete for; special training will be essential. Establish some best practices of agencies that have developed TSM&O job descriptions, career paths, etc.

Activity	Organization and Staffing Element	Sponsor(s)	Comments
Review curricula of secondary and graduate schools related to TSM&O to identify key gaps and best practices to produce “TSM&O-ready” entry level employees	<ul style="list-style-type: none"> Staff Development Recruitment and Retention 	FHWA/ITS PCB Program, AASHTO, NCHRP	Entry-level TSM&O employees generally are not well served by current academic offerings
ITS PCB Program	Office of the Assistant Secretary for Research and Technology Capacity Building Program.		ITS Professional
ITS-A	Intelligent Transportation Society of America.		

Table 4.6 Suggested National Activities to Support Improvements in Collaboration

Activity	Collaboration Element	Sponsor(s)	Comments
Develop guidance for formal TIM agreements with a special focus on aspects that improve their long-term viability	<ul style="list-style-type: none"> Public Safety Agency Collaboration 	FHWA	There is no available guidance that directly addresses preconditions for more effective agreements
Develop case study document regarding incentive-based towing and recovery agreements	<ul style="list-style-type: none"> Public Safety Agency Outsourcing/public-private partnership 	FHWA	There are consultants who specialize in these arrangements
Poll State DOTs to determine extent of outsourcing; document current practices	<ul style="list-style-type: none"> Outsourcing/public-private partnership 	Operations Academy™, NOCoE, FHWA	There is a clear trend toward greater outsourcing that implicates issues such as maintenance of core capacities and performance contracting
Develop methods for accommodating TSM&O activities and their resource requirements in both conventional statewide and metropolitan planning	<ul style="list-style-type: none"> MPO/RTPA/Local government collaboration 	FHWA, NOCoE	FHWA and NCHRP have developed important guidance material
Identify promising examples of collaborative operational management involving State and local entities	<ul style="list-style-type: none"> MPO/RTPA/Local government collaboration 	FHWA, AASHTO, Association of Metropolitan Planning Organizations (AMPO), NOCoE	Real-time operational management involving different jurisdictions (ICM) is becoming more important, bridging an operational gap between traditional freeway and arterial operations silos

Appendix A. Implementation Plan Priority Actions

This appendix provides a summary of suggested implementation plan priority actions for each dimension along with the frequency of the action being cited at the workshop locations.

Table A.1 Business Processes Priority Actions

Action Items	Times Cited
Create regional/statewide TSM&O plan/program/TSM&O Program Plan	13
Integrate TSM&O into TIP/LRTP/Other statewide/regional plans/existing planning processes	8
Develop TSM&O business case for various key stakeholders	4
Establish methods to evaluate TSM&O vs. capacity options, including B/C	3
Modify project development process to accommodate TSM&O	3
Prepare statewide TIM plan/program as standalone activity	2
Design a performance based programming process (all projects)	1
Establish forum to discuss/evaluate/recommend promising technologies, processes and policies	1
Identify institutional mechanism to shorten planning horizons to facilitate TSM&O solutions	1
Undertake corridor performance-based improvement projects	1
Establish communications plan (explaining ops strategies benefits)	1
Update existing ITS Strategic Plan (incorporate districts)	1
Create process to integrate signal maintenance and upgrades into asset mgt.	1
Seek opportunities for greater involvement with planning partners	1
Establish a pool of funding for TSM&O	1
Pilot FHWA INVEST model for operations and maintenance sustainability assessment	1

Table A.2 Systems and Technology Priority Actions

Action Items	Times Cited
Improve IT/ITS procurement (including applying best practice)	5
Assess/update regional/statewide ITS architecture/deployment plan	4
Improve traveler info systems/technology (collection and display)	2
Improve TIM info dissemination/exchange	2
Review/develop data sharing practices/policies (TIM, CAD, traffic control, etc.)	2
Establish ITS Qualified Products List	2
Investigate standard communications protocol to facilitate interoperability	1
Investigate need/level for traffic signal standardization	1
Implement comprehensive signal operations and management program for central control	1
Identify needed technical capacities/KSAs for IT/ITS	1
Develop/implement ITS training and rotation program	1
Design strategy/plan to institutionalize TSM&O freeway and arterial apps through pilots	1

Action Items	Times Cited
Develop TSM&O asset management system/performance guidelines	1
Improve awareness/training on systems engineering approach	1
Expand ITS systems (traffic signal integration, transit, info sharing)	1
Improve rural TMC function	1
Deploy travel management/traveler info responsive to weather	1
Develop DMS guidance and additional deployment	1
Evolve systems and technology to actively coordinate traffic (e.g., corridor adaptive ramp metering)	1
Optimally operate arterials	1
Increase participation in TMC and software systems discussions/decisionmaking	1
Formalize use of ICM (TMC operating procedures, agency coordination strategies, etc.)	1

Table A.3 Performance Measurement Priority Actions

Action Items	Times Cited
Update TSM&O performance measurement plan/program/policy/data business plan	13
Agree upon and leverage TIM performance measures	2
Identify performance measures and structure to illustrate benefits	2
Incorporate TSM&O into performance-based planning documents and guidance	1
Share/disseminate performance data/info with partners	1
Consider forum for discussing and evaluating data needs and integration opportunities	1
Evaluate sources of data (internal vs. third party)	1
Identify/develop PMs for dashboard (freeway and arterial)	1
Establish/implement a travel time reliability monitoring program (SHRP 2 L02)	1
Create modeling plan and tools for supporting TSM&O analysis	1
Develop process to formally measure before and after effects of TSM&O improvements	1

Table A.4 Culture Priority Actions

Action Items	Times Cited
Prepare TSM&O outreach/communications material; document lessons learned/success stories	11
Develop TSM&O business case/marketing plan/campaign	9
Institute TSM&O knowledge sharing (e.g., though identified experts and peer exchanges)	2
Establish proactive relationship with public service providers	1
Introduce executive policy/directives in support of TSM&O/ITS/total system management	1
Establish TSM&O executive steering committee to set vision and strategic priorities	1
Recruit and select TSM&O advocates beyond HQ to facilitate education	1
Identify team of TSM&O champions at senior management and division head levels	1

Table A.5 Organization and Staffing Priority Actions

Action Items	Times Cited
Review/define org structure for TSM&O/Develop business case for TSM&O section	4
Develop TSM&O staffing plans	4
Design succession plans	3
Create career maps/paths and position descriptions	3
Provide technical training, mentoring, encourage staff participation in national forums	2
Provide TSM&O point of contact for each Region to advance development of TSM&O concepts and projects	2
Reorganize existing HQ division/District to emphasize TSM&O/corridor performance	1
Create new program framework to accommodate TSM&O	1
At management level, focus on PM plans and accountability to optimize staff utilization and efficiency	1
Hold TSM&O summit	1
Conduct additional CMMs	1

Table A.6 Collaboration Priority Actions

Action Items	Times Cited
Participate in/advance TIM training	3
Establish a forum to build better interagency relationships and improve TIM practices	3
Institute corridor platforms/forums for improved collaboration/ops strategies/TIM	3
Execute MOU with State police/fire/PSAs for TIM practices	2
Perform overall assessment of stakeholder groups' ability to advance TSM&O	2
Conduct Regional Operations Forum	2
Update/implement TIM strategic plan	1
Conduct outreach to partners for improved transportation management	1
Disseminate IM best practice to local jurisdictions	1
Create formal institutional structure to enhance reliability PM collaboration and coordination	1
Identify best practices in overcoming risk and liability issues pertaining to TSM&O	1
Leverage university relationships	1

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July 2015