Improving Transportation Systems Management and Operations (TSM&O)

Capability Maturity Model Workshop White Paper

Systems and Technology

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Notice

Quality Assurance Statement

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Executive Summary

Background

Research done through the Second Strategic Highway Research Program (SHRP 2) 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) and its six dimensions of organizational capabilities. This White Paper focuses on Systems and Technology as one of the central dimensions of capability needed to support effective transportation systems management and operations (TSM&O) – including collaboration with public safety agencies, MPOs, local government, and public-private partnerships The Paper summarizes the TSM&O state-of-the-practice based on the Workshops and subsequent implementation plans developed at 23 sites selected by FHWA and the American Association of State Highway and Transportation Officials (AASHTO) as part of SHRP 2 Implementation.

Scope

The paper includes the following material:

- A description of the SHRP 2 research and workshop process related to the institutional and process aspects of TSM&O including a description of the CMM self-assessment framework and its application to the Systems and Technology dimension.
- A discussion of the state-of-the-practice regarding Systems and Technology in terms of their key elements including capability levels self-assessed at the workshops.
- A description of key synergies between Systems and Technology and the other dimensions of capability and evaluation of managers span of control to affect improvement.
- Best practice examples and references.
- Suggested actions to address Systems and Technology needs on a national level.
- An Appendix presenting the common implementation plan priority actions for the Systems and Technology dimension.

State of the Practice Findings for TSM&O Systems and Technology

Key findings from the workshops included:

ITS Architectures

- *Regional and statewide ITS architecture documents and use*. A critical requirement for continuous improvement of TSM&O is a rigorous and systematic systems engineering approach. All states/regions in the workshops have some kind of an ITS architecture (either statewide or regional) consistent with Federal standards and the national ITS architecture; however, the use of the architecture for project planning or procurement varied widely. The value of a strong architecture was recognized and revising or updating the architecture was one of the action items mentioned most often for this dimension in the workshops.

Project Systems Engineering/Testing and Validation

- *Improve awareness and training*. The systems engineering process was generally employed by DOTs and MPOs for ITS projects. When the National Architecture program was initially rolled out by the U.S. DOT, there were many training opportunities afforded to the State DOTs that were specific to systems engineering processes. It was often noted in the workshops that system engineering training options once offered by the U.S. DOT would be helpful if reinstituted. Although training programs specific to systems engineering may still exist, an increased awareness of these training opportunities would benefit many State DOT programs.

- *Procurement challenges.* Often times States noted that purchasing ITS hardware and software introduced great challenges due to the way that State agencies procure IT equipment. The internal process can take too long resulting in the purchase of outdated products and requires several levels of approvals; when requirements are not clearly defined, unsuitable items are purchased. There are additional challenges with agency enterprise requirements (such as low bid, security requirements, etc.), which might not align with specific ITS or TSM&O requirements.

  Developing relationships with information technology (IT) groups and an understanding of IT procurement processes as they relate to TSM&O would also be useful from two perspectives: helping the TSM&O group understand the IT processes and informing IT groups about the unique aspects of procuring TSM&O technologies. The need to improve the way ITS elements are procured was the most noted action item resulting from the workshops.

- *Keeping pace.* There were quite a few workshop locations that pointed out the challenge of keeping pace with rapidly evolving technology and the difficulties this creates, such as obsolescence of deployed equipment, outdated specifications, legacy equipment's incompatibility with newer equipment, incompatibility with deployed software, and maintenance capabilities. There also were 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.* Working together in a region requires standards that support the interoperability of various systems and facilitation of the interchange of field and central system hardware and software operations. Some State DOTs have made interoperability of systems a priority.

- *Standards.* Standards developed for the ITS industry are used to harmonize data communications, database exchanges, and information displays among diverse systems. It is essential that standards be integrated into the system development and acquisition program. Workshop participants noted that it was necessary to update standards regularly to stay on the forefront of quickly evolving technologies, with interoperability as the motivating goal.

- *Documentation.* ConOps and project architectures exist for technology projects, but they often lack important information components such as cost elements, performance requirements, and evaluation. When strong documentation exists it paves the way for expansion and solid standardization of processes. Although an important part of the systems engineering process, a ConOp was not necessarily identified as a required element, except for larger, complex projects or where federal funding requirements necessitated developing one.

- *Approved vendor product lists.* Agencies find that having qualified product lists facilitates purchasing ITS elements and can reduce the time needed to acquire products. This listing in essence pre-certifies products meeting the requirements and interoperability needs of the system.

- *Arterial Expansion.* Agencies had a good grasp on freeway management and each workshop location had deployed freeway management systems in their urban areas. Not as well deployed or integrated into their freeway management systems were arterial signal systems. About half of the workshop locations had incorporated signal systems into the freeway management centers, and many noted an interest in expanding or including arterial signal systems. Workshop action items centered on developing plans and institutionalizing TSM&O freeway and arterial applications and performance guidelines.

Synergism

Central to the Systems and Technology dimension are Business Processes and planning documents such as the statewide architecture and ConOps 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 is another dimension with strong linkages, with the need for coordination with many stakeholders a core element in the systems engineering process.

State DOT and Regional Implementation Plan Priorities

The leading participant-suggested actions for Systems and Technology include:

- *Improving Information Technology (IT) and ITS Procurement*. From a State DOT perspective, procurement and purchasing responsibilities were generally allocated to an external State agency largely out of the control of the DOT. When the procurement group was within the DOT structure, the process was more efficient. Agency relationships external to the DOT needed attention; it was generally understood that there was a lack of awareness of the intricacies of procuring ITS elements in the larger procurement groups. Discussions often recommended increased attention to the relationship with the purchasing group and somehow increasing that group's awareness of the special needs of procuring ITS elements. It was also noted that streamlining the purchasing processes could be enhanced by developing or updating qualified vendor lists.

- *Updating Regional and Statewide ITS Architectures*. Implementation plans that addressed ITS architecture actions generally focused on assessing and updating existing architectures in need of revisions. Most workshop participants agreed on the importance of having and using a statewide or regional architecture, in that the architecture process: supports relationships among technology selection and deployment entities and relates it to needed functionalities; generally engages the FHWA Division office; and engages regional stakeholders such as MPOs and local agencies.

Best Practices and National Needs

This white paper describes example best practices and reference material regarding the implementation plan priority needs noted above. The paper also suggests supportive national actions to improve Systems and Technology including: compiling examples of best practices for the use of Statewide and Regional Architectures; developing a basic webinar module focused on ITS procurement processes; compiling resources related to training regarding the systems engineering process and standards implementation; developing a clearinghouse of standard specifications for frequently procured TSM&O technology; and compiling best practices and strategies for ITS device maintenance and maintenance programs, and keeping pace with rapidly changing lifecycle considerations. Important roles were seen for FHWA, AASHTO, the National Operations Center of Excellence, ITE, JPO, CITE, and NHI in supporting these efforts.

1.0 TSM&O 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. Best practice TSM&O is being developed as an integrated program to optimize the performance of existing multimodal infrastructure through implementation of systems, services, and projects to optimize capacity and improve the security, safety, and reliability of the transportation system.

1.1 TSM&O and the Capability Maturity Model

The Second Strategic Highway Research Program (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. One project identified 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 defined by six critical 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 Capability Maturity Model (CMM) – widely used in the Information Technology industry – to develop a self-assessment framework designed to help transportation agencies identify their current strengths and weaknesses and related actions needed to improve their capabilities for effective TSM&O – in effect, a roadmap for "getting better at getting better."

1.2 CMM Self-Assessment Workshops

The TSM&O CMM framework has been used as the basis for the development of a facilitated one-day self-assessment workshop process for State DOTs and regions. The CMM workshops are intended to improve the effectiveness of TSM&O applications and activities by assisting the unit managers and key technical staff with day-to-day oversight of TSM&O-related activities, as well as DOT partners, including public safety agencies, MPOs, local governments, and the private sector.

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

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

capability. The current challenges and problems identified by workshop participants are used to identify actions needed to improve capability, which are subsequently embodied in an implementation plan to improve the effectiveness of TSM&O.

Senior agency leadership is involved in a pre-workshop briefing and their approval of the implementation plan is required as a precondition of Federal financial assistance for the SHRP 2 Implementation Assistance program sites.

1.3 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:

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

Three dimensions are institutional:

- **Culture,** including technical understanding, leadership, outreach, and program legal authority;
- **Organization and Staffing,** including programmatic status, organizational structure, staff development, and recruitment and retention; and
- **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.

This structure of critical key dimensions of capabilities and their levels as self-assessed was used as the basis for the determination of the current state of the practice in the Business Processes dimension as discussed in the sections that follow.

1.4 CMM Self-Assessment Workshops Analyzed

This white paper synthesizes findings, as of December 2014, from 23 of 27 sites selected by FHWA and AASHTO in 2013 as part of the SHRP 2 Implementation Assistance Program. These 23, listed in Table 1.1, include 19 State DOTs (statewide or district focus) and four regional entities (including two MPOs).[2]

Table 1.1 Self-Assessment CMM Workshop Locations Analyzed in this White Paper

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

[2] For a detailed discussion of prior workshops and those selected for the SHRP 2 Implementation Assistance Program, see the Organizing for Reliability – Assessment and Implementation Plan Development Final Report.

2.0 Summary of All Capability Dimensions

As background to this discussion of the Systems and Technology dimension in this white paper, it is useful to understand all the CMM dimensions in terms of the comparative capability levels and related initiatives. Table 2.1 presents the range of self-assessment levels by CMM dimension and capability level for the 23 workshop locations analyzed in this white paper.

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

	Capability Self-Assessment			
Dimension	**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, is specific to each state/region, and represents the consensus of workshop participants. The scores cannot be used for cross-site comparison, as some states/regions were tougher self-graders than others were. Nevertheless, within a given state/region, the scores for each dimension appear to reflect the relative level of capability among the dimensions. However, certain general conclusions can be drawn:

- Most locations assessed themselves at the "performed" or "managed" level (often somewhere in between) for most dimensions.
- Only two locations rated themselves as Level 4 in specific dimensions.
- Only a few agencies indicated reaching the level of "integrated" on more than two dimensions.
- While the aggregate distributions among several dimensions were similar (see Figure 2.1), this result masks very different distributions within individual agencies; that is, strengths and weakness differed among agencies responding to varying conditions.

- Collaboration and Systems and Technology are the strongest dimensions; for Collaboration, this reflects in part the impact of recent FHWA incident management training and other collaboration outreach; for Systems and Technology, this reflects an advancement in technology deployment over the past 10–15 years.

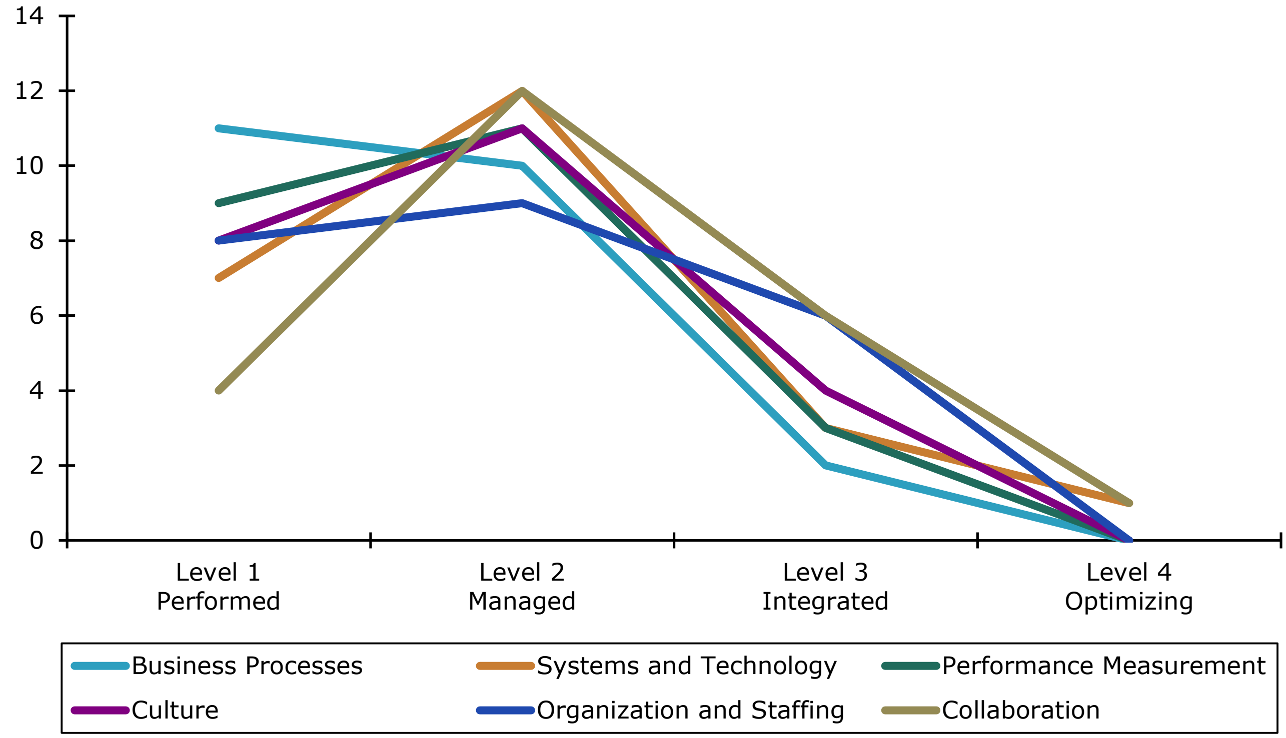

Figure 2.1 Graph. Distribution of Self-Assessments (23 Workshops)

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

Within a given dimension, there is often a significant gap between best practice and average practice among states/regions. 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 what best practice is and are working within their institutions to develop essential capabilities.

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 synergy among technical and institutional dimensions, as suggested in Figure 2.2. 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 (Culture).

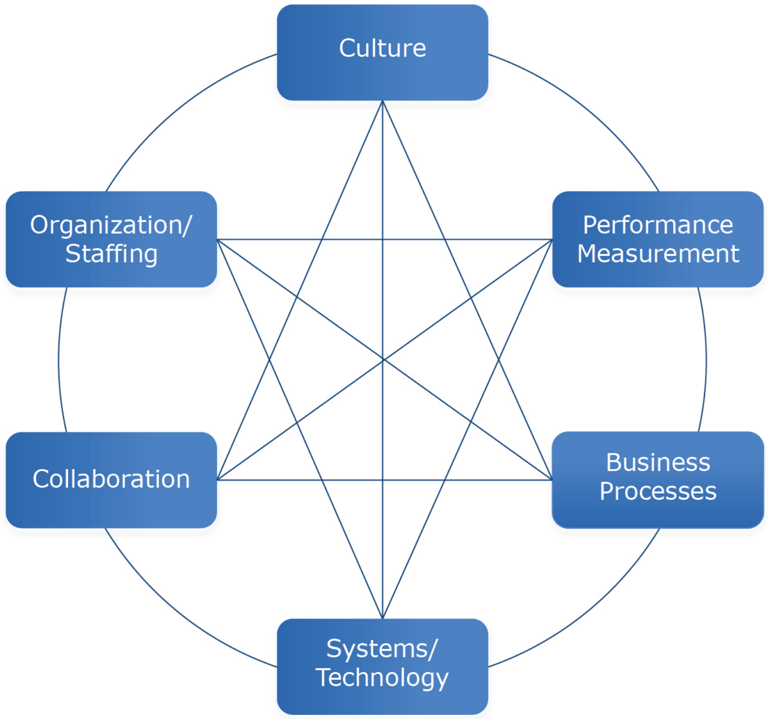

Figure 2.2 Graph. Synergy among Dimensions of Capability

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

2.2 General Implementation Plan Priorities for All Six Dimensions

Essential actions and products identified through the workshop and implementation plan process are presented below to establish some context regarding consideration of implementation plan recommendations for all six dimensions from the 23 workshops. A wide variety of actions are recommended across the six dimensions, including plans, processes, agreements, business cases, and organizational and staffing recommendations, each of which has a mutually reinforcing effect on overall capability.

Business Processes

- Develop a statewide/regional TSM&O program plan
- Integrate TSM&O into the conventional state and metropolitan planning process

Systems and Technology

- Update both regional and statewide system architectures for new/emerging TSM&O applications
- Improve ITS systems procurement process and/or relationships with agency IT unit

Performance Measurement

- Develop a plan for performance measures, data, and analytics
- Secure agreement from the public safety community on measures for incident management

Culture

- Develop a persuasive business case for TSM&O
- Develop a communications/outreach plan/branding for stakeholders

Organization and Staffing

- Define an appropriate organizational structure for the TSM&O program
- Identify core capabilities needed and develop related staffing and training plan

Collaboration

- Improve collaboration related to TIM including participating in TIM training and establishing a forum for building interagency relationships

  Align partners' TSM&O objectives and interact on a regular basis.

3.0 State of the Practice for the Systems and Technology Dimension

3.1 The Systems and Technology Dimension

Systems and Technology reflects the systems engineering requirements of TSM&O, including systems architecture, concepts of operation and interoperability, standardization, and documentation processes. It does not focus on the actual technology infrastructure, but rather focuses on key processes and aspects of technology procurement, integration, operations and technology planning. The capability-level criteria used in the self-assessments for this dimension are shown in Table 3.1.

Table 3.1 Self-Assessment Workshop Levels of Capability Maturity for Systems and Technology

	Systems and Technology Criteria for Level Achievement
Capability Level 1	Ad hoc approaches to system implementation without consideration of systems engineering and appropriate procurement processes
Capability Level 2	Regional or statewide ConOps and architectures developed and documented with costs included; appropriate procurement process employed
Capability Level 3	Systems and technology standardized and integrated on a regional or statewide basis (including arterial focus) with other related processes and training as appropriate
Capability Level 4	Architectures and technology routinely upgraded to improve performance; systems integration/interoperability maintained on continuing basis

Among the 23 Workshops, the average self-assessed capability for Systems and Technology is 2.02 – with seven sites at Level 1 and four sites at Level 3 or 4. Among dimensions selected for inclusion in Implementation Plans, Systems and Technology appeared in 14 plans. Figure 3.1 indicates how the Systems and Technology dimension was assessed relative to the other dimensions.

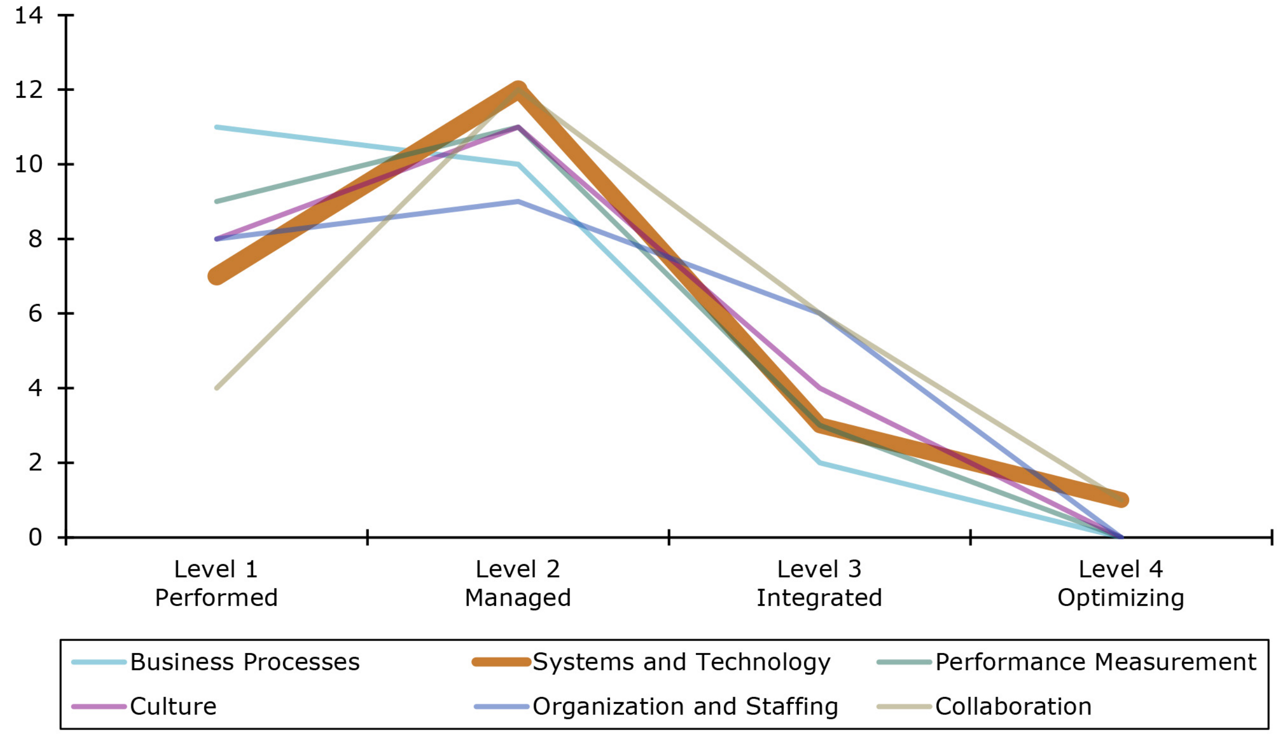

Figure 3.1 Graph. Systems and Technology Compared to Other Dimensions of Capability

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

The discussion of the state of the practice regarding the Systems and Technology dimension below is divided into key elements based on the approach used in the *AASHTO Guide to Transportation Systems Management and Operations*:

- Regional architectures;
- Project systems engineering/testing and validation; and
- Standards/interoperability.

The material that follows discusses the current state of play in each key element.

3.2 Regional Architectures

- **Regional and statewide ITS architecture documents and use.** A critical requirement for continuous improvement of TSM&O is a rigorous and systematic systems engineering approach. Clear consensus-based concepts of operations shared by all key participants are essential to identifying appropriate roles and relationships for each TSM&O application. The related ITS systems architecture provides a common framework for planning, defining, and integrating ITS deployments. All states/regions in the workshops have some kind of an ITS architecture (either statewide or regional) consistent with Federal standards and the national ITS architecture; however, the use of the architecture for project planning or procurement varied widely. In many instances, some workshop participants (not directly involved with technology or TMC operations) were not involved first-hand with the ITS architecture development and were not familiar with how such a tool could be used. In some cases, regional ITS architectures were developed by MPOs; while State DOTs were partners, they were not the "owners" of the regional ITS architecture. Most states/regions have developed systems architectures with extensive Federal guidance, and the modest pace of deploying new applications has made updates less compelling. The deployment of new applications and technologies, however, such as active traffic management and integrated corridor management, highlights the need for updates. Many participants did recognize the need to update regional or statewide architecture. At the same time few State DOTs have the in-house capacity for systems engineering. ITS is added onto capital projects piecemeal without a rigorous systems approach, often exploiting an opportunity rather than fulfilling a need. The value of a strong architecture was recognized and revising or updating the architecture was one of the action items mentioned most often for this dimension in the workshops.

State DOT technical staff – especially at the regional or district level – have a well-developed understanding of systems and technology issues, in part because of Federal support but also because of professional interest in technology.

3.3 Project Systems Engineering/Testing and Validation

- **Improve awareness and training.** The systems engineering process was generally employed by 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. When the National Architecture program was initially rolled out by the U.S. DOT, there were many training opportunities afforded to the State DOTs that were specific to systems engineering processes. It was often noted in the workshops that system engineering training options once offered by the U.S. DOT would be helpful if reinstituted (see the Organization and Staffing Dimension). A catalogue of best practices associated with system engineering processes would also be helpful in increasing the awareness and use of the systems engineering process, thereby advancing operations. Although training programs specific to systems engineering may still exist, an increased awareness of these training opportunities would benefit many State DOT programs.

  As expansion occurs and new technologies enter TMCs, lack of staff development has become 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 (see the Collaboration and Organization and Staffing Dimensions). In addition to the systems engineering training requested, general training on technology aspects of ITS elements and internal TMC functions are needed to advance TSM&O programs. DOTs have rotational training programs that often do not include a slot for a TMC post. Developing ITS training programs and getting TMCs in the rotation were noted by several locations as a way to increase staffing capabilities and overall agency knowledge of systems and technologies.

- **Procurement challenges.** Often times States noted that purchasing ITS hardware and software introduced great challenges due to the way that State agencies procure IT equipment. The internal process can take too long resulting in the purchase of outdated products and requires several levels of approvals; when requirements are not clearly defined, unsuitable items are purchased. There are additional challenges with agency enterprise requirements (such as low bid, security requirements, etc.), which might not align with specific ITS or TSM&O requirements. Several States mentioned concerns about their ability to procure the latest equipment when ITS is buried in large "new construction" projects and contractors are looking for the least expensive acceptable product that meets whatever requirements have been included in the procurement package.

  One way to potentially streamline procuring ITS equipment would be to develop qualified product lists (see approved vendor bullet below), although higher costs might become an issue when too few vendors qualify on the list for certain products. FHWA funding structures can make it difficult for States and regions to update their procurement processes. Developing relationships with information technology (IT) groups and an understanding of IT procurement processes as they relate to TSM&O would also be useful from two perspectives: helping the TSM&O group understand the IT processes and informing IT groups about the unique aspects of procuring TSM&O technologies. The need to improve the way ITS elements are procured was the most noted action item resulting from the workshops.

- **Outsourcing.** Some State DOTs have had success in outsourcing TMC operations (operators and service patrols). This has been especially helpful in situations when there have been internal staffing and budget restrictions. By outsourcing TMC staffing, the DOT also is removed from the cycle of hiring and training of operators and gains more flexibility for increasing or decreasing staff levels. Outsourcing staff at the TMCs was generally viewed as a successful practice when performance criteria were tied to payment conditions (see Organization and Staffing Dimension).

- **Keeping pace.** There were quite a few workshop locations that pointed out the challenge of keeping pace with rapidly evolving technology and the difficulties this creates, such as obsolescence of deployed equipment, outdated specifications, legacy equipment's incompatibility with newer equipment, incompatibility with deployed software, and maintenance capabilities. There also were 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.

  Specific maintenance and asset management challenges were mentioned in several places, including difficulty with maintaining equipment and keeping pace with equipment maintenance. Staff and budgets have not kept pace with deployments and several locations outsource their device maintenance duties. Maintenance responsibilities might be split between different groups (i.e., TMC/district maintenance), causing additional coordination challenges.

3.4 Standards/Interoperability

- **Interoperability.** Working together in a region requires standards that support the interoperability of various systems and facilitation of the interchange of field and central system hardware and software operations. Some State DOTs have made interoperability of systems a priority. Legacy systems can constrain an agency's future equipment purchasing flexibility or limit expansion options. There is a reluctance to upgrade large legacy systems when they are incompatible with newer equipment. Interoperability is often an issue for systems maintained by various agencies within a region, such as voice and data communications between a DOT and Public Safety Agency (PSA) or transit agency; furthermore, incompatible systems can impact the ability to share data within and across agencies. Data generated by TSM&O devices and analysis can help to support other agency functions if it is available and able to be integrated into those processes. This in turn can help increase agency support and respect for TSM&O. Several workshops identified the need for state police Computer Aided Dispatch (CAD) integration with the regional/statewide TMC.

- **Standards.** Standards developed for the ITS industry are used to harmonize data communications, database exchanges, and information displays among diverse systems. It is essential that standards be integrated into the system development and acquisition program. Workshop participants noted that it was necessary to update standards regularly to stay on the forefront of quickly evolving technologies, with interoperability as the motivating goal. By reorienting standards away from technical specifics to functional requirements allowed for an improved ability to keep pace with technology and open standards allowed for more flexibility in procurements.

- **Documentation.** ConOps and project architectures exist for technology projects, but they often lack important information components such as cost elements, performance requirements, and evaluation. When strong documentation exists it paves the way for expansion and solid standardization of processes. Continuing to advance the documentation for technology projects would benefit most all agencies, specifically in the areas of costs and performance measures. Ad hoc approaches to system implementation, with limited documentation, were oftentimes still employed, thereby holding back the success of agencies' programs. Although an important part of the systems engineering process, a ConOp was not necessarily identified as a required element, except for larger, complex projects or where federal funding requirements necessitated developing one.

- **Approved vendor product lists.** Agencies find that having qualified product lists facilitates purchasing ITS elements and can reduce the time needed to acquire products. This listing in essence pre-certifies products meeting the requirements and interoperability needs of the system. The challenge of having (and continually maintaining) a good set of specifications for field equipment was cited in several workshops. Even a very good vendor product list becomes problematic if the set of specifications on which it is based does not reflect new products or technologies in the marketplace.

- **Arterial Expansion.** Agencies had a good grasp on freeway management and each workshop location had deployed freeway management systems in their urban areas. Not as well deployed or integrated into their freeway management systems were arterial signal systems. About half of the workshop locations had incorporated signal systems into the freeway management centers, and many noted an interest in expanding or including arterial signal systems. Workshop action items centered on developing plans and institutionalizing TSM&O freeway and arterial applications and performance guidelines. Other systems expansions were often noted for traveler information, transit coordination, traffic incident management, computer aided dispatch integration, and ramp metering.

4.0 Relationships to Other Capability Dimensions

4.1 Synergy

As noted in Section 3.1, the synergies among the six TSM&O CMM dimensions are key defining characteristics of their critically. Each dimension is directly dependent on other specific dimensions to support improving capabilities. The three process dimensions are interdependent, but they, in turn, are also dependent on supportive institutional dimensions. In nine of 23 sites, systems and technologies were assessed in the lower two levels of the capability model, indicating that a focus on Systems and Technology needed to occur in order to advance operations. It was observed that the Systems and Technology dimension was central to the Business Processes dimension and planning documents such as the statewide architecture and ConOps associated with technology projects so there is a bidirectional arrow linking these dimensions. Links to the Organization and Staffing dimension were identified in the workshops due to the need for additional systems engineering and other technical training. Collaboration is another dimension highlighted in the workshops with strong linkages, with the need for coordination with many stakeholders a core element in the systems engineering process. These relationships are suggested in Figure 4.1.

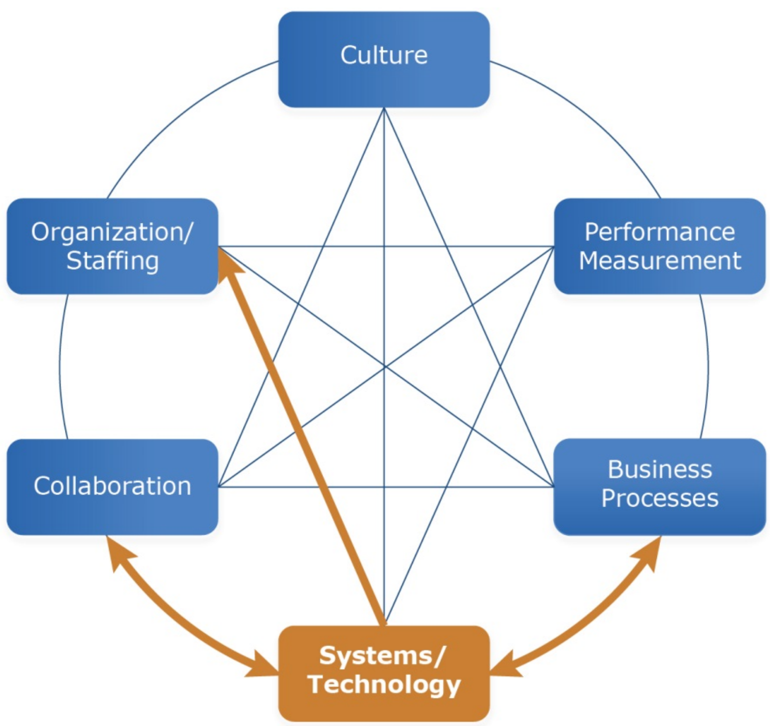

Figure 4.1 Graph. Key Synergisms between Systems and Technology and Other Dimensions

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

4.2 Span of Control

The CMM workshops were focused on middle managers involved with TSM&O. This staff is typically at the third or fourth level within State DOT central office, second or third level in State DOT districts/regions, and is specialized staff in MPOs. These individuals have responsibility for visible functions such as TMC operations, incident management, or snow and ice control. Despite their lack of formal authority, some of the more effective individuals are seen by their peers as "champions" whose influence is exerted through energy, experience, agency knowledge and long-standing relationships.

These individuals appear to be well aware of Systems and Technology challenges and diligently work to increase the awareness of it in the agency as well as expand deployments; however, they may be limited in their span-of-control regarding staffing levels at TMCs, expansion of freeway or arterial systems, and other budget heavy considerations. Nevertheless, in the workshops, participants were very conscious of the status of their systems and technologies even though their implementation plan task necessarily requires upper management buy-in and initiatives. It was generally agreed that action items could be implemented and generate substantive positive change for this dimension.

5.0 Implementation Plan Capability Improvement Actions

A majority of agencies included some aspect of Systems and Technology in their Implementation Plans to improve agency capability. Within these sites, the two highest priorities were to assess and/or update the regional or statewide ITS architecture plan and to improve ITS procurement processes. One State DOT rated at the highest level of maturity ranking for this dimension through a long-standing, well-funded program that has implemented a statewide transportation management program based in the major population area of the State with both freeway and arterial management capabilities. Typical participant-suggested actions for advancement to the next level of capability in Systems and Technology dimension are presented below in order of frequency of inclusion:

- Improve IT/ITS relationship, particularly for procurement (including applying best practice)
- Assess/update regional/statewide ITS architecture/deployment plan
- Improve traveler info systems/technology (collection and display)
- Improve TIM information dissemination/exchange/integration
- Review/develop data sharing practices/policies (TIM, CAD, traffic control, etc.)
- Develop ITS qualified products list
- Investigate standard communications protocol to facilitate interoperability
- Investigate need/level for traffic signal standardization
- Identify needed technical capacities/KSAs for IT/ITS
- Develop/implement ITS training and rotation program
- Develop strategy/plan to institutionalize TSM&O freeway and arterial applications through pilots
- Develop TSM&O asset management system/performance guidelines, including integrating updated lifecycle considerations in the asset management process
- Improve awareness/training on systems engineering approach
- Expand ITS systems (traffic signal integration, transit, information sharing)
- Improve rural TMC functions
- Develop and deploy travel management/traveler info responsive to weather
- Develop Dynamic Message Sign (DMS) guidance and additional deployment

- Develop the systems and technologies to actively coordinate traffic (e.g., corridor adaptive ramp metering)
- Deploy technologies and strategies to optimally operate arterials
- Increase participation in TMC and software systems discussions/decision making.

The appendix presents the key implementation plan steps commonly identified for these priorities. The highlights of these actions focus on two areas: improving ITS/IT procurement and updating ITS architectures.

5.1 Improve IT/ITS Procurement

The priority actions of agencies placing a high priority on procurement processes related to two issues:

- From a State DOT perspective, procurement and purchasing responsibilities were generally allocated to an external State agency largely out of the control of the DOT. When the procurement group was within the DOT structure, the process was more efficient. Agency relationships external to the DOT needed attention; it was generally understood that there was a lack of awareness of the intricacies of procuring ITS elements in the larger procurement groups. Discussions often recommended increased attention to the relationship with the purchasing group and somehow increasing that group's awareness of the special needs of procuring ITS elements. Suggestions included developing an informational document/resource to explain TSM&O implementations' special requirements, developing a more formal agreement on procurement processes/protocols, and raising the issue to a CEO/senior management level at both agencies (DOT and IT).
- Streamlining the purchasing processes could be enhanced by developing or updating qualified vendor lists. By expending a certain level of effort up front on pre-qualifying vendors, a procurement process that saves time and effort down the road can be developed.

5.2 Assess/Update Regional/Statewide ITS Architecture/ Deployment Plan

Implementation plans that addressed ITS architecture actions generally focused on assessing and updating existing architectures in need of revisions. Most workshop participants agreed on the importance of having and using a statewide or regional architecture, in that the architecture process:

- Supports relationships among technology selection and deployment entities and relates it to needed functionalities;
- Generally engages the FHWA Division office; and
- Engages regional stakeholders such as MPOs and local agencies.

Closely related to these two priorities were discussions regarding the importance of the system engineering process and how each agency employed this process.

6.0 Best Practice Examples

As noted above, all CMM workshop sites have existing ITS architectures and follow the systems engineering process, essential to achieving capability maturity in this dimension. The distinguishing question is how mature is their architecture process and how ingrained the systems engineering process is in their technology deployments. Beyond these two aspects, the systems and technology actions included expanding technology deployments and harnessing the CMM as these deployments occur. In some locations, updates to the ITS architecture were in process, so current and relevant actions were underway.

Utah DOT. The most notable program to showcase Systems and Technology is that of Utah DOT. Utah has a statewide TMC in the Salt Lake City area and regional TMCs in other areas of the State. It has a centralized software system for both freeway and arterial management. Utah DOT assessed itself as having a strong ITS architecture with robust interoperability among nearly all jurisdictions (e.g., camera sharing) based on a legacy of strong architecture planning. ConOps existed and were applied to new technology design (e.g., variable speed limit deployments), and procurement processes were consistent statewide. One proposed action to come out of the self-assessment process was to capture ITS lessons learned and share these internally with their organization.

Georgia DOT. The Georgia Department of Transportation (GDOT) was another program to showcase aspects of the Systems and Technology dimension. GDOT has a structured process in place for deploying technology solutions, including use of ConOps. GDOT's ITS architecture supports relationships among technology selection and deployment and relates it to needed functionalities. The agency has a good relationship with its IT department (e.g., working together in selecting software for cameras and in ITS device maintenance) and local agencies use their qualified products listing (QPL). GDOT has a common statewide traffic signal controller platform. The agency also seeks out and applies new technologies through participation in national forums (ITS-America).

Oregon DOT. The Oregon Department of Transportation (ODOT) originally developed the Oregon Statewide ITS Architecture in 1998 to guide the deployment of ITS applications in Oregon over a 20-year period and to meet Federal funding requirements. In addition to a statewide ITS plan, a number of regional ITS plans have been developed throughout Oregon at the regional and local levels (including transit and airports). ODOT effectively applies a long-standing systems engineering process and projects generally have ConOps. Architectures are coordinated well with regional strategic plans, having been originally developed as components of the plans. The TSM&O plan was developed using the statewide architecture; this architecture does not guide project prioritization but promotes implementation standardization. Interoperability of systems is a goal and priority at ODOT and other agencies in Oregon. They have a qualified product list for signals and most ITS equipment/assets are obtained through price agreements.

Maryland SHA. The Coordinated Highways Action Response Team (CHART) is a joint effort of the Maryland Department of Transportation (MDOT), Maryland Transportation Authority, and Maryland State Police, in cooperation with other Federal, State, and local agencies. The CHART system is fully integrated and interoperable statewide and includes local partners with agreements and up-to-date architectures in place. It is a fairly mature system; processes and methodologies are institutionalized with paths for succession when needed. Systems architectures are in place and used regularly, including in the budgeting process. CHART has a systems integration manager on staff with an established relationship with the Division of Information Technology (DoIT), which can be beneficial when DoIT places constraints on procurements. The system has advanced data management and warehousing capabilities (with the Regional Integrated Transportation Information System (RITIS)), which facilitates intrastate coordination.

7.0 Addressing Needs on the National Level

The weakness and related implementation plan actions identified in common by many State DOTs (and their partners), as represented by their implementation plans, suggests an agenda of needs for research, guidance, and training. Consistent with the CMM dimensions, this agenda is focused on process and institution improvements not substantially addressed in the support materials developed among peers or by AASHTO, FHWA, and other entities. There are strong supporting materials targeting many of the systems and technology needs identified in the section above (see Best Practices and References below). Suggestions are presented in Table 7.1.

Table 7.1 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	Regional Architecture	ITS JPO (official web site), NHI, PCB, CITE Courses	T3 Webinars or list-serves could broadcast and raise awareness of available current resources
Develop basic webinar module focused on ITS procurement processes	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	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	Standardization	NOCoE	Systems and Technology are search items
Compile resources related to training regarding the standards implementation (testing and training)	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	Standardization	NOCoE	

Activity	Systems and Technology Element	Sponsor(s)	Comments
Compile best practices and strategies for ITS device maintenance, ITS maintenance programs, and keeping pace with rapidly changing lifecycle considerations	Overall	FHWA 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

NOCoE National Operations Center of Excellence

ITE Institute of Transportation Engineers

ASHTO American Association of State Highway and Transportation Officials

NHI National Highway Institute

PCB Professional Capacity Building

JPO Joint Program Office

CITE Consortium for ITS Training and Education.

8.0 References

AASHTO TSM&O Guidance: Systems and Technology Dimension. AASHTO's web-based TSM&O Guidance follows the six dimensions of TSM&O capability described in this white paper, including Systems and Technology. It is designed for transportation agency managers whose span of control relates to the operations and management of the roadway system, including policy makers and program managers for ITS and TSM&O at both the State and regional level. It incorporates insights from a review of the state of the practice in TSM&O among transportation agencies into a well-accepted change management framework that identifies doable steps toward mainstreaming TSM&O on a continuously improving basis. Specific guidance for systems and technology is cited here for advancing an agency currently at Level 1 to Level 2 within the CMM framework. Other level changes within the framework can be found on the AASHTO TSM&O Guidance web site.

http://www.aashtotsmoguidance.org/guides/ST_L2.pdf

The requirements for a regional architecture are defined by Part 940 of the Code of Federal Regulations.

http://law.justia.com/us/cfr/title23/23-1.0.1.11.47.html and
http://www.ops.fhwa.dot.gov/its_arch_imp/policy.htm#sthash.5GbnyUl6.dpuf

Systems Engineering. A systems engineering analysis is required for ITS projects using Federal funding.

http://ops.fhwa.dot.gov/int_its_deployment/sys_eng.htm

ITS Architecture. The FHWA Office of Operations ITS Architecture Implementation site with the guidance and resources necessary for implementing the Final Rule on Architecture and Standards Conformity (issued on January 8, 2001).

http://ops.fhwa.dot.gov/its_arch_imp/index.htm

> "**National ITS Architecture.**" Information about the committee to be formed to develop a regional architecture.
>
> http://www.iteris.com/itsarch/
>
> "**Turbo Architecture: A Tool for Leveraging the National ITS Architecture**"
>
> http://www.fhwa.dot.gov/publications/publicroads/00mayjun/turbo.cfm
>
> "**Introduction to the National ITS Architecture.**" An on-line course that provides an introduction to the National ITS Architecture.
>
> http://www.citeconsortium.org/course/introduction-to-the-national-its-architecture/

Applying a Regional ITS Architecture to Support Planning for Operations: A Primer, U.S. DOT. FHWA-HOP-12-001, February 2012.

www.ops.fhwa.dot.gov/publications/fhwahop12001.

Standards Implementation

In addition, standards are available for a broad range of ITS applications, communication, information exchange, databases etc. Standards are used for communication between a central computer and field equipment (traffic signals, dynamic message signs, highway advisory radio, etc.). Database standards are available to ensure that data are archived in a manner that will enhance the agency's ability to share the information with other agencies and jurisdictions. It is essential that standards be integrated into the system development and acquisition program. Overview and detailed information on the entire range of ITS standards can be found at http://www.standards.its.dot.gov/.

Managers need training that provides an overview of the standards framework and an appreciation of their benefits, while technical professionals involved with the specification, acquisition, and testing of standards require more detailed instruction. A listing of available ITS standards training can be found at: http://ops.fhwa.dot.gov/int_its_deployment/standards_imp/training.htm.

http://ops.fhwa.dot.gov/int_its_deployment/standards_imp/standards.htm

U.S. DOT JPO ITS Professional Capacity Building Program/ Advancing ITS Education ePrimer. The ITS ePrimer educates transportation professionals about fundamental concepts and practices related to ITS technologies. This on-line resource can help practicing professionals and students better understand how ITS is integrated into the planning, design, deployment, and operations of surface transportation systems. See Module 2: Systems Engineering.

http://www.pcb.its.dot.gov/eprimer/module2.aspx.

Appendix: Steps to Implement Common Implementation Plan Priority Actions for Systems and Technology Dimension

The steps listed below identify the most common priority actions identified by workshop participants when developing their implementation plans. Although the actions themselves are not stated, they generally address improvement in each of the systems and technology elements. The steps for each action were developed by the workshop site core team, assisted by a template of facilitator-supplied suggested steps based on workshop outputs, and structured consistent with the basic CMM guidance presented in the AASHTO TSM&O Guidance.

Regional architectures

1. Assess, update, and use regional and Statewide ITS architectures

    a. Revisit methodologies to encompass holistic TSM&O environment and apply to future revisions

Project systems engineering/testing and validation

1. Develop and implement ITS-related training program

    a. Maintain and/or improve awareness and use of systems engineering approach

    b. Investigate rotation program for electrical engineers to enhance systems engineering state of practice

2. Develop systems and technology to collect and display real-time transportation data to actively and coordinate traffic and integrate city and county traffic signals and transit technology

3. Establish new operating procedures at the TOC to support ICM, develop strategies for coordinating with local agencies to improve freeway/arterial coordination, and formalize agreements with appropriate arterial management agencies for future ICM corridors

Standards/interoperability

1. Seek opportunities to reform, streamline, and improve the current TSM&O procurement process

    a. Develop relationships and agreements with procurement entities relating to software, hardware, and IT services

    b. Develop a clearinghouse of standard specifications for frequently procured TSM&O technology

c. Develop ITS qualified product list

2. Implement communications with traffic signals to support central control and management from TOC; implement a comprehensive signal operations and management program, leveraging a new centralized signal control system

    a. Investigate need for and level of standardization for traffic signals statewide

3. Investigate need for standard communications protocol among systems' interface to facilitate interoperability, including CAD dispatch integration

4. Define TSM&O data/system requirements that support the exchange of information among State and local agencies to improve safety/mobility, coordinate traffic incident management, support emergency transportation operations, and facilitate multimodal traveler information

    a. Improve TSM&O communications capabilities and information exchange protocols for major incidents

    b. Develop CAD information sharing plans and procedures.

Other Actions – Maintenance/Asset Management

1. Evaluate existing ITS devices asset management needs (upgrade/replace/remove) and resource implications

2. Establish a TSM&O asset management strategy that includes life cycle considerations for maintenance and replacement

3. Develop asset management performance guidelines by

    a. Completing inventory of ITS devices and assets

    b. Developing a business plan for maintenance and replacement

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