Institutional Architectures to Improve Systems Operations and Management

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The Second Strategic Highway Research Program

America's highway system is critical to meeting the mobility and economic needs of local communities, regions, and the nation. Developments in research and technology—such as advanced materials, communications technology, new data collection technologies, and human factors science—offer a new opportunity to improve the safety and reliability of this important national resource. Breakthrough resolution of significant transportation problems, however, requires concentrated resources over a short time frame. Reflecting this need, the second Strategic Highway Research Program (SHRP 2) has an intense, large-scale focus, integrates multiple fields of research and technology, and is fundamentally different from the broad, mission-oriented, discipline-based research programs that have been the mainstay of the highway research industry for half a century.

The need for SHRP 2 was identified in *TRB Special Report 260: Strategic Highway Research: Saving Lives, Reducing Congestion, Improving Quality of Life* published in 2001 and based on a study sponsored by Congress through the Transportation Equity Act for the 21st Century (TEA-21). SHRP 2, modeled after the first Strategic Highway Research Program, is a focused, time-constrained, management-driven program designed to complement existing highway research programs. SHRP 2 focuses on applied research in four areas: Safety, to prevent or reduce the severity of highway crashes by understanding driver behavior; Renewal, to address the aging infrastructure through rapid design and construction methods that cause minimal disruptions and produce lasting facilities; Reliability, to reduce congestion through incident reduction, management, response, and mitigation; and Capacity, to integrate mobility, economic, environmental, and community needs in the planning and designing of new transportation capacity.

SHRP 2 was authorized in August 2005 as part of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The program is managed by the Transportation Research Board (TRB) on behalf of the National Research Council (NRC). SHRP 2 is conducted under a memorandum of understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and the National Academy of Sciences, parent organization of TRB and NRC. The program provides for competitive, merit-based selection of research contractors; independent research project oversight; and dissemination of research results.

Notice

The project that is the subject of this report was a part of the second Strategic Highway Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical committee and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

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SHRP 2 STAFF

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FOREWORD
William Hyman, *SHRP 2 Senior Program Officer, Reliability*

A large number of strategies aimed at improving travel time reliability focus on highway operations. To be successful, operational strategies often require a collaborative and coordinated effort among many transportation organizations and within their key units. For example, effective work zone management within a transportation agency cuts across organizational boundaries and involves construction, maintenance, safety, and operations personnel. More significantly, many operational strategies, particularly traffic incident management, require strong cooperation from many different organizations, such as transportation departments, police, fire, emergency medical services, and towing and recovery.

The objective of this research was to undertake a comprehensive and systematic examination of the way agencies should be organized to successfully execute operations programs that improve travel time reliability. The following types of questions were examined at the outset of this research: How does operations fit into a transportation agency's overall program? What changes can be made in agency culture and training to promote operations? Which local and regional public agencies and private-sector organizations are essential to the various aspects of operations? Are there emerging technologies, systems, or organizational structures that can be used to advance intra-agency and interagency communications and therefore operations?

The research addressed a large number of topics concerning organizational and institutional approaches that could enhance highway operations and travel time reliability. The most fruitful investigation was identification of the Capability Maturity Model, used extensively in the information technology field for organizational self-assessment and continuous improvement of quality and reliability. The researchers recognized that a version of the Capability Maturity Model could be developed and applied to highway operations and in turn travel time reliability. Elements defining different levels of maturity include culture/leadership, organization and staffing, resource allocation, and partnerships. As a part of the research, two companion publications were produced—this report and a guide—and refined through workshops involving operations managers, executives, and others.

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Online version of this report: www.trb.org/Main/Blurbs/165285.aspx.

Executive Summary

Background on Research and Guidance

Many transportation agencies explicitly recognize the idea that we can't build our way out of congestion. However, few state departments of transportation (DOTs) or local government transportation entities have focused effectively on how to continue to fulfill their mobility mission in an environment of capacity and financial constraints. If the full-service potential of an investment in an existing network (especially the freeway network) is to be realized, then state DOTs and local and regional transportation entities, together with their partner public safety agencies (PSAs), must move beyond capacity provision and maintenance to engage in active systems operations and management (SO&M) of the network's available capacity, including aggressive minimization of disruptions.

The SHRP 2 Reliability focus area addresses the root causes of unreliable travel and identifies the role of performance measures, strategies, planning integration, and institutional issues related to supporting improved reliability. The L06 project focuses on nonrecurring congestion (NRC) as the principal source of delay and unreliability on the nation's roads. SO&M is defined by a set of conventional strategies that focus on responding to various causes of the unpredictable but highly disruptive losses of service associated with NRC.

The project includes both research and guidance relating to the institutional preconditions for effective management of NRC. The objective of the project is to identify the preconditions to institutionalizing SO&M as a continuously improving formal agency program. The key features of this project include the following:

- Evaluation of the current range of SO&M program effectiveness among state DOTs and the key process and institutional features that are associated with the more effective programs;
- Analysis of the apparent relationships and interactions among three dimensions: program effectiveness, required technical and business processes, and supportive institutional and organizational arrangements;
- Development of a capability maturity model to systematically relate increasing levels of technical and business process maturity and the key institutional changes that support those levels; and
- Provision of self-evaluation–based guidance for agencies to guide managed changes within their institutional architecture that will support more effective SO&M programs.

Purpose of the Project

The purpose of the project is to identify strategies by which existing transportation agencies can adjust their institutional architecture—including culture, organization and staffing, resource allocation, and partnerships—to support more effective SO&M. The report identifies new models that can be applied in the future.

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The report develops and provides the basis for the *Guide to Improving Capability for Systems Operations and Management* (Parsons Brinckerhoff et al., 2011), including an examination of current state DOT practice and insights from other sectors with strong operational orientations. It establishes a systematic guidance framework based on the traceable relationships between the technical and business process features most supportive of effective SO&M and the institutional architecture that supports such processes.

Systems Operations and Management

The concept of congestion management has evolved since the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991. Whereas recurring (peak-period) congestion has long been the focus of congestion management activities, an improved understanding of the causes of traffic delay and disruption has led to a new focus: the unpredictable delay and disruption of nonrecurring events such as major crashes, weather, construction, and special-event disruptions—NRCs that are responsible for over half of all delay (as well as for most system unreliability). Intelligent transportation systems (ITS) technology has matured to support improved communication, analysis, and controls; furthermore, a set of increasingly well-understood SO&M procedures and protocols has evolved, capitalizing on this technology, and demonstrating significant leverage to reduce the impacts of NRC. There are several excellent best-practice examples of SO&M applications by state DOTs in a few major metropolitan areas in the United States.

Effective SO&M Applications to Reduce NRC

The applications that have been developed for NRC are typically centered within the larger highway jurisdictions—state DOTs, toll entities, and large local government transportation agencies—together with their public safety partners. Although their focus is often on highways, these applications are also used for major arterials and rural routes. These conventional strategy applications include the following:

- Incident management, including multijurisdictional, integrated corridor management in response to crashes, breakdowns, hazardous material spills, and other emergencies that are responsible for up to 30–35% of delay—and most unreliability—in major metropolitan areas;
- Road weather management in response to heavy rain and wind and snow and ice, which can constitute from 5–10% of delay in some areas;
- Work zone traffic management focused on traffic control plans to minimize the impacts of reduced capacity, constituting anywhere from 10–20% of total delay;
- Special-events planning and management to accommodate event patrons and bystanders with minimum traffic disruption; and
- Active traffic management using lane use and speed control to minimize flow disruption and incidents, as well as managing diversions and the operation of diversion routes, in response to both recurring and nonrecurring congestion.

Table ES.1 outlines the benefits of SO&M strategy applications. Despite the proven benefits of SO&M, the state of the practice is modest and uneven. A few states have demonstrated the payoffs from aggressive SO&M applications. In many other states, however, while some ITS technology has been deployed, there is a limited commitment to implementing best-practice procedures and developing the partnerships required to capitalize on the technology. Even within individual states, the levels of application are uneven across metropolitan areas, reflecting the limited commitment at the statewide policy level.

Unique Process and Institutional Demands of SO&M

Implementing effective congestion management applications places demands on a transportation agency's institutional environment that are at odds with those of capacity development,

Table ES.1. Systems Operations Benefits

	Benefits and Benefit–Cost Ratios	Safety Impact	Mobility Impact	Energy/ Environmental Impact
Traffic incident management	Incident duration reduced 30–50%	High	High	High
• Safety service patrols	2:1 to 42:1	High	High	High
• Surveillance and detection	8:1	High	High	High
Road weather information systems	2:1 to 10:1; crash rates reduced from 7–80%	High	High	High
Traveler information dynamic message signs	3% decrease in crashes; 5–15% improvement in on–time performance	Low	High	Low
Work zone management	2.1 to 40.1; system delays reduced up to 50%	High	Medium	Medium
Active Traffic Management	Throughput increased by 3–7%; decrease in incidents of 3–30%	High	High	Medium

Source: U.S. Department of Transportation, Intelligent Transportation Systems Joint Program Office, 2009.

safety, and maintenance that constitute the legacy context. This is especially true for NRC—as reflected in the common and characteristic features of SO&M applications that determine effectiveness. SO&M applications are typically

- Reactive and responsive to unpredictable events on a 24/7 basis;
- Dependent on situational awareness and communications technology;
- Applied at the corridor scale or network level;
- Based on teamwork;
- Communications intensive;
- Dependent on performance monitoring and are evaluated through the impact on system performance measured in real time;
- Using dynamic high technology and systems engineering; and
- Dependent on outside partners not under the control of a transportation agency, including PSAs and local government.

These unique features establish a set of specific preconditions for the achievement of an effective SO&M program and indicate the need for certain technical processes, systems, and performance-tracking measures that are tailored to address these characteristics. The processes, in turn, cannot be established without a supportive institutional framework.

The Importance of Institutional Architecture

It is increasingly clear that the current modest focus on SO&M is almost entirely a product of the conventional legacy context of many transportation agencies today—a civil engineering culture, an inherited organization structured for construction and maintenance, the existing capital programs' claims on scarce resources, and difficulties in forging the necessary partnerships with outside entities. Culture, leadership, priorities, organization and staffing, resources, and relationships make up the institutional setting for change in existing transportation agencies.

In this project, institutional architecture will focus on these substantial nontechnical features that describe whether, how, and with whom an agency pursues SO&M. It is therefore important to distinguish *institutional architecture* from *technical and business processes* (such as planning/programming, systems development, and performance measurement) and from the *program* of SO&M applications (such as incident management or road weather information).

The research in this report includes the determination of the common aspects of the programs and the technical and business processes of the states that appear to have more effective operations, but only to the extent that those processes identify the needed institutional architecture. For example, an effective incident management program requires an interrelated sequence of planning, systems engineering, resource allocation, procurement, project development and implementation, and procedural coordination. All these processes, in turn, depend on key elements of a supportive institutional setting (i.e., leadership, legal authorization, organized responsibilities, staff capabilities, available resources, and working partnerships).

Basic Hypothesis and Study Methodology

The central hypothesis of the research for this project is that there is a traceable relationship from effective NRC applications, through the technical and business processes that are needed for their implementation, to the characteristics of a supportive institutional framework. In order to develop a more structured understanding of these relationships, this research was conducted in three parts:

- Identification of the more effective transportation agencies through the evaluation of their program characteristics (done with available statistics and program descriptions);
- Determination of the technical and business process features that are utilized to support program effectiveness (through interviews and secondary materials); and
- Identification of the institutional characteristics that appear to be essential in the development, support, and sustainment of the key process features.

The conclusions from a survey and other research methods identified the key variables of SO&M-related technical and business processes essential to effective programs—and were documented as the basis for determining the features of institutional architecture needed to support such processes. These have been structured into a capability maturity model form. The analysis was supported by a review of organizational development research literature focused on the institutional characteristics of operations versus product-oriented organizations in the private sector and the change management strategies being used to improve organizational effectiveness.

Application of the Capability Maturity Model

The most relevant of the private-sector change management approaches is the capability maturity model (CMM), developed in the information technology industry to help companies produce quality software. The CMM is based on the recognition that specific process features—such as performance measurement and documentation—are essential for program effectiveness and that they must be present at defined levels of criteria-based maturity to achieve industry-acceptable levels of effectiveness. The CMM provides a self-managed, systematic approach to making process improvements that support increasingly consistent, repeatable, reliable, and efficient outcomes.

The key features of the CMM approach include the following:

- Goals: The conditions that must exist for key process areas/elements to be achieved in an effective and lasting way.
- Maturity levels: Levels of achievement defined by specific criteria. They advance toward a desirable end-state in which processes are managed by continuous improvement, typically structured from the ad hoc, through increasing levels of definition and reliability, to fully manageable.

- Process elements: The related categories of activities that, if performed well, will achieve the goals.
- Strategies/practices: The means by which higher maturity levels are achieved for each process element.

In CMM applications in IT and other process areas, improved levels of maturity are based on self-evaluation and on identifying strategies to reach the next criteria-defined level. The model has been used as the basis for standardized steps, commandments, or stages as problem-solving recipes in several application areas.

Research Findings: Processes and Their Institutional Support Implications

In this project, the concept of capability maturity has been adapted and extended to fit the transportation service context. Both process and institutional elements are addressed, defined, and structured to fit transportation agency practice and context. The key elements have been defined through the research, with incremental levels of improvement benchmarked to current average and best SO&M practice today for all process and institutional elements. Importantly, the research identified the apparent correlation between process improvements associated with increased program effectiveness and related, supportive institutional configurations (also called levels).

Table ES.2 illustrates examples of the relationships as suggested by the research. The examples indicate a strong correlation between institutional features and the effectiveness of SO&M applications. As indicated, there are specific relationships between key business and technical processes for effective SO&M and supportive institutional features. The key processes and their institutional implications include the scope of operations in the field; technical processes; systems and technology development; and performance monitoring, measurement, and analysis.

The scope of applications in the field includes the scope of the program and its responsiveness to the array of NRC problems experienced in various geographic and network contexts. The more fully developed, long-standing programs are in transportation agencies where the limits on capacity enhancement have been acknowledged in policy; where senior leaders have consistently supported a standardized, expanding, and sustainable SO&M program; and where capable staff is evident, resources rationally relate to key needs, and partner relationships are somewhat formal.

Technical processes include planning and programming, systems engineering (including concept of operations), project development and ITS asset management (in terms of the ability to implement and maintain systems supporting key operations), and development of field procedures in support of systematic and comprehensive program development. Process development requires upper management recognition of the need to formalize SO&M at a statewide level, with a full set of standardized activities in parallel with those of other core programs, such as planning, programming, project development, and maintenance. It also requires the identification of the organizational units responsible, an accountability mechanism, supporting resources, and appropriate professional capacities.

Systems and technology development requires the availability of effective platforms to provide the needed situational awareness, control devices, communications, and basic information resources, as well as technology deployment in terms of standardization and cost-effectiveness. Without a formal, managed SO&M program and experienced systems engineering staff (at both DOT central office and district levels), achieving standardization, a rational systems platform, and technology improvement and upgrading are not possible. In addition, since some SO&M applications involve external players in their concepts of operations, there is a need for external systems coordination, which is unlikely without a level of formal partnering.

Performance monitoring, measurement, and analysis are necessary, especially in the use of outcome measures to evaluate procedures, projects, and the overall program. Performance

Table ES.2. Relationships among Effective SO&M Applications, Supportive Processes, and Their Institutional Implications

Characteristics of Effective Applications	Examples of Supportive Processes	Examples of Institutional Implications
Responsiveness to an event • Situational awareness system • Amount of prepositioned equipment	• Program scoping • Integration into planning and programming • ITS project development and implementation	• Staff capable of analysis • Aligned partners with regard to concept of operations (ConOps) • Adequate resources for necessary infrastructure and staff • Coordinated organizational units (central office and districts) • Customer-service performance culture
Targeting of application • Quality of surveillance and reporting information (discrimination) • Level of forecasts, analytics	• Availability of data • Outcome performance measurement	• Staff capable of analysis
Aggressiveness of application • Coordination/cooperation level among parties • Use of performance measures to improve • Assertion of jurisdiction regarding ability to employ best practice • Agreed-upon ConOps among partners	• Full realization of ConOps • Documentation of current practice as basis for improvement • Systematic platform and technology development	• Culture oriented to customer service and performance measurement • Continuous-improvement orientation • Accountability of individuals, units for performance • Full legal authority
Integration among applications • Interoperability/integration of communications and systems • Common standards and protocols • Integration with external data sources (e.g., road weather)	• Systems engineering process • Shared ConOps and architecture	• Degree of interagency integration
Coverage and density of applications • Full needs-based program scope—including all relevant strategies, urban and rural—based on planning/budgeting • Level of deployment, areawide and per unit area	• Development of standardized applications • Integration into the planning process	• Adequate resources from a needs-based, multiyear life-cycle budget—predictable, sustainable • Mission focus on entire network

measurement is the basis for a transportation agency's accountability for any mission related to mobility and safety, including increases in reliability. Policy remains merely assertion, and accountability meaningless, without the ability to determine the impacts of investments and actions. Thus, performance measurement plays a fundamental role in the culture and business model of an operations-committed transportation agency. The review, survey, and analysis of SO&M in a selected sample of state DOTs suggested a spectrum of process effectiveness—from an ad hoc approach where SO&M is not considered as a program with distinct process and organizational arrangements to agencies where SO&M is considered as a key part of the agency mission, with its own tailored business and technical process and distinct organizational arrangements. These relationships can be calibrated in terms of levels of maturity per the CMM conventions, showing how improved processes are related to changes in institutional architecture,
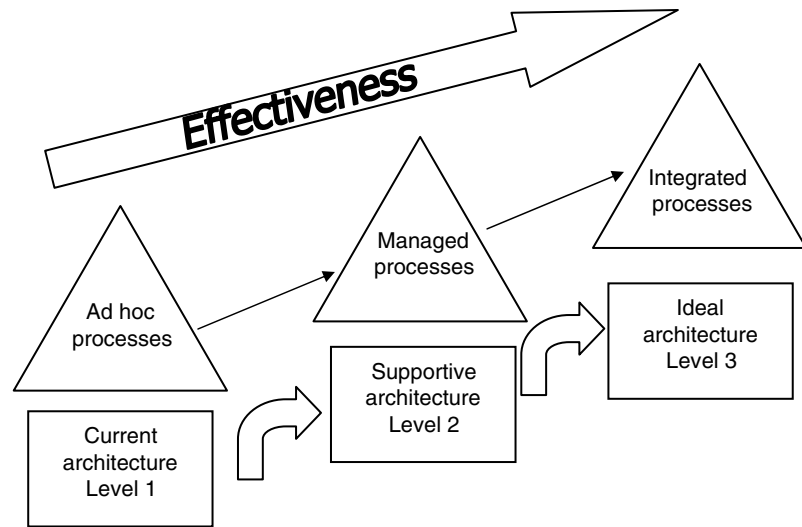
Figure ES.1. Institutional architecture maturity relationship to increasing process capability.

toward a target of fully integrated processes with the appropriate ideal architecture (see Figure ES.1).

Key Findings Related to SO&M Institutional Architecture

Within the concept of increasing maturity of SO&M processes, the research suggested the following combination of four categories of key institutional elements to be addressed to provide a supportive institutional context for SO&M:

- Culture/leadership;
- Organization and staffing;
- Resource allocation; and
- Partnerships.

Each of these four elements can be represented on a spectrum of maturity as reflected in the state DOT analysis and suggested in Figure ES.1. The current architecture in many transportation agencies is Level 1. At Level 1, the four categories of institutional elements can be described as follows:

- Culture and leadership have a strong civil engineering orientation, including legal authority and leadership and program structure substantially focused on construction and maintenance programs. This legacy orientation includes unrealistic assumptions about the level-of-service benefits from modest capacity programs, and is accompanied by limited knowledge of the potential of SO&M, by limited interest in opportunities offered by external events to advance operational capabilities, and by limited ability to facilitate change and capitalize on such opportunities. (Limited knowledge is reflected in the low expectations of users and other stakeholders regarding operations potential.) This perspective is often reflected in a fuzzy agency mission and in the absence of a formal policy commitment to, or stakeholder support for, customer mobility needs backed by realistic strategies and performance accountability.
- Organization and staffing are configured for construction and maintenance project development, often leaving SO&M functions (i.e., ITS, traffic engineering, TMC management) fragmented and in various traditional chains of command, with limited staff capacity in certain technical areas necessary to improve operations.

- Resource allocation is without formal accommodation for ITS-related investments. These resources are often viewed as the first place to cut.
- Partnerships (interjurisdictional roles and relationships) among operations participants, including PSAs, local governments, MPOs, the private sector, are exacerbated by informal and unstable partner relationships in congestion management activities.

Capability Maturity Levels of Institutional Architecture

Level 1 is reflected by the many transportation agencies that are transitioning into SO&M as an identifiable, managed activity. At the other end of the maturity scale is Level 3—an ideal agency culture, fully staffed within an efficient organizational structure, a transparent resource allocation process for SO&M, and formal relationships with partners. Between the transitioning situation and the ideal is Level 2, already evident in some state DOTs that are committed to formalizing SO&M as a core program and are making changes to rationalize organization, staffing, resource allocations, and partner relationships toward that end. These relationships reveal a pattern of institutional evolution toward configurations that are increasingly supportive of effective SO&M processes. The three distinct levels of institutional capability maturity have been defined as follows:

- Level 1: Ad hoc. An architecture that reflects a legacy of civil engineering culture in which SO&M activities are accommodated on an ad hoc and informal basis, typically as a subsidiary part of maintenance or capital project arrangements. This level, as exhibited in transitioning states, is reflected in a legacy organizational structure and informal resource allocation, fragmented SO&M activities, ad hoc project-oriented business processes, and a narrow SO&M program with no clear sense of performance.
- Level 2: Rationalized. An architecture exhibited in mature states that reflects an appreciation of SO&M as a distinct activity, with adjustments in arrangements, resources, and roles to accommodate the distinct features of SO&M.
- Level 3: Mainstreamed. A hypothetical, fully integrated ideal of an architecture in which SO&M is considered a core mission, with appropriate formal and standardized arrangements (equivalent to other core programs) configured to support continuous improvement.

The relationships between the process levels and their capabilities on the one hand and the institution architectures and their supporting features on the other constitute the framework for an institutional capability maturity model for SO&M. Table ES.3 summarizes the concept of the related levels of process and institutional maturity pictured in Figure ES.1. The levels of process maturity for each key process element are directly related to the levels of maturity of the key institutional elements described.

The project research provided considerable detail regarding the criteria for the three levels of institutional maturity. (Process maturity is not addressed in detail in this project other than to provide structure for the criteria of levels of institutional maturity.) Table ES.4 presents the criteria that define the institutional architecture levels. Each cell within the table represents either a point of departure or a target for improving architecture to the next level. Transportation agencies can plot their current situation and their targets for improvement.

Capability Improvement Strategies at Each Level

For each of the four elements of institutional architecture, there is a set of generic strategies that have been and can be used to make the required adjustments to move up a level in institutional maturity. The strategies have their own related tactics associated with each level of maturity. The interpretation of strategies changes with successive levels. The differences reflect the increasingly

Table ES.3. Correlation between Process Maturity Levels and Institutional Architectural Levels

Program and Process Capabilities	Level 1 Transitioning	Level 2 Mature	Level 3 Integrated
Scoping	Narrow and opportunistic	Needs based and standardized	Full range core program
Technical processes	Informal, undocumented	Planned, mainstreamed	Integrated, documented
Technology and systems development	Project oriented, qualitative	Rational quantitative evaluation	Standardized C/E systems/platforms
Performance measurement	Outputs reported	Outcomes used	Performance accountability
	↑	↑	↑
Institutional Architecture Elements	**Level 1 Ad Hoc**	**Level 2 Rationalized**	**Level 3 Mainstreamed**
Culture/leadership	Mixed, hero driven	Championed/ internalized across disciplines	Customer mobility committed
Organization and staffing	Fragmented, understaffed	Aligning, trained	Professionalized
Resource allocation	Project level	Criteria-based program	Sustainable budget line item
Partnerships	Informal, unaligned	Formal, aligned	Consolidated

managed, formalized, and mainstreamed status achieved in the movement from one level to the next. There is a logical sequence to the focus of each element of institutional architecture to reach the next level of capability. For example, regarding resources, moving from Level 1 to Level 2 may involve a systematic determination of needs, whereas moving from Level 2 to Level 3 may involve formal budgeting. There is a parallel progression for all the strategies. Key strategies associated with each institutional architecture category are shown in Table ES.5.

Using the Model as Guidance

For use as guidance in improving institutional maturity, the above strategies for transitioning from one level of maturity to the next are presented in a series of steps and strategy matrices. In developing the detailed guidance framework, the four standard rules of maturity models are applied:

- Each incremental level of maturity within a given element of institutional architecture establishes the basis for the agency's ability to progress to the next higher level of effectiveness.
- Levels cannot be skipped.
- Each level of technical and business processes needs specific institutional support.
- The overall level of maturity for an organization is defined by the lowest level of institutional maturity of any element.

The *Guide to Improving Capability for Systems Operations and Management* (Parsons Brinckerhoff et al., 2011) is presented in a series of tables that allow the user to define the agency point of departure. The tables indicate the next logical step in maturity in terms

Table ES.4. Criteria for Institutional Capability Maturity

Elements	Levels of Capability Maturity		
	Level 1 Ad Hoc	Level 2 Rationalized	Level 3 Mainstreamed
Culture/ leadership	**Mixed, hero driven** • Operations value not widely appreciated (lack of message). • Middle management heroes promote program. • Full legal authority not established.	**Championed/internalized across disciplines** • Visible agency leadership citing operations leverage, cost-effectiveness, and risks. • Customer outreach and feedback.	**Commitment to customer mobility** • Customer mobility service commitment accepted as formal core program. • Clear legal authority for operations roles; actions among transportation agency, public safety agencies (PSAs), local government clarified.
Organization and staffing	**Fragmented, understaffed** • Legacy roles: Some fragmentation of key functions and boundaries, both horizontally and vertically. • Hero driven: Reliance on key individual for technical knowledge and champions for leadership.	**Aligned, trained** • Transportation Management Center (TMC) focus with vertical and horizontal authority or responsibility alignment for operations for the life of a project. • Accountability to top management. • Core capacities established with knowledge, skill, ability specifications, training, and performance incentives in clear career paths.	**Integrated** • Top-level management position with operations orientation established in central office and districts. • Professionalization and certification of operations core capacity positions including performance incentives.
Resource allocation	**Project level** • Resource allocation at project level, ad hoc, unpredictable, buried, invisible. • Apparent limited eligibility of existing funds for operations.	**Criteria-based program** • Budget allocation for operations driven by transparent criteria on effectiveness and life-cycle needs basis. • Funding levels based on relationship to identified needs.	**Sustainable budget line item** • Operations is a formal, visible, and sustainable line item in agency's budget—capital, operating, and maintenance. • Trade-offs between operations and capital expenditures considered as part of the planning process.
Partnerships	**Informal, unaligned** • Nontransportation entities unaligned with transportation objectives, procedures relying on informal personal basis. • Outsourcing to private sector used for isolated functions.	**Formal, aligned** • Rationalization of responsibilities by formal agreements across institutions (transportation agency, PSAs, private). • Outsourcing revised to meet agency technical, staffing, and management objectives.	**Consolidated** • High level of operations coordination (memorandums of understanding) among owner/operators with TMC consolidation. • Outsourcing performance managed while maintaining agency's core capacities.

Table ES.5. Basic Maturity Strategies for Institutional Elements

Strategies for Elements	Criteria for Levels		
	Level 1 Ad Hoc	Level 2 Rationalized	Level 3 Mainstreamed
Culture/leadership • Undertake educational program on SO&M as customer service. • Exert visible senior leadership. • Establish formal core program. • Rationalize state DOT authority. • Internalize customer service performance as ethic. • Commit to continuous improvement as agency mode.	Mixed, hero driven	Championed/ internalized across disciplines	Commitment to customer mobility
Organization and staffing • Establish top-level SO&M executive structure. • Establish appropriate organizational structure. • Identify core capacities. • Determine and allocate responsibility, accountability, and incentives.	Fragmented, understaffed	Aligned, trained	Integrated
Resource allocation • Develop program-level budget estimate. • Introduce SO&M as a top-level agency budget line item. • Develop acceptance of sustainable resourcing from state funds. • Use performance and life-cycle costs as resource allocation tool. • Develop methodology for trade-offs.	Project level	Criteria-based program	Sustainable budget line item
Partnerships • Agree on operational roles and procedures with PSAs. • Identify opportunities for joint operations activities with local government/metropolitan planning organizations (MPOs). • Develop procedures that accommodate partners' goals and maximize mobility (minimum disruption). • Rationalize staff versus outsourcing activities, responsibilities, and oversight.	Informal, unaligned	Formal, aligned	Consolidated

of (a) the criteria for each level of each strategy and (b) the steps to move to the next level. The general directions for using the guide and the steps used in the guide are as follows:

- Step 1. Identify the element of interest (culture/leadership, organization and staffing, resource allocation, or partnerships). Note that all elements are necessary, but the state DOT may be at a higher level of maturity in certain elements. Priority focus should be on the element at the lowest level of maturity.
- Step 2. Self-evaluate the agency's current level of maturity to determine the point of departure (current level). Use the model criteria for each element to determine the agency's current level of maturity.

- Step 3. Identify the target level and inspect the numbered strategies for each element to move up to the next level. Each element has several associated maturity improvement strategies. Determine the priority strategy based on the current level and the amount of change needed to get to the next level.
- Step 4. Review each general strategy template for guidance to move to the next level: Level 1 to Level 2, or Level 2 to Level 3. For each element, there is a separate, detailed guidance template in a standard format.

These steps are further illustrated in Chapter 7.

Managing Improvements in Institutional Maturity

The guide provides the steps that must be taken to improve institutional maturity toward architectures more supportive of effective SO&M. However, the opportunities to take the steps recommended will vary widely by agency and context—as well as with the span of control of the agency's leadership. It is apparent from experience that opportunities for change vary from limited and incremental to more significant, often in response to external factors. There are often multiple drivers of change—or a sequence of drivers—that provide impetus for increased focus on SO&M. It is important to recognize the barriers and constraints that inhibit change. Table ES.6 indicates the principal barriers to change.

Managed Change

Managed change, in which leadership within an organization makes deliberate changes in program, process, or institutional arrangements, represents a discontinuity with the existing legacy arrangements and is openly acknowledged as such. The drivers for these more discrete changes tend to be a combination of professional predisposition and agency leadership—to articulate the need for change in a way that makes the need more widely apparent and to oversee a program of appropriate changes (as specified in the transition to a higher level). Each of these types of managed change is described briefly below:

- *Middle-Management-Led Change.* Committed professionals can have a significant impact from the inside out and up.
- *Top-Management-Led Change.* In a few instances, SO&M has been encouraged by new CEO leadership that institutes new policy mandating or authorizing a department wide process to

Table ES.6. Barriers to Institutional Change

Change Elements	Barriers
Culture/leadership	- Limited public and elected-leader support. - Significant capacity construction program. - Limited internal middle management support. - Fuzzy legislative authority.
Organization and staffing	- Absence of experienced SO&M manager(s). - Shortfall or turnover in qualified staff. - Staffing-level constraints.
Resource allocation	- State funding ineligible for SO&M. - Competition for resources from other program backlogs. - No performance outcome measures.
Partnerships	Conflicting partner priorities.

improve SO&M that involves consolidating and strengthening the systems operations functions at a statewide program level in both the central office and key districts.

Externally Driven Change

Events outside the control of management have been the key driver of change in SO&M. Several versions have been observed among state DOTs regarding significant increments in attention to SO&M. These include event-driven change, incident-driven change, constraint-driven change, federal program incentives change, and new regional institutional configuration.

- *Event-Driven Change.* Anticipated major traffic impacts in response to major external events have been a common stimulus to significant change. Major one-time or annual sports events (e.g., Olympics or auto races) and conferences are the two most prevalent types of events for which extensive planning is undertaken to preserve general mobility and minimize disruption while accommodating the event. These anticipated events often require significant improvements in operational capacity, including new infrastructure, special procedures, and new relationships.
- *Incident-Driven Change.* Major unplanned events causing major disruptions have been the most common cause of across-the-board improvements in SO&M. These incidents include natural disasters (e.g., earthquakes, hurricanes, floods), major weather events such as snowstorms, and major traffic incidents, ranging from crashes to extensive seasonal recreation congestion. With the disruption, delay, and loss of system reliability associated with such major NRC events—especially those with high public and policy visibility—the need for specific changes in one or more operations activity becomes compelling, with strong public and policy support or imperatives. Immediate action is usually required as a matter of agency credibility, including the need to demonstrate visible change and positive outcomes. Although the response is often limited to a specific activity, there are a few cases where the response to a particular event and location has been extended by management to the statewide program level, and often accompanied by changes in process and institutional arrangements.
- *Constraint-Driven Change.* In the face of financial or environmental limitations, expensive capital projects to increase highway capacity are often infeasible. SO&M then gains credibility as a relatively inexpensive way to improve the efficiency of the existing roadway. This driver of change becomes most apparent where congestion levels are extremely high and capacity improvement opportunity limitations are openly acknowledged by the transportation agency and accepted by traditional highway stakeholders.
- *Federal Program Incentives Change.* The use of federal funds has introduced planning and systems architecture requirements that have increasingly focused on performance measurement. FHWA has also promoted research, technical exchange, and definitions of current best practice and provided dedicated funding. These actions have increased the visibility and legitimacy of ITS and SO&M within transportation policy and encouraged state and local involvement.
- *New Regional Institutional Configuration.* Some substate entities (e.g., local governments, MPOs) have taken initiatives involving cooperative regional efforts for interagency collaboration in improving SO&M and have involved state DOTs as one of several cooperative entities.

Building on Change-Driven Momentum

Effectively capitalizing on such events requires that the agency have a general strategy in place to seize these opportunities to extend and standardize specific program and organizational changes into improved day-to-day SO&M across the agency as a whole. Even in constrained contexts, it can be extremely valuable to have an improvement program ready for potential utilization as

circumstances permit, focusing on the key elements most directly implicated by any externally driven change but also using the momentum for more general improvements.

Institutional Innovation and Alternative Models

There are many examples of transportation agencies finding innovative ways to address the challenges of SO&M. Following are examples of innovation within existing transportation agencies, as well as alternative models for delivery of SO&M strategies.

Innovation within Existing Transportation Agencies

Over the last 15 years, many states have built transportation management centers (TMCs), installed ITS technologies over increasing segments of their major networks, deployed safety service patrols, and developed interagency approaches to incident management and traveler information. Several states have established benchmarks for the state of the practice in certain of the basic NRC-oriented strategy applications (Table ES.7).

Table ES.7. Institutional Best Practice Examples

- An increasing number of states have quick clearance laws to support the removal of stopped vehicles from obstructing the road. Florida DOT (FDOT), for example, carried out an aggressive statewide campaign of signage, radio spots, billboards, and brochures to inform the public about the law and its benefits.

- Both the FDOT Rapid Incident Scene Clearance (RISC) program and Georgia DOT Towing and Recovery Incentive Program (TRIP) are public–private partnerships that use both incentive payments and disincentive liquidated damages to ensure shortened clearance times for heavy vehicle wrecks; these programs have reduced the average clearance times by 100%.

- Oregon DOT has used a set of unique contractor requirements (staged tow trucks, traffic supervision, and public advisories) as part of effective work zone traffic control.

- Detroit metropolitan area transportation agencies are part of a regional multiagency coalition that tracks and manages weather problems and treatment strategies, including flexible interjurisdictional boundaries for efficient operations.

- The 16-state I-95 Corridor Coalition has supported an operations academy, which is a two-week residential program designed to provide middle and upper managers in state DOTs with a thorough grounding in various aspects of SO&M state of the practice.

- The Maryland DOT Coordinated Highways Action Response Team (CHART) is a formal, multiyear budgeted ITS and operations program with an advisory board that provides oversight and strategic direction. It is chaired by the deputy administrator/chief engineer for operations and includes district engineers, the director of the Office of Traffic and Safety, the director of the Office of Maintenance, the Maryland State Police, the Maryland Transportation Authority, the Federal Highway Administration, the University of Maryland Center for Advanced Transportation Technology, and various local governments.

- Washington State DOT (WSDOT) has formalized interactions among units and managers involved in its SO&M program. TMC managers from around the state meet every 6 weeks to coordinate with regional Incident Response Program managers, who in turn meet quarterly for operations coordination with the state patrol. TMC managers and incident response managers coordinate activities and issues by meeting with the statewide traffic engineers group and the maintenance engineers group.

- The Oregon Transportation Commission moved some capacity funding to the operations program to create an Operations Innovation Program that awards funding to projects selected on a competitive basis for their potential to demonstrate innovative operations concepts related to congestion mitigation and freight mobility.

- Virginia DOT has reorganized its senior management to include a deputy director for operations and maintenance responsible for all SO&M activities, as well as maintenance resources.

- WSDOT has made a strong and transparent commitment to performance measurement as evidenced by the quarterly *Gray Notebook,* which tracks performance based on five WSDOT legislative goals, including mobility/congestion, and includes regular updates on progress in the application of operations strategies such as incident management and HOT lanes.

Alternative Models

In addition to incremental change, the project evaluated a wide range of alternative institutional models from existing sources in the United States and through discussion with key professionals. Descriptive information of some models was also derived from international sources. The four models are activity outsourcing, program outsourcing (public–private partnerships), new cooperative operating collaboration, and the public utility model.

Activity Outsourcing

This model assumes systematic outsourcing of certain SO&M functions at the activity level, such as safety service patrols, TMC operations, and asset management—per current practice in a few states, but with the transportation agency maintaining program and individual activity contract management responsibility. While several states outsource TMC operations and safety service patrols in some metropolitan areas, only two states have substantially outsourced most of these activities on a statewide basis.

Program Outsourcing (Public–Private Partnerships)

This model is presumed to apply to a statewide program, although components can occur at different rates on a regional basis. This is distinguished from activity outsourcing by its inclusion of an entire set of activities (e.g., all real-time operations activities) into a single contract, with a program manager reporting to a separate public–private entity, and including management of other service providers on a large-scale geographic basis. There is no statewide U.S. example (although such PPP models are in use for some U.S.-tolled facilities), but the U.K. Highway Authority has established subnational regions (like state DOT districts) under which most operational and related maintenance functions are performed by a combination of dedicated staff and contractors.

New Cooperative Operating Collaboration

New regional operations relationships have been established either through a consolidation of the SO&M responsibilities (state and local) of existing public agencies into a new entity or through a new set of planning and operations collaborative relationships. These types of organizations reflect willingness on the part of state DOTs to devolve complex metropolitan or regional multijurisdictional operating activities rather than lead such efforts themselves. Some have coordinated planning functions and one or more real-time operations functions, such as traffic conditions analysis and dissemination (e.g., TransCom in the New York City metropolitan area); TMC; and arterial or freeway operations, such as Las Vegas Freeway and Arterial System of Transportation (FAST), the Denver Region Traffic Signal System Improvement Program (TSSIP), and the Niagara International Transportation Technology Coalition (NITTEC) in New York and Ontario. Similarly, there are organizations for incident management and high-occupancy toll (HOT) lane operations (e.g., TranStar in Houston); bridge and tunnel operations coordination and resource allocation (e.g., Bay Area Toll Authority in the San Francisco region); and weather information development and dissemination (e.g., the Clarus Initiative).

Public Utility Model

This model, presumed to apply to a statewide program, is by definition privately managed and funded by user fees, under public policy and regulatory oversight. There is no known example in highway-related SO&M. The closest examples are regional transit authorities that provide transit operations at the metropolitan (or regional) scale with professional management and

local and state government boards of directors. These authorities are not self-supporting from user fees and depend on state and local tax sources. An emerging version of a public utility model may be public authority or private HOT and toll road development and operations at the network level. This represents a high level of operational control over a limited set of facilities, but examples already exist where SO&M applications are managed by such entities including, in some cases, control of the law enforcement function. This model has limited relevance at the present time in the absence of a separate financial base via user fees and a pricing orientation. In the long run, the introduction of mileage fees, possibly combined with publicly regulated private operating franchises, might approximate this model.

Bringing the Future Forward Faster

It is the premise of the report that all major transportation infrastructure owner agencies—state, regional, and local—will undergo a major shift in mission toward a greater emphasis on real-time SO&M if they are to maintain their relevance in maintaining and improving mobility. This shift is an inevitable consequence of the limitations to capacity enhancement and the promise of intelligent transportation technology. It is likely that the potential of aggressive SO&M has not yet been conceived, because new concepts and improved systems and strategies continue to evolve. Yet it is clear that the key features of the institutional context—as set forth in this project—constitute the principal barrier to realizing the full promise of SO&M. Evolving more supportive institutional architecture is not really discretionary—it is inevitable.

Introduction

Focus on Reliability and Nonrecurring Congestion

There are two types of highway congestion, each with its own characteristic causes: recurring congestion (RC) and non-recurring congestion (NRC). RC happens with regular and predictable occurrences related to capacity shortfalls such as regular peak delays. NRC is caused by unpredictable events such as accidents and bad weather conditions or occasional occurrences such as special events.

The delay, disruption, and accident impacts caused by NRC—and the resultant lack of service reliability—are increasingly understood as the major service concern to travelers and shippers who place a high value on reliability and predictability. This project targets the efforts of transportation and partner agencies to manage NRC and minimize its effects on travel. The scope of work for this project targets five conventional SO&M strategy applications related to NRC: crash- and breakdown-related incident management, road weather management (snow and ice), construction work zone traffic management, special events planning/management, and active traffic management.

While the focus of this project is on NRC, the institutional issues addressed for NRC substantially incorporate those that deal with recurring congestion (RC), such as signalization, ramp metering, and lane management. Therefore, within the context of this report, the term "congestion management" refers to the organized efforts to reduce both types of congestion.

Target Audience and Utilization

The research for this report focused on state DOTs. State DOTs own almost all the interstates (and other freeways and expressways) and 70% of the principal arterials. These are the high-volume, interregional facilities with limited redundancy, where interruptions of service can have major consequences. To date, state DOTs have also been the principal actor in statewide and regional SO&M activities. Nevertheless, other transportation agencies have an increasing level of involvement—including larger local governments with significant regional arterial ownership, as well as metropolitan planning organizations (MPOs) and public safety entities that play key roles, often in partnerships with state DOTs. Therefore, the term "transportation agency" has been used throughout, except when referring specifically to state DOT experience.

The key target audience of the guidance is senior management, including senior managers, program managers, and unit-level managers, in both central and regional offices of state DOTs.

Organization of the Report

Eight chapters follow this introductory chapter. Chapter 2 provides the framework for this research, states the basic hypothesis, and details the methodology followed. Chapter 3, Theory on Process-Related Organizations and Change Management, reviews the relevant contributions made in the fields of organizational development and change management. Chapter 4 describes the interview and survey process used to develop the hypothesis. Chapters 5–6 present the findings from the survey that indicate the processes that require institutional support and that identify the key institutional features supportive of effective processes and programs. Chapter 7, The Institutional Capability Maturity Model as the Structure for Guidance, presents the structure for a stepwise approach for institutional maturity improvement. Chapter 8 identifies alternative scenarios of overall institutional change. Finally, Chapter 9 describes alternative models in lieu of incremental change. In addition, the appendices provide detailed guidance on strategies and tactics.

Background, Hypothesis, and Methodology

This chapter highlights the significance of NRC and the level of conventional strategy applications deployed to date. It identifies the business process needs of effective SO&M and develops a hypothesis about the relationship with institutional architecture.

Focus on NRC

Over the last decade, new metropolitan highway capacity increases have averaged less than 2% per year, outpaced by growth in vehicle miles traveled (VMT). Highway level-of-service (LOS) continues to deteriorate in major metropolitan areas in most states, as growing demand exceeds available capacity. These capacity shortfalls result in increasing, recurring (peak) congestion. Given current budgets, as well as environmental and energy constraints, there is little likelihood that new capacity will be made available at the network level to substantially relieve this type of congestion.

At the same time, NRC related to crashes, bad weather, highway construction/maintenance, and special events produce additional delays and disruptions that are largely independent of the capacity situation. Table 2.1 presents the causes of congestion by level of urbanization. NRC is responsible for more than half of the total delay and most of the lack of reliability experienced on the U.S. highway system. The negative impact of NRC on highway operations is even more pronounced in smaller urban and rural areas. This unpredictability is of special concern in a society that values reliability and just-in-time service.

NRC also heightens crash potential. Every minute of lane blockage from crashes, breakdowns, or weather can translate into 3 to 7 min of flow recovery after the lanes are cleared. Secondary crash likelihood increases by 2 to 3% for each minute of queue continuation.

Effective Strategy Applications to Reduce NRC

Specific effective strategy applications to reduce the impacts of NRC are known but are nowhere near being used to their potential. Minimizing the causes of NRC involves reducing the incidence or the causes of unreliability through either pre-event actions (e.g., speed control, advisories, deicer application) or postevent minimization of the impact of the incidence (e.g., rapid crash clearance, rapid snow removal). The strategy applications themselves combine the following:

- ITS applications—typically a control device and communications infrastructure or software-based platforms (capital projects that need to be engineered);
- Related procedures and protocols (that need to be developed and documented)—actions are taken in real time by participants in conjunction with the ITS applications; and
- Development of concepts of operations as a tool to identify roles, infrastructure, and information transfer (requiring agreement among participants), upon which the procedures and protocols are based.

The strategy applications that have been developed for NRC are typically centered within the larger highway jurisdictions—state DOTs, toll entities, and the large local government transportation agencies—together with their public safety partners. Although the focus is often on expressways, the applications are also used for major arterials and rural routes. These conventional strategy applications include the following:

- Incident management, including multijurisdictional integrated corridor management in response to crashes, breakdowns, hazardous materials spills, and other emergencies;
- Road weather management in response to heavy rain and wind, snow, and ice;
- Work zone traffic management focused on traffic control plans to minimize the impacts of reduced capacity;
- Special events planning and management to accommodate event patrons with minimum traffic disruption; and
- Active traffic management using lane use and speed control to minimize flow disruption and incidents, as well as managing diversions and the operation of diversion routes.

Table 2.1. Percentage of Contribution to Total Delay in Urban and Nonurban Areas

Cause of Delay		Large Urban Areas >1 Million Population	Small Urban Areas 0.1–1.0 Million Population	Rural
Recurring Causes	Network Demand > Capacity	29–37	20–26	0
	Poor Signal Timing	4–5	6–10	2
	Total Recurring	**33–42**	**26–36**	**2**
Nonrecurring Causes	Crashes	35–36	19–26	26
	Breakdowns	6–7	6–10	25
	Work Zones	8–19	26–27	39
	Weather	5–6	7–10	7
	Special Events/Poor Information	1	<1	0
	Total Nonrecurring	**55–69**	**58–73**	**97**

Source: Summarized in Lockwood, 2006. From FHWA table combining recurring congestion data (TTI) and nonrecurring congestion data (ORNL).

The first four strategy applications to improve reliability are well understood, and best practices are visible in a several locations. However, active traffic management—the most aggressive approach to avoiding disruption and managing when it happens—is in the early stages of development in both the United States and Western Europe.

The Potential of SO&M Regarding NRC

As suggested in Figure 2.1 and Table 2.2, the best practice examples provide convincing evidence that these strategy applications can have significant impacts on otherwise deteriorating service, while providing visible evidence of the agency's commitment to addressing the mobility challenges facing its customers. Figure 2.1 illustrates a range of impacts on the

Source: FHWA, ITS Benefits and Costs Database.

Figure 2.1. Best practice incident management reduction.

duration of delays—over 50% reduction in one case—as a result of incident management.

Table 2.2 illustrates the broad range of other strategy applications and their impacts. Safety service patrols reduce incident clearance times and related accidents; up-to-date traveler information systems provide improvements in trip reliability; ramp and lane operations management increases throughput; and work zone management minimizes disruption. Of special importance are the high benefit–cost of these strategy applications and the potential for networkwide improvement, compared with the more focused and expensive investments in capacity.

Systems Operations and Management

The concept of SO&M has evolved since the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). SO&M refers to the broad notion that transportation agencies can apply a set of known strategy applications to maintain and improve highway service in the face of recurring peak-period congestion and nonrecurring events such as major crashes, weather, and special event disruptions. There are several excellent best practice examples of SO&M applications on the part of state DOTs in a few major metropolitan areas in the United States. They include highly integrated incident management, well-managed work zone control, and innovative traveler information programs. However, these examples obscure a more general reality: at the statewide level (even in states with the well-known examples), best practice is confined to one or two congested metropolitan areas, and even in those areas, only a narrow range of strategy applications is applied. Therefore, there is significant opportunity for improving this generally low level of implementation.

Table 2.2. Systems Operations Benefits

	Benefits and Benefit–Cost Ratios	Safety Impact	Mobility Impact	Energy/Environmental Impact
Traffic incident management	Incident duration reduced 30–50%	High	High	High
• Safety service patrols	2:1 to 42:1	High	High	High
• Surveillance and detection	8:1	High	High	High
Road weather information systems	2:1 to 10:1; crash rates reduced from 7–80%	High	High	High
Traveler information dynamic message signs	3% decrease in crashes; 5–15% improvement in on-time performance	Low	High	Low
Work zone management	2:1 to 40:1; system delays reduced up to 50%	High	Medium	Medium
Active Traffic Management	Throughput increased by 3–7%; decrease in incidents of 3–30%	High	High	Medium

Source: U.S. Department of Transportation, Intelligent Transportation Systems Joint Program Office, 2009.

Best practice indicates that important improvements in system reliability depend largely on the noncapital, noncapacity measures that are at the core of SO&M, and that this is an arena in which transportation agencies can make significant gains even as travel demand grows—despite current financial and construction constraints. Furthermore, the barriers are no longer technical, since most SO&M strategies, systems, and technologies are well understood, even commoditized. What appears to be lacking are features that are normal for other transportation agency (state or local) core programs, such as construction and maintenance (e.g., comprehensive plans and programs, effective technical processes, consistent technology, and robust performance orientation). As can be seen in construction and maintenance, these basic business processes must be supported by a clear mission commitment, visible leadership, organizational alignment, technical capacities, aligned partnerships, and a supportive professional culture. In this project, these nontechnical considerations are defined as the institutional architecture.

The Level of SO&M Deployment Related to NRC

Over the last 15 years, many states have built transportation management centers (TMCs), installed ITS technologies over increasing segments of their major networks, deployed safety service patrols, and developed interagency approaches to incident management and traveler information. Several states have established benchmarks for the state of the practice in certain of the basic NRC-oriented strategy applications (see Table 2.3).

Nevertheless, the state of the practice is uneven. Several states with major metropolitan congestion have made modest progress with only nominal SO&M applications. In many states, some ITS technology has been deployed, but there is a limited commitment to the improvement and implementation of the procedures and development of the partnerships required to capitalize on the technology. Even within individual states, the levels of application are uneven across metropolitan areas, reflecting the limited commitment at the statewide policy level.

Furthermore, the level of investment seems to be plateauing. For example, according to the Texas Transportation Institute 2009 Urban Mobility Report, only 74 of 90 cities surveyed have an incident management activity—covering on average less than two-thirds of the highway system. Figure 2.2 indicates the deployment level of basic ITS systems in the top 70 metropolitan areas as determined by a 2008 Bureau of Transportation Statistics survey (U.S. Department of Transportation, Research and Innovative Technology Administration, 2009b). From an investment point of view, few states spend as much as 2% of their total DOT budgets on SO&M and, even in those states, recent financial shortfalls have led to program cuts in some of the most cost-effective activities such as safety service patrols.

Meanwhile, the gap between both RC and NRC, and transportation agency efforts to manage that congestion and associated disruptions, is growing.

Commitment to Improving SO&M

It is apparent that the larger transportation agencies—especially state DOTs—exhibit a strong capital program orientation with a civil engineering culture, organizational structure, internal business processes, and resources that have evolved to support

Table 2.3. Examples of Institutional Best Practice

- An increasing number of states have quick clearance laws to support the removal of stopped vehicles from obstructing the road. Florida DOT (FDOT), for example, carried out an aggressive statewide campaign of signage, radio spots, billboards, and brochures to inform the public about the law and its benefits.

- Both the FDOT Rapid Incident Scene Clearance (RISC) program and Georgia DOT Towing and Recovery Incentive Program (TRIP) are public–private partnerships that use both incentive payments and disincentive liquidated damages to ensure shortened clearance times for heavy vehicle wrecks; these programs have reduced the average clearance times by 100%.

- Oregon DOT has used a set of unique contractor requirements (staged tow trucks, traffic supervision, and public advisories) as part of effective work zone traffic control.

- Detroit metropolitan area transportation agencies are part of a regional multiagency coalition that tracks and manages weather problems and treatment strategies, including flexible inter-jurisdictional boundaries for efficient operations.

- The 16-state I-95 Corridor Coalition has supported an operations academy, which is a 2-week residential program designed to provide middle and upper managers in state DOTs with a thorough grounding in various aspects of SO&M state of the practice.

- The Maryland DOT Coordinated Highways Action Response Team (CHART) program is a formal, multiyear budgeted ITS and operations program with an advisory board that provides oversight and strategic direction. It is chaired by the deputy administrator/chief engineer for operations and including district engineers, the director of the Office of Traffic and Safety, the director of the Office of Maintenance, the Maryland State Police, the Maryland Transportation Authority, the Federal Highway Administration, the University of Maryland Center for Advanced Transportation Technology, and various local governments.

- Washington State DOT (WSDOT) has formalized interactions among units and managers involved in its SO&M program. TMC managers from around the state meet every 6 weeks to coordinate with regional Incident Response Program managers, who in turn meet quarterly for operations coordination with the state patrol. TMC managers and incident response managers coordinate activities and issues by meeting with the statewide traffic engineers group and the maintenance engineers group.

- The Oregon Transportation Commission moved some capacity funding to the operations program to create an Operations Innovation Program that awards funding to projects selected on a competitive basis for their potential to demonstrate innovative operations concepts related to congestion mitigation and freight mobility.

- Virginia DOT has reorganized its senior management to include a deputy director for operations and maintenance responsible for all SO&M activities, as well as maintenance resources.

- WSDOT has made a strong and transparent commitment to performance measurement as evidenced by the quarterly *Gray Notebook,* which tracks performance based on five WSDOT legislative goals, including mobility/congestion, and includes regular updates on progress in the application of operations strategies such as incident management and HOT lanes.

capacity development and maintenance. This orientation is strongly supported by external constituencies and by a near-complete span of control over the resources necessary to deliver on-time and on-budget capital and maintenance programs. This is not a reflection of transportation agency competence. For example, on average, state DOTs manage large programs with complex processes and make continuous improvements in technology, process, and outcomes. Over the past several decades, transportation agency management has subjected both the project development process and asset management to self-conscious and deliberate reengineering that has supported continuous improvement in competencies, efficiency, and effectiveness. By contrast, SO&M has not yet evolved the same kind of tailored program, business processes,
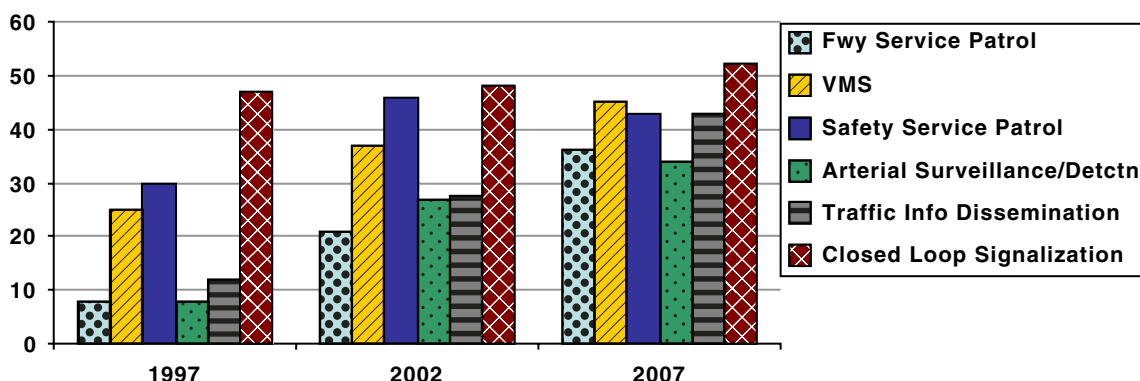
Color version of this figure: www.trb.org/Main/Blurbs/165285.aspx.

Figure 2.2. Percentage of relevant deployment in urban areas.

relationships, and measures that are required for improved efficiency and effectiveness.

Unique Process and Institutional Demands of SO&M

Implementing effective congestion management applications makes demands on a transportation agency's institutional environment that are at odds with those of capacity development, safety, and maintenance that constitute the legacy context. These demands reflect common and characteristic features of SO&M applications that determine their effectiveness. SO&M applications are typically

- Reactive and responsive to unpredictable events on an around-the-clock basis;
- Dependent on situational awareness and communications technology;
- Applied at the corridor scale or network level;
- Based on teamwork and communications intensive;
- Dependent on performance monitoring and evaluated through the impact on system performance measured in real time;
- Based on the use of dynamic high technology and systems engineering; and
- Dependent on outsiders—partners who are not under the control of a transportation agency, including PSAs and local government.

Figure 2.3 illustrates these features and the requirements they place on specialized infrastructure, custom-tailored business processes, and various institutional arrangements.

Institutional Reality

The failure to capitalize on the potential of SO&M is not for lack of concepts, technology, or even money. Institutional issues are a significant part of this phenomenon. With only some notable exceptions, few transportation agencies have business models committed to making the most effective use of existing capacity.

FHWA administers an annual traffic incident management self-assessment of (TIM SA) for 86 urban jurisdictions (states, regions). This one of the few sources that rate transportation agency practices and progress in the program and institutional areas (called "strategic" in the FHWA survey), as well as the more tactical and support-oriented areas related to incident management-specific procedures and protocols. In the strategic area, respondents rate progress in how incident management programs are organized, resourced, tracked supported and sustained. Since incident management is a core strategic for SO&M in general, the assessment provides a useful reflection of current state progress. The self assessments indicated that, at the program level, SO&M remains substantially informal regarding program status, formal interagency relationships and performance tracking. As reported in the 2009 assessment, "Despite progress in the Strategic

Figure 2.3. Essential process and capabilities to realize SO&M strategy application effectiveness.

area, the five questions receiving the lowest mean score in the TIM SA are in this section" (U.S. Department of Transportation, FHWA, 2009a).

The interviews with state DOTs and other transportation managers conducted as part of this project and anecdotal sources indicated that the barriers are substantially institutional and are related to the embedded civil engineering culture in transportation agencies; limited understanding of outside stakeholders and decision-makers; state DOT leadership with other priorities; organization and staffing oriented to project development and maintenance; funding commitments; and unaligned partners.

The Importance of Institutional Architecture

There has been considerable speculation about the slow pace of mainstreaming SO&M as a formal, state transportation agency core program, especially given its low cost and effectiveness. Even though the concepts and technologies are increasingly well understood, there remains a substantial gap between best practice and average practice within and among states. The slow uptake on this potential by transportation agencies is, therefore, not a result of lack of technical understanding—or from an absence of available best practice models. It is increasingly clear that the current modest focus on SO&M is substantially a product of the conventional legacy context of many transportation agencies today—a civil engineering culture and an inherited organization structured for construction and maintenance—the existing capital programs' claims on scarce resources and difficulties in forging the necessary partnerships with outside entities. These factors of culture, leadership, priorities, organization and staffing, resources, and relationships constitute the institutional setting for change in the existing transportation agencies—both state DOTs and other major highway entities.

The term "institutional architecture" has been applied to the overall configuration of these elements in a transportation entity context. However, until institutional architecture is defined and analyzed by its components and until the dynamics of, and relationships among, those components are clarified, it cannot become the subject for useful discussion or management. A major focus of this project, therefore, is to define and describe institutional architecture, so that it can be subject to change management.

In this project, institutional architecture focuses on the substantial nontechnical features that describe whether, how, and with whom an agency pursues SO&M. It is therefore important to distinguish *institutional architecture* from *technical and business processes* (such as planning/programming, systems development, and performance measurement)

and from the *program* of SO&M applications—such as incident management or road weather information.

The research in this report does include determination of the common aspects of the programs and technical and business processes of the states that have more effective operations but only to the extent that those processes identify the needed institutional architecture. For example, an effective incident management program requires an interrelated sequence of planning, systems engineering, resource allocation, procurement, project development and implementation, procedural coordination, and so forth. All these processes, in turn, depend on key elements of a supportive institutional setting—leadership, legal authorization, organized responsibilities, staff capabilities, available resources, and working partnerships. This report focuses on the institutional implications; it does not provide program or process guidance.

Institutional architecture encompasses more than just agency organization. It includes leadership, staffing, resources, partnerships, and the prevailing culture. Culture, in particular, is a key element of institutional architecture as it refers to the values, assumptions, and priorities of the agency, agency staff and leadership, the expectations of users, and the policy environment. It is the pervasive legacy culture of transportation agencies that is least susceptible to management and it is the slowest component of institutional architecture to change.

It is the premise of this project to capitalize on the full potential of SO&M, which is substantially dependent on the level of support provided by theses institutional features.

Basic Hypothesis of the Report

As indicated, the business process characteristics needed for an effective SO&M program are substantially different from those associated with the traditional transportation agency capital programs. It is a reasonable assumption that these characteristic processes make special institutional demands on leadership, organization, staffing, resources, and relationships. These demands might be different from those around which transportation agency conventions and configurations have formed, especially if the needed business processes are to be mainstreamed within the agency's normal activities on a continuing basis.

To develop a more structured understanding of these relationships, this research was conducted in three parts:

- Identification of the apparently more effective transportation agency programs via known program characteristics;
- Determination of the technical and business process features that are needed to support program effectiveness (through interview and secondary materials); and

- Identification of the institutional characteristics that appear to be essential in the development, support, and sustainment of the key process features.

The primary focus of this report is the institutional framework. Processes (business and technical) are identified as part of the research, but only to clarify the needed institutional architecture. Neither program nor process-specific guidance is presented.

Study Methodology

The overall methodology used to identify the chain of influence between institutional architecture and program effectiveness follows and is described in Chapters 3 through 7. The core of this analysis was the identification of traceable relationships from the more effective transportation agency SO&M programs to institutional architecture through the medium of business processes. A general hypothesis was developed that institutional architecture is related to the level of consistency by which agency business processes support effective programs—and specifically the business processes that support SO&M programs (see Figure 2.4).

A review of organizational development theory was used to assist in pinpointing key process and institutional features that differentiate service and operations-oriented organizations from those with a project or product focus (in addition, key concepts from the process improvement literature suggested a framework for change management).

A general range in transportation agency SO&M program effectiveness was derived from information available about various transportation agency program activities, processes, and effectiveness. Certain states were clustered into a group appearing to have more fully developed programs—which are called mature states—and a group with SO&M activities transitioning toward fuller programs, called transitioning states. A survey of selected state DOTs (from both groups) was conducted to determine relationships between program effectiveness and key business process and institutional factors. The survey questionnaire was structured around the basic hypothesis and the indications from the organizational development literature.

The conclusions from the survey and research identifying the key variables of SO&M-related business processes essential to effective programs and that related most closely to more effective processes were documented as the basis for determining the features of institutional architecture needed to support these processes (which, in turn, enable effective programs and structured into a capability maturity model form).

INSTITUTIONAL FRAMEWORK

The values, capabilities, arrangements, and resources to support and sustain the program qualities below.

PROCESSES

The business processes and systems required to facilitate required business processes.

PROGRAM

A needs-responsive, performance-driven, comprehensive, cost-effective, statewide SO&M program.
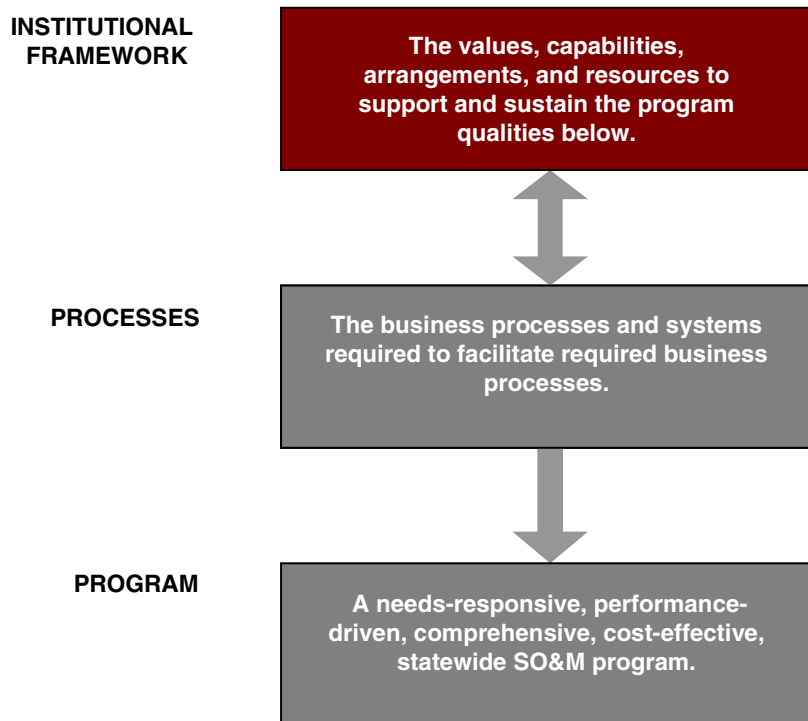
Figure 2.4. Basic hypothesis.
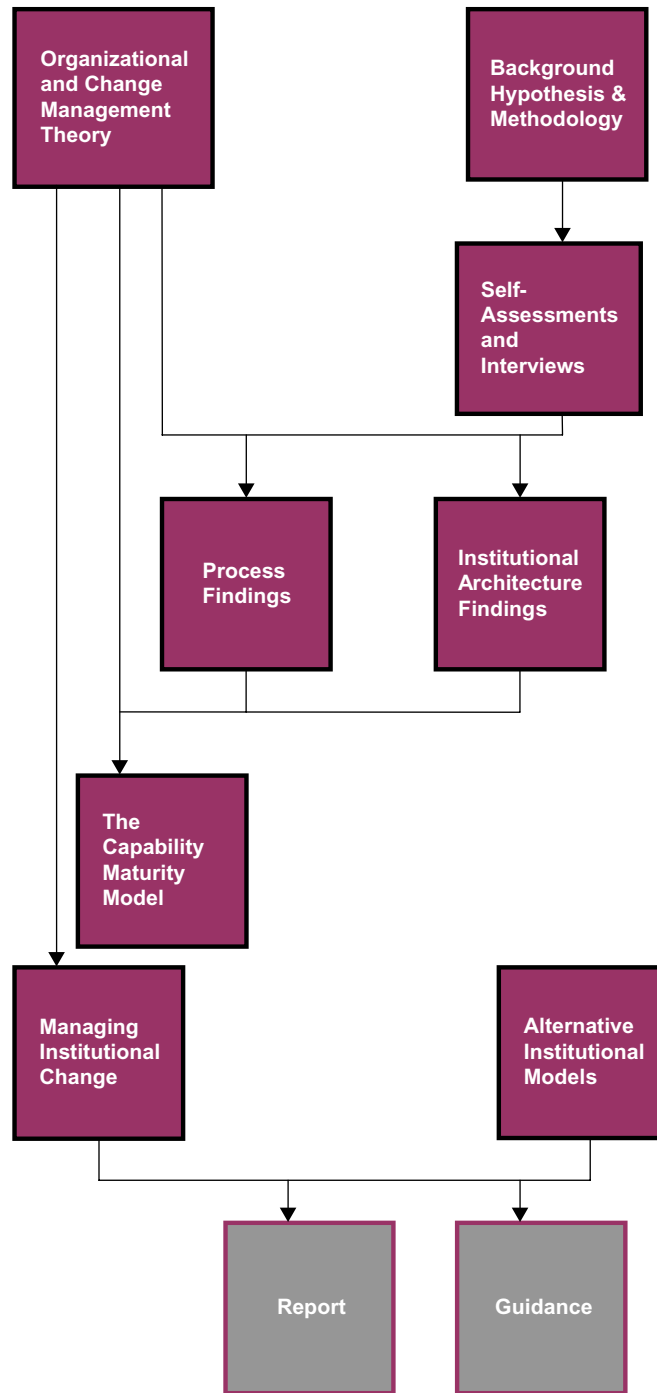
Figure 2.5. Study methodology.

The process levels indicated were then used in combination with interview indications and the insights of organization development theory and relevant international practice to identify and structure institutional elements into incremental capability maturity model processes.

A guidance framework for institutional change, based on self-evaluation and change management opportunities, was developed. Overall, change management scenarios were defined and illustrated in which the guidance can be applied ranging from incremental to event driven (Chapter 8).

Alternative institutional models to incremental change were reviewed and detailed guidance was prepared that focused on the specific set of strategies needed to transition each of the four key elements to the next level of maturity. These strategies are presented in the accompanying guide. See Figure 2.5 for an illustration of this methodology.

Theory on Process-Related Organizations and Change Management

In this chapter, the contributions from organizational development theory and change management in the private sector are described for a better understanding of institutions with a real-time operational orientation and to establish a framework for change management.

There are two key challenges in the development of guidance regarding institutional architecture:

- Identifying the relationship between effective programs and the process and institutional characteristics that are more versus less supportive; and
- Structuring an approach to incremental institutional change based on identification of key change elements and a process to manage the change.

As a background to the analysis and related guidance development, a survey of previous research, in both the transportation and the organizational development literature, was undertaken. From this review, potential contributions from theory and practice were identified in the form of characteristics of service versus product organizations.

Previous Institutional Research Within the Transportation Arena

The unique requirements of SO&M were first recognized within the National ITS Architecture created in the early 1990s, which introduced a framework consisting of three layers: transportation, communications, and institutional. The transportation and communications layers are technical layers in which the actual ITS architecture components reside. Most of the earlier efforts with an institutional focus were concerned with barriers to ITS technology-intensive project implementation at a time when the technology itself was a major challenge to staff capacities.

Relationships Between Business Processes and Institutional Architecture

That "institutional issues pose more of a challenge than technical ones" (DeBlasio, 1994) has been expressed in various studies regarding SO&M. However, the content of this common observation has received only modest investigation and analysis. There have been few systematic analyses of transportation agencies—including state DOTs—that looked broadly at the relationships among programs, processes, and institutions. Nevertheless, guidance for the improvement of institutional architecture in support of improved business process and program effectiveness requires the development of an analytic framework for institutional architecture that highlights considerations relevant to incorporating an operations-oriented function into a capital project development institutional legacy.

While there has been considerable attention to specific business processes (such as systems engineering, procurement, and planning), a framework to address the connections among specific processes and institutional elements on a systematic basis has received only modest attention. This layer is recognized in the formal ITS architecture as the "nontechnical" layer and designated for policies, funding incentives, working arrangements, and jurisdictional structures that include planning for operations and associated collaborations (U.S. Department of Transportation, FHWA, 2009d).

After the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), USDOT sponsored a set of investigations of these nontechnical project development barriers in federally funded operational tests and models deployment initiatives. The issues were first addressed in a broad state-DOT context in *The Changing State DOT* (Lockwood, 1998). The *Intelligent Transportation Primer* also includes a chapter by Lockwood—The Institutional Challenge: An Aggressive View—that addresses institutional issues (Lockwood, 2000b). At the same time, a set of Case Studies in Project Planning and

Development, developed for FHWA, identified key potential barriers to deployment, including awareness, operations and maintenance burdens, multijurisdictional coordination, staff technical capacity, and public–private partnership issues (U.S. Department of Transportation, FHWA, 2000). An NCHRP report, *Incorporating ITS into the Transportation Planning Process* (Mitretek and PB Consult, Inc., 2002), was the first comprehensive attempt to look at the need for institutional change.

Other publications at this time also addressed specific institutional issues (Berman et al., 2005; Briggs and Jasper, 2001; Gifford, 2003; Horan, 2002; Hyman et al., 2000; Poister, 2004; Sussman, 2005). The cultural dimension of institutional characteristics has also been addressed in the article Systems Management and Operations: A Culture Shock (Lockwood, 2005b). Most recently, FHWA's joint program between the Office of Operations and Office of Planning has focused on arrangements in the form of agreements and organizational structures both within and among transportation agencies, largely in metropolitan areas, as presented in *Regional Transportation Operations Collaboration and Coordination: A Primer for Working Together to Improve Transportation Safety, Reliability, and Security* (U.S. Department of Transportation, FHWA, 2002b).

Change Management Process Development

A separate stream of research has focused on change management processes in SO&M-related areas. The concept of organizational self-evaluation is well established in the highway arena. FHWA and ITE have sponsored substantial self-evaluation efforts related to incident management, traffic operations and emergency management. By the structure of the evaluation questions, these efforts implied the direction of positive change regarding those activities. AASHTO's *The 21st Century Operations-Oriented State DOT* (Lockwood, 2006) and the *Guide for Emergency Transportation Operations* (Lockwood, 2005a) took a broader, if less detailed, approach—using the concept of self-evaluation and incremental improvement, combining several processes and institutional elements.

Private-Sector Contributions to Organizational Theory and Process Management

Given the modest contribution to identifying institutional architecture relevant to SO&M in the transportation literature, a survey of the organizational development field was undertaken to identify concepts and frameworks that might be relevant to identifying key issues that distinguish service entities (with an operations focus) from product entities (with a project focus).

Relationships Between Service versus Product Organizations and Institutional Architecture

Most of the existing organizational development literature and case studies relate to private-sector experience with success measured in commercial terms. Therefore, as part of this project, the differences in characteristics of product-oriented (such as traditional state DOTs) and service-driven (operations) organizations were identified. The purpose of this analysis is to learn from service entities and the institutional characteristics (cultural, leadership, organization, and resource) that differentiate the two—as an analogy to the transition that is implied from a product-oriented highway agency to one with a customer service orientation as per SO&M. Table 3.1 summarizes the differences observed in the private sector between product and service providers.

The observations in the private sector appear to accord well with the differences between the legacy context within transportation agencies, focused on the capital program, and many of the features observed in such agencies with a greater SO&M orientation. These characteristics provide focus for identifying the key components of transportation agencies that must be addressed.

There are important differences between the product- versus service-oriented entities—some of which are reflected in the transportation literature as well. These include the following:

- The focus on time (performance) as a feature of service based on outcomes;
- The horizontal organization implied by the need to integrate several processes;
- The importance of close-to-the-service decision making for service provision in a dynamic context;
- The need for a flat organizational structure for greater on-the-spot discretion;
- The focus on the service customer and accountability;
- The need for knowledge sharing; and
- An incremental approach.

These characteristics supported the development of the key business process and institutional issues to be included in the survey and analysis activities of this project as discussed in the next chapter, and the subsequent development of the Institutional Capability Maturity Model framework.

Private-Sector Change Management Theory and Methods

There is a large body of theoretical literature on process improvement and quality, organizational development, organizational maturity, and change management in the private sector, which has been categorized in various ways by scholars.

Table 3.1. Key Institutional Differences Between Product and Service Entities

Product-Oriented Entities	Service-Oriented Entities
Culture	
Tasks are broken down into specialized, separate parts	Employees contribute to the common tasks of the department
Time management style: focus on what's important	Time management style: Focus on what's urgent and important
Leadership	
More frequent normative leadership styles	More frequent situational leadership styles
Businesses typically organized vertically	Services organized horizontally around linked, end-to-end business processes
Centralized decision making	Decentralized decision making; decisions are made at point of contact by empowered employees
Organization	
Multifunction teams are present but managed by leaders in a hierarchy	Foundation is multifunctional teams, often self-directed and self-managed
Coordination across functions is easier, given all resources within a unit are supporting the same product	Coordination across functions is complex because the supporting entities may not always be interlinked
Tasks are rigidly defined in most situations	Tasks are adjusted and redefined through employee teamwork
Strict hierarchy of authority and control, many rules	Less hierarchy and control, fewer rules
Most communication is vertical	Frequent horizontal communication
Internal stakeholder accountability	External stakeholder accountability
Institutionally supported professional growth	Self-generated and informal professional development
Resource Allocation	
Target-driven innovation based on competitive market analysis	Incremental innovation based on individual initiatives, technical competence, and knowledge sharing
More readily available outcome-based incentives	Less readily available outcome-based incentives

Source: Thatchenkery, n.d. (b).

Engineering, software, and project development have all played a role in developing a framework that identifies the key features needed to improve the efficiency and effectiveness of processes for some product or operations.

Efforts to organize these concepts into a systematic framework that can be used to manage product or process improvement include quality methods, process change theories, and organizational development theory.

There are several quality improvement methodologies, such as Total Quality Management and, more broadly, the Baldrige Process, that offer useful and relevant frameworks that identify many of the key features of the process and institutional arrangements. However, most are oriented toward products rather than services. Their structures and emphasis do not correlate completely with the real-time service aspects of SO&M, and certain key institutional issues receive only secondary consideration (e.g., resources and partnerships).

Process change theories include approaches such as business process reengineering and various capability maturity models that focus on process capability and its measurement with regard to product qualities. Capability maturity models have been widely applied to software and have been utilized in other sectors.

Organizational development theory focuses on strategies intended to change the beliefs, attitudes, values, and structure of organizations so that they can better adapt to new technologies, markets, and challenges. There are various schemes by which organizations are analyzed for purposes of explaining or facilitating change, such as contingency theory and punctuated equilibrium.

Because many of these theories and methods are based on product-oriented organizations, largely in the private sector, they have limited relevance. In addition, most of them do not include issues likely to be important when introducing a new program focus into an existing culture, including introducing

new values and norms, changing the functional organizational design or the internal and external relationships, or shifting/modifying the power and locus of decision making.

Process Improvement and Maturity Concepts

The most relevant of the private-sector change management approaches is the capability maturity model (CMM), developed in the IT industry. The CMM is based on the recognition that specific process features—such as performance measurement and documentation—are essential for program effectiveness and that they must be present at defined levels of criteria-based maturity to be acceptably effective (based on software quality and a low likelihood of error, for example). In the CMM, organizations that want to optimize their systems must evolve on a self-evaluation basis—via performance measurement—toward processes that are increasingly consistent, repeatable, reliable, and efficient in support of systemwide effectiveness.

The CMM concept was initially developed by Carnegie Mellon University for the U.S. Department of Defense. Subsequently, the Project Management Institute (PMI) has adopted organizational maturity as a concept, known as OPM3, for assessing and improving the performance of an organization's project management capabilities. The OPM3 model and the British Office of Government Commerce's Project Management Maturity Model (PMMM) have been adapted to numerous different disciplines in both the public and the private sectors, including product development, service delivery, and systems acquisition.

The key features of the CMM approach include the following:

- Goals: The conditions that must exist for key process areas/elements to be achieved in an effective and lasting way.
- Maturity levels: Levels of achievement, defined by specific criteria, toward a desirable end-state in which processes are managed by continuous improvement, typically structured from the ad hoc through increasing levels of definition and reliability to fully manageable.
- Process elements: The related activities that, if performed well, will achieve the goals.
- Strategies/practices: The means by which higher maturity levels are achieved for each process area.

In the absence of benchmarks, and given substantially different points of departure, continuous improvement requires identifying improvements based on self-evaluation. This concept has been used as the basis for standardized steps, commandments, or stages as problem-solving recipes. Based on the research, general criteria have been identified for incremental levels of process capability for each process element.

Within this framework, four standard rules of maturity models are applied:

- Each incremental level of maturity within a given element establishes the basis for the entity's ability to progress to the next–higher level of effectiveness.
- Levels cannot be skipped.
- Each level of technical and business processes needs specific institutional support.
- The overall level of maturity for an organization is defined by the lowest level of institutional maturity of any element.

Applicability of Maturity Approach to Transportation Agencies

In this project, the concept of capability maturity has been extended to fit the transportation service context. Both process and institutional elements are addressed, defined, and structured to fit transportation agency practice and context—with each element definition determined in the survey and research. Incremental levels of improvement are defined for all elements. Importantly, the research identified the apparent correlation between processes improvements associated with increased program effectiveness and institutional configurations (also called levels). Figure 3.1 diagrams this basic concept of the model adaptation to include and relate both process and institutional characteristics.

This concept also included a focus on the key elements of the process dimension and of the institutional dimension. These elements (shown as rows in Table 3.2) are presumed to be the key features that make up the dimension and which vary with increased process maturity and with changes in institutional architecture. Specific criteria define the levels, derived from their relationship with program effectiveness as determined in the state DOT survey and analysis.

Advantages of the CMM Approach

The CMM approach combines many features that make it attractive for application in the public sector SO&M arena, including the following:

- Building on the real-world experience of user entities across a range of achievement;
- Identification of key features of process that must be addressed to achieve definable performance-related targets;
- A self-evaluated point of departure, with clarity about the direction of change;
- Provision of clear incremental levels of maturity toward a vision of best practice;
- Provision of a standard language and framework for identifying and prioritizing actions;
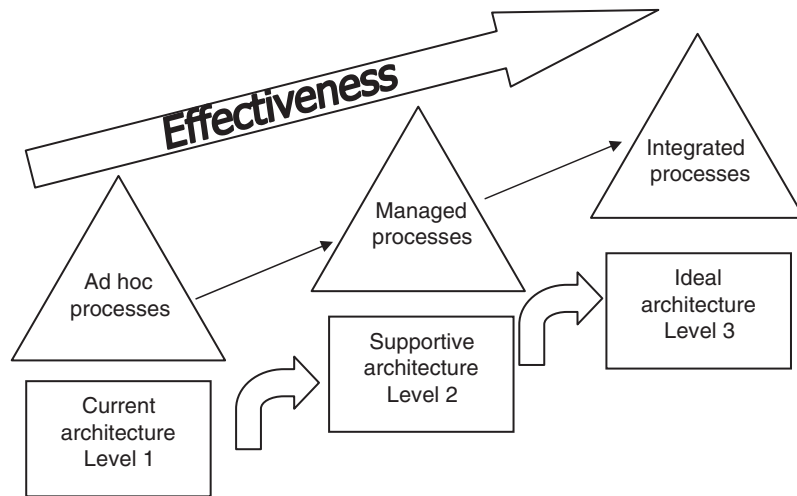
Figure 3.1. Institutional architecture maturity relationship to increasing process capability.

- Potential for collaboration within and among agencies and individuals, vertically and horizontally;
- Scalable applications that can be viewed and used at various levels of detail; and
- A positive approach that establishes defined benchmarks for future development, as opposed to a backward-looking (problem solving) approach that by its nature seeks to identify causes of past shortcomings.

Another key feature of the CMM approach is that it is based on an appreciation of an entity's strengths—what appears to be working—and how to build on such strengths to reach an improved level of capability. This aspect of the CMM approach also reflects the spirit of the appreciative inquiry approach in the organizational development field and offers the advantage of shifting focus from evaluation of past problems and apportionment of blame to existing strengths, future potential, and opportunities for collaboration (Thatchenkery, n.d. [a]). Such an approach emphasizes identifying the challenge (documentation, performance measurement), appreciation of the positive (building from the current level of maturity) and seeing the improved target ahead by being able to trace a clear path to best practice.

Table 3.2. Relationship Between Process Capability and Institutional Architecture

Process Elements	Increasing Levels of Process Capability to Support Effective Programs		
	Level 1	Level 2	Level 3
Element A	Criteria	Criteria	Criteria
Element B	Criteria	Criteria	Criteria
Element C	Criteria	Criteria	Criteria
	↑	↑	↑
Institutional Elements	Changes in Institutional Architecture Support of Process Levels		
	Level 1	Level 2	Level 3
Element A	Criteria	Criteria	Criteria
Element B	Criteria	Criteria	Criteria
Element C	Criteria	Criteria	Criteria

Survey Research Methodology

As described in this chapter, interviews and a survey were used to identify the business process and institutional characteristics of the states that had more comprehensive SO&M programs (identified initially from secondary data).

Interviews and Survey

Based on the hypothesis presented in Chapter 2 and the insights provided by organizational development and process improvement theory and practice in Chapter 3, a survey approach was developed to systematically identify key business processes essential to more effective programs and the institutional features that appear to support these processes. The purpose of the survey and interviews was not to identify specific states as exemplary; rather, it was to determine general relationships, business processes, and institutional architecture that appear to be associated with the more effective states.

This three-step approach was followed:

- Step 1: Identification of clusters of states with similar commitment to and development of effective SO&M programs.
- Step 2: State DOT management interviews and surveys of selected states.
- Step 3: Analysis of the survey and interviews to identify key relationships between business processes and institutions.

The range of business process and institutional differences among states was also assessed.

Step 1: Identification of More Effective States—Reliance On Indirect Indicators

There is no available performance outcome data that can be used to directly identify the more effective transportation agency SO&M programs on an absolute scale. Therefore, only a broad category evaluation of a transportation agency's relative commitment and probable effectiveness could be made. Identification of more mature transportation agency programs versus those that are still transitioning toward more comprehensive and effective programs was assessed by combining the few sources that cover most or all transportation agencies. As indicated in the following list, the data include sources that indicate levels of deployment, performance reporting (if any), self-evaluation of the status of applied strategies, issue self-reporting, level of participation in national programs, topic-specific citations, and anecdotes. The indicators and sources included the following:

- Survey on the extent of deployment of ITS infrastructure—reported at the metropolitan level for the top 70 metropolitan areas in terms of percentage of freeway miles under detection and surveillance, coverage of safety service patrols, level of ITS integration. (Source: U.S. Department of Transportation, Research and Innovative Technology Administration, 2009b.)
- State programs in traveler information—511 program and travel time information on dynamic message signs. (Source: U.S. Department of Transportation, FHWA, 2011.)
- Incident management—self-assessment score (72 regions). (Source: U.S. Department of Transportation, FHWA, 2009a.)
- State authorizing legislation regarding quick incident clearance. (Source: Dunn and Latoski, 2003.)
- Level of participation in operations/ITS initiatives including the following:
  - ITS deployment activities. (Sources: I-95 Corridor Coalition, 2009; Gary-Chicago-Milwaukee Corridor Coalition, 2009.)
  - TMC pooled fund participation. (Source: U.S. Department of Transportation, FHWA, 2009e.)
  - Road weather management and Remote Weather Information System (RWIS) stations. (Source: U.S. Department

of Transportation, Research and Innovative Technology Administration, 2009c.)

- ○ Integrated corridor management projects. (Source: U.S. Department of Transportation, FHWA, 2009c.)
- ○ VII demonstration projects. (Source: U.S. Department of Transportation, Research and Innovative Technology Administration, 2009a.)
- ○ Congestion management partnerships. (Source: U.S. Department of Transportation, FHWA, 2009b.)
- ○ AASHTO Subcommittee on Systems Operations and Management (SSOM) meetings. (Source: Authors' notes, 2005–2009.)
- Application of performance measures. (Source: Cambridge Systematics et al., 2006.)
- Institutional issues, including the following:
  - ○ Systems Operations as a Core Function: A Scan of the State of the Practice. Interview-based survey of selected state DOTs, conducted for the Virginia DOT, covering planning, DOT configuration, budgeting, partnerships, marketing, and operations practices. (Source: Virginia Transportation Research Council, 2005.)
  - ○ Regional transportation operations collaboration and coordination self-assessment that included a combination of institutional and process issues. (Source: U.S. Department of Transportation, FHWA, 2002a.)
  - ○ State DOT organization charts that were made available by AASHTO.
- States were not ranked, given the varied and unweightable indicators, but were instead divided into the following three clusters based on the previous seven categories of information:
  - ○ Mature states—the 20% of state DOTS with the highest levels of deployment in metropolitan areas, highest self-evaluation score, most comprehensive state legislation, and the highest levels of participation in the range of national, regional, and association activities.
  - ○ Transitioning states—the next 30% of state DOTs, using the same clustering scheme.
  - ○ Other states.

Ten states appear consistently across the range of indicators and were clearly identifiable as the most active states. These states were distinguishable as more mature. An additional 15 states, while less clearly distinguishable, fell into the second (transitioning) group, where significant progress toward a more comprehensive SO&M program (as measured by the indicators) appears to have been made. These states had ongoing plans to introduce improved strategy applications and business processes supportive of SO&M (such as output performance measures). The remaining 25 states are in the earlier stages of SO&M program development.

The top two clusters provided the basis for selecting states for the survey and interviews. Both methodologies were designed to identify the relationships between these state DOTs—in terms of program scope and effectiveness—and their business processes and institutional characteristics. The purpose of this evaluation was primarily to identify the generic characteristics of the more mature states as a group, as differentiated from the transitioning states.

Step 2: State DOT Management Interviews and Survey

Brief but structured telephone interviews were carried out with eight key state DOT operations staff personnel to attempt to identify the business processes and institutional characteristics that are common among the ten mature states as differentiated from the transitioning states. Interviews were also conducted with program management personnel from the mature and transitioning states to provide a wider representative sampling.

Business process-related questions included the following:

- Scope of the program as indicated by the program description;
- Technical processes—status of standard concepts of operations and architecture, documentation of field procedures, communications platforms, performance measures reporting, and use;
- Technology and systems development as reflected in deployment data and participation in applications specific initiatives; and
- Use of performance measures.

Institutional-related questions included the following:

- Departmental structure—number of districts with transportation management centers (TMCs) and range of strategies applied;
- Culture and leadership—formality of operations mission, relative program priority, expression in policy documents, dashboards, degree of senior championship of SO&M at central office and districts, accountability for operations attainments;
- Authorization—existence of state budget category for SO&M, key legal authorities for field activities;
- Planning and resource allocation—formal resource allocation for SO&M, staff positions;
- Organization—degree of consolidation within central office and districts, executive level of responsibility (compared to other programs), core capacities identified; and

- Partnerships—degree of formality with PSAs, level of outsourcing and private-sector contract management approach.

The interviews were designed to determine the presence or absence of these features and their basic qualitative characteristics, based on the personal views of the interviewee. Because interview responses were not for attribution by individual or specific state, the candid responses provided previously undocumented perspectives on strengths and weaknesses of the agency's programs and business processes and the institutional context to draw general conclusions about the transportation agencies.

In addition to the selected interviews, a brief written response survey was administered to 22 state DOT representatives at the 2008 annual meeting of the AASHTO Subcommittee on Systems Operations and Management. The same basic questionnaire structure was used for both the interviews and the survey, addressing both program/process and institutional issues, but the survey only required yes/no or short-phrase answers. The survey instrument is included as Appendix C.

Step 3: Analyze Data, Survey, and Interviews

The empirical data, survey, and interviews were conducted to identify key relationships between SO&M programs and business processes, comparing mature states with transitioning states to determine key institutional characteristics that support effective programs. To relate institutional architecture to the apparent level of SO&M program impacts, the approach needed to identify the key business processes that appeared to be essential to effective programs, as well as to distinguish varying levels of effectiveness. Therefore, in this step, the range of responses in the survey was analyzed in two parts. The first part determined the range of practices in the business processes that directly supported the SO&M program. This included an identification of the institutional implications of the key processes. This analysis was then used, in the second part, to consider the institutional differences among the state DOTs surveyed to more rigorously determine the key institutional differences and their relative roles in supporting improved business processes.

These two analyses are discussed in the next chapter.

Research Findings: Processes That Need Institutional Support

This chapter presents the conclusions drawn from the interviews, surveys, and literature regarding the relationships between effective programs and the supportive business and technical processes. These relationships then form the basis for the institutional architecture guidance.

The central hypothesis of this research, as set forth in Chapter 2, is that there is a traceable relationship between effective NRC strategy applications—via the business and technical processes needed to develop, implement, and sustain the strategies—and a supportive institutional framework. An analysis was made of key features of the strategy applications in terms of the needed process functions and their institutional implications.

Strategy Application Features That Impact Performance

Improving the effectiveness of SO&M means improving the effectiveness of the individual strategy applications. Effective NRC strategy applications have a range of characteristics, which are more or less satisfied and which determine the performance impact of the strategy. Example characteristics of the strategies are discussed in this section.

Incident Management

Incident management in response to crashes, breakdowns, hazmat spills, and other emergencies is improved by widespread deployment of surveillance and detections technology, faster detection of incidents and improved information about the nature of incident based on improved surveillance and detection technology, around-the-clock manned TMCs rapid arrival of first responder based on effective interoperable interagency (center-to-center and center-to-field and field-to-field) communications and dispatch, correct identification of needed response resources based on prepared procedures, effective traffic control based on clear interagency incident command,

effective systems for dissemination of incident information to other jurisdiction and the public, pre-agreed-upon diversion plans for various incident locations, quick clearance based on appropriate partnerships with private towing and recovery and/or prepositioned equipment, cooperative interagency after-action analysis and shared performance objectives.

Road Weather Management

Improvement of road weather management in response to heavy rain and wind, snow and ice is based on contracts for acquisition and data feeds of weather predictions, deployment of environment-sending stations and microconditions monitoring, analysis of pretreatment routines for varying conditions, standards protocols for equipment standby and callout, clear authority and procedures for alert levels, and appropriate contract with local and/or private contractors for treatment and clearance.

Work Zone Traffic Management

Focused on traffic control plans to minimize the impacts of reduced capacity, work zone traffic management is based on clear state specifications and guidance for contractor traffic control plan; forecasts of potential traffic impacts; integration of TCP with corridor ITS systems; contractor training; state–contractor decision systems and coordination mechanism; availability of standby law and enforcement and towing, as appropriate; preestablished contract limits; effective enforcement of hours of capacity-impacting activities; availability of public information; and coordination among jurisdictions regarding simultaneous capacity-constraining events.

Special Events Planning and Management

Special events planning and management to accommodate event patrons with minimum traffic disruption is based on

the development of a standard template for recurring events, establishment of an interagency task force and command structure, appropriate roles for traffic and law enforcement entities, availability of temporary traffic control devices, advanced warning of the public, elected officials and specific stakeholder groups, development of advanced interagency planning teams, forecasting of travel impacts, development of diversion plans, integration of multiple traffic control devices on an areawide and inter-jurisdictional basis, postevent reviews for future involvement.

Active Traffic Management

Active traffic management, using lane use and speed control to minimize flow disruption and incidents and managing diversions and the operation of diversion routes, is based on interagency working group among both transportation and law enforcement, interoperable interagency communications, clear operations command at TMC level across jurisdictions, clarity in legal authority, predicted traffic response based on archived data, multijurisdictional TMC, real-time performance measurement and analytics for control regimes, deployment of appropriate control information infrastructures, preeducation of users, preplanning of advisory messages.

Common Parameters of Performances

Through inspection of the NRC strategies and the requirements for effectiveness as stated, it is apparent that, despite individual strategy differences, there are a few key parameters of strategy application common across all the strategy applications that determine the degree of effectiveness. This strategy-neutral set of characteristics includes the following:

- Responsiveness to event: Speed with which the principal remedial action is taken (reflected in response or clearance time).
- Targeting of application: Accuracy of determining problem and application of correct strategy where needed.
- Aggressiveness of application: Strength of application in meeting the requirements on site in most efficient manner.
- Integration among strategy applications: Coordination of activities required for full synergistic effectiveness.
- Coverage and density of strategy applications: Availability of strategy components geographically.

Improving common characteristics is dependent on the conduct of certain key technical and business processes.

These processes, in turn, are supported more or less by key features of the agency's institutional framework.

Relationships Among Strategy Effectiveness, Needed Processes, and Supportive Institutional Features

Table 5.1 illustrates examples of these relationships and indicates that there is traceability between institutional features and effectiveness of strategy applications.

This form of traceability between program effectiveness and institutional framework is at the core of this project. It is important to note, however, that the relationships are not strategy application-specific; that is, the elements of the institutional architecture discussed in this report are those that apply commonly to all the strategies.

Key Findings Related to Process

The types of relationships described provided the basis for the general hypothesis relating program to process and process to institutional framework. This basic concept was used to review the potential contributions of organizational development theory and quality assurance practice, as well as lessons from observable international practice, and, in combination, to identify and describe the few institutional characteristics that seem to be most closely related to more effective programs and related business processes.

Taken together, these analyses indicated four key crosscutting aspects of processes required for development:

- Scope of applications in the field: Program scope and responsiveness to the array of NRC problems experienced in various geographic and network contexts.
- Technical processes: Includes planning and programming process, systems engineering (including concept of operations), project development and ITS asset management (in terms of the ability to implement and maintain systems supporting key operations), and development of field procedures in support of systematic and comprehensive program development.
- Systems and technology development: Availability of effective platforms to provide the needed situational awareness, control devices, communications and basic information resource, and technology deployment in terms of standardization and effectiveness costs.
- Performance monitoring, measurement, and analysis: Especially concerns the use of outcome measures to evaluate procedures, projects, and overall program.

Table 5.1. Relationships among Effective SO&M Applications, Supportive Processes, and Their Institutional Implications

Characteristics of Effective Applications	Examples of Needed Support from Processes	Examples of Institutional Implications of Process Requirements
Responsiveness to event • Situational awareness system • Amount of prepositioned equipment	• Program scoping • Integration into planning and programming • ITS project development and implementation	• Staff capable of analysis • Aligned partners with regard to concept of operations (ConOps) • Adequate resources for necessary infrastructure and staff • Coordinated organizational units (central office and districts) • Customer-service performance culture
Targeting of application • Quality of surveillance and reporting information (discrimination) • Level of forecasts, analytics	• Availability of data • Outcome performance measurement	• Staff capable of analysis
Aggressiveness of application • Coordination/cooperation level among parties • Use of performance measures to improve • Assertion of jurisdiction regarding ability to employ best practice • Agreed-upon ConOps among partners	• Full realization of ConOps • Documentation of current practice as basis for improvement • Systematic platform and technology development	• Culture oriented to customer service and performance measurement • Continuous-improvement orientation • Accountability of individuals, units for performance • Full legal authority
Integration among applications • Interoperability/integration of communications and systems • Common standards and protocols • Integration with external data sources (e.g., road weather)	• Systems engineering process • Shared ConOps and architecture	• Degree of interagency integration
Coverage and density of applications • Full needs-based program scope, including all relevant strategies—urban and rural—based on planning/budgeting • Level of deployment—areawide and per unit area	• Development of standardized applications • Integration into the planning process	• Adequate resources from a needs-based, multiyear life-cycle budget—predictable, sustainable • Mission focus on entire network

Program Scoping

Definition

This aspect encompasses the range of SO&M strategy applications intended to maintain and improve levels of service and safety for the highway system. The strategy applications are based on well-understood conventions of systems engineering and related procedures and protocols—for which both state-of-the-practice guidance and best practice examples exist.

Indicators and Range

The key parameters that have an impact on effectiveness relate to the why, the where, and the how of the implementation of strategy applications:

• *Whether the applications are targeted and configured accurately to the problem and context.* Few state DOTs or local or regional transportation agencies have conducted a systematic analysis of potentially cost-effective SO&M applications by problem, function, geography, network, and travel type. The 22 transitioning agencies typically exhibit strategy applications focused on the most seriously disruptive causes (incident management in heavily congested areas, RWIS in major snow and ice belts, and construction) and only in selected or congested regions. There appears to be only modest corridor-level consistency as facilities go across jurisdictional lines and between urban and rural areas. A small number of DOTs have somewhat more fully developed programs for coverage of all congested freeways (as indicated in the BTS semiannual ITS deployment survey). Few are developing arterial applications.

- *Application aggressiveness.* The ability of applications, as revealed in concepts of operations, ITS architectures, procedures and protocols, and so forth, to achieve full, effective, and responsive implementation in terms of the intended objective. The level of impact in NRC reduction is difficult to determine without the utilization of performance measures. Several of the mature state DOTs are now using outcome measures related to travel time and several measures specific to intermediate performance, such as incident response time.

- *Comprehensiveness and consistency.* The applications are systematically related to user problems encountered by location (i.e., regions), consistent on both a network and condition basis, and appropriate to all functional classes. A few states identify safety "black spots" or winter-weather-sensitive locations for positioning of permanent or temporary equipment. However, there has been little development of warrants that would provide guidance for consistent applications. The range of SO&M deployed by region varies widely: 35–40% of metropolitan freeways have some kind of surveillance and about 40% are covered by safety service patrols (U.S. Department of Transportation, Research and Innovative Technology Administration, 2009b).

Technical Processes

Definition

Technical processes are the replicable, routine activities undertaken to define, develop, manage, support, and implement any program. They include the conventions of planning, programming, budgeting, engineering, project development, procurement, and deployment or implementation.

Indicators and Range

In most major transportation agencies, conventional capital and maintenance project development are supported by well-defined technical processes. A parallel set of processes for SO&M must be defined and standardized. In addition, such processes must be documented to ensure consistency and sustainability and to reduce the dependence on individuals and special relationships as the basis for efficient implementation. In the transitioning states, the standardization of technical processes for SO&M improvements is in the early stages. Key indicator levels include formal mission, vision, and goal establishment; SO&M integration into the planning/design process; regular programming and budgeting of SO&M within agencywide activities; project development and procurement processes development and documentation; and ITS asset management systems.

Formal Mission, Vision, and Goal Establishment

A leadership decision to make a major program adjustment may require a change in the agency's formal statements of organizational intent. Several of the state DOTs surveyed in this project have made changes in their public and external expressions or orientation. In some cases, these changes have occurred as part of a formal strategic planning process involving significant reconsideration of agency roles in a changing context for transportation improvements. In a few instances, an increased orientation to customer and performance (leading to greater attention to operations) has emerged out of formal process reengineering and quality methods, such as business process reengineering, balanced scorecards, and Baldrige certification.

SO&M Integration into the Planning/Design Process

For the most part, statewide comprehensive planning does not include facility-level specificity. As a result, the few statewide ITS or SO&M plans have been limited to the most mature programs, despite the general requirements in planning for federal aid investments. There have also been only a few metropolitan ITS/operations plans, typically MPO-led efforts. However, even the mature states have done limited planning. Systems engineering consistency also varies widely. The mature states have largely completed statewide architectures to comply with federal requirements, but in the absence federal aid requirements, many states and districts within states lack formal architectures and agreed-upon concepts of operations. There is considerable standardization and guidance in systems design, developed with the systems engineering process and required for federal aid projects through the FHWA systems engineering and ITS architecture guidance.

Regular Programming and Budgeting of SO&M within Agencywide Activities

SO&M capital budgeting is typically ad hoc and project or initiative specific, conducted alongside the agency process or on an as-needed basis. Only two states address SO&M as a stand-alone, multiyear, and annual budgeting process at the same level of formality as other core programs. Even in those states with the more formal resource allocation process, the scopes are limited to freeway applications and do not include arterial investments.

Project Development and Procurement Processes Development and Documentation

SO&M capital improvements are typically developed on an ad hoc basis (by project champions), often on a firefighting

basis or piggy-backed on the transportation agency's existing project development process for conventional traffic engineering improvements. Project development in ITS presents a set of challenges relating to collaboration, resource adequacy, and planning/engineering integration that require an organized management approach. Federal aid and industry guidance is available for systems integration and software development, and several states have developed an ITS project development process in this fashion. However, this process is often inappropriate to the scale of SO&M projects and the technologies involved.

ITS Asset Management Systems

Initial investments in ITS technology are typically in a high-maintenance mode and often in need of replacement or upgrading. While systematic asset management is being institutionalized for highway assets, the ITS components are just being introduced on a limited basis, often integrated with other highway assets.

Technology and Systems Development

Definition

SO&M is dependent on a framework of systems platforms and supporting ITS devices to achieve situational awareness, communications, analysis, information dissemination, archiving, and operation of field control devices.

Indicators and Range

Systems platform robustness and consistency, as well as technology evolution, are indicators of technical capability. Key indicator levels include standardized platform capabilities and systematic technology selections.

Standardized Platform Capabilities

At the statewide level, standardized, integrated operating platforms are essential to interoperability and to achieving situational awareness and communication. In the mature states, systems platforms are becoming increasingly standardized and technical staff capabilities are improving. The transitioning state DOTs have often deployed basic, first-generation ITS technology (surveillance, detection, and communication), but applications are not statewide and full integration has not been established. In many cases, there is

variation in the systems between early deploying and later-deploying metropolitan areas. There are also concepts of operations or architectures, systems platforms, and devices that are not standardized. Key issues include lack of common data definitions, archiving capabilities, and ability to accept external inputs. The legacy of unique systems is a barrier to cost-effective management and upgrading. This lack of consistency constrains functionality and interoperability across the state and limits the degree of state-level situational awareness and archiving.

Systematic Technology Selections

State DOTs and other transportation agencies vary in the currency of their technologies, as has already been indicated. Until recently, technology selection has been qualitative or price-based, without systematic, quantitative evaluation. A standard approach to selecting and upgrading systems is a key reflection of an organized approach. A few states, especially those with fewer metropolitan districts, have a rationalized approach to technology evaluation.

Performance Measurement

Definition

Performance measurement is the determination of a strategy application's effectiveness in terms of reduction in delays and travel times, travel time reliability, severity of crashes, and quality of traveler information. Performance measurement and reporting are used internally as a management tool to improve applications and to guide cost-effective investments, and they are used externally to evaluate the overall program impact and for communication with customers and elected officials.

Indicators and Range

The status of performance measurement for improved operations is a key reflection of the transportation agencies' understanding of and commitment to SO&M. The interviews and survey conducted for this project, while not detailed in this area, indicated that there is a set of key issues that are necessarily related:

- Commitment to continuous improvement;
- Development of strategy applications affects evaluation for the purpose of benchmarking improvement;
- Development of outcome measures;

- Reporting of and accountability for performance; and
- Evaluation of staff performance.

The range exhibited includes development of standards, use of outcome measures, and performance-related data acquisition process.

Development of Standards

There have been some self-evaluation instruments for SO&M, such as for signal operations and incident management. However, there are no accepted standards or warrants for the applications' performance. Benchmarking efforts are generally informal. An FHWA survey indicates that the mature states identified in this project's survey had developed measures that were oriented to meeting the SAFETEA-LU performance reporting requirements, including some outcome measures related to speed and travel time, incident numbers and duration, and some operations activities output data. In addition, a few districts in a few states are measuring incident-related times for procedural improvements. However, the current lack of common definitions and uniform means of recording and archiving the information substantially reduces the utility of much of the available data and makes it virtually impossible to manage a program toward improved effectiveness. A recently completed NCHRP study developed the needed standards, but few states are considering their adoption.

Use of Outcome Measures

Only outcome measures (i.e., impact on service levels) are true measures of program improvement and success, but with very few exceptions (and those on a pilot basis), performance data are not being used to tune strategy applications in the context of a commitment to continuous improvement. A few of the mature states use output data to improve their activity effectiveness. The development of performance measures, systems, data, and the analytics to utilize them requires a considerable time frame.

Performance-Related Data Acquisition Process

The increasing focus on performance data both for strategy applications analysis and improvement and for accountability reporting—internally and externally—places a significant burden on the acquisition, development, and analysis of performance data—both outputs and outcomes. Whereas output measures (such as the event time-stamping in incident response) can be helpful in tuning up procedures, the performance metrics related to reliability are related as well to travel time and delay measurement. Some travel-time data can be modeled, using volume and capacity relationships assumptions and facility-level detection (where available)—especially over long time periods—but real-time analysis on a regional or corridor basis is increasingly seen as dependent on vehicle speeds and travel time and variance measurements, requiring either extensive loop detector deployment and maintenance or vehicle probe data (that must be acquired from the private sector). The costs of extensive detection (especially on arterials and outside congested areas) must be weighed against its advantages in discrete areas and provision of volume data. In both cases, there are complex analytics that require experimentation and experience to produce useful data. Very few states have made this investment.

Process Maturity as a Bridge to Defining Improvements in Institutional Architecture

In this report, the concept of capability maturity is applied to both process and institutional characteristics based on the recognition that those aspects of process essential for program effectiveness must be present at defined levels of criteria-based maturity to be effective. Process maturity levels are identified for the purposes of indicating the types of change needed to advance toward increasingly supportive institutional architecture related to culture, organization and staffing, and resources and partnerships.

It should be noted that whereas the maturity model approach is used to structure the relationship between process maturity and supportive institutional architecture, the guidance is focused on improving institutional architecture—not on business or technical processes.

Levels of Process Maturity

The range of process capabilities determined in the survey and interviews can be defined into three capability maturity levels. The lowest level (Level 1, or L1) is identified with the state of SO&M associated with a transitioning transportation agency. A logical increment (Level 2, or L2) has been observed in the more mature transportation agency practice and represents current best practice, as determined from project research. The highest level of capability (Level 3, or L3) is not directly observable among transportation agencies, but is extrapolated as the presumed ideal outcome of the vectors of improvement in capability established by L2.

Level 1: Transitioning

The point of departure for most state DOTs determined by the survey performed by this project was in a situation where SO&M strategy applications were becoming somewhat standardized, but on an ad hoc basis. At this level, SO&M is recognized as an issue. Individuals are charged with certain specific projects or activities at the project level. The process is siloed and hero-driven. This state of play is illustrated by many of the transitioning transportation agencies. What is often missing are the formalizing and documentation of plans and procedures, the full range of professional capacities that provide for institutionalizing good practices, standardization of systems, and performance monitoring, all of which provide the basis for improving program effectiveness.

Level 2: Mature

SO&M is recognized as an agency activity and is beginning to be managed as a program. Business processes are being developed and standardized. Capabilities are being developed at the unit level, but are program-unstable and dependent on particular staff. This state of play is illustrated by many of the "mature" state DOTs and other transportation agencies. What is missing at this level is often statewide coverage and consistency, a clearly understood appropriate project development process, full integration into programwide resource allocation decisions, and the use of outcome measures to support the appropriately expanded role of SO&M within the agency's overall mobility improvement portfolio.

Level 3: Integrated

Providing a best practice-defined benchmark for each of the business processes (often defined by current best practice or analogies in other industries) is Level 3. At this level, SO&M is established as a program with predictable outcomes. Activities are developed using standard processes (e.g., planning, systems engineering, project development, budgeting) and effectiveness is measured and used to support a program of continuous process improvement. Best practices are installed and measured consistently within the program framework that characterizes the mature states described.

Table 5.2 presents SO&M processes in an operations maturity framework at the conceptual level used in the model, illustrating the four key aspects of business processes, the levels of maturity, and the general descriptions of each level.

As part of the determination of institutional architecture, a further breakdown of the business processes into specific activities was developed. Table 5.3 further defines the criteria that distinguish among the three levels of capability. These criteria indicate the capabilities at each level and suggest the types of actions that must be taken to advance to the next level of capability, such as documentation, training, and performance measurement. Although process levels are not a direct focus of the guidance, the definitions of process levels provided the basis for determining the necessary institutional characteristics for each aspect needed to move processes up in level.

Table 5.2. The Process Maturity Framework Used in the Model at a Conceptual Level

Key Aspects	Level of Capability Maturity		
	Level 1 Transitioning *Getting organized: unique ad hoc activities at project level, siloed, hero driven*	**Level 2 Mature** *Developing methods and processes: capabilities developed at the strategy application level, but unintegrated*	**Level 3 Integrated** *Best practice integrated, documented and measured consistently within program framework*
Program scoping	Narrow and opportunistic	Needs based and standardized	Full-range core program
Technical processes	Informal, undocumented	Planned, mainstreamed	Integrated, documented
Technology and systems development	Project oriented; qualitative evaluation	Implementation using a rational process for evaluating and prioritizing	Standardized, cost-effective systems/platforms
Performance measurement	Outputs reported	Outcomes used	Performance accountability

Table 5.3. The Criteria for Process Maturity

Business Process	Levels of Capability Maturity		
	Level 1 Transitioning	Level 2 Mature	Level 3 Integrated
Program scoping	**Narrow and opportunistic** • Mission vague—ad hoc operations activities based on regional initiatives, with limited central office support • Narrow/ITS-project based, low-hanging fruit • Absence of statewide service standards	**Needs based and standardized** • Operations business case made as needed; mobility-based multistrategy application program • Consistent statewide strategy applications related to specific problems, desired outcomes by function, geography, network	**Full-range core program** • Full-staged program of synergizing functionalities • Operations as key trade-off investment with other improvements in terms of mobility management • Program extended to lower jurisdictions
Technical processes	**Informal, undocumented** • Projects/issues handled on firefight basis with only modest formal regional/district planning (but no standard template) • Minimal concepts of operations and architecture, procedures ad hoc/no consistency, National Incident Management procedures compliance • No/limited documentation	**Planned** • Strategic planning and budgeting of staged improvements including maintenance and construction implications ("exercising the plan") • Concepts of operations and related processes developed, including major communications structure • Procedures and protocols fully exploit systems	**Integrated and documented** • Integrated operations-related planning, budgeting, staffing, deployment, and maintenance both within operations and with statewide and metropolitan area planning • Full documentation of key concepts of operations, procedures and protocols
Technology and systems development	**Qualitative, opportunistic** • Technologies selected at project level ("big bang") • Limited understanding of operating platform needs • Mixed data items • Lack of appropriate procurement process	**Evaluated platforms** • Basic stable technology for existing strategy applications, evaluated on qualitative basis and incremental • Identification of standardized, statewide interoperable/integrated operating platforms and related procurement procedures • Continuity of operations plans in place	**Standardized, interoperable** • Systematic evaluation/application of best available technology/procedure combinations with evolution • Standard technology platforms developed/maintained • Assets inventoried
Performance measurement	**Outputs reported** • Concept of continuous improvement absent • Projects lack objectives: measurement of outputs only with limited analysis/remediation • Output measures reported • Limited after-action analysis	**Outcomes used** • Procedures exercised • Outcome measures developed and used for improvement • Outcome measures reported	**Performance accountability** • Continuous improvement perspective adopted (requires intra- and interagency after-action analysis) • Accountability and benchmarking at unit and agency level via regular outcome performance reporting—internal and public

Research Findings: Institutional Architecture Characteristics That Support Effective Programs

This chapter focuses on the development of an institutional maturity model. A key finding from consideration of the practices of the mature versus transitioning states was the apparent direct relationship between some business processes—as described in the previous chapter—and their dependency on institutional support.

Process Implications for Institutional Architecture

Each of the key process dimensions discussed in Chapter 5 is dependent on the following key features of institutional architecture: scoping implications, technical process implications, systems and technology implications, and performance measurement.

Scoping Implications

The selection and implementation of various application strategies—the program scoping—is the mechanism through which the SO&M-related services are actually delivered in the field in real time. Impact on level of service will depend on the applications selected, where they are deployed, and how well they are implemented. The promise of SO&M and its cost-effectiveness in maintaining and improving mobility is directly proportional to the nature of the implementation, such as the service needs addressed, extent of SO&M applications, aggressiveness of the applications (compared to best practice). The more fully developed, long-standing programs are in transportation agencies where the limits on capacity enhancement have been acknowledged in policy; where senior leaders have consistently supported a standardized, expanding, and sustainable SO&M program; and where capable staff is evident, resources rationally relate to key needs, and partner relationships are somewhat formal.

Technical Process Implications

The nature of SO&M strategy applications (low-cost and distributed) and their key features (critical information, communication and control systems and related technology, the necessity of situational awareness, and performance feedback) require custom-tailored processes in parallel with existing conventions for capital programs. Process development requires upper-management recognition of the need to formalize SO&M at a statewide level with the full set of standardized activities in parallel with those of other core programs, such as planning, programming, project development, and maintenance. It also requires the identification of the organizational units responsible, an accountability mechanism, supporting resources, and appropriate professional capacities.

Systems and Technology Implications

Without a formal managed SO&M program and experienced systems engineering staff (at both DOT central office and district levels), achieving standardization, rational systems platform, and technology improvement and upgrading is not possible. In addition, since some strategy applications involve external players in their concepts of operations, there is a need for external system coordination. However, this is not likely without a level of formal partnering.

Performance Measurement

Performance measurement is the basis for a transportation agency's accountability for any mission related to mobility and safety—including increases in reliability. Policy remains merely assertion, and accountability meaningless, without the ability to determine the impacts of investments and actions. Thus, performance measurement plays a fundamental role in the culture and business model of an operations-committed

transportation agency. Performance measurement and reporting also structures organizational reporting and accountability among units and individual managers in the organization. In addition, performance measurement is fundamental to resource allocation in association with performance standards and targets. It is (or should be) fundamental to the political process associated with the justification of funding for new and/or ongoing programs. Increasingly, state legislatures are beginning to demand this type of information during their budgeting processes. Finally, effective partnerships can be forged only in the context of an agreement on measures and related remediation and improvements.

The Key Categories of Institutional Characteristics

In the following discussion, the findings were analyzed in terms of the four categories of institutional characteristics for the range of variation across the DOTs and for their implications regarding institutional differences between mature and transitioning states that appeared to be relevant to the more effective business processes. These findings—combined with evidence from organizational theory—suggest that there are four key categories of institutional characteristics that capture important relationships between business processes and institutions:

- *Culture/leadership* related to the level of understanding and potential leverage of SO&M, as reflected in values, mission, leadership, and related legal arrangements and strategy applications, and as demonstrated by leadership.
- *Organization and staffing* related to how structure aligns responsibilities and accountabilities vertically and horizontally, consistent with capabilities and incentives at the staff level.
- *Resource allocation* for operations and capital, and the degree of transparency and sustainability in relationship to program improvement.
- *Partnerships* in terms of degree of alignment and stability in objectives, procedures, roles, and relationships.

The findings for each characteristic are presented below, including definition of the characteristic, indicators found in data or survey, and the related range of variation. While at a high level the identified characteristics of institutional architecture correlate well with conventional wisdom, the specific features of each characteristic and the distinct relationships between levels of business process capability and specific institutional architectures have been illuminated. Whereas most of the examples are drawn from state DOT experience, many of the same features apply to larger local government transportation entities.

Culture and Leadership

Definition

Culture is a broad term that includes how an agency reflects (and embodies) the professional orientation toward SO&M and the overall public policy context that defines the transportation agency's mission and public expectations. The perspective on culture is descriptive rather than analytical, as the observations come from various sources, including the survey, interviews, and existing literature.

Indicators and Range

Culture has a series of components that establish the context for professional, policy, organizational norms, and user/stakeholder expectations and that together substantially enable (or inhibit) program modifications. There are nine key aspects of culture that are relevant.

Vision evidencing a clear commitment to SO&M as a customer service-focused core mission of the transportation agency. An implicit and shared vision of the future of transportation infrastructure services is an essential component. Formalizing this vision and interpreting the transportation agency's role in the form of its mission is important where culture is changing or needs to change, as it establishes the baseline for SO&M strategy applications and their relevance. SO&M is increasingly, if indirectly, included in the mission of most of the mature transportation agencies (and many of the transitioning agencies) in language that refers to level of service or congestion. Whereas few explicitly call out operating the system as part of the mission, visible program components, especially TMCs and safety service patrols, have sometimes been branded with catchy names intended to market their public purpose. A formal strategic planning process, including an adjustment in the formal statement of goals and objectives to relate to systems operations and management, can be an important signal of a change in culture.

Politics and public policy. Public policy is projected in both formal programmatic terms—as embodied in law and regulations—and the more informal political process through legislative and stakeholder influence on resource allocation. The expectations include visible (politics, media) expressions of public satisfaction or dissatisfaction regarding agency performance in dealing with congestion (especially NRC). The expectations establish the context for SO&M actions, including both focus and boundaries. They include both informal and formal expressions. The informal expressions are the presumptions regarding proper role of the public agency in providing facilities and services and their general quality level. The formal expressions comprise the authorizing environment for the agency's activities, including conventions regarding

customary responsibilities and activities, state resource allocation, and legal scope as per state government mandates, committee jurisdictions, and other federal and state program mandates.

Level of public expectations. In general, the level of expectations regarding SO&M are low, based on experience and on lack of official commitment. There are occasions (major traffic disruptions, special events) when there is a focus on SO&M, usually in terms of inadequate response or the need to prepare for an expected problem. However, the external environment that influences transportation policy (elected officials, key legislative committees, organized stakeholder associations, media) rarely shows continuing interest in or support for aggressive SO&M at the program level—especially in terms of investment or staffing—even in the more mature states. Even in the limited instances where senior management has publicly declared a commitment to operations, there has been limited external interest or support. In part, this shows that many external decision makers and interests have considerable stakes in maintaining the conventional programs, which they often view as already underfunded, with SO&M seen as a diversion. The states with dominant or substantial small urban and rural environments, where recurring congestion is modest, are especially slow in recognizing that NRC is the major source of disruption and delay.

Agency and professional background, values, and level of technical knowledge regarding SO&M conventions. This includes professional, technical, and institutional values; background of management and staff; assumptions about what is the norm regarding the job of transportation professionals and the related lifestyle in offices and the field; the relevance of special technical knowledge; and the bureaucratic and civil service culture of public agencies. The dominance of civil engineering and civil service cultures in both mission and capability is a principal feature of the legacy context in most transportation agencies—with a professional orientation to medium-tech, organized capital project implementation on a nine-to-five basis, and with substantial span of control over the project environment. Newer (younger) professionals are introducing a systems-oriented, technology-comfortable element into this environment, and gradually introducing a technology-oriented and partner-dependent performance regime.

Technical understanding of the potential of SO&M compared to other service improvement programs and investments. Institutionalization of operations necessarily depends on the level of technical appreciation by staff and management of the potential for leveraging improved operations. It must also be based on an understanding of the basic concepts of SO&M, as well as of the more detailed specialty knowledge regarding individual applications. Few senior transportation agency managers have an SO&M background or seem to project a clear understanding of its potential. In some of the mature states identified in this project, technical understanding of the potential of operations has spread beyond operations staff, resulting from a combination of conditions including reconciliation to capacity constraints and CEOs with previous operations exposure, strong middle management or technical champions, and a major disruptive event. The transitioning states typically have one or two of these conditions.

A business model, focused on systems management. The traditional state DOT business model and the larger local governments is revealed in both stated assumptions (about its role, the role of its partners, its intentions, and its commitment to delivering improved levels of service) and unstated presumptions. The traditional transportation agency model evolved during a long period of successful development of new capacity. The business model was designed to construct and maintain safe and adequate upper-level highway facilities at a level to meet the peak-period demands of future growth. Part of this model has been unstated presumptions, including the transportation agency's relative independence of service providers, lack of need to communicate with users, and a presumption that impacts of external events was substantially outside the agency's influence—with congestion considered to be the outcome of uncontrollable factors (behavioral, weather, business patterns) that are not the responsibility of the transportation agencies. It is also not considered the responsibility of the public safety community whose actions may add to congestion in the pursuit of their different mission.

Impact of new technology-related developments. The prevailing business model for state DOTs (and many local transportation and public works entities) remains focused on providing and physically maintaining basic roadway capacity and viewing congestion as a symptom of capacity shortfalls that, in the long-term, may be overcome. However, there are a few instances where this traditional business model is beginning to transition to something closer to mobility management responsibility. The impact of vehicle tracking and communications with systems users, the federal interest in performance, examples of aggressive management from abroad, in combination with constraints on capacity additions, have led to some initiatives that support modest changes in the traditional business model.

Visible leadership. Leadership in SO&M implies change management and visibility and identification of individual senior managers (central office and districts) with an SO&M mission, both internally and externally. The lack of familiarity with SO&M and the lack of external support contribute to inhibit such visibility. In addition, top management in most state DOTs and most local government entities have been reluctant to commit to a formal SO&M program, as they are concerned with over-promising and raising expectations that cannot be met in areas where visible success is dependent on factors outside of the agency's control. Furthermore, many state DOT

CEOs come from outside transportation and most serve short terms that challenge the momentum of altering the current program. This concern is reinforced by an authorizing environment, which, while forceful in regarding on-time, on-budget performance for construction, has no parallel expectations from operations other than to minimize exposure in the press.

Federal influence versus state and local priorities. The well-established federal-aid transportation program is a major influence on the culture of state and local transportation agencies (and directly on the program priorities and process as well). Federal aid accounts for nearly 40% of state capital expenditures and the grant conditions, regulations, and technical leadership of FHWA and FTA substantially shape state DOT, MPO, and local government priorities. SO&M has not long been part of the federal aid program (and many operations costs were not eligible for federal aid until recently). The federal ITS and Operations program was only formalized in 1997 as part of TEA-21 with the establishment of an FHWA office, ITS deployment funds (since discontinued), and clarification of program intent and broad funding eligibility and a modest requirement for MPOs to consider SO&M. The legacy FHWA capital programs and related funding still dominate the federal-state and MPO relationships.

Relationship to Program and Business Process Capabilities

The development of a formal SO&M program requires a strategic framework to structure and asserts the priorities of the needed business process development. The imperative for making these efforts and the political and policy permission to do so depends on an understanding, on the part of policy and management leadership, of the potential of SO&M. It also depends on a willingness to make changes in the current status quo—requiring effort, resources, and disruption.

Organization and Staffing

Definition

Organization refers to the structure of and relationships among the functional units and individual managers and technical staff. Staffing refers to the availability of needed technical and managerial capabilities.

Indicators and Ranges

Organization is only roughly reflected in the formal organization charts, because DOTs have important noncharted relationships that may be dominant. Nevertheless, the following characteristics are widely observed at the state level. In addition, whereas local government transportation agencies do not share the same organizational structure as state DOTs, many of these same issues are present.

Authority of top management. Position in management hierarchy, relative to top management of other mission-related programs (maintenance and project development), has a significant impact on the ability of an SO&M program to secure resources and align authority. SO&M is rarely represented by an undivided portfolio even at the second level within most state DOT central offices and districts. There is a more varied mix in local governments when the traffic engineering unit may be separate from public works. This subsidiary status has an impact on the entire range of program, resource, and process issues.

Organizational structure as it relates to clarity of roles, authorities, responsibilities, and reporting relationships. All state DOTs—and most local government entities—are characterized by an organizational structure that has evolved for construction and maintenance project development. In such a structure, various systems operations functions (e.g., ITS, traffic engineering, TMC management) are fragmented or decentralized across several traditional chains of command. At the state scale, the level of fragmentation versus consolidation applies to both a state DOT central office and at the district level, depending on the scale of each. It also includes the relationships between them. As most SO&M activities are relatively new, there is often a lack of clarity about which unit is responsible for which activity or data. Both functional and geographic boundaries are unclear in terms of the following:

- Roles and relationships among regional TMCs, districts, and the central office regarding program development;
- Functions, support, and point-of-contact available to districts from central office units;
- Guidance from the central office regarding applications priorities (with funding support) and consistency regarding platform, standards, data, and so forth; and
- Standardized chain-of-command at the regional and district levels regarding incident management field activities among all players.

Decentralization. The degree of local discretion versus central oversight (i.e., centralization versus decentralization) varies among states, particularly in response to size, with the larger states having decentralized most program development to the regions. Central office influence varies widely at the district level (where most SO&M services are developed and delivered), with greater independence evident in the larger, multidistrict states. Degrees of fragmentation are evident from organization charts, with traffic engineering, ITS, TMC-based activities and maintenance often under different chains of command in both central offices and regional ones.

Alternative models. There are three different styles among mature states:

- Functional (operations related): state DOTs where the central office tends to be focused on a single type of activity or project;
- Divisional (geography related): state DOT districts operating substantially independent of the state DOT central office; and
- Matrix (combined): discussed in principle but not observed in practice.

There appears to be a trade-off between statewide standardization and regional initiative incentivization. At the regional level within state DOTs, the same issue is reflected in the degree to which operations activity is focused on transportation management centers (TMCs).

Hierarchy. Even in states where there is a range of SO&M activities currently taking place, these activities have not been consolidated in the form of a formal program at the top-level division within the state DOT hierarchy, equivalent to maintenance and construction. SO&M activities are typically managed either as subsidiary components of a maintenance program, on a stand-alone ad hoc basis, or organized at the district level around a TMC. The Virginia Transportation Research Council survey cited earlier collected and reviewed state DOT organization charts (Virginia Transportation Research Council, 2005). This review revealed that several states have designated system operations units or divisions within their central offices and established new second-tier positions to provide oversight of operations activities.

Responsibility, accountability, and incentives. Blurred or divided lines of responsibility make performance accountability difficult. Central office managers typically have a limited direct contact with strategy applications in the field (except in small states) and, given the lack of performance information, do not hold project and regional activities managers accountable for the effectiveness of SO&M activities. As with the traditional capital program, the accountability focuses on project performance in terms of budget and schedule matters rather than in terms of measurable improvements in service. Largely absent is a clear framework of incentives (rewards) for individual and unit efforts.

Technical capacity and staffing level. As reflected in the presence or absence of the needed core capacities to develop and manage key SO&M activities, much of SO&M to date has been conducted by professionals benefiting from on-the-job training. Many state operations activities appear to be developed and sustained by the intense and entrepreneurial efforts of middle-level unit manager champions who work within the existing system to implement projects. These activities have been observed to stall in terms of extension or improvement when the champion leaves his or her position. Most of the mature states have been or are now identifying the needed core capacities.

Shortage of key expertise. There is a shortage of program-level managers in the public sector as a whole, for both central office and district-level positions, as states and the private sector compete for the limited number of experienced professionals. Even though several states have developed job specifications with indicated knowledge, skill, and ability criteria, they have been unable to fill such jobs directly. A key component is the set of measures taken to develop and support staff professional development and to clarify their roles and careers in the departmental structure, including training, certification, rewards and incentives, active recruitment, and retention activities. A few states have set up their own internal training activities or developed consortia academies for training purposes.

Outsourcing. The difficulty in finding staff with the necessary capabilities, combined with constraints on staff sizes and hiring delays, has led some states into outsourcing a range of field functions, such as TMC operations, safety service patrols, maintenance, and systems development.

Relationship to Program and Business Process Capabilities

There is a high level of agreement that structure follows strategy and that decisions about organizational design must link clearly to agency intentions regarding improving business processes. The focus of these characteristics is to develop an organizational structure and staff capacities that are capable of developing and managing the key business processes, and of developing the systems needed for SO&M functions and for positioning SO&M within the agency at a level commensurate with other core programs.

Resource Allocation

Definition

The key resources that are subject to agency-level policy are capital resources for systems and technology (and their maintenance) and operating resources in terms of staff positions and related support.

Indicators and Ranges

There is limited information or knowledge regarding the level of expenditures related to SO&M by state DOTs, even within the DOTs themselves. Some of the key indicators include SO&M expenditures as an eligible use of state and federal funds; resource adequacy in terms of relationships between

criteria-defined needs and available funding; staffing allocation; and transparent criteria for resource allocation.

SO&M expenditures as an eligible use of state and federal funds. To date, SO&M activities have been funded at a level that rarely merits its own budget category. As SO&M expands, the lack of clear funding source becomes an issue. Congestion management and air quality (CMAQ) funds have been passed through to metropolitan areas for ITS investments, though rarely related to NRC. Federal-aid ITS deployment funds were, in the past, a major source of capital investment for state DOTs. The end of these programs has left SO&M competing for resources with well-established programs. In some cases, there is the additional issue of whether SO&M investments are an eligible use of state or federal funds—capital, operating, or maintenance. There appears to be wide variation among the states on this issue.

In several states, legislative committees have explicitly excluded SO&M expenditures as an eligible use for certain state funding categories. What is clear is that few states have an SO&M program budget category that is considered in the multiyear or annual programming and budgeting process.

Resource adequacy in terms of relationships between criteria-defined needs and available funding. SO&M has not been a formally defined program with its own budget category. Lacking line item status, it is without a known traceable funding level history. Only two states have clearly defined SO&M line item budgets. Without aggregated expenditures, management has little idea of what has been spent or budgeted for SO&M as compared to the established programs. Although, exclusive of occasional major ITS infrastructure investments and regular snow and ice control reserves, SO&M annual expenditure levels rarely exceed 2% of total state capital budgets, funding levels are always a concern, especially in the competition with legacy construction and maintenance programs for scarce resources. Only a small number of the mature states have undertaken a systematic SO&M planning/programming effort that provides a defensible basis for defining priority services and applications deployment, costs, and payoffs with a staging approach.

Staffing allocation. A similar picture is apparent regarding staff resources, especially in the large number of states with hiring freezes or cutbacks in total staff slots. Whereas small numbers of slots have often been allocated (sufficient to manage a small program), staffing for cost-effective SO&M expansion at both the central office and district levels has not been made available. Part of the problem is that the lack of formal program status means that it is difficult to know what is spent in aggregate on SO&M activities.

Transparent criteria resource allocation. SO&M is not a high-level program or budget category in nearly all states. Almost all senior managers in state DOTs have no more than a general idea of the total resources allocated in aggregate to SO&M activities. Given the unfunded core program backlogs, current resource allocation is based largely on modest departures from past trends in capital and maintenance expenditures, not in a systematic, criteria-driven, cost-effectiveness framework for overall multiprogram resource allocation in which SO&M could effectively compete. Furthermore, states have not identified trade-offs among alternative investments (capital versus operations) to best serve state DOT's mobility mission. To make matters worse, during budget cutbacks, several states have cut extremely effective SO&M services, such as safety service patrols, which have a limited internal or external constituency. The lack of a predictable transparent resource allocation process, including clear and accepted criteria for allocation and presumed sustainability, renders the effective implementation of SO&M difficult.

Relationship to Program and Business Process Capabilities

It is obvious that program development requires capital and staff resources to develop and manage the business processes associated with the program. The lack of resources creates a vicious circle in which lack of capability undercuts the ability to make the case for increased capability.

Partnerships

Definition

Partners are organizations—public or private—whose cooperation is essential to the execution of key SO&M strategy applications. They include PSAs (police, fire, and emergency services), other state agencies (toll authorities and environmental agencies), local governments, and regional planning and transit authorities.

Indicators and Ranges

All of the key strategy applications addressing NRC require the coordinated actions of several jurisdictional entities—both transportation and nontransportation—for effectiveness. There are four key types of jurisdictional issues:

- *Mixed ownership.* Metropolitan areas require cooperation among local governments, the MPO, and the state DOT in both making ITS improvements and in real-time operations on roads, especially on both a corridor basis (for strategies such as incident management) and an areawide basis (for special events).
- *Multimodal opportunities.* Transit operations involvement is relevant to planned events and major incidents where, with the support of operator coordination and traveler

information, a modal opportunity exists to provide options for travelers and possible reductions in congestion impacts.

- *Functional authority.* Incidents involving public safety and law enforcement are the primary jurisdiction of police (state and local) emergency response, whereas medical issues involve fire and emergency medical entities. Law enforcement and emergency response entities typically have command in crash settings, with the state DOTs providing support services, especially in relation to traffic control.
- *Private services.* Private towing and recovery services and contracted private entities for patron safety service and asset management are also key players in the best practice concepts of operations for NRC strategy applications. The relationships vary from contract to legal and administrative arrangements.

As suggested in Table 6.1, it is apparent that these entities all have different functional or geographic priorities that must be reconciled for effective, cooperative application of the conventional NRC strategies, where several parties play key roles. This reconciliation is often developed to a workable arrangement on an informal basis. However, such temporary arrangements often deteriorate with turnover in personnel and cannot be relied as the basis for sustainable improvement.

A longer-range concern is the limits on interagency cooperation and collaboration to achieve the highest level of strategy application. The existing jurisdictional configuration—established for generations—may not support the most effective approach to NRC. Indeed, other countries exhibit more consolidated jurisdiction.

Presently, state DOTs—and larger local government transportation agencies—have various business models regarding the allocation of various SO&M functions among DOT staff, private-sector entities, and other public entities (both public safety and general purpose local government). Business models vary in the level of state DOTs' proactiveness in asserting transportation interests; in the degree to which DOT personnel execute some functions; and in the level and type of collaboration with (and in some cases devotion to) MPOs, local governments, and PSAs. There is also a range of relationships

with the private sector in the degree and amount of outsourcing. Public and private partnerships are increasingly a critical component of systems operations in response to such issues as lack of coordination, instability, and reduced effectiveness. Key issues include alignment and partnerships with public agencies for effective field procedures and private-sector partnerships for effective field procedures.

Alignment and partnerships with public agencies for effective field procedures. With few notable exceptions, partnerships with PSAs, other state agencies, local governments, and MPOs have been based largely on a legacy of informal understandings, evolved for reasons that have little to do with optimality. Rather, they are the heritage of custom, presumed legal jurisdiction, policies regarding agency size, and other factors. There are a series of issues that require close cooperation if the effectiveness of SO&M is to be improved, including clarification of legal authority, standardization of roles, consistent interagency postevent follow-up, and management of private-sector third parties such as towing and recovery. The absence of more formal commitments (memoranda of understanding, revised regulations, and co-training) and agreed-upon roles and procedures undercuts more aggressive systems operations. An informal approach also limits the potential to achieve no-cost procedural modifications (evidenced in some states) that can accommodate priorities of partners without compromising their own in areas of incident management, environmental control, and integrated corridor management. There is a parallel set of issues relating to the relationships between state DOTs (particularly but not only in interstate corridors), the general-purpose local governments who own or manage major arterials (especially those that are part of freeway-arterial corridors), and the MPOs, which are responsible for planning. There have been a few bellwether formal public-public partnerships in metropolitan areas in the form of regional operations collaboration, formalized with charters and sustainable over a decade or more, typically in metropolitan areas where there are relatively few jurisdictions. Appendix D presents examples of several types of collaboration among state DOTs, local governments, MPOs, and other regional entities.

Table 6.1. Agency Mission Priorities

Mission	Transportation Agency	Local Government	Law Enforcement	Fire and Emergency	Private Contractor
Law enforcement	Low	Low	High	Medium	Low
Emergency response	Medium	Medium	High	High	Low
Responder safety	High	High	High	High	High
Congestion management	High	Medium	Low	Low	Medium

Private-sector partnerships for effective field procedures. Private-sector outsourcing has been increasing in the larger states as an important means of delivering several of the key operations services in the field, including TMC operations, safety service patrols, towing, routine maintenance response, work zone traffic control, supply of traveler information, and routine ITS and traffic control asset maintenance. Experience to date has raised concerns relating to the clarity and standardization of scopes and relationships and the performance management of contractors. In addition, substantial outsourcing raises the question of the transportation agency's ability to retain its core capabilities. The scale of these activities suggests the importance of a comprehensive and consistent statewide approach to determine the appropriate type and level of staff core capacity, and to develop procurement and contract management procedures that insure maximum effectiveness.

Relationship to Program and Business Process Capabilities

Many of the factors underlying the ability to develop effective working partnerships supporting NRC strategy applications are outside the transportation agency's span of control. Functions key to the effectiveness of these applications can be provided by partners, both public and private. A basic business process involves joint planning with local governments and MPOs and execution of strategy applications in the field. Strategy application effectiveness is directly proportional to the partners' ability to share the transportation agency's interests—especially those related to reduced delay and disruption—

while pursuing their own objectives. In the public sector, this goes beyond cooperation to partners' willingness to adjust the manner in which their objectives are met to achieve the objective of minimizing delay. In the private-sector contractor environment, it places emphasis on carefully structured performance-based contractual conditions.

Summary Conclusions Regarding Key Institutional Characteristics Supporting Effective Business Processes

The combination of the survey and interview findings, previous state DOT-oriented research, and the identified characteristics of different types of private-sector entities converged to reveal four characteristic traits associated with the differences between the more product-oriented entities (transitioning transportation agencies with a modest SO&M focus) and those that appeared to have a stronger operations orientation (as represented by the more mature state DOTs). Table 6.2 summarizes the key findings in the mature versus transitioning state DOTs in the four key institutional categories.

Moving in the directions exhibited by the more mature entities involves coping with four principal challenges: culture, organizational structure, resource allocation process, and partnerships.

The culture has a strong civil engineering orientation, including legal authority and leadership and program structure substantially focused on construction and maintenance programs. This legacy orientation includes unrealistic assumptions about

Table 6.2. Comparison of Institutional Characteristics: Mature versus Transitioning Process Agencies

Institutional Element	Institutional Element Features Associated with Transitioning Process Agencies Called "Ad Hoc"	Institutional Element Features Associated with Mature Process Agencies Called "Rationalized"
Culture/Leadership	• Construction project development legacy dominant • Lack of visible policy or leadership for SO&M • SO&M not a formal program • Fuzzy legislative authority regarding roles in field	• SO&M understood and supported by top management • SO&M has core program status • Clear legal authority for operations roles in field • Customer level of service acknowledged as key mission
Organization/Staffing	• Subordinate role and divided portfolios of SO&M managers • Shortfall/turnover in qualified staff • Components of SO&M in fragmented units	• Top level SO&M management positions established in central office and districts • Professionalization and certification of operations core capacity positions
Resource Allocation	• No dedicated program budget • Lack of standardization/documentation • No performance outcome measures	• Operations is formal, visible sustainable budget line item • Trade-offs between operations and capital expenditure considered
Partnerships	• Differing partner priorities unresolved • Fuzzy role of private sector	• High level of operations coordination among key players in service delivery • Outsourcing performance managed while maintaining agency's core capacities

the level of service benefits from modest capacity programs, and is accompanied by limited knowledge of the potential of SO&M and limited interest in, or ability to facilitate change and capitalize on opportunities offered by external events to advance operational capabilities. (Limited knowledge is reflected in the low expectations of users and other stakeholders regarding operations potential.) This perspective is often reflected in a fuzzy agency mission and the absence of a formal policy commitment to, or stakeholder support for, customer mobility needs, backed by realistic strategies and performance accountability.

The organizational structure is configured for construction and maintenance project development, often leaving SO&M functions (e.g., ITS, traffic engineering, and TMC management), fragmented and in various traditional chains of command, with limited staff capacity in certain technical areas necessary to improve operations.

Resource allocation processes are without formal accommodation for ITS-related investments. These resources are often viewed as the first place to cut.

Partnerships (interjurisdictional roles and relationships) among operations participants, including PSAs, local governments, MPOs, and the private sector, are exacerbated by informal and unstable partner relationships in congestion management activities.

The experience of the more mature states suggests that addressing these challenges is essential to the development of more effective programs and strategy applications.

Process Maturity as a Bridge to Identifying Levels of Maturity

Whereas strategies to improve technical and business *processes maturity* are not the focus of this project, process levels of maturity have been used as a device to structure a set of corresponding levels of *institutional maturity*. Table 6.2 depicts the range of institutional characteristics based on the process maturity level supported. A characteristic set of institutional features associated with transitioning process agencies is called "ad hoc." A corresponding set of institutional features is associated with agencies exhibiting more mature processes.

As described in Chapter 5 and illustrated in Table 6.3, a parallel, three-level distinction for institutional maturity was developed from correlations of institutional maturity with the three distinct levels of process maturity by adding a third (ideal) level called mainstreamed. Each level of process maturity is associated with changes in institutional architecture.

Level 1 is reflected by the many transportation agencies that are transitioning into SO&M as an identifiable managed activity. At the other end of the maturity scale is Level 3—an ideal agency culture, fully staffed within an efficient organizational structure, a transparent resource allocation process for SO&M, and formal relationships with partners. Between the transitioning situation and the ideal is Level 2, already evident in some state DOTs that are committed to formalizing SO&M as a core program and are making changes to

Table 6.3. Correlation between Process Maturity Levels and Institutional Architectural Levels

Program and Process Capabilities	Level 1 Transitioning	Level 2 Mature	Level 3 Integrated
Scoping	Narrow and opportunistic	Needs based and standardized	Full range core program
Technical processes	Informal, undocumented	Planned, mainstreamed	Integrated, documented
Technology and systems development	Project oriented, qualitative	Rational quantitative evaluation	Standardized C/E systems/platforms
Performance measurement	Outputs reported	Outcomes used	Performance accountability
	↑	↑	↑
Institutional Architecture Elements	Level 1 Ad Hoc	Level 2 Rationalized	Level 3 Mainstreamed
Culture/leadership	Mixed, hero driven	Championed/internalized across disciplines	Customer mobility committed
Organization and staffing	Fragmented, understaffed	Aligning, trained	Professionalized
Resource allocation	Project level	Criteria-based program	Sustainable budget line item
Partnerships	Informal, unaligned	Formal, aligned	Consolidated

rationalize organization, staffing, resource allocations, and partner relationships toward that end. These relationships reveal a pattern of institutional evolution toward configurations that are increasingly supportive of effective SO&M processes.

The three distinct levels of institutional capability maturity have been defined as follows:

- *Level 1: Ad Hoc.* An architecture reflecting a legacy civil engineering culture in which SO&M activities are accommodated on an ad hoc and informal basis, typically as a subsidiary part of maintenance or capital project arrangements. This level, as exhibited in transitioning states, is reflected in a legacy organizational structure and informal resource allocation, fragmented SO&M activities, ad hoc project-oriented business processes, and a narrow SO&M program with no clear sense of performance.
- *Level 2: Rationalized.* An architecture exhibited in mature states that reflects an appreciation of SO&M as a distinct

activity, with adjustments in arrangements, resources, and roles to accommodate the distinct features of SO&M.
- *Level 3: Mainstreamed.* A hypothetical, fully integrated, ideal architecture in which SO&M is considered a core mission, with appropriate formal and standardized arrangements (equivalent to other core programs) configured to support continuous improvement.

In combination, the relationships between the process levels and their capabilities, on the one hand, and the institution architectures and their supporting features, on the other, constitute the Institutional Capability Maturity Model. Table 6.4 presents the criteria that define the institutional architecture levels in greater detail. Each cell represents either a point of departure or a target for improving architecture to the next level. It provides criteria for each element at each level, but it does not provide guidance on the strategies for moving to the next level. Transportation agencies can plot their current state of play and targets for improvement.

Table 6.4. Criteria for Institutional Capability Maturity

	Levels of Capability Maturity		
Elements	**Level 1 Ad Hoc**	**Level 2 Rationalized**	**Level 3 Mainstreamed**
Culture/ leadership	**Mixed, hero driven** • Operations value not widely appreciated (lack of message). • Middle management heroes promote program. • Full legal authority not established.	**Championed/internalized across disciplines** • Visible agency leadership citing operations leverage, cost-effectiveness, and risks. • Customer outreach and feedback.	**Commitment to customer mobility** • Customer mobility service commitment accepted as formal core program. • Clear legal authority for operations roles; actions among transportation agency, public safety agencies (PSAs), local government clarified.
Organization and staffing	**Fragmented, understaffed** • Legacy roles: Some fragmentation of key functions and boundaries, both horizontally and vertically. • Hero driven: Reliance on key individual for technical knowledge and champions for leadership.	**Aligned, trained** • Transportation Management Center (TMC) focus with vertical and horizontal authority or responsibility alignment for operations for the life of a project. • Accountability to top management. • Core capacities established with knowledge, skill, ability specifications, training, and performance incentives in clear career paths.	**Integrated** • Top-level management position with operations orientation established in central office and districts. • Professionalization and certification of operations core capacity positions including performance incentives.
Resource allocation	**Project level** • Resource allocation at project level, ad hoc, unpredictable, buried, invisible. • Apparent limited eligibility of existing funds for operations.	**Criteria-based program** • Budget allocation for operations driven by transparent criteria on effectiveness and life-cycle needs basis. • Funding levels based on relationship to identified needs.	**Sustainable budget line item** • Operations is a formal, visible, and sustainable line item in agency's budget—capital, operating, and maintenance. • Trade-offs between operations and capital expenditures considered as part of the planning process.

Table 6.4. Criteria for Institutional Capability Maturity (continued)

Elements	Levels of Capability Maturity		
	Level 1 Ad Hoc	Level 2 Rationalized	Level 3 Mainstreamed
Partnerships	**Informal, unaligned** • Nontransportation entities unaligned with transportation objectives, procedures relying on informal personal basis. • Outsourcing to private sector used for isolated functions.	**Formal, aligned** • Rationalization of responsibilities by formal agreements across institutions (transportation agency, PSAs, private). • Outsourcing revised to meet agency technical, staffing, and management objectives.	**Consolidated** • High level of operations coordination (memorandums of understanding) among owner/operators with TMC consolidation. • Outsourcing performance managed while maintaining agency's core capacities.

The Institutional Capability Maturity Model as the Structure for Guidance

Guidance for improving institutional maturity is presented in the *Guide to Improving Capability for Systems Operations and Management.* In this chapter, the structure of the guide is outlined based on the institutional maturity framework developed in Chapter 6. For further elaboration of the basic strategies for advancing in maturity for each of the elements, refer to the guide. The stepwise process used in the guide is illustrated at the strategy summary level. The complete strategy templates are included in the guide.

The Institutional Capability Maturity Model

The model is designed to identify changes in a transportation agency's institutional characteristics that will be more supportive of the business processes that are required for effective SO&M. The goal of the model is to support mainstreaming of the key business processes that are necessary for effective SO&M, which may differ from those developed for the existing capital and maintenance programs. The institutional architecture must support documented, reliable, consistent, and integrated processes that are based on rational evaluation and performance-driven improvements on a continuous basis.

The elements of the institutional dimension and their levels of increasing maturity (in terms of supporting more effective programs) were presented in the previous chapter. Each incremental level of maturity within a given element of institutional architecture establishes the basis for the agency's ability to progress to the next higher level of effectiveness. The following should be noted:

- Levels cannot be skipped.
- Each level of business processes needs specific institutional support.
- The overall level of maturity for an organization is defined by the element of institutional architecture at the lowest level.

The Improvement Strategies

For each of the four elements of institutional architecture, there is a set of generic strategies that can be used to make the required adjustments. The generic strategies have their own related tactics associated with each level of maturity. Key strategies associated with each institutional architecture category are outlined below and further broken down in subsequent tables.

- *Culture/Leadership Strategies*
  - Undertake educational inreach/outreach.
  - Exert senior leadership.
  - Establish formal core program.
  - Rationalize transportation agency legal authorities for facility management.
  - Internalize continuous improvement as agency mode/ethic.
- *Organization and Staffing Strategies*
  - Establish top-level SO&M executive structure.
  - Establish appropriate organizational structure.
  - Identify core capacities for SO&M.
  - Determine allocation of responsibility, accountability, and incentives.
- *Resource Allocation Strategies*
  - Develop program-level budget estimate.
  - Introduce SO&M as a top-level agency budget line item.
  - Develop acceptance of sustainable resourcing from state funds.
  - Develop methodology for trade-offs.
- *Partnerships Strategies*
  - Agree on operational roles and procedures with PSAs.
  - Identify opportunities for joint operations activities with local government/MPOs.
  - Develop procedures that accommodate partners' goals and maximize mobility (minimum disruption).
  - Rationalize staff versus outsourcing activities, responsibilities, and oversight (business model).

Capability Improvement Strategies at Each Level

The interpretation of strategies changes with successive levels. The differences reflect the increasingly managed, formalized, and mainstreamed status achieved in the movement from one level to the next. There is a logical sequence to the focus of each element of institutional architecture to reach the next level of capability. For example, regarding resources, moving from Level 1 to 2 may involve a systematic determination of needs, whereas moving from Level 2 to 3 may involve

formal budgeting. There is a parallel progression for all the strategies. Table 7.1 illustrates how the strategies relate to the criteria levels.

Basic Guidance Steps

For use as guidance in improving SO&M effectiveness, the Institutional Capability Maturity Model is presented in a series of steps and strategy matrices, one for each element. The use of the model is a stepwise process.

The general directions for use follow.

Table 7.1. Basic Maturity Strategies for Each Institutional Element

Strategies for Elements	Criteria for Each Level		
	Level 1 Ad Hoc	Level 2 Rationalized	Level 3 Mainstreamed
Culture/leadership • Undertake educational program regarding SO&M as customer service • Exert visible senior leadership • Establish formal core program • Rationalize state DOT authority • Internalize continuous improvement as agency mode/ethic	Mixed, hero driven	Championed/internalized across disciplines	Mobility committed
Organization/staffing • Establish top-level SO&M executive structure • Establish appropriate organizational structure • Identify core capacities • Determine, allocate responsibility, accountability, and incentives	Fragmented, understaffed	Aligning, trained	Integrated
Resource allocation • Develop program-level budget estimate • Introduce SO&M as a top-level agency budget line item • Develop acceptance of sustainable resourcing from state funds • Develop methodology for trade-offs	Project level	Criteria-based program	Sustainable budget line item
Partnerships • Agree on operational roles and procedures with PSAs • Identify opportunities for joint operations activities with local government/MPOs • Develop procedures that accommodate partners' goals and maximize mobility (minimum disruption) • Rationalize staff versus outsourcing activities, responsibilities, and oversight	Informal, unaligned	Formal, aligned	Consolidated

Table 7.2. Basic Institutional Capability Maturity Elements and Levels

Institutional Elements	Level 1 Ad Hoc	Level 2 Rationalized	Level 3 Mainstreamed
Culture/ leadership	Mixed, hero driven	Championed/ internalized across disciplines	Commitment to customer mobility
Organization and staffing	Fragmented, understaffed	Aligned, trained	Integrated
Resource allocation	Project level	Criteria-based program	Sustainable budget line item
Partnerships	Informal, unaligned	Formal, aligned	Consolidated

Step 1

Identify the element of interest (culture/leadership, organization/staffing, resource allocation, partnerships, as shown in Table 7.2). Note that all elements are necessary, but the agency may be at a higher level of maturity in certain elements. Priority focus should be on the element at the lowest level of maturity.

Step 2

Self-evaluate the agency's current level of maturity to determine the point of departure (see Table 7.2). Use the model criteria for each element to determine the agency's current level of maturity.

Step 3

On the Levels and Objectives for Improvement table, identify the target level and inspect the numbered strategies for each element to move up to the next level. Table 7.3 shows an example of the table for Culture/Leadership. Each element has several associated maturity improvement strategies. Deter-

mine the priority strategy based on the current circumstances and the amount of change needed to get to the next level.

Step 4

Review each general strategy table for guidance to move to next level: Level 1 to Level 2 or Level 2 to Level 3. Following each general strategy table are separate numbered and detailed strategies in a standard format for each element. Figure 7.1 shows an example of a strategy for Culture/Leadership. The strategies include the following:

- Relationship to program and process;
- Identification of how the institutional change supports improved SO&M business processes and more effective strategy applications;
- The points of departure (levels of capability);
- Additional criteria/descriptions for the user to determine current level;
- Description of the ultimate target level (Level 3);
- Capability improvement strategies;
- Strategies for moving from Level 1 to Level 2 or from Level 2 to Level 3; and
- Responsibilities.

Table 7.3. Example of Levels and Objectives for Improvement Table for Culture/Leadership

Strategies to Advance Level	Level 1 Ad Hoc	Level 2 Rationalized	Level 3 Mainstreamed
1. Undertake educational program	**Value of SO&M not yet widely appreciated.**	**Role of SO&M in providing service improvements widely understood.**	**SO&M fully appreciated.**
	From L1 to L2: Role of SO&M in providing service improvements widely understood. Drill down regarding the relevance of operational performance to the DOT customer service mission.	*From L2 to L3: SO&M fully appreciated.* Undertake persuasive "road show" to communicate new DOT focus to customers—policy makers and the public.	
2. Exert senior leadership	**Lack of management priority.**	**Visible senior support agencywide.**	**Stable SO&M leadership.**
	From L1 to L2: Visible senior support agencywide. Exert senior management leadership visibly throughout organization and across disciplines regarding SO&M leverage and cost-effectiveness.	*From L2 to L3: Stable SO&M leadership.* Identify and accept risks associated with expanding and intensifying new mission.	
3. Establish formal core program	**SO&M is a set of ad hoc activities.**	**SO&M is a formal mission and program with supporting policy.**	**New state DOT business model.**
	From L1 to L2: SO&M is a formal mission and program with supporting policy. Update mission in light of SO&M business case for mobility in light of minimum new capacity.	*From L2 to L3: New state DOT business model.* Introduce SO&M as formal core DOT program, at the same level as project development and maintenance.	
4. Rationalize transportation agency authority	**SO&M ambitions limited by legacy assumptions.**	**Effective span-of-control needs identified.**	**Effective span of control negotiated.**
	From L1 to L2: Effective span-of-control needs identified. Identify and describe opportunities to rationalize current presumed legal or regulatory constraints regarding DOT's activities.	*From L2 to L3: Effective span of control negotiated.* Legitimize SO&M and partner role rationalization via policy and legislative initiatives.	
5. Internalize continuous improvement as agency mode or ethic	**Limited progress orientation.**	**Adoption of continuous progress concept.**	**Continuous improvement approach internalized.**
	From L1 to L2: Adoption of continuous progress concept. Develop concepts of continuous improvement with examples toward achieving performance-driven best practice.	*From L2 to L3: Continuous improvement approach internalized.* Support culture of continuous improvement with clear targets and incentives for individuals and units.	

Culture/Leadership Strategy 5: Internalize Continuous Improvement as Agency Mode or Ethic

Relationship to Program and Process
With an objective of building toward best practices, cost-effective process and program improvements are necessarily incremental. Continuing improvement to and beyond the state of best practice requires development and management of a continuous improvement process built around performance measurement, analysis, and procedural improvement.

Points of Departure (Levels of Capability) and Related Improvement Strategy

Level 1: Limited Progress Orientation
In a Level 1 organization, activities are started (set and forget) without regard to the potential for improving effectiveness through learning and are likely to plateau at modest levels, given the lack of performance feedback and improvement. Lack of ideal performance measurement often is used as an excuse for business-as-usual approaches.
    The following strategies can help raise a Level 1 organization to Level 2:

• Identify long-range ideal practice concepts as targets for improvement.

• Identify basic performance measures, both activity based (to start) and outcome based (ultimately).

• Establish a standardized performance-based continuous improvement process, including documentation, performance monitoring and measurement, postevent briefing, and process adjustments.

Level 2: Adoption of Continuous Progress Concept
In a Level 2 organization, the DOT is broadly committed to improving SO&M in terms of both technologies and procedures on a continuous incremental basis.
    The following strategies can raise a Level 2 organization to Level 3:

• Support a culture of continuous improvement with clear policy and incentives for an individual's and unit's performance or innovation.

• Set incremental performance improvement targets, measure effectiveness, and improve approaches to all services, both in office and in field.

• Use performance to determine program modifications and resource allocation.

Level 3: Continuous Improvement Approach Internalized
In a Level 3 organization, the presumption is that continuous improvement is desirable and sustainable.

Responsibility
This strategy must be initiated in a top-down manner and be a shared approach involving all staff.

Figure 7.1. Example strategy for Culture/Leadership.

Managing Institutional Change

The *Guide to Improving Capability for Systems Operations and Management* indicates *what* needs to be done institutionally to provide a supportive basis for more effective SO&M programs and processes. However, *how* these changes will be implemented is an additional challenge that will vary from context to context and be highly dependent on circumstances and leadership. In this chapter, alternative change scenarios are addressed. The limits on management span of control are recognized, and opportunities are noted.

A change management strategy designed to improve SO&M effectiveness requires adjustments in both the process and institutional dimensions. Changes in process maturity are difficult and unlikely without supportive changes in institutional architecture. However, changes in institutional architecture that are supportive of improved SO&M process and programs are not likely to happen without a deliberate change management strategy.

Change Management Modalities: Contribution of Theory

Within organizational theory (Thatchenkery, n.d. [c]), authors classify change management approaches by the characteristics of the change management process itself: temporal pattern (thoroughgoing or incremental), scale (fine tuning or full-blown transformation), and sources and nature (emergent, planned, or contingent).

For systems operations capability maturity improvement, the incremental nature of the changes and their scale within the maturity model concept has been indicated. A special challenge is the consideration of how such change is to be brought about.

- *Emergent approaches* (evolutionary change) are bottom-up, typically introduced via innovative projects or procedural improvements in specific program areas (such as ITS), and are championed by middle-level unit managers.

(Within state DOTs, this signifies central office or regional management positions).
- *Planned approaches* (managed change) are defined as top-down and rational processes (such as those undertaken in various agency-level strategic developments), and transformation efforts that may not survive a change in leadership or in an environment interrupted by external challenges. There is a modest literature on managed change, including various staged models.
- *Contingency models* (externally driven) are defined as changes that occur externally. These may occur as a result of these factors:
  - Major events that impact an organization's credibility;
  - Being part of a broader shift that includes an organization, such as statewide level performance measurement initiatives and reduction-in-force measures;
  - Legislative mandates, such as privatization; and
  - Initiatives from sources outside the transportation agency, such as PSAs or the private sector.

Evolutionary Change

Changes in many of the components of maturity may occur without deliberate management. In general, changes in a large organization's program, process, and institutions take place gradually in small increments. There are important sources of inertia in program, process, and institutional structure that include defined professional orientations, well-established and widely understood legacy mission, long-standing and well-developed roles and relationships, and considerable external stakeholder support. Changes at odds with any of these features occur only gradually, especially if they compete for scarce management time, require new expertise, or are perceived as diverting resources or introducing risks. The input received from the interviews conducted by this project suggests the range of barriers facing managed change as shown in Table 8.1.

Table 8.1. Barriers to Institutional Change

Change Elements	Barriers
Culture/leadership	• Limited public and elected-leader support. • Significant capacity construction program. • Limited internal middle management support. • Fuzzy legislative authority.
Organization and staffing	• Absence of experienced SO&M manager(s). • Shortfall or turnover in qualified staff. • Staffing-level constraints.
Resource allocation	• State funding ineligible for SO&M. • Competition for resources from other program backlogs. • No performance outcome measures.
Partnerships	• Conflicting partner priorities.

Nevertheless, this type of change is always occurring—although gradually—as the result of a range of forces relating to education, workforce, political values and issues, and transfer of technology from other fields. An example of this type of gradual change is the increased penetration of formal asset management into the standard transportation agency culture.

Managed Change

Managed change, in which leadership within an organization makes deliberate changes in program, process, or institutional arrangements, represents a departure from the existing legacy arrangements and is openly acknowledged as such. The drivers for these more discrete changes tend to be a combination of professional predisposition and agency leadership—to articulate the need for change in a way that makes the need more widely apparent, and to oversee a program of appropriate changes (as specified in the transition to a higher level). A description of each of these types of managed change follows.

In middle-management-led change, committed professionals can have a significant impact from the inside out and up. There are two versions that have been observed in the SO&M context. The first may be referred to as *regionally developed islands of excellence.* In several state DOTs where there is significant decentralization, individual regional/district leadership has been able to develop strong regional-level SO&M programs without significant support on a statewide basis from central office divisions. Several states exhibit wide variation among districts/regions regarding SO&M programs within the state, even where transportation settings are comparable. These achievements usually require strong and independent support from district executives and aggressive district operations leadership. They can serve as models for the

entire DOT when statewide operations initiatives are undertaken as a matter of policy.

The second version of middle-management-led change may be termed *statewide intrapreneurship.* This version of change at the statewide level has also been widely observed. It is based on initiatives of individual champion-middle managers in central office SO&M divisions. This type of change is often technology led, where SO&M activities are at an early stage of development in which the payoff from modest improvements, such as deploying basic ITS systems and establishing TMCs, are obvious and nondisruptive. At this stage, the challenge relates to deployment of ITS systems. However, capitalizing on this infrastructure in terms of procedures and partnerships quickly reaches a point where organization and resources from the central office are required—sometimes with statewide implications—and are typically outside the span of control of middle-management champions. In addition, this type of change is extremely fragile owing to its dependence on an individual rather than on a program. In several cases, state DOT activities have lost momentum with the departure of champions.

Top-management-led change has been observed in the few instances in which SO&M has been encouraged by new CEO leadership that institutes a new policy mandating or authorizing a department wide process to improve SO&M that involves consolidating and strengthening the systems operations functions at a statewide program level, in both the central office and the key districts. The difficulties faced with a top-down approach are reflected in the slow pace of improvements made in many states beyond initial deployments; change is further inhibited by the limited tenure of agency CEOs. In addition, a major strategic reorientation must compete for management attention and agency resources and carries with it the risks of limited stakeholder and legislative support—unless carefully sold.

Span of Control

The types of changes at the levels of higher capabilities may become more difficult within the existing institutional context, at least at the organization level. There is a limit to the span of control of a transportation agency's top management. Some of the operational needs involve other parts of the agency with varied mission focus or other agencies, and resources that simply may not be available in the agency context. In state DOTs, the span of control of an operations division or of district management is even more limited.

As illustrated in Table 8.2, initial changes in the institutional architecture may be accomplished with relatively little disruption of the legacy arrangements and with only modest dependence on external support. However, the greater degrees of change regarding culture, resources, and partnerships involve actions and commitments in agency- or even state-level policy, as well as action by state legislators and other agencies.

Externally Driven Change

Events outside the control of management have been the key driver of change in SO&M. Several versions have been observed among state DOTs regarding significant increments in attention to SO&M. These include event-driven change, incident-driven change, constraint-driven change, federal program incentives change, and change resulting from a new regional institutional configuration. There are often multiple drivers of change—or a sequence of drivers—that provide impetus for increased focus on SO&M.

Event-Driven Change

Anticipated major traffic impacts in response to major external events have been a common stimulus to significant change. Major one-time or annual sports events (e.g., Olympics, auto races) and conferences are the two most prevalent, for which extensive planning has been undertaken to preserve general mobility and minimize disruption while accommodating the event. These anticipated events have required significant improvements in operational capacity, including new infrastructure, special procedures, and new relationships.

Incident-Driven Change

Unplanned events causing major disruptions have been the most common cause of across-the-board improvements in SO&M. These incidents include natural disasters (earthquakes, hurricanes, and floods), major weather events such as snow storms, and major traffic incidents, ranging from crashes to extensive seasonal recreation congestion. With the disruption, delay, and loss of system reliability associated with such major NRC events—especially those with high public and policy visibility—the need for specific changes in one or more operations activity becomes compelling, with strong

Table 8.2. Span of Control for Institutional Change and Relationship to Position

Major Dimensions of Change	Level 1 Ad Hoc	Level 2 Rationalized	Level 3 Mainstreamed
Program	Mixed, unfamiliar— hero driven	Championed/internalized across disciplines	Mobility committed
Processes	Fragmented, understaffed	Aligning, trained	Professionalized
Institutional	Project level	Criteria-based program	Sustainable budget line item

public and policy support or imperatives. Immediate action is usually required as a matter of agency credibility, including the need to demonstrate visible change and positive outcomes. Although the response is often limited to a specific activity, there are a few cases where the response to a particular event and location has been extended by management to the statewide program level, and often accompanied by changes in process and institutional arrangements.

Constraint-Driven Change

In the face of financial or environmental limitations, expensive capital projects to increase highway capacity are often infeasible. SO&M then gains credibility as a relatively inexpensive way to improve the efficiency of the existing roadway. This constraint-driven change becomes most apparent where congestion levels are extremely high and capacity improvement opportunity limitations are openly acknowledged by the transportation agency and accepted by traditional highway stakeholders.

Federal Program Incentives Change

The use of federal funds has introduced planning and systems architecture requirements and has increasingly focused on performance measurement. FHWA has also promoted research, technical exchange, and definitions of current best practice. FHWA also provides dedicated funding. These actions have increased the visibility and legitimacy of ITS and SO&M within transportation policy and encouraged state and local involvement.

New Regional Institutional Configuration

A number of substate entities (such as local governments and MPOs) have taken the initiative to establish cooperative regional efforts for interagency collaboration in improving SO&M. State DOTs have been involved as one of several cooperative entities.

Building on Change-Driven Momentum

In response to some of the major external events, key external stakeholders, policy makers, and the public have developed expectations of a specific transportation agency response: to minimize the potential impact of similar events in the future. It is no surprise, therefore, that major external events have been associated with enabling, if not forcing, change associated with nearly all of the significant progress made by several of the state DOTs with more mature programs. The events reduce the barriers to otherwise difficult or expensive organizational changes, increased funding, and changed relationships with external partners (such as law enforcement). Transportation change managers—middle or top management—can capitalize on the opportunity to institute such important changes otherwise not possible.

However, effectively capitalizing on such events requires that the agency have a general strategy in place to seize these windows of opportunity to extend and standardize specific program and organizational changes into improved day-to-day SO&M across the agency as a whole. Even in constrained contexts, it can be extremely valuable to have an improvement program "on the shelf" for potential utilization as circumstances permit, focusing on the key elements most directly implicated by any externally driven change, but also using the momentum for more general improvements.

Change Management Tactics

The Institutional Capability Maturity Model is not the complete recipe for change management; it provides a framework for determining what needs to be done and the strategies for making institutional changes in a direction that is more supportive to aggressive congestion management. However, the strategies themselves must be managed and carried out by appropriate staff. This report and the guide are not intended to provide general change management tactics. There is substantial existing strategic management literature, including such approaches as process engineering, balanced scorecards, and Baldrige criteria. Each of these approaches includes a version of the standard, generic steps of change management that would be generally applicable to all the components of guidance. The following steps are typical.

First is the joint (consensus) identification of the problem/opportunity/challenge within the change manager's span of control or influence to create a sense of urgency. This activity is clearly relevant to institutional maturity for congestion management, as evidenced by the shift of the focus of an agency's culture toward operations—based on both the constraints facing alternative service improvement options and the potential of congestion management opportunities. An understanding of these technical issues is an essential point of departure.

Second is the development of a vision and the definition of the general changes needed, as well as the specifics of the priority components, which may be limited by the change manager's span of control (see below). This activity corresponds to adopting the Institutional Capability Maturity Model as the template for managed change and developing a commitment to use it on a continuing basis as a component of formal strategic planning.

The third step involves creating or building a team of change agents. The team may be composed of individuals with specified responsibilities, or it may be a task force. Application of the maturity model requires the formation of a team

or unit with the responsibility of applying the method with the appropriate units within the agency.

The next step is sharing the vision and creating buy-in among the widest possible group of staff that are needed to understand and support the changes. The Institutional Capability Maturity Model is applied in a self-evaluation context. Key management and staff evaluate their current situation with regard to the level criteria and develop their own custom-tailored version of the next steps and strategies to get there, thus developing an internalized understanding and buy-in to the changes required.

Fifth is empowering the change agents with the necessary support, resources, and authority to make the necessary changes. Installing the maturity model as a continuing strategic change process requires both a broad, shared understanding of the objectives and staff capability to manage and monitor the change commitments made for each element in the maturity framework. Each of the level transition strategies is a task to be managed.

Finally, it is important to use an incremental approach to create visible, early wins to generate momentum and wider support. This is focused on results, not activities.

Alternative Institutional Models

In this chapter, alternative models of change in institutional arrangements are addressed. The models range from incremental to new institutions. The contributions of theory and experience in relevant countries are reviewed.

Evolution or Revolution

As indicated, higher levels of capability require greater institutional change. The transition across levels may become increasingly difficult within the existing institutional context. Owing to limitations on the span of control of top management (authorization, staffing, labor, partnership constraints), it may be more practical and politically easier to adopt a new model for key parts of the transportation agency's SO&M program. Such a model may be forced on some or all of the SO&M activities by external events.

The Models

"Models" refers to institutional arrangements for certain management and operational activities that are a departure from incremental change within the existing institutional framework of organizational roles, resources, and partner relationships. These alternative models have typically been applied to a given function statewide, or a set of functions on a geographical basis. The arrangements may relate to changes in responsibilities for major functions, as between levels of government or with the private sector.

   A range of institutional models has been reviewed from existing sources in the United States and through discussion with key professionals. In addition, information descriptive of some models has been derived from international sources. The first three models described below are representative of U.S. (and, where noted, international) experience; the fourth model is currently in use in the public utility sector. In the following discussion, the four models are described and are compared with each other against a baseline of the existing institutional structure, assuming an incremental approach. (A separate discussion of other international models concludes this chapter.) It should be noted that while the examples below are described in available material, there is minimal literature describing the models in terms of the four institutional elements by which they are compared.

Activity Outsourcing

This model is presumed to apply to a statewide program, although its components can occur at different rates on a regional basis. This model assumes systematic outsourcing of certain SO&M functions at the activity level, such as safety service patrols, TMC operations, and asset management, as per current practice in a few states, but with the transportation agency maintaining program and individual activity contract management responsibility. While several states outsource TMC operations and safety service patrols in some metropolitan areas, only two states have substantially outsourced most of these activities on a statewide basis.

Program Outsourcing (Public–Private Partnerships)

This model is presumed to apply to a statewide program, although its components can occur at different rates on a regional basis. This is distinguished from activity outsourcing by its inclusion of an entire set of activities (e.g., all real-time operations activities) into a single contract, with a program manager reporting to a separate public–private entity, and including management of other service providers on a large-scale geographic basis. There is no statewide U.S. example (although such public–private partnership models are in use in some U.S. tolled facilities), but the U.K. Highways Agency has established subnational regions (like state DOT districts) under which most operational and related maintenance functions are performed by a combination of dedicated staff and contractors.

New Cooperative Operations Collaboration

New regional operations relationships have been established either through a consolidation of the SO&M responsibilities (state and local) of existing public agencies into a new entity or through a new set of planning and operations collaborative relationships. These types of organizations appear to reflect willingness on the part of state DOTs to devolve complex metropolitan or regional multijurisdictional operating activities, rather than lead such efforts themselves.

There are several entities of this type in the United States, most of which were established in the 1990s, that were incentivized by FHWA incentive funding (currently less available). These entities do not assume all of a state DOT's SO&M functions and activities and have dedicated purposes that vary widely. Some have coordinated planning functions and one or more real-time operations functions, such as traffic conditions analysis and dissemination (TransCom), TMC, arterial and/or freeway operations (FAST, TSSIP, NITTEC, FAST-TRAC), incident management and HOT operations (TranStar), bridge and tunnel operations coordination and resource allocation (BATA), and weather information development and dissemination (CLARUS).

As this model exists in several versions in the United States, several examples have been described and compared to illustrate key features and differences, presented in Appendix E. The most interesting features include:

- Membership and lead agency—typical local government-led consortium.
- Scope and span of control over distinct regional activities—wide variation, but normally includes local and state facilities.
- Degree of formality of formation—legislation or memorandum of understanding.
- Use of TMC and colocation—in most cases.
- Funding—typically voluntary from multiple sources.

Public Utility Model

This model, presumed to apply to a statewide program, is by definition privately managed and funded by user fees, under public policy and regulatory oversight. There is no known example in highway-related SO&M. The closest examples are regional transit authorities that provide transit operations at the metropolitan (or regional) scale, with professional management and local and state government boards of directors. These authorities are not self-supporting from user fees, and they depend on state and local tax sources. An emerging version of a public utility model may be public authority or private HOT and toll road development and operations at the network level. This represents a high level of operational

control over a limited set of facilities, but examples already exist where SO&M applications are managed by such entities including, in some cases, control of the law enforcement function. This model has limited relevance at the present time, in the absence of a separate financial base via user fees and a pricing orientation. In the long run, the introduction of mileage fees, possibly combined with publicly regulated private operating franchises, might approximate this model.

Combinations and Evolutions

The above alternatives are not entirely exclusive and some evolutions are clearly possible. For example, the first two models are not inconsistent with an incremental approach as a response to resource limitations or a performance management driven policy, with state DOTs maintaining essential control over policy, resources, and activities. At each stage in such an evolution, more and more attention to performance (oversight rather than execution) is implied. With each stage, there are also more substantial changes in the roles of public entities.

In Table 9.1, the four models are described and compared to the incremental approach in terms of the key institutional elements. The last row in the table also assesses the likelihood of each model to advance SO&M quickly.

Implications of Alternative Models Regarding Key Institutional Issues

The following sections expand on the implications of these alternative models relative to the key elements of institutional architecture.

Culture and Leadership

The incremental approach, as a baseline, is structured toward increasing levels of understanding and orientation toward SO&M as a formal program. Outsourcing and public–private partnerships introduce partial or substantial changes in the business model, reflecting not only an introduction of a new DOT mission and responsibility (and improved cooperation with other public entities) but also an adjustment in the appropriate role of the public sector versus the private sector, e.g., the public sector sets policy and standards and provides performance-based oversight to private sector entities who actually perform the function. The policy underlying such a change in the business model is already evident in large-scale asset management contracts of several states and is also reflected in public–private toll road development. The development of a new public entity represents a public acceptance of the importance of SO&M and the need for intensive cooperation. The

Table 9.1. Characteristics of Alternative Institutional Models

Model	Baseline— Incremental Change *Managed incremental improvements as per Operations Capability Maturity Model with minimal change in organization (current status, most DOTs)*	Activity Outsourcing *Selected operations activities individually outsourced*	Program Outsourcing (PPP) *Outsourcing all field activities into single contract, including oversight—on long-term basis to achieve partnership (U.K. Highway Authority, toll authority model)*	New Cooperative Operating Entity *Establishment of regional operating entity as joint venture of agencies with regional operations-related jurisdiction*	Public Utility *Independent entity with separate management and resource base, enterprise management, and public regulation*
Culture	• Dependency on widespread understanding/ acceptance of oper-ational mission • Slow to change via external, internal education	• Presumes increased understanding/ acceptance of operational mission as core function • Change in mindset from execution to oversight • Reduction in direct customer contact	• Reduced depen-dency on internal understanding/ acceptance of operational mission as core function • Change in mindset from program execu-tion to performance oversight • Reduction in direct customer contact	• New culture of customer service	• Established with operations-oriented culture
Leadership	• Heavily dependent on external (political) factors • Requires leadership	• Heavily dependent on external (politi-cal) factors • Presumes degree of mainstreaming	• May be influenced somewhat by outsourcing orientation • Presumed partner-ship orientation management	• (Presumably) selected to new mission	• Leadership selected for operations experience and leadership
Organization and Staffing	• Consolidation of fragmented units • Development of full functions required • Shortfall in technical and management • Need for training in specialties	• Reduced staffing requirements • Development of full functions required • Core capacity maintenance	• Minimal staffing requirements • Development of full functions required for planning/funding only • Core capacity maintenance	• Minimal staffing requirements • Establishment of full functions required for plan-ning/funding only • Core capacity maintenance	• Organization developed specifically for real-time service provision • Full operational functions provided • Technical capacity retained from market • Flexibility in staff as needed
Resource Allocation	• (Programming and budgeting assumed) • Reduced fragmenta-tion and increased span of agency con-trol of resources	• Establishes activity level resource commitment • Impact of changes in level is external • Flexibility in response	• Establishes program level resource commitment • Funding level explicitly related to performance • Impact of changes in level is external • Flexibility in response	• Likely to outsource most functions • Establishes program level resource commitment • Funding level explic-itly related to performance	• Independent funding source from state budget or user fees
Partnerships	• Relationships informal • Slow realignment due to independent missions, resources • Relationships formal (MOU)	• Performance contracting	• Performance contracting	• Performance contracting	• Presumes assumption of key roles as essential for effective oper-ations • Involves realloca-tion of functions from DOTs, PSAs
Capability to Advance SO&M Quickly	• Moderate	• Moderate • Note: Can be combined with program outsourc-ing and/or new cooperative entity models	• High	• High	• High

public utility model represents a more radical (and not yet realized) change in the business model away from a public agency to an enterprise model. This approach may be approximated in the context of regional private toll road operations.

Dedicated and sustained leadership is needed to introduce and maintain changes from the legacy context to any reconfiguration of roles or resources. Such changes are also dependent on unique circumstances (limited number of key players) and, to date, special external pressures, such as financial shortfalls, coordination problems, or major disruptions.

Organization and Staffing

The establishment of a stand-alone, purpose-dedicated entity provides staffing flexibility and some relief from civil service constraints, and clarifies accountability for the chartered SO&M functions. These models are, by definition, designed to substitute for state DOT staff and to acquire special capability at a competitive cost. From a management and accountability point of view, it is shifting the state DOT staff function from concern with execution to a focus on outcomes and, at the same time, highlighting the need to identify core capacities.

Resource Allocation

Although the cost of SO&M as a proportion of overall state DOT budgets (exclusive of snow and ice control) is small, rarely above 2%, SO&M expenditures are frequently seen as competing with well-established and justified maintenance programs (and sometimes capital) for scarce resources—the challenge, in effect, being one of policy. In some instances, the transition toward more outsourcing has been hampered by legislative and stakeholder resistance to diversion of funds.

The first two alternative models monetize certain components of an SO&M program that may overcome staffing constraints and create a visible budget item. Outsourcing programs are on annual or multiyear contracts, providing different levels of stability. Competitively bid longer-term contracts permit the private entity to invest in more efficient service delivery. While this represents a degree of formalization of an SO&M program, it has also made these elements vulnerable to budget cuts. A new operating entity is likely to involve a budget as a matter of agreement among the participating entities, but is also subject to individual participant budget variation. A new utility like entity, by definition, has its own source of funding (such as dedicated taxes or tolls).

Partnerships

A key feature exhibited by the current, more mature state DOTs is the formalization of partnerships via memoranda, joint training, and regular performance review. The development of a special-purpose entity, by definition, finesses much of the partnership alignment problem, some of which is subsumed in an interagency agreement. Partnerships and new entities are also likely to be dependent on outsourcing and the public–private partnerships involved, and permit resolution of most partnership issues via contract.

The International Perspective

In the review of alternative institutional models that might be relevant to the U.S. context, international comparisons were made among countries that share sufficient cultural similarities such that differences in other institutional elements can be revealing.

There is limited written material on institutional models internationally. One of the key sources is the 2006 FHWA Scan of Active Traffic Management. The U.K. Highways Agency has recently completed an as-yet-unreleased scan of incident management experience in six countries: Holland, France, Australia, United States, Germany, and Sweden. This *Investigation and Evaluation of Road Incident Management Approaches: International Initial Review Report* was conducted in part by members of this project team and provides a useful up-to-date parallel to the FHWA scan. A comparison of the U.K. and U.S. scans interestingly reveals a grass-is-greener phenomenon, with the U.K. observers admiring the range of experimentation in the United States and the U.S. observer admiring the simpler institutional structures with a national transportation agency, single law enforcement entity, and apparently closer coordination among agencies from a single level of government outside the United States.

Given the availability of written material and direct contacts, the comparisons were focused on the United Kingdom and Australia, with limited consideration of the Netherlands, France, and Japan. Account must be taken for the fact that these countries are smaller (in population and size) and less diverse than the United States and vary considerably in their national and subnational government structures. For example, it is difficult to compare the activities of the U.K. (national) Highways Agency or the Dutch Ministry of Transport, Public Works, and Water Management (Rijkswaterstaat) with a state DOT, although they bear similar types of responsibilities.

The variations in institutional models in the United Kingdom, Australia, and the Netherlands reflect a high national priority on traffic management. In particular, all three countries focus on reliability, reflecting a consensus of the relative leverage of managing NRC. This priority translates into some key differences from typical U.S. state DOT policy in terms of these items:

- Explicit congestion management policy;
- Clear divisional responsibility for operations;

- Formal planning and budgeting for operations;
- Specific professional specialty and training;
- Use of operations-related performance criteria to measure agency functions; and
- A high degree of outsourcing.

Australia and the Netherlands share the strong operations orientation of the United Kingdom, but geographic differences lead to different models. In Australia, closer to the U.S. legacy model, traffic management is at the state and regional (urban) level, but also exhibits strong transportation–law enforcement relationships and a strong focus on performance measurement. Unlike in the United Kingdom, operations are not a stand-alone division or budget. The Netherlands, with its simpler institutional framework, has taken an even more aggressive step with active traffic management and the introduction of GPS-based road pricing by 2011. While the culture and institutional arrangements are quite different in Japan, there is a similarity with the United Kingdom and Netherlands in the consolidation of authority for operations in a single agency—the national police—and in strong public–private partnerships, especially in the provision of traffic information.

Appendix A presents a comparison of the United States, United Kingdom, and Australia regarding planning, implementation, operations, and maintenance of ITS and SO&M, insofar as they suggest relevant models.

Reallocation of Roles

A noticeable difference emerging in the international scans is the impact of (relative) institutional simplicity derived from the major role played by the national government in nonfederal countries. This eases the ability to develop a policy consensus and minimizes the jurisdictional fragmentation. In particular, this is visible in the differences between such countries' national unified goals process (which involve various aspects of systems operations and management, such as incident management, making it easier for many countries to develop consensus) and the U.S. National Traffic Incident Management Coalition

(NTIMC), which require a higher level of effort in reaching agreement even on high-level principles alone.

The most striking example of the evolution of the U.K. Highways Agency over the last decade, regarding the delivery of both operations and maintenance services, is outsourcing to private entities. The road network is divided into 14 operational areas, with each area managed by a managing agent contractor. England has also been divided into four traffic-operations regions. The formal mission has developed a much stronger focus on reliability, safety, and information, as evidenced by the aggressive implementation of active traffic management schemes. This network operations focus has led to a set of institutional changes in its support. The following organizations within the Highways Agency contribute to incident management:

- The Traffic Officer Service represents an increase in the Highways Agency's role in incident and emergency management, taking over non–law enforcement traffic management role from the police (including incident command in minor incidents). This service includes a fleet of patrol vehicles that operates in coordination with the regional control centers, supporting incident and emergency services, with highways and law enforcement personal colocated.
- The private sector and the regional managing agent contractors maintain a strategic network to meet service level agreements. They play a key role in managing incidents by providing tactical incident management to the Traffic Officer Service and asset repair required as a result of incidents.
- The National Traffic Control Centre, National Incident Liaison Officers, and the Highways Agency Information Line are countrywide (similar to statewide) organizations that coordinate among regions and major emergencies as necessary.

This model represents a combination of focus on operations in the transportation agency, a renegotiation of a more active role for the Highways Agency among the key players in some of those highway operations, dedicated incident response function, and aggressive recourse to the most aggressive strategy applications.

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Glossary

business processes. Consist of the organized activities carried out in common to develop and implement SO&M, including scoping, planning, programming and budgeting, systems and technology engineering, project development, and performance measurement.

congestion management. The set of highway SO&M actions taken to minimize the causes and impacts of congestion, both recurring and nonrecurring.

effectiveness of NRC strategy application or program. Refers to the measurable impact of such application on the outcomes of congestion management, specifically in terms of reduction in delay and improvement in reliability and safety.

institutional architecture. A research term that refers not only to organizational characteristics—such as organizational structure, policy/mission, leadership/staff, resources/technology—but also to the prevailing culture and values, legal framework (including legislative bodies and political administration), and partnering relationships among organizations, both formal and informal.

mainstreaming. Becoming an integral part of core agency activities. A mainstreamed concept is widely understood and accepted by the agency (as well as its partners and constituents) at all levels. It is fully integrated into the agency-wide culture, business processes, budgeting, organization, and staffing.

nonrecurring congestion (NRC). The portion of congestion attributable to traffic delays and disruptions caused by random, unpredictable, and transitory events, including vehicular crashes and breakdowns, weather, road construction activity, and planned special events. The causes of NRC together produce about half of total delay and most of the system unreliability, and they contribute to safety problems.

recurring congestion (RC). The portion of total delay caused by the everyday, predictable delay that occurs from supply-demand imbalance at peak periods. It is addressed by such strategy applications as ramp metering, signalization, and demand management through pricing.

reliability. The major factor affected by NRC, which is, by virtue of its causes, unpredictable. It is measured by the variation in travel times for identical trips. The lack of predictability is what requires drivers to allow extra time to reach their destinations by a given time. For example, a driver may allow 30 min for a trip that usually takes 20 min.

strategy applications. The set of known transportation systems and operations management conventions related to user services directed at the causes of congestion—e.g., incident management, work zone traffic control, traveler information.

systems operations and management (SO&M). A term applied to a program of ITS infrastructure and related real-time activities targeted at maintaining or improving the performance of the existing transportation infrastructure in response to the causes of both recurring and nonrecurring delay, disruption, unreliability, and related safety and security problems.

U.S. Institutional Arrangements Compared with England and Australia

Table A.1. U.S. Institutional Arrangements Compared with England and Australia

		International Differences		
	Institutional Issues Related to Preconditions for Effective Congestion Management	**United States (Typical Large State DOT)**	**England The Highways Agency (HA)**	**Australia**
Plan	Accommodation in strategy portfolio • Overall priority/visibility in DOT program • Contact with/support of relevant external stakeholders • Key strategies employed	• Not highest priority—even in congested states • Not discussed with legislature • No direct reporting, accountability to legislature or public • Different strategy mixes among states	• Congestion management is given high priority • HA has a Network Operations division covering traffic operations and network strategy • Single strategy for Strategic Road Network • Performance measures relating to journey time reliability, maintenance standards, and response times	• Congestion management is becoming more important, but priority is still given to providing new highway infrastructure • Congestion management is responsibility of state and/or local government • Different strategies among the states • Privately owned toll roads are operated by the concessionaire • Performance measures tend to focus on reducing accidents rather than improving journey time reliability or congestion
	Integration: How operations are budgeted and planned in context of other programs (construction, maintenance)	• Practice varies widely among states—urban and rural • Operations not in formal planning or budgeting process at state level; rarely at regional level (via MPOs) • No line item in state budget for operations • Functional divisions do not include operations at first level—stovepiping	• Operations (on road and control room) included in planning and budgeting process at national level for the next four years • HA and police roles clearly set out following review in 2003 • Traffic Management Act requires highway authorities to work together to secure the expeditious movement of traffic	• Operations is not listed separately in most state budgets • Queensland identifies operations as 2% of total highways budget

(continued on next page)

Table A.1. U.S. Institutional Arrangements Compared with England and Australia (continued)

	Institutional Issues Related to Preconditions for Effective Congestion Management	International Differences		
		United States (Typical Large State DOT)	England The Highways Agency (HA)	Australia
Implement	Systems engineering technical capacity • Organizational structure • Allocation of responsibilities between central office and regions	• DOT regions quite independent in program development • Lack of availability of trained technical and management staff	• Operations is a key part of Highway Agency's work • HA directly employs and trains traffic officers and control room operators • Regional structure based around seven regional control centers • National Traffic Control Centre provides traffic information and strategic diversion routing on a national basis	• Most states have a traffic management center. Some are joint ventures with city councils—e.g., Queensland and Brisbane. • Some states, including New South Wales (NSW), Queensland, and Western Australia, have recently set up on-road patrols
Implement	Regional, situational awareness		• HA is at forefront in using ITS to deal with recurrent congestion • National standards for technology on motorways and trunk roads	• Federal ITS framework architecture to allow development of local projects while ensuring interoperability
Implement	Sustainability and transparency of budget for congestion management		• Adequate resources for motorway network • HA is looking into diverting some existing resources onto trunk road network • HA is taking on vehicle recovery role for broken down vehicles on trunk road network	• Level of resourcing and functionality varies between states and within states. Brisbane Traffic Response Units have target response time of 10 min; there is a lower level of patrol outside of the city. Sydney has 10 traffic commanders on patrol 24/7, with reduced resources elsewhere in NSW. Western Australia only patrols between 06:00 and 18:30.
Operate	Interagency cooperation • Operational; management and coordination; agency cultures and priorities • Formality of relationships	• Police and fire have incident command by law but different priorities form DOTs • DOTs support and communicate • Some outsourcing of TMCs, SSP, ITS maintenance	• Incidents are generally led by HA • Police have different priorities than HA and only take lead for injury accidents and suspected criminality • Roles and responsibilities of HA and police are formally agreed upon • Highway infrastructure and ITS maintenance is outsourced	• Emergency services have incident command • Incident response units support and provide information to traffic management center
Operate	Coordinated execution	• Relationship with public safety agencies subsidiary and informal • Cultures of law enforcement not interested in traffic	• Formal relationship between HA, police, and other emergency services	• Formal relationship with police. In some cases (e.g., NSW), officers are permanently based in the traffic management center.
Operate	Performance focus via use of objective-related performance measures	• Performance measures limited to outputs, not outcomes	• HA is measured on safety and journey time reliability • Culture of continuous improvement	• Targets tend to focus on improving safety but only on maintaining the status quo with regard to congestion and journey time reliability • Focus tends to be on providing new infrastructure

Table A.1. U.S. Institutional Arrangements Compared with England and Australia (continued)

Institutional Issues Related to Preconditions for Effective Congestion Management	International Differences		
	United States (Typical Large State DOT)	England The Highways Agency (HA)	Australia
Maintain ITS asset management	• ITS assets undermaintained (lack line-item budget)	• Asset management is included in planning and budgeting process • ITS maintenance is out-sourced • Database of all ITS assets, including age and condition	• Federal government funds maintenance of AusLink roads. Some states claim they receive too little to properly maintain aging assets. • ITS maintenance is not sep-arately identified in budgets • Privately owned toll facili-ties maintain their own equipment

State DOT Process and Institutional Interviews

Table B.1. SHRP 2 L06 Systems Operations State-of-Play State DOT Survey: Questions and Prompts

Dimensions: General Questions	Indicators as Observed in State DOTs (Bulleted Items Are Prompts for Interviews)	
	L-1: Architecture Supporting Transition from Ad Hoc to Managed (Activities Initiated on Agencywide Basis)	**L-2: Architecture Supporting Transition from Managed to Integrated (Establishment of Integrated Program)**
Background • Number of districts • Number of districts with TMC (big vs. little) • Number of TMCs with full range of strategies		

A. Culture
 	
• Is operations mainstreamed as a key DOT mission?
• Where does operations stand in the mind of agency management in terms of its relative importance as an activity and as a responsibility?
  ○ In terms of public documents
  ○ In terms of dashboard
  ○ In terms of mobilization
	• The potential service leverage (value) of operations is not widely appreciated in the DOT
	• Operations is not yet specifically identified in standard public DOT policy documents along with capacity improvements, safety, and maintenance
	• There is no DOT dashboard—or if there is, traffic level-of-service is not publicly reported on the dashboard
	• Systems operations is not yet recognized as a specific discipline but is done by maintenance or other staff
	• TMCs and safety service patrols (SSP) do not exist—or not in all metro areas and/or not 24/7
		• The value of operations is widely understood in the DOT
		• DOT commitment to operations is clear at the agency level and made public in a policy document that shows it as equally important as construction, safety, and maintenance (such as mobility management)
		• There is a dashboard and operations performance reported as outcomes (reductions in delay due to operations)
		• Systems operations is recognized as a distinct discipline (job specs, training)
		• Incident management and SSP operate 24/7

B. Leadership • Is there a leader or champion of ITS/operations—within the central office or at the district level? • Is the district engineer/administrator held responsible for progress in improving operations?	• There is no champion of ITS and operations in central office (at either the CEO or first-tier division head level) • District administrators/engineers are not champions for operations, nor are they accountable to the central office regarding systems performance	• The CEO is a champion of ITS and operations as evidenced in public statements and memos to staff or • A division head in the central office is the champion • Some or all districts have operations programs • District engineers held accountable for improving operations program in reporting to CEO
C. Authorization • Does the state budget have a formal operations program? • Does the state DOT have the authorities needed for incident management?	• There is not a defined (published) operations program for systems operations at the statewide level • The state does not have a driver move-it law or quick clearance authority	• There is a defined (published) operations program for systems operations at the statewide level • The state has driver move-it law and DOT has quick clearance authority

Table B.1. SHRP 2 L06 Systems Operations State-of-Play State DOT Survey: Questions and Prompts (continued)

Dimensions: General Questions	Indicators as Observed in State DOTs (Bulleted Items Are Prompts for Interviews)	
	L-1: Architecture Supporting Transition from Ad Hoc to Managed (Activities Initiated on Agencywide Basis)	**L-2: Architecture Supporting Transition from Managed to Integrated (Establishment of Integrated Program)**
D. Resource Allocation Process • Is the budget for operations mainstreamed on the same terms as the budgeting for construction and maintenance (needs development, allocations based on need, visible in the normal process)? • Has the central office made slots available to build operations staff?	• There is no statewide plan for operations at the statewide level that indicates specific strategies to be developed • Funding is ad hoc and unpredictable. There is no statewide operations budget. Budget resources for operations are an ad hoc process from year to year, with funds coming out of maintenance and construction budgets, federal earmarks, etc. • Staffing is a problem for lack of slots	• There is an up-to-date document describing the statewide operations program—a statewide systems operations plan (please send) • ITS/operations have a separate multiyear budget (at least for some activities) that is part of the normal agency budgeting process—and visible as a line item (tell me what it is). Operations funds are allocated statewide by central office. • Staffing slots are available to add operations staff to central office and districts
E. Organization • Are previously fragmented activities related to systems operations (ITS, systems, TMCs, traffic engineering) now consolidated with the central office? • Is the responsibility/authority for systems operations a second-, third-, or fourth-tier responsibility within the central office (as compared with the counterpart maintenance and project development/construction responsibility)? • At what level within the district hierarchy is the highest–level, full time operations manager (Assistant DE, deputy assistant DE, or lower)? • Have core capacities for operations staff been formally identified (and job spec'd)?	• Highest level central office manager with 100% SO&M responsibility is two or three levels down from the CEO (and not responsible for maintenance or project development). • Within both central office and districts, ITS, operations, and traffic engineering are separate responsibilities • District level operations activities are the responsibility of a manager two or three levels down from the district engineer/administrator • Core capacities for operations have not been identified, nor job specs developed • Some but not all of the incidents and emergencies at the district level are handled in a TMC	• Highest-level manager with 100% responsibility for operations reports directly to CEO, chief engineer, or COO • Within the central office, operations, traffic engineering, and ITS have been consolidated into systems operations • At district level, there is coordinated planning, budgeting, and maintenance related to ITS/operations under a single manager who reports to the district engineer • Core capacities have been identified in terms of an integrated staff capability for systems operations planning, design, implementation, and maintenance • All regional real-time operations, including emergencies, are handled out of the TMCs
F. Technical Capacities/Processes • Has each major district developed and documented (key) operations for IM, traveler information? • Have statewide standards and existing architectures? • Are procedures and protocols documented for each major SO&M activity (standardized)? • Has technology for communications and field devices been standardized? • Do the major districts report incident clearance times by type? Do any districts report incident first response time?	• Technical expertise rests principally in a few individual champions (without any clear succession) • Operational concepts, procedures, and protocols for incident management, traveler information, and freeway operations are not documented at the district level or standardized by central office • Districts do their own thing regarding selection of technology	• Core capacities have been identified in a document. Job specs, training, and certification exist for key operations positions at central office and districts. • Documented, formal operational concepts exist for all the operations activities • Technology for communications and control devices has been standardized statewide
G. Partnerships (public service agencies, local government, private sector) • Do formal written agreements exist between PSAs and DOT for incident management (for clearance time targets and for on-site and office procedures)? • Where TMC or SSP functions are outsourced, has the concept of performance management been adopted?	• DOT has informal working relationships with police and fire entities—principally at the district level—regarding incident management (not written) • DOT outsources some operations functions (TMC, SSP) but doesn't really have a performance-based contract	• DOT has formal co-training, written agreements with police and fire entities regarding basic incident management procedures and targets • DOT is in its second/third generation of outsourcing some operations functions (TMC, SSP) and has evolved a performance-based contract

AASHTO Subcommittee on Systems Operations and Management (SSOM) Questionnaire

Structure of DOT	
	Provide numerical answers
• Number of districts	
• Number of major metro districts	
• Use of operations unit incorporating more than one district (sometimes called regions)	
• Number of districts/regions with TMCs	

Legacy Culture and Degree of "Mainstreaming" of Systems Operations			
Mark with "X"	**Managed**	*Mark with "X"*	**Integrated**
	The potential service value (leverage) of operations is not widely appreciated in the DOT at senior management level.		The value of operations is widely understood in the DOT.
Comments:			
	Operations is not yet explicitly identified in standard public DOT policy documents as a major DOT mission.		DOT committed in DOT policy/plan documents to operations as equally important as construction, safety, and maintenance.
Comments:			
	DOT and MPO planners have little or no contact with DOT systems operations staff.		Systems Operations and Management (or congestion management) is directly addressed as a need and strategy in the DOT's long-range plan.
Comments:			
	There is some kind of a performance dashboard, but level of service changes (not just volumes) from month to month are not reported.		There is a dashboard and Operations performance reported as outcomes (reductions in delay due to operations).
Comments:			

Leadership—In Central Office and Districts			
Mark with "X"	Managed	Mark with "X"	Integrated
	There is no real champion of ITS and operations in Central Office (at either the CEO or first tier division head level). What tier (indicate below)?		The CEO is a champion of ITS and operations at the top management level, as evidenced in public statements and memos to staff.
Comments:			
	District Administrators/Engineers are not champions for Operations, nor are they accountable to the Central Office regarding systems performance.		District Engineers held accountable for improving Operations program in reporting to CEO.
Comments:			
	DOT Central Office relationships with public safety community are informal—on a personal basis.		DOT has obtained clear legislative authority for incident-related Move It and Quick Clearance—and DOT vehicles are authorized as emergency vehicles (can use shoulders, light).
Comments:			

Resource Allocation Process			
Mark with "X"	Managed	Mark with "X"	Integrated
	Funding is ad hoc and unpredictable. There is no statewide budget and funds are allocated largely at the individual district level from capital and maintenance funds.		ITS/Operations have a separate line item multiyear budget (at least for some activities) that is part of the normal agency budgeting process.
Comments:			
	Lack of funds is a major constraint to improving program as planned.		Staffing is the major constraint to improving/expanding program as planned.
Comments:			

Organizational Structure			
Mark with "X"	Managed	Mark with "X"	Integrated
	Highest-level Central Office manager with 100% SO&M responsibility is two or three levels down from the CEO.		Highest-level manager with 100% responsibility for Operations reports directly to CEO or chief engineer.
Comments:			
	Maintenance and Systems Operations are under single management at the highest or second-highest level in the Central Office and Districts.		Maintenance and Systems Operations are under separate management at the highest or second-highest level in the Central Office and Districts.
Comments:			

	Within both Central Office and Districts, ITS, Operations, and Traffic Engineering are all separate responsibilities.		Within the Central Office, ITS, Operations, and Traffic Engineering have been consolidated into "Systems Operations."
Comments:			
	Systems Operations for incidents, traveler information, and local emergencies are divided between various units within each highway district.		Systems Operations for incidents, traveler information, and local emergencies are all handled in a TMC (where they exist).
Comments:			
	Technical expertise rests principally in a few individual champions.		Core capacities have been identified in a document. Job specs, training, and certification exist for key operations positions at Central Office and Districts.
Comments:			

Program/Project Development Processes			
Mark with "X"	**Managed**	*Mark with "X"*	**Integrated**
	Individual projects at both District and Central Office levels are developed on an ad hoc basis by individual heroes.		A standard project development process for Systems Operations projects has been developed and is used for all major projects.
Comments:			
	Operational concepts, procedures, and protocols for incident management, traveler information, and freeway operations are not documented at the District level or standardized by Central Office.		Documented, formal operational concepts exist for all the Operations activities.
Comments:			
	Districts do their own thing regarding selection of technology.		Technology for key systems platforms has been standardized statewide.
Comments:			
	There is no statewide (business) plan for operations at the statewide level that indicates specific strategies to be developed (resources, staging).		There is an up-to-date document describing the statewide operations program—a statewide Systems Operations plan.
Comments:			
	For Operations activities such as incident management, some output data (number, type, duration) are collected.		For Operations activities such as incident management, some outcome measures (changes in delay) are measured and used for improving procedures.
Comments:			

Partnerships (public service agencies, local government, private sector)				
Mark with "X"	**Managed**	**Mark with "X"**	**Integrated**	
	DOT has informal working relationships with police and fire entities—principally at the District level—regarding incident management (not written).		DOT has formal co-training, written agreements with police and fire entities regarding basic incident management procedures and targets.	
Comments:				
	TMC operations and safety service patrol are performed by agency personnel.		DOT is in its second/third generation of outsourcing some Operations functions (TMC, SSP) and has evolved a performance-based contract.	
Comments:				

Examples of Regional Operations Collaboration

Table D.1. Examples of Regional Operations Collaboration

Name and Location	When Started	Members	Operational Activities
TRANSCOM	1986	• Metropolitan Transportation Authority ○ NYC Transit ○ MTA Bridges and Tunnels • Connecticut Department of Transportation • New Jersey Department of Transportation • New Jersey State Police • New Jersey Transit Corporation • New Jersey Turnpike Authority • New York City Department of Transportation • New York City Police Department • New York State Bridge Authority • New York State Department of Transportation • New York State Police • New York State Thruway Authority • Port Authority of New York and New Jersey • PATH	**Operations Information** • Collects and disseminates real-time regional incident and construction information. • During major incidents, construction, and special events, helps marshal regional resources for incident response, including its member agencies' variable message signs and highway advisory radio. • Provides services under contract to the I-95 Corridor Coalition. **Construction Coordination** • Maintains a long-term database of all construction projects planned or under way **Special Events** • Assists with interagency coordination for special events. **ITS** • TRANSMIT: Vehicles equipped with transponders for electronic toll collection are used as probes on roadways for real-time determination of travel times and speeds and for the detection of incidents. • TRANSCOM Regional Architecture: Integrates member agencies' ITS, allowing for the electronic sharing of information among the agencies' operations centers. • Trips123: Website with real-time information and transit trip planning services for the general public. • Interagency Remote Video Network (IRVN): Enables the sharing of member agencies' CCTV feeds.
TranStar	1993	• The Texas Department of Transportation • Harris County • The Metropolitan Transit Authority of Harris County • The City of Houston	**Incident Management** • Monitors traffic incidents with more than 600 regional closed-circuit television cameras (CCTVs). • Dispatches vehicles to remove debris or hazardous materials. • Communicates with emergency vehicles about the most direct routes to an accident scene. • Motorist Assistance sends tow trucks to stalled vehicles.

Table D.1. Examples of Regional Operations Collaboration (continued)

Name and Location	When Started	Members	Operational Activities
			• Dynamic message signs (DMS). • Synchronized traffic signals, speed sensors. • Highway Advisory Radio. • Ramp meters and other devices. • Transit authority is a partner, and there are HOT lanes, but TranStar does operations on all roads.
Freeway and Arterial System of Transportation (FAST)— Las Vegas	2003	• RTC • Clark County • NDOT • City of Henderson • City of Las Vegas • City of North Las Vegas	• Operates the TMC. • Ramp meters. • DMS. • Signal timing. • Lane-use control signs. • Each entity (e.g., city, county) maintains the physical equipment and power for traffic signals, while FAST is responsible for timing, traffic signal synchronization, and the communication network.
MTC-BATA	1997	• Part of the Metropolitan Transportation Commission (MTC), San Francisco Bay Area	• The Bay Area Toll Authority (BATA) administers programs and allocates all toll and other revenues (except the $1 seismic surcharge) from the seven state-owned toll bridges. BATA funds the day-to-day operations, facilities maintenance, and administration of the bridges.
TSSIP (Denver)	2003	• Denver Regional COG, Colorado DOT, 28 local governments	• Works with the Colorado DOT and local governments to coordinate traffic signals on major roadways in the region. • Facilitates the implementation of a regional vision for transportation operations using both technology and regional partnerships.
NITTEC	1995	• Buffalo and Fort Erie Public Bridge Authority • City of Buffalo • City of Niagara Falls, New York • City of Niagara Falls, Ontario • Erie County • Ministry of Transportation, Ontario • New York State Department of Transportation • New York State Thruway Authority • Niagara County • Niagara Falls Bridge Commission • Niagara Frontier Transportation Authority • The Niagara Parks Commission • Niagara Region • Town of Fort Erie	• Traffic Operations Center (TOC). • Closed-circuit television (CCTV). • Dynamic message signs (DMS). • Highway Advisory Radio (HAR). • TRANSMIT: Gathers vehicle travel time information. • Road Weather Information System (RWIS). • Skyway Closing System: Advanced warning system that alerts motorists to closures on the Buffalo Skyway. • Advanced Traffic Controllers (ATC): Traffic counting stations that transmit real-time traffic information to the TOC.
• FAST-TRAC • Road Commission for Oakland County	1992	• Oakland County, Michigan • Local governments • MDOT	• Operates a TMC. • Website with real-time traffic information. • Traffic signal control in response to congestion. • Special event management. • Maintains a database of road construction projects. • Variable message signs.
CLARUS	Designed 2004–2005; tested 2006	• FHWA • NOAA • A number of states	• Research and development initiative to demonstrate and evaluate the value of Anytime, Anywhere Road Weather Information that is provided by both public agencies and the private weather enterprise to the breadth of transportation users and operators.

Table D.1. Examples of Regional Operations Collaboration (continued)

Name and Location	When Started	Members	Operational Activities
AZTech	1996	• Led by the Maricopa County Department of Transportation and Arizona DOT—more than 75 public and private agencies • Arizona DOT • Arizona Department of Public Safety • Arizona State University • Maricopa County • Valley Metro • Phoenix • Mesa • Glendale • Peoria • Scottsdale • Eight other cities or towns, local police, and fire departments.	• AZTech supports the following efforts along with its public and private partners: • Traveler Information at the Phoenix Sky Harbor International Airport. • Regional Emergency Response Team (REACT): Focuses on incidents on arterials. • When an incident occurs, one incident commander from each agency reports to the command post. The command post will then implement the correct plan of action. • Phoenix International Raceway (PIR) Special Event Management. • Coordinate between TMCs so all use the same communication protocols and can easily share information.

Example of Change Management Program for a State DOT

Table E.1. *Example of Change Management Program for a State DOT*

Agency Self-Evaluation-Based Issues/Needs	Related Maturity Framework Strategies	Implementation Responsibility
Agencywide goals and objectives do not clearly identify systems operations and management as core program with related strategies.	*Strategy:* Revise agency goals and objectives to clearly prioritize system operations as leading service strategy.	
	Immediate Action Priorities	
	Update/clarify statewide mission, goals, objectives, and related performance measures applicable to all programs. Make business case for systems operations as a core program.	Draft by Operations Division with regions for top management consideration
	Systematic identification of statewide baseline customer service improvement opportunities (safety, mobility, security) and potential benefits and incremental strategies for meeting those needs—as a framework for regional planning.	Operations Division with regions (via Statewide Operations Strategic Plan and regional plans)
Performance needs to be continuously measured.	*Strategy:* Develop program for performance measurement for all system operations applications sufficient for use in measuring enhanced application strategy effectiveness, improving programs, and supporting accountability (internally and externally).	
	Immediate Action Priorities	
	Identify standard short-term surrogate measures (output and event data) that can be used to improve effectiveness of systems operations strategies until outcome measures (travel time) become available.	Operations Division with regions
	Determine the small set of robust performance measures (outputs and outcomes) and data collection needs to be used statewide to improve operations procedures, internal investment decisions, and accountability, and for external traveler information systems.	Operations Division with regions
	Introduce accountability process for assessing the effectiveness of operations activities between top management and those who control resources in Central Office and regions/districts.	System Operations Directorate with top management
	Develop program to implement use of performance data directly in planning and in fine-tuning strategy applications (after action analysis).	Operations Division with regions

(continued on next page)

Table E.1. Example of Change Management Program for a State DOT (continued)

Agency Self-Evaluation-Based Issues/Needs	Related Maturity Framework Strategies	Implementation Responsibility
	Additional Steps to Advanced Capabilities	
	Establish process to incorporate performance measurement into standards as statewide traffic data on travel conditions become available.	Operations Division with regions
	Develop approach for objective evaluation of ITS/operations projects, both to identify cost-effective improvements and to compare with other nonoperations investments.	Operations Division with regions
	Identify strategy to involve partners routinely in use of performance measurement as part of after-action analyses and strategy applications improvements.	Operations Division with regions
	Develop a statewide monitoring system to assemble and make available real-time regional and statewide systems information (such as travel time, weather, and incidents) for reporting, coordination, and archiving for use in analysis and accountability.	Operations Division with regions
	Expand performance monitoring and reporting beyond interstate system in key corridors.	Operations Division with regions and MPOs
Lack of clarity on where and to whom district/regions should go in Central Office for guidance, support, and assistance. The functional relationships among district level SO&M and related traffic engineering and maintenance responsibilities unclear with regard to district-level operations.	***Strategy:*** Organizational structure tailored to operations efficiency with authority levels appropriate to core program.	
	Immediate Action Priorities	
	Clarify regional functions, roles, responsibilities, and accountability—technical and administrative—to support the evolving role of regions as service centers.	Systems Operations Directorate
	Reduce inefficient fragmentation and improve alignment of roles, responsibilities, authority in Central Office (Operations Division, Traffic Engineering, and Security) and in regions.	Systems Operations Directorate and top-level management
	Additional Steps to Advanced Capabilities	
	Establish regions as service centers with TMCs as regional/district operational focus and command posts (TOCs).	Operations Division with regions
	Consolidate statewide incident management and emergency operations activities in Central Office (Emergency Response and Field Operations).	Operations Division
Shortage of qualified systems operations technical expertise and no effective process for developing that expertise.	***Strategy:*** Develop statewide position specifications, staffing, succession plans, and career incentives.	
	Immediate Action Priorities	
	Establish career path concepts and position descriptions for operations and develop mentoring activities and performance incentives for operations staff.	Systems Operations Directorate with regions
	Determine core capacities (KSAs) needed in Central Office and the regions and develop uniform position descriptions, potential training needs, and recruitment and retention measures.	Systems Operations Directorate with regions
	Expand program for technical training (management and technical) beyond emergency and incident management to the full range of operations functions. Includes an in-house "operations academy."	Systems Operations Directorate with regions
Inadequate project definition and a lack of standards in the ITS project development process—including contracting and procurement support—are major burdens on regions.	***Strategy:*** Identify, develop, and document standardized and integrated project development process.	
	Immediate Action Priority	
	Develop and document an appropriate project development process—i.e., appropriate to typical systems operations projects—proceeding from commitment to budgeted projects through procurement, deployment. Should build on existing documented Agency Project Development Process.	Operations Division with regions and support from ASD and Scheduling and Contract Division

Table E.1. Example of Change Management Program for a State DOT (continued)

Agency Self-Evaluation-Based Issues/Needs	Related Maturity Framework Strategies	Implementation Responsibility
State government-wide procurement and information systems guidelines and requirements inappropriate to ITS projects.	Conduct analysis of procurement options available; review model processes employed by other DOTs and NCHRP 3-77, ITS Procurement Guidelines. Determine areas where revisions and simplifications are needed.	Systems Operations Directorate
The value/role of ITS in operations and maintenance is not adequately understood by many in agency's administration/construction arena. The life-cycle cost implications of ITS are not well-recognized in the budgeting process.	*Strategy:* Integrate systems operations ITS infrastructure improvements into other construction/maintenance projects through consideration in their development process.	
	Immediate Action Priorities	
	Refine the process for including systems operations measures in construction/maintenance projects by clarifying input of both traffic engineering and other work zone traffic measures into the Agency Project Development Process—consistent with the recent Federal Rule on Work Zone Safety and Mobility.	Systems Operations Directorate and districts
	Explicitly address ITS upgrading and maintenance in long-term budgeting.	
No consistent policy on the role and type of outsourcing regarding costs and retention of core capacity. The roles and relationships among the various outsourcing contractors, agency, and the PSA community are not clearly defined.	*Strategy:* High level of formal systems operations coordination among agency, PSAs, and private service providers.	
	Immediate Action Priority	
	Identify issues and options in refined/rescoped approach to out-sourcing TMCs, safety service patrol, and asset management to meet overall agency technical, staffing, and management objectives regarding staffing levels and core-capacity retention.	Operations Division with regions
	Additional Steps to Advanced Capabilities	
	Conduct broad comparison across a range of issues—including cost, staffing limitations, flexibility, performance management, access to technology, etc. Refine/rescope approach to outsourcing in terms of contracting procedures, performance management, and time frame of contracts.	Systems Operations Directorate
	Review business model for agency future role and related core capacities and liabilities regarding type and extent of in-house versus outsourced responsibilities.	Top-level management policy
Dedicated, committed sources of funding are needed so that districts (regions) can prioritize and plan. Budget allocation process for SO&M capital, operating, and maintenance is unclear, hampering development of regional SO&M programs.	*Strategy:* Identify, develop, and document standardized and integrated programming, budgeting, and resource allocation processes.	
	Immediate Action Priorities	
	Establish system operations as a top-level agency budget line item to be treated administratively in a manner equivalent to other major budget categories.	Top-level management policy
	Develop and standardize transparent and criteria-driven budgeting and resource allocation process for systems operations, involving districts, regions, and Central Office perspectives in regional budget development.	Top-level management policy
	Develop a statewide plan for ITS and systems operations that combines a rollup of regional plans with statewide special systems needs. These should include mid- and long-term needs-based estimates of resource requirements to upgrade the program to acceptable service standards.	Operations Division based on regional plans and statewide programs

Table E.1. Example of Change Management Program for a State DOT (continued)

Agency Self-Evaluation-Based Issues/Needs	Related Maturity Framework Strategies	Implementation Responsibility
	Additional Steps to Advanced Capabilities	
	Include operations infrastructure needs in maintenance budgeting at the statewide and regional levels.	Systems Operations Directorate
	Ensure that resource allocation accounts for special legacy maintenance burden, megaprojects, and issues of donor–donee districts.	Task force to develop standardized approach
	Develop and standardize process for incorporation of ITS into highway projects.	Task force to develop process

Related SHRP 2 Research

Integrating Business Processes to Improve Travel Time Reliability (L01)

Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes (L05)

Evaluating Alternative Operations Strategies to Improve Travel Time Reliability (L11)

Improving Traffic Incident Scene Management (L12)

A Framework for Improving Travel Time Reliability (L17)