



# TRAFFIC OPERATIONS ASSET MANAGEMENT SYSTEMS (TOAMS)

PART 1: STUDY FINDINGS

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# Table of Contents

Chapter 1 INTRODUCTION.....	1
MOTIVATION AND OBJECTIVES.....	1
Motivation.....	1
Objectives .....	1
DESCRIPTION AND METHODOLOGY.....	2
Project Description.....	2
Terminology.....	2
Methodology .....	2
ORGANIZATION OF THIS REPORT.....	3
 Chapter 2 BACKGROUND AND LITERATURE REVIEW.....	5
INTRODUCTION .....	5
BACKGROUND .....	5
Traffic Operations.....	6
Traffic Operations Asset.....	6
Asset Management.....	7
LITERATURE REVIEW .....	9
Integrating Operations and Planning .....	9
Obsolescence Planning .....	12
Operations Asset Management .....	12
SUMMARY .....	14
 Chapter 3 TOAMS SURVEY RESULTS.....	17
INTRODUCTION .....	17
SURVEY RESULTS .....	18
Traffic Operations Assets Implementation.....	18
Formal Procedures for TOAM.....	16
TOA Management Data.....	21
TOA Maintenance Policies.....	24
TOA Assessment Methods .....	27
The Use of TOA for Level of Service Monitoring .....	29
Issues and Priorities .....	30
OBSERVATIONS .....	34
 Chapter 4 FRAMING THE NEXT GENERATION OF TOAMS.....	37
INTRODUCTION .....	37
OBsolescence PLANNING .....	41
SOFTWARE SYSTEMS .....	42
MAINTENANCE CONTRACTING AND LABOR EXPERTISE .....	44

## Table of Contents

Chapter 5 SUMMARY AND RECOMMENDATIONS .....	47
SUMMARY .....	47
1. Connecting investment and performance. ....	47
2. Improving configuration planning.....	47
3. Promoting public-private partnerships (PPPs) .....	47
RECOMMENDATIONS .....	48
1. Develop maintenance procedure standards including maintenance contracting. ....	48
2. Develop configuration standards.....	48
3. Develop a traffic operations guide under the auspices of AASHTO .....	48
4. Forecast technological advancement and analyze possible impacts .....	48
5. Improve the implementation of analytical procedures .....	49
6. Explore comparable industries in the management of traffic operations asset ...	49

## List of Appendix

### Appendix A Survey questionnaire

## List of Figures

- Figure 2.1** Generic Asset Management Components (FHWA, 1999)
- Figure 2.2** Planning and Operations as Separate Processes (NCHRP, 2002)
- Figure 2.3** Scope of Linking Planning and Operations (FHWA, 2004d)
- Figure 2.4** Traditional Operations and Planning versus ITS (NCHRP, 2002)
- Figure 2.5** Operations Asset Components (FHWA, 2004b)
- Figure 3.1** Geographic Distribution of Respondents
- Figure 4.1** General Planning Framework
- Figure 4.2** Traffic Operations Life Cycle
- Figure 4.3** System Engineering “V” Diagram (Office of Operations, FHWA)
- Figure 4.4** System Architectures on SSAM Systems (FHWA, 2004a)

## List of Tables

- Table 3.1** Use of Software for TOAMS by State Agency
- Table 3.2** Rate of Importance for Proprietary TOAMS Software to State Agencies
- Table 3.3** Rate of Importance for In-House TOAMS Software to State Agencies
- Table 3.4** TOA Application by State
- Table 3.5** Frequency of TOA Uses by State
- Table 3.6** Formal Procedures for Managing TOA Device
- Table 3.7** Formal Procedures for Managing TOA System
- Table 3.8** TOA Management Data
- Table 3.9** TOA Maintenance Policies
- Table 3.10** TOA Assessment Methods
- Table 3.11** The Use of TOA for Level of Service Monitoring
- Table 3.12** Importance of TOAMS Operational Issues
- Table 3.13** Importance of TOAMS Initiatives
- Table 3.14** Preferences indicated by State Transportation Agencies on TOAMS
- Table 4.1** Group Interactions within TOAMS Activities

## List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
CCTV	Closed-Circuit Television
CVISN	Commercial Vehicle Information Systems and Networks
DOT	Department of Transportation
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
HOV	High Occupancy Vehicle
IT	Information Technology
ITS	Intelligent Transportation Systems
LOS	Level of Service
MRUTC	Midwest Regional University Transportation Center
NCHRP	National Cooperative Highway Research Program
OS	Operating Systems
PPPs	Public-Private Partnerships
RWIS	Road Weather Information Systems
SAFETEA-LU	Safe, Accountable, Flexible, Efficient transportation Equity Act: A Legacy for Users (SAFETEA-LU)
SSAM	Signal Systems Asset Management
TMC	Traffic Management Center
TOA	Traffic Operations Asset
TOAM	Traffic Operations Asset Management
TOAMS	Traffic Operations Asset Management Systems
TSM&O	Transportation System Management and Operations
VMS	Variable Message Sign
WisDOT	Wisconsin Department of Transportation

## Executive Summary

Asset management principles have been increasingly adopted by transportation agencies to identify various investment strategies and optimize the expenditure of public funds. A large percentage of transportation budgets are targeted toward the construction and maintenance of pavements and bridges. Based on this financial commitment, management systems for pavements and bridges have been developed and widely adopted throughout the United States and elsewhere.

To improve the safety and efficiency of transportation systems, public agencies are striving to enhance the operations components of their roadway networks. States have deployed emerging Intelligent Transportation Systems (ITS) and other traffic operations technologies and now recognize the need for up-to-date asset management tools and strategies. Management systems for transportation operations, though, have not been developed or implemented as extensively as management systems for pavements and bridges.

The efforts in promoting traffic operations asset management systems (TOAMS) face significant difficulties. Two fundamental reasons explain this situation. First, asset management principles have been continuously developed based on traditional transportation assets of pavements and bridges. Traffic operations assets (TOAs), on the other hand, have different characteristics with greater uncertainties when determining assets' life-cycle. As a result, asset management principles will need some fundamental adjustments when implemented for TOAMS.

Second, the integration of two culturally different activities, operations and planning, creates immense confusions among practitioners. This is especially crucial when addressing analytical tools compatibility, scope of analysis (local vs. regional), and limited training received by planning practitioners about operations and vice versa.

This study categorizes three key themes on critical issues related to TOAMS:

- *Connecting investment and performance.* The lack of a measurable indicator in current system management for TOAs causes a weak link between investment strategies and systems performance. A justifiable investment strategy is critical, however, it requires a complete data inventory for developing a robust performance indicator as the basis of performance's assessment.
- *Improving configuration planning.* Information management is critical especially related to how information is used and reproduced during planning processes. Current confusions among practitioners are on what roles and how they should communicate with each other in the context of TOAMS. Responsibilities of each group are not clearly defined resulting improper executions of traffic operations tasks. It is critical to enhance the collaboration among groups involved within TOAMS activities.
- *Promoting public-private partnerships (PPPs).* Guidelines in implementing PPPs are widely available, including a number of concerns to be anticipated. However,

part of the efforts should include documenting state best practices in transportation management, which current discussions on PPPs are limited found. This causes only a few lessons could be learned from other states transportation agencies in how PPPs were implemented. A special attention should also be given on the implementation of PPPs in the area of traffic operations since it is relatively new in the area of traffic operations traffic operations.

# Chapter 1 INTRODUCTION

This document is the final report for project 08-14 sponsored by the Midwest Regional University Transportation Center (MRUTC). The project consists of developing a framework for Traffic Operations Asset Management Systems (TOAMS) to provide support for investments in preservation and improvement of traffic operations assets (TOA). In the remainder of this section, research team presents the motivation for this work and the objectives of the study. An overview of the tasks for the project and an outline for the remainder of the report are presented.

## ***MOTIVATION AND OBJECTIVES***

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### **Motivation**

Asset management principles have been increasingly adopted by transportation agencies to identify various investment strategies and optimize the expenditure of public funds. A large percentage of transportation budgets are targeted toward the construction and maintenance of pavements and bridges. Based on this financial commitment, management systems for pavements and bridges have been developed and widely adopted throughout the United States and elsewhere.

To improve the safety and efficiency of transportation systems, public agencies are striving to enhance the operations components of their roadway networks. States have deployed emerging Intelligent Transportation Systems (ITS) and other traffic operations technologies and now recognize the need for up-to-date asset management tools and strategies. Management systems for transportation operations, though, have not been developed or implemented as extensively as management systems for pavements and bridges.

### **Objectives**

This report provides a comprehensive analysis of the framework for TOAMS. National efforts are described in this report to support effective TOAMS. In general, the objectives of this report are to present survey results, assessment, and gap analysis of existing operations asset management systems in the United States; to deliver a summary of a national peer exchange to developing a framework for alternative concepts and partners; to analyze the topic areas based on the information gathered and discussions at the peer exchange; and to select concepts for preferred businesses and information technology (IT) models for TOAMS.

## ***DESCRIPTION AND METHODOLOGY***

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### **Project Description**

The scope of the project includes an assessment of current asset management systems for operations infrastructure including ITS, traffic signalization, and associated network and information architecture. The research effort brings together transportation professionals to discuss and advance the state of the practice for traffic operations asset management. The project will culminate with a recommendation of concepts leading to development of a next generation TOAMS. The information will be used to formulate a phase II proposal to create and administer a multi-state pooled-fund pilot of TOAMS.

### **Terminology**

TOA is defined as a transportation infrastructure that is more active and more dynamic than traditional transportation facilities. Unlike pavement and bridge infrastructures, TOA—such as signs, signals, and ITS devices—respond and control current traffic conditions. TOA are tangible and intangible components—for example communication links, networks, servers, fiber optics, data, and software—that require a different set of technical expertise.

Traffic Operations Asset Management Systems (TOAMS) is therefore a systematic process of maintaining, upgrading, and operating physical assets of ITS devices and other traffic operations hardware and systems. This system management combines a number of approaches (engineering, business management, and economic) and the latest computer-aided technology.

### **Methodology**

The process for identifying framework for TOAMS involved several steps. The first step required that current TOAMS practices at state transportation agencies be assessed. A total of 33 participants from 16 states responded to an online survey. In addition, the survey also gauged areas of interest and potential participants in the peer exchange.

The second step was to plan a peer exchange. Topic areas to be discussed in the peer exchange were agreed upon, based on preliminary results from the survey as well as conversations throughout a number of teleconferences held by the planning committee. The four topic areas were obsolescence planning, software systems, maintenance contracting and labor expertise. A total of 25 people—from 10 state Department of Transportation (DOTs), American Association of State Highway and Transportation Officials (AASHTO), and the University of Wisconsin at Madison—gathered for the peer exchange, where key themes for further analysis and refinement were identified.

The third step was to further analyze and refine three key themes that emerged during the peer exchange: connecting investment and performance; improving planning process; and promoting public-private partnerships.

The fourth step was to select preferred business and information technology (IT) models for TOAMS.

Finally, a proposal for a phase II effort to create and administer a multi-state pooled-fund pilot of a new generation TOAMS was formulated.

## ***ORGANIZATION OF THIS REPORT***

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Following information provided in previous sections, and for further development of TOAMS framework, chapter 2 presents and defines a set of essential terms for TOAMS. In addition, the chapter reviews some background information including existing literatures in the topic area. Clear and commonly understood definitions of terms like features and characteristics are essential for effective communication.

The other chapters in this report present results of research steps discussed in the methodology section. Chapter 3 provides a synthesis of the current-state-of-practices for managing TOA, based on results of an online survey to state transportation agencies.

Chapter 4 presents an overall picture of the state of practice and the common themes identified from program to program. The chapter also covers information gathered during the national peer exchange in April 2008 in Milwaukee.

Chapter 5 provides summary and recommendations for next steps in the development of framework for TOAMS.



## **Chapter 2 BACKGROUND AND LITERATURE REVIEW**

### ***INTRODUCTION***

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On August 10, 2005 President Bush signed into law the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). This new law establishes extensive new resources and opportunities to advance investments in transportation throughout the country including the area of traffic operations. Comprehensive and strategic investments for traffic operations need to be made in delivering cost-effective congestion management as well as ITS deployment to ensure public accessibility and public mobility.

With more funding available to advance the area of traffic operations, a number of implications on management and operations were assessed. SAFETEA-LU creates opportunities for states to provide managed lanes such as High Occupancy Vehicle (HOV) facilities in advancing congestion management. The law also indicates the needs for Real-Time System Management Information Program for both monitoring traffic conditions and sharing information, which includes ITS Commercial Vehicle Information Systems and Networks (CVISN). With this information system, it is expected that traffic congestion is eased, responses to severe weather and accidents are improved, and security is enhanced. In addition, the law identifies the needs for a strong ITS Research and Development program to support the efficient and effective ITS deployment. In addressing a number of traffic operations devices and systems in place, SAFETEA-LU signifies their interoperability (Office of Transportation Management, Office of Operations, FHWA, 2005).

These advancements will lead to more complex of traffic operations assets consisting of physical, systems, and personnel components. Consequently, systematic fact-based tools and processes to produce the information needed by decision makers to effectively allocate these traffic operations assets are crucial. The need for a management system for traffic operations is now recognized; the systems have been widely adopted for pavements and bridges. The system is not only for effective management of traffic operations assets but also for effective performance with other transportation infrastructures to produce the information identifying the right mix of resource allocations. Further, this will allow transportation professionals to maintain, upgrade or replace assets that contribute to reaching transportation system performance goals (Office of Operations, FHWA, 2004).

### ***BACKGROUND***

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A few common terminologies are used to standardize the discussion in this study. The following sections deliver background information on traffic operations, traffic operations assets, asset management, and traffic operation asset management.

## Traffic Operations

There is not any single professionally-defined terminology for *traffic operations*. A dictionary-based definition taken from *Encarta* and a definition for *transportation operations* – the terminology is used interchangeably with *traffic operations* – is suggested as follow (FHWA, 2005):

controlling of organized activities: the supervising, monitoring, and coordination of activities of a transportation network.

## Traffic Operations Asset

TOAs are part of transportation infrastructure. However, a broad range discussion on transportation infrastructure concentrates on issues of construction and rehabilitation of pavements and bridges. In term of characteristics, 6 basic characteristics of TOA relative to pavements and bridges are identified (FHWA, 2005):

- *Considerably Shorter Service Lives* – bridges lasts between 75 and 100 years, while pavement structures last between 40 and 60 years, with surface replacements required every 10 to 15 years;
- *Lower Replacement Costs* – cost to replace TOA is relatively lower than costs to reconstruct a road or replace a bridge are;
- *More Dynamic in Nature* – unlike pavement and bridges that are static entities, TOA is more dynamic and, thus, requires ongoing monitoring and adjustments;
- *Higher Incidence of Failure* – a failure on a traffic operations system can cause a network of, for example, signals to stop working;
- *Both Tangible and Intangible Components* – Signal assets include communication links, software, fiber optics, data, and networks to connect and control electronic components; and
- *More System-Wide Interdependencies* – decisions about signal systems must consider interrelationships across different system components to address issues such as timing coordination and compatibility issues of the equipment.

Asset management systems are based on quality information to support fact-based decision making tied to performance. Thus, pavements and bridges share with TOA on the needs of assets inventory (location or characteristics), condition information including reported problems, work history activities including maintenance records, cost and performance model parameters, and staff availability. Despite these shared needs, a number of basic differences on TOA data and information characteristics relative to pavements and bridges are identified as follow (FHWA, 2004a):

- Inventory data is more heterogeneous, covering distinct sets of information for intersections, different types of equipment, and systems components,
- Information about the characteristics of materials or components used and systems—model numbers, serial numbers, vendor information, and functional specifications as opposed to materials composition, design and structural properties,

- Greater emphasis on recording work activities performed and needs identified than condition tracking over time,
- Real-time information on performance status and failure,
- Greater scope of interdependencies across different system and subsystem components—if one is replaced, do the others also need replacement? and
- More detailed information of traffic characteristics (e.g., turning movements, speeds, variations in traffic by time-of-day, day-of-week, and season) and changes in these characteristics over time for selecting appropriate control strategies and determining detailed operating parameters.

The discussions on the characters of TOA as well as data and information collected lead to a definition of TOA as transportation infrastructures that are more active and more dynamic. Further, TOA (such as signs, signals, and ITS devices) respond to and control current traffic conditions. They involve tangible and intangible components (for example communication links, networks, servers, fiber optics, data, and software version), which require specialized technical expertise.

## **Asset Management**

Despite the fact that transportation asset management has been widely adopted in pavements and bridges, there are still a number of different definitions used. The following asset management definition is used for the purpose of this report:

Asset management is a systematic process of operating, maintaining, and upgrading physical assets cost-effectively. It combines engineering and mathematical analyses with sound business practice and economic theory. Asset management systems are goal-driven and, like the traditional planning process, include components for data collection, strategy evaluation, program selection, and feedback. The asset management model explicitly addresses integration of decisions made across all program areas. Its purpose is to maximize benefits of a transportation program to its customers and users, based on well-defined goals within available resources (FHWA, 1999).

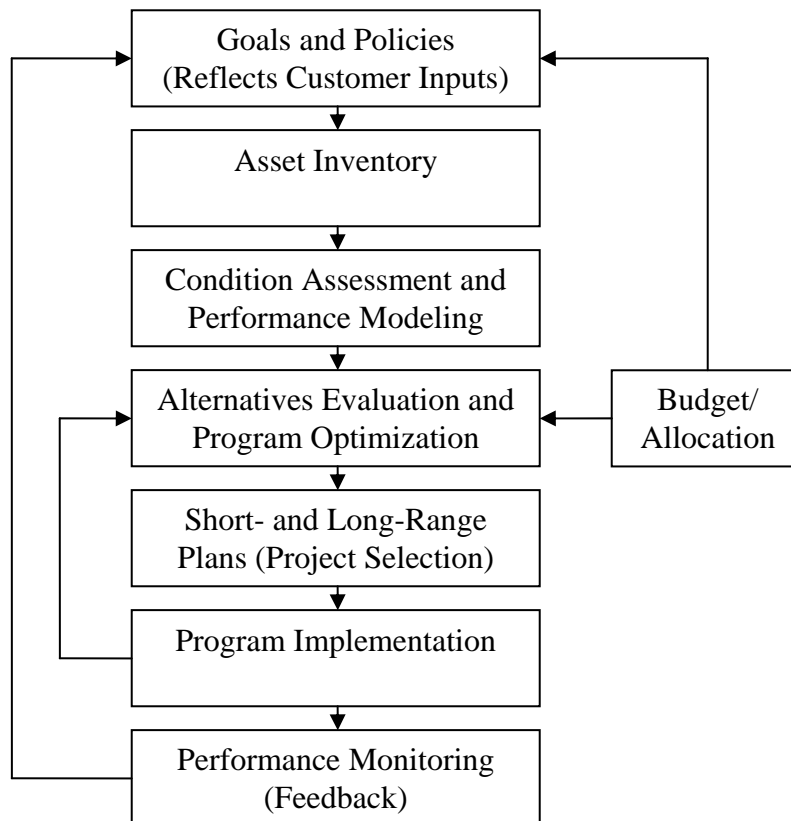
The asset management guiding principles are (FHWA, 1999):

- Customer focused
- Mission driven
- System oriented
- Long-term in outlook
- Accessible and user friendly
- Flexible

Further, an asset management system should also include (FHWA, 1999):

- Strategic goals
- Inventory of assets (physical and human resources)
- Valuation of assets
- Quantitative condition and performance measures
- Measures of how well strategic goals are being met
- Usage information
- Performance-prediction capabilities
- Relational databases to integrate individual management system
- Consideration of qualitative issues
- Links to the budget process
- Engineering and economic analysis tools
- Useful outputs, effectively presented
- Continuous feedback procedures

The generic framework for asset management systems has been widely adopted for transportation infrastructure management (Figure 2.1).



**Figure 2.1** Generic Asset Management Components (FHWA, 1999)

# LITERATURE REVIEW

## Integrating Operations and Planning

Operations and Planning have been traditionally two different systems that work independently, with different cultures and different requirements. On one hand, operations have been procedure oriented (NCHRP, 2002) with a short-range travel demand analysis or real-time focus, and limited consideration on overall regional transportation system goals and objectives (FHWA, 2004d). On the other hand, planning has been project oriented (NCHRP, 2002), focuses on infrastructure projects and a long-range travel demand analysis, including funding constraints (FHWA, 2004d). These two different activities have been conducted as parallel processes with little interaction. They are housed in two separate institutions, conducted with different time horizons with different set of goals and measurement criterion (NCHRP, 2002) (Figure 2.2). Despite the gaps occur in the area of communications, perspective, and cooperation (NCHRP, 2002), they share the goal of enhancing system performance (FHWA, 2004d).

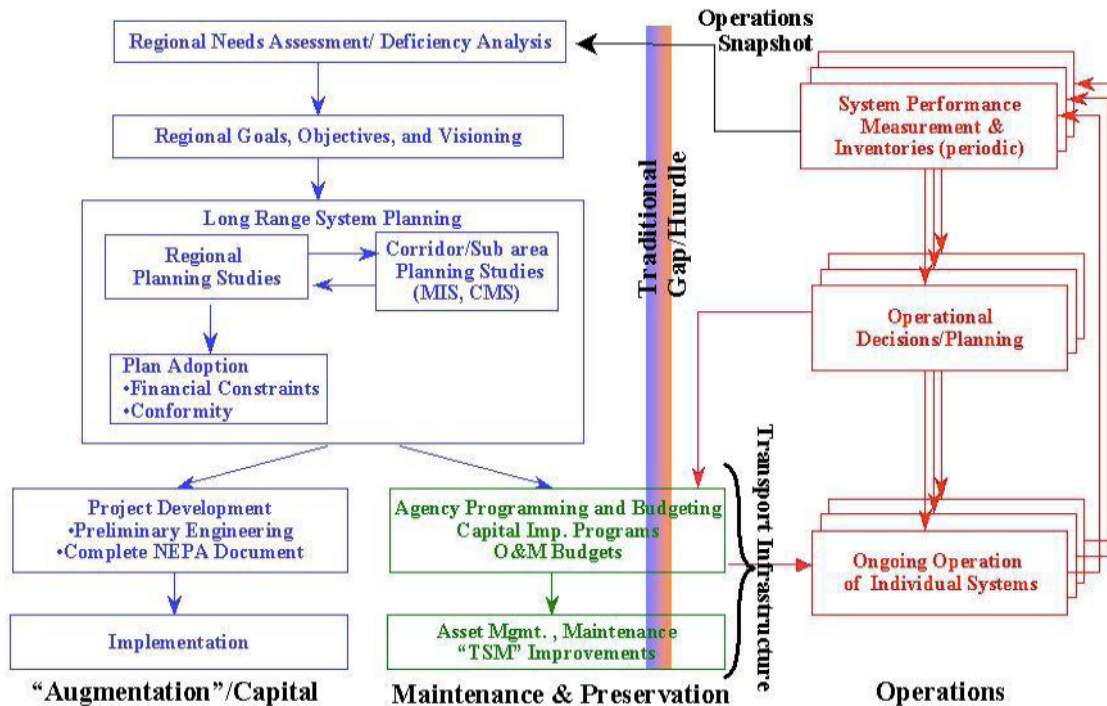


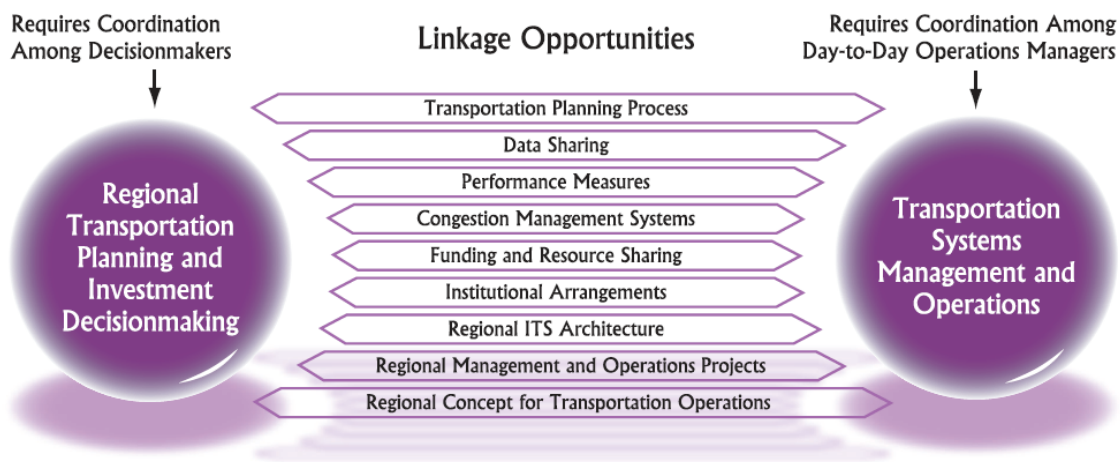
Figure 2.2 Planning and Operations as Separate Processes (NCHRP, 2002)

Dramatic changes have occurred since the traditional transportation planning process was developed decades ago. In particular, changes in the environment and concerns within which transportation decisions are made (NCHRP, 2002). Congestion has been a central issue in the transportation systems, yet becomes more challenging to mitigate. The attempt in integrating transportation planning and operations becomes more feasible to help ensure that regional transportation investment decisions reflect full consideration of all available strategies and approaches to meet regional goals and objectives (FHWA,

2004d). In addition, the coordination between planners and operators will effectively address issues such as (NCHRP, 2002):

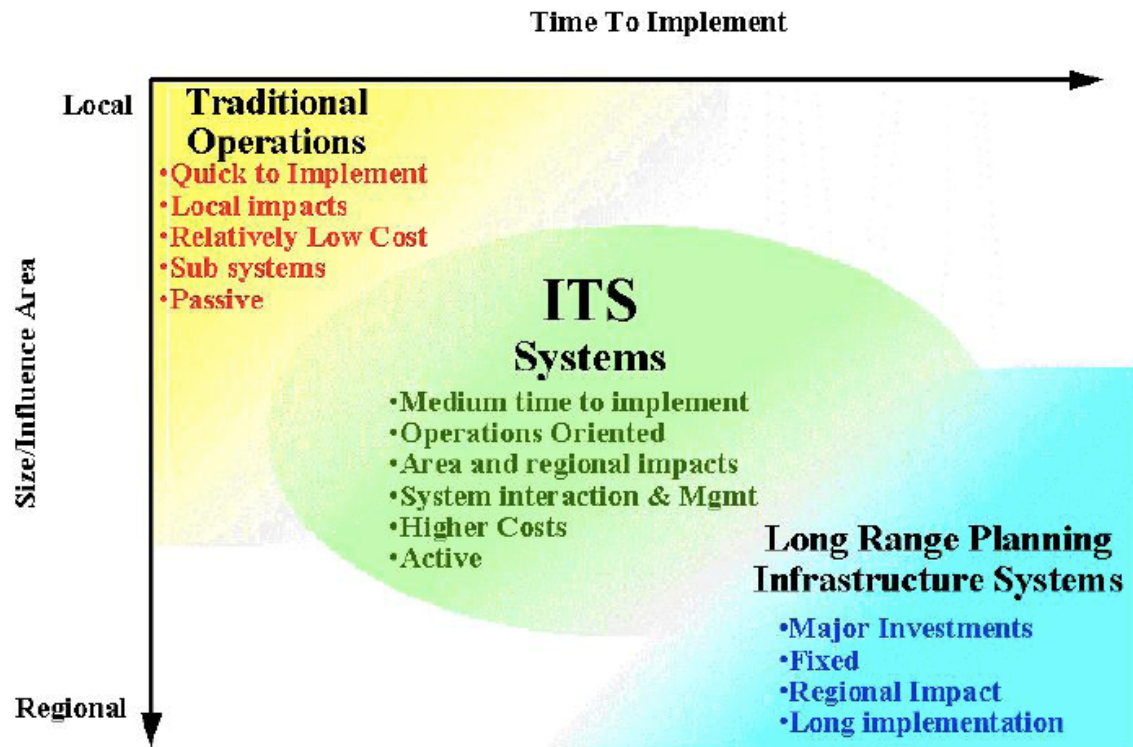
- *Growing and changing transportation demand.* Expanding capacity of our transportation infrastructure is no longer effective due to certain limits such as funding, rights-of-way availability, and environmental concerns.
- *Growing impacts of disruption.* Transportation infrastructure becomes more fragile and subject to break down, resulting incidents and other inevitable disruption.
- *Changing concerns of decision-makers and the public.* There is increasing needs to make government more effective, therefore, small incremental changes are desirable than massive and disruptive investments for new infrastructure. Planners are charged with helping decision-makers reach informed short-term decision while preserving options for the long-term.
- *New service attributes required.* Public have higher expectations due to service orientation of the U.S. economy.
- *Private sectors entry into transportation services.* The increasing transportation-related products or services offered by private sectors needs to be incorporated into the transportation decision-making process.

SAFETEA-LU indicates that transportation system management and operations (TSM&O) should be advanced. On one hand, an effective regional management and operations requires collaboration and coordination of all related agencies and across jurisdictions in order to improve the security, safety, and reliability of transportation systems (FHWA, 2004d). On the other hand, regional transportation planning and investment decision-making also requires coordination and collaboration among state or local agencies including general public (FHWA, 2004d). That is, linking planning and operations will facilitate these needs, and exploit a number of opportunities through greater coordination and collaboration (Figure 2.3).



**Figure 2.3** Scope of Linking Planning and Operations (FHWA, 2004d)

ITS plays a significant role in linking planning and operations. The deployment of ITS begins to alter the unique characteristics of decision in operations, for example its system-wide implementation and elements that serves overall systems (NCHRP, 2002). Although ITS components have much longer planning cycle than traditional operations components, they are very different from the traditional planning that focuses on long-term service improvements, such as peak congestion and major infrastructure investments (NCHRP, 2002).



**Figure 2.4** Traditional Operations and Planning versus ITS (NCHRP, 2002)

Despite the benefits discussed earlier, a number of challenges are identified that possibly occur during the process of linking planning and operations, such as (FHWA 2004d):

- Most analysis tools are oriented toward calculating benefits of major infrastructure investment not operations. Therefore, it is difficult to demonstrate the benefits of making investment in the area of operations.
- Pre-dominant perception that operations are local, not regional, has discouraged local officials to discuss in a regional level.
- Lack of training among planning staffs about operations activities as well as operations staffs about planning activities
- Limited funding to pay for capital needs of major infrastructure may cause delay in funding for operational programs and strategies. Similarly, limited funding available to fund ongoing operations.

## **Obsolescence Planning**

Considering current innovations in technology as well as changing economic condition, infrastructure obsolescence is most likely to happen (Lemer, 1996). Obsolescence is a condition where an infrastructure is no longer able to meet changing expectations (Lemer, 1996). Planning for obsolescence is about addressing concerns in how long should infrastructure be functioning, however, there is no direct answer for an explanation. There are four factors causing an obsolete condition: technological, regulatory, economic, and values or behavioral changes (Lemer, 1996). Further discussion on these factors will be provided later in chapter 4.

Service life (the time for infrastructure to be used) is normally assumed when designing a plan for infrastructure, instead of physical life (the time for infrastructure to fail). Infrastructure tends to fail sooner than the actual physical life, thus, predicting physical life may mislead the infrastructure analysis. In regard to planning for obsolescence, service life is useful when making investment decision (Lemer 1996).

There are four strategies can be pursued for obsolescence mitigation (Lemer, 1996):

- Provide flexibility in an infrastructure plan or design to respond the driving factors
- Minimize the uncertainties of an infrastructure in meeting the expected performance
- Monitor performance for necessary adjustment to be made
- Refurbish and retrofit early to accommodate change

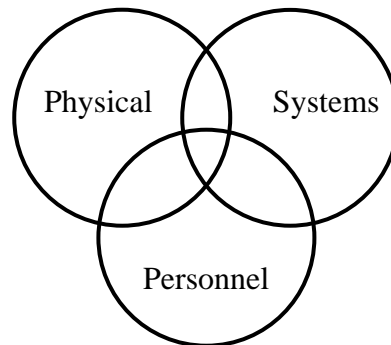
## **Operations Asset Management**

The effort in implementing asset management principles to traffic operations is relatively new. The needs were recognized by the FHWA's Office of Operations and Office of Asset Management, which have collaborated in developing the analytical and procedural foundation for managing operations assets. The primary challenge is that goals and objectives used for TOA performance measures are inefficiently linked to decision makers during resource allocation processes (FHWA, 2004a). In order to promote strategic resource allocations leading to sound transportation investment, holistic approaches are identified (FHWA, 2004b):

- Associated goals and objectives
- Linkages between goals, objectives, and performance
- Trade-offs between alternative improvements
- Engineering and economic evaluation results
- Impacts of varying asset life cycle and investment cycle time horizons

A new dimension of asset management, particularly for operations assets, is identified, which consists of three key components. These components are *physical* (the specific physical assets that make up a system), *systems* (hardware, software, communications infrastructure that connects and controls the systems), and *personnel* (the staff resources available for operating and maintaining the assets/systems) (Figure 2.5) (FHWA, 2004b). The new dimension facilitates the creation of a sound transportation investment made by strategically selecting investment scenarios keying to capabilities and performance of operations assets (FHWA, 2004b, 2004c). Further, the new dimension eases the integration of TOA and other transportation infrastructure assets in searching the most efficient resource allocation. Therefore, in order to adopt the operations asset management practices by operation professionals, all efforts should be concentrated on the following objectives (FHWA, 2004b):

- Establish an analytical foundation through development of analysis capabilities, life-cycle cost analyses, performance measures, and alternative investment scenarios,
- Create linkages that integrate management of operations asset analysis results into the transportation asset management process, and
- Obtain the full benefits of transportation asset management by embracing the process and its principles to become the way of doing business.



**Figure 2.5** Operations Asset Components (FHWA, 2004b)

A survey of states current practices on signal systems asset management explored the relationship of operations assets components, and assessed how investment allocation were made by states agency for maintenance as well as improvement. The survey indicated the following conclusions that states agencies are (FHWA, 2004c):

- Tracking and managing their signal systems at varying levels of sophistication depending on system scale complexities,
- Maintaining basic inventory tracking and maintenance management systems,
- Considering trade-offs between technology and staff resources in making resource allocation decision,
- Taking into account performance goals and level of service measures with respect to end user,

- Ensuring that programs, projects and services are delivered in the most effective way available, using a number of software variations,
- Making informed decisions based on quality information and analytic tools,
- Monitoring of actual performance and costs, and use of this feedback to improve future decisions, and
- Identifying and evaluating a wide variety of options for achieving performance goals.

In addition to these results, however, some issues are noted (FHWA, 2004c):

- Relatively few agencies maintain data on failure rates and historical repair costs in their inventory tracking that are important for doing more preventive maintenance—instead of reactive;
- Performance goals and level of service measures are only taken into account at the site-specific level as opposed to system-wide level;
- Some agencies have implemented integrated management systems to link inventory data, maintenance management, and customer request management for well informed decisions;
- Many agencies operate in a reactive mode and both staff and analytical tools for data reduction and analysis are scarce, leading to not well-informed decisions;
- Performance and costs monitoring systems are being used but not to their potential or in support of investment decision-making due to lack of data, lack of resources (staff to process and analyze the data), and the inability to integrate information across systems in relation to one set of goals and objectives; and
- Resource limitations constrain the set of feasible options for improving system performance.

## ***SUMMARY***

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TOAMS is therefore a systematic process of maintaining, upgrading, and operating physical assets of ITS devices and other traffic operations hardware and systems. This system management combines engineering, business management, and economic approaches, including the latest computer-aided technology.

Two activities are employed in TOAMS, operations and planning. Combining these activities requires additional efforts because of the characteristics difference among them. However, the literatures suggest that combining both activities will ease the implementation of TOAMS.

TOAMS will generally follow asset management framework discussed earlier. However, specific business processes, tools, and techniques of TOAMS will vary from traditional implementation of asset management for pavement and bridge. The unique characteristics of TOA presented in earlier in this section will be the starting point in

developing framework for TOAMS. The following discussion on survey results as well as conversation during the peer exchange format will help devise TOAMS approaches.

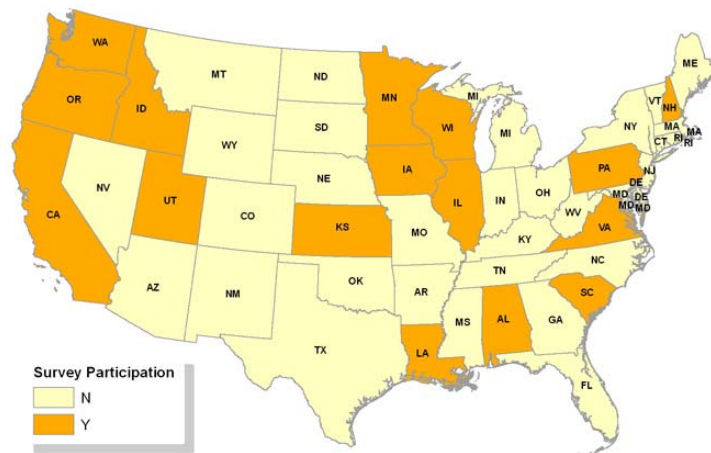


# Chapter 3 TOAMS SURVEY RESULTS

## INTRODUCTION

A TOAMS questionnaire survey was sent out to transportation-related agencies in the United States—public, private, and non-profit—to synthesize the current-state-of-practices for managing traffic operations assets, such as CCTV cameras, pavement sensors, VMS controllers, 511 telephone dial-in service, and road weather information systems (RWIS). The survey was administered through a web-based survey system by the MRUTC at the University of Wisconsin-Madison (UW-Madison). A link to the online survey website was sent out by Wisconsin Department of Transportation (WisDOT).

During the months of November 2007 – January 2008, a total of 33 participants from 16 states responded the survey. For states with multiple respondents, we present the consistent responses. Thus, the survey presents a characterization based on 32 percent of the population.



**Figure 3.1** Geographic Distribution of Respondents

A total of 23 questions were asked in the survey, with both open-ended and close-ended questions. Of these 23 questions, respondents answered 16 questions in average. In other words, an average of 30 percent of the total 23 questions in the survey were unanswered. 16 participants have responses above the average—that is, responding to at least 18 survey questions. There are 2 participants that responded to all questions. Two questions have the least responses, question #22 (best practices that other states can learn from – 9 responses) and question #23 (TOAMS tools or documents may be shared – 8 responses). The full survey and the responses are presented in Appendix A.

## **SURVEY RESULTS**

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### **Traffic Operations Assets Implementation**

Table 3.1 shows the responses for the use of proprietary software or in-house software to support TOAMS (questions #4 and #5; presented in Appendix A). Half of participants indicated the use of software for each category. Among them, 5 participants indicated using a combination of both types of software in order to manage TOA; 6 remaining agencies used either proprietary or in-house TOAMS software. Of those using proprietary software, they considered the software as important in facilitating the management of traffic operations assets. One participant listed using AASHTO bridge software and Pennoni Traffic Signal Software. Although those agencies that used in-house software did not provide any examples of their software, they determined the software was important for statewide planning and budgeting as well as maintaining the high level of functionality.

**Table 3.1** Use of Software for TOAMS by State Agency

	Do you have proprietary software	Do you have in-house developed software
Yes	8	8
No	8	8

For those participants using either proprietary or in-house software, a rating of importance was collected—1 being high and 5 being low; table 3.2 and table 3.3 show the results. For example, Utah DOT indicated that they did not use either one of the software, they specified that “the software (operations management systems) is in development, TO [traffic operations] items will be included with overall UDOT asset management.”

**Table 3.2** Rating of Importance for Proprietary TOAMS Software to State Agencies

States	Rating
California	2
California	1
Oregon	1
Kansas	3
Pennsylvania	1 - AASHTO bridge software; Pennoni Traffic Signal Software
Virginia	2
Washington State	1
Wisconsin	4

**Table 3.3** Rating of Importance for In-House TOAMS Software to State Agencies

States	Rating
California	2
Illinois	4
Minnesota	1 – It is essential to maintaining the high level of functionality
Oregon	1
Kansas	3
Pennsylvania	Very
Virginia	Important for statewide planning and budgeting only
Washington State	1

For the purpose of this survey, a total of 11 primaries TOA (devices and systems) are used as a base level of program components. These TOA are:

- 511 Telephone Dial-in Service
- CCTV Cameras
- Loop Detectors
- Pavement Sensors
- Signal Systems
- VMS Controllers
- Advanced Traffic Management Systems
- Advanced Traveler Information Systems
- Automated Crash Notification Systems
- Incident Management Systems
- Road Weather Information Systems

Participants were asked whether they do manage the selected TOA components. As shown in table 3.4, the survey indicates every agency manages CCTV cameras for traffic surveillance and RWIS, while 94 percent of the participants use loop detectors, pavement sensors, variable message sign (VMS) controllers, and signal systems. Furthermore, TOA that were not managed by state agencies are Automated Crash Notification Systems (69 percent), 511 Telephone Dial-in Service and Advance Traveler Information Systems, both at 31 percent. In total, 83 percent of participants manage TOA in their agency, while 17 percent do not actually manage or possess at least one of them.

**Table 3.4 TOA Application by State**

	We Manage It		We Don't Have It		TOTAL	
511 Telephone Dial-in Service	11		5		16	
	69%	8%	31%	17%	100%	9%
CCTV Cameras	16		0		16	
	100%	11%	0%	0%	100%	9%
Loop Detectors	15		1		16	
	94%	10%	6%	3%	100%	9%
Pavement Sensors	15		1		16	
	94%	10%	6%	3%	100%	9%
Signal Systems	15		1		16	
	94%	10%	6%	3%	100%	9%
VMS Controllers	15		1		16	
	94%	10%	6%	3%	100%	9%
Advanced Traffic Management Systems	13		3		16	
	81%	9%	19%	10%	100%	9%
Advanced Traveler Information Systems	11		5		16	
	69%	8%	31%	17%	100%	9%
Automated Crash Notification Systems	4		9		13	
	31%	3%	69%	31%	100%	8%
Incident Management Systems	12		3		15	
	80%	8%	20%	10%	100%	9%
Road Weather Information Systems	16		0		16	
	100%	11%	0%	0%	100%	9%
TOTAL	143		29		172	
	83%	100%	17%	100%	100%	100%

→ Percentage comparison between “manage” and “don’t have”  
 ↓ Percentage comparison across TOA

Table 3.5 summarizes the frequency of TOA uses. Most of responses indicated that they use TOA in a daily basis (69 percent), followed by yearly or never (14 percent), and weekly (10 percent). In daily uses, CCTV cameras received the highest responses (14 percent), followed by signal systems and VMS controllers (12 percent), and then loop detectors and Advanced Traffic Management Systems (11 percent). For the frequency of yearly or never, Automated Crash Notification Systems received the most responses at 33 percent, and then Advanced Traveler Information Systems at 17 percent, and equally at 11 percent are 511 Telephone Dial-In Service, pavement sensors, and Incident Management Systems. For weekly frequency, the highest responses received by RWIS (23 percent), and then pavement sensors, signal systems and VMS controllers (15 percent).

For the monthly and once every six months frequency, which each of them received 4 percent of total responses, the highest responses received by pavement sensors for monthly (40 percent) and RWIS for once every six month (40 percent).

**Table 3.5** Frequency of TOA Uses by State

	Daily		Weekly		Monthly		Once every six months		Yearly or never		Total	
511 Telephone Dial-in Service	8		1		0		0		2		11	
	73%	9%	9%	8%	0%	0%	0%	0%	18%	11%	100%	8%
CCTV Cameras	13		1		0		0		0		14	
	93%	14%	7%	8%	0%	0%	0%	0%	0%	0%	100%	11%
Loop Detectors	10		1		1		0		0		12	
	83%	11%	8%	8%	8%	20%	0%	0%	0%	0%	100%	9%
Pavement Sensors	6		2		2		1		2		13	
	46%	7%	15%	15%	15%	40%	8%	20%	15%	11%	100%	10%
Signal Systems	11		2		0		0		0		13	
	85%	12%	15%	15%	0%	0%	0%	0%	0%	0%	100%	10%
VMS Controllers	11		2		0		0		1		14	
	79%	12%	14%	15%	0%	0%	0%	0%	7%	6%	100%	11%
Advanced Traffic Management Systems	10		0		0		1		1		12	
	83%	11%	0%	0%	0%	0%	8%	20%	8%	6%	100%	9%
Advanced Traveler Information Systems	8		0		0		1		3		12	
	67%	9%	0%	0%	0%	0%	8%	20%	25%	17%	100%	9%
Automated Crash Notification Systems	0		0		0		0		6		6	
	0%	0%	0%	0%	0%	0%	0%	0%	100%	33%	100%	5%
Incident Management Systems	9		1		1		0		2		13	
	69%	10%	8%	8%	8%	20%	0%	0%	15%	11%	100%	10%
Road Weather Information Systems	6		3		1		2		1		13	
	46%	7%	23%	23%	8%	20%	15%	40%	8%	6%	100%	10%
Total	92		13		5		5		18		133	
	69%	100%	10%	100%	4%	100%	4%	100%	14%	100%	100%	100%

→ Percentage comparison across frequency  
 ↓ Percentage comparison across TOA

## Formal Procedures for TOAM

The presence of systematic mechanisms in decision making processes for traffic operations asset management is identified by asking questions about the implementation of a number of some key formal procedures. These procedures are grouped into two categories:

- Operational procedures:
  - Budget Planning for Maintenance and Replacement
  - Communications Network Management
  - Dedicated Staff
  - Make Purchase Decision(s)
  - Propose New Improvement Projects
  - Schedule Maintenance Repair and/or Replacement
  - Written Guidelines
- Analytical procedures:
  - Estimate Personnel Needs
  - Field Equipment Inventory
  - Maintenance Record and Management
  - Make Assessment on Deficiencies
  - Perform Life-cycle Cost Analysis
  - Performance Monitoring
  - Spare Parts Inventory

Table 3.6 shows how these procedures were implemented for TOA devices, which is suggesting that budget planning for maintenance and replacement, dedicated staff, field equipment inventory, and proposed new improvement projects are the most popular processes implemented by state transportation agencies (10 percent), followed by communications network management and make purchase decisions (9 percent).

For managing CCTV cameras, the main formal procedure implemented was field equipment inventory (11 percent). Both dedicated staff and propose new improvement projects procedures performed for CCTV cameras management (10 percent).

Pavement sensors management, field equipment inventory (13 percent), and propose new improvement projects (11 percent) were reported as primary procedures. Ten percent of participants responded for budget planning for maintenance and replacement as another major procedure for this asset.

For loop detectors, 4 procedures were reported equally at 10 percent as the primary procedures for its management. They are budget planning for maintenance and replacement, dedicated staff, field equipment inventory, and propose new improvement projects. Further, VMS controller management were performed by implementing

communication network management, dedicated staff, and field equipment inventory, all at 10 percent.

For the management of signal systems, the primary procedure reported was field equipment inventory (11 percent). The next major procedures implemented were budget planning for maintenance and replacement, dedicated staff, and propose new improvement projects (10 percent).

Lastly, for 511 telephone dial-in service management, the primary procedures performed were budget planning for maintenance and replacement (15 percent), make purchase decisions (12 percent), and propose new improvement projects (12 percent). Ten percent reported that dedicated staff was also another major procedure for the management of this traffic operations asset.

Table 3.7 summarizes the management of TOA systems, where the total percentages for procedures performed were close one another from 5–10 percent, except for perform life-cycle cost analysis procedure that received 2 percent. Among the primary procedures performed to manage TOA systems were dedicated staff (10 percent), budget planning for maintenance and replacement (9 percent), field equipment inventory (9 percent). Other major procedures were make assessment on deficiencies (8 percent), make purchase decisions (8 percent), propose new improvement projects (8 percent), and schedule maintenance repair and/or replacement (8 percent). Seven percent of the responses were indicated for communications network management and estimate personnel needs. Six percent of respondents identified maintenance records and management, performance monitoring, and written guidelines. Five percent of the responses noted spare parts inventory.

For the management of automated crash notification systems, only 2 responses were received, one each for budget planning for maintenance and replacement (50 percent) and maintenance record and management (50 percent).

For advanced traveler information systems management, the percentage of responses varied tightly from 7 to 10 percent, except for three procedures of maintenance record and management (5 percent), perform life-cycle cost analysis (3 percent), and spare parts inventory (3 percent). The primary procedures were dedicated staff and propose new improvement project (10 percent). Eight percent responses were received for budget planning and maintenance and replacement, communication network management, field equipment inventory, make assessment on deficiencies, performance monitoring, and written guidelines. Lastly, estimate personnel needs, make purchase decisions, and schedule maintenance repair and/or replacement procedure received 7 percent of responses.

Similarly, formal procedures for the management of advanced traffic management systems were almost equally implemented, ranging from 5 to 9 percent of total responses. One percent of responses were received for perform life-cycle cost analysis. Of these primary procedures, they were field equipment inventory (9 percent), make assessment

on deficiencies (9 percent), propose new improvement projects (9 percent), schedule maintenance repair and/or replacement (9 percent), budget planning and maintenance and replacement (8 percent), communication network management (8 percent), dedicated staff (8 percent), make purchase decisions (8 percent), written guidelines (8 percent). Seven percent responses received for estimate personnel needs, 6 percent for both maintenance record and management and spare parts inventory, and 5 percent for performance monitoring.

For managing incident management systems, the primary procedure performed was dedicated staff (13 percent). Following this procedure were budget planning for maintenance and replacement (9 percent), estimate personnel needs (9 percent), make assessment on deficiencies (9 percent), make purchase decisions (9 percent), performance monitoring (9 percent), and written guidelines (9 percent). The remaining procedures were field equipment inventory (7 percent), schedule maintenance repair and/or replacement (7 percent), communications network management (5 percent), propose new improvement projects (5 percent), maintenance record and management (4 percent), spare parts inventory (4 percent), perform life-cycle cost analysis (2 percent).

For the management of RWIS, the primary procedures performed were field equipment inventory (12 percent), budget planning for maintenance and replacement (11 percent), and dedicated staff (11 percent). Other major procedures were maintenance record and management (7 percent), make assessment on deficiencies (7 percent), make purchase decisions (9 percent), propose new improvement projects (8 percent), schedule maintenance repair and/or replacement (9 percent), and spare parts inventory (7 percent). Five percent of responses received for estimate personnel needs and performance monitoring, while 1 percent of responses for perform life-cycle cost analysis and written guidelines.

**Table 3.6** Formal Procedures for Managing TOA Device

	CCTV Cameras		Pavement Sensors		Loop Detectors		VMS Controllers		Signal Systems		511 Telephone Dial-in Service		TOTAL	
Budget Planning for Maintenance and Replacement	9	8	9	9	9	10	10	55						
	16%	8%	15%	10%	16%	10%	16%	8%	18%	10%	18%	15%	100%	10%
Communications Network Management	10	7	6	11	9	6	49							
	20%	9%	14%	9%	12%	7%	22%	10%	18%	9%	12%	9%	100%	9%
Dedicated Staff	11	7	9	11	10	7	55							
	20%	10%	13%	9%	16%	10%	20%	10%	18%	10%	13%	10%	100%	10%
Estimate Personnel Needs	6	4	5	5	6	3	29							
	21%	5%	14%	5%	17%	6%	17%	4%	21%	6%	10%	4%	100%	5%
Field Equipment Inventory	12	11	9	11	11	2	56							
	21%	11%	20%	13%	16%	10%	20%	10%	20%	11%	4%	3%	100%	10%
Maintenance Record and Management	8	6	6	8	8	1	37							
	22%	7%	16%	7%	16%	7%	22%	7%	22%	8%	3%	1%	100%	7%
Make Assessment on Deficiencies	6	5	4	6	3	6	30							
	20%	5%	17%	6%	13%	5%	20%	5%	10%	3%	20%	9%	100%	5%
Make Purchase Decision(s)	10	7	7	9	8	8	49							
	20%	9%	14%	9%	14%	8%	18%	8%	16%	8%	16%	12%	100%	9%
Perform Life-cycle Cost Analysis	2	1	2	2	1	2	10							
	20%	2%	10%	1%	20%	2%	20%	2%	10%	1%	20%	3%	100%	2%
Performance Monitoring	5	4	4	6	4	6	29							
	17%	4%	14%	5%	14%	5%	21%	5%	14%	4%	21%	9%	100%	5%
Propose New Improvement Project	11	9	9	9	10	8	56							
	20%	10%	16%	11%	16%	10%	16%	8%	18%	10%	14%	12%	100%	10%
Schedule Maintenance Repair and/or Replacement	8	5	6	8	8	3	38							
	21%	7%	13%	6%	16%	7%	21%	7%	21%	8%	8%	4%	100%	7%
Spare Parts Inventory	9	6	7	8	9	1	40							
	23%	8%	15%	7%	18%	8%	20%	7%	23%	9%	3%	1%	100%	7%
Written Guidelines	6	2	3	9	5	4	29							
	21%	5%	7%	2%	10%	3%	31%	8%	17%	5%	14%	6%	100%	5%
<b>TOTAL</b>	<b>113</b>	<b>82</b>	<b>86</b>	<b>112</b>	<b>102</b>	<b>67</b>	<b>562</b>							
	20%	100%	15%	100%	15%	100%	20%	100%	18%	100%	12%	100%	100%	100%

→ Percentage comparison across TOA Device  
 ↓ Percentage comparison across formal procedures

**Table 3.7** Formal Procedures for Managing TOA Systems

	Automated Crash Notification Systems		Advanced Traveler Information Systems		Advanced Traffic Management Systems		Incident Management Systems		Road Weather Information Systems		TOTAL	
Budget Planning for Maintenance and Replacement	1		5		7		5		8		26	
	4%	50%	19%	8%	27%	8%	19%	9%	31%	11%	100%	9%
Communications Network Management	0		5		7		3		5		20	
	0%	0%	19%	8%	27%	8%	12%	5%	19%	7%	100%	7%
Dedicated Staff	0		6		7		7		8		28	
	0%	0%	23%	10%	27%	8%	27%	13%	31%	11%	100%	10%
Estimate Personnel Needs	0		4		6		5		4		19	
	0%	0%	15%	7%	23%	7%	19%	9%	15%	5%	100%	7%
Field Equipment Inventory	0		5		8		4		9		26	
	0%	0%	19%	8%	31%	9%	15%	7%	35%	12%	100%	9%
Maintenance Record and Management	1		3		5		2		5		16	
	6%	50%	19%	5%	31%	6%	13%	4%	31%	7%	100%	6%
Make Assessment on Deficiencies	0		5		8		5		5		23	
	0%	0%	22%	8%	35%	9%	22%	9%	22%	7%	100%	8%
Make Purchase Decision(s)	0		4		7		5		7		23	
	0%	0%	17%	7%	30%	8%	22%	9%	30%	9%	100%	8%
Perform Life-cycle Cost Analysis	0		2		1		1		1		5	
	0%	0%	40%	3%	20%	1%	20%	2%	20%	1%	100%	2%
Performance Monitoring	0		5		4		5		4		18	
	0%	0%	28%	8%	22%	5%	28%	9%	22%	5%	100%	6%
Propose New Improvement Project	0		6		8		3		6		23	
	0%	0%	26%	10%	35%	9%	13%	5%	26%	8%	100%	8%
Schedule Maintenance Repair and/or Replacement	0		4		8		4		7		23	
	0%	0%	17%	7%	35%	9%	17%	7%	30%	9%	100%	8%
Spare Parts Inventory	0		2		5		2		5		14	
	0%	0%	14%	3%	36%	6%	14%	4%	36%	7%	100%	5%
Written Guidelines	0		5		7		5		1		18	
	0%	0%	28%	8%	39%	8%	28%	9%	6%	1%	100%	6%
TOTAL	2		61		88		56		75		282	
	1%	100%	22%	100%	31%	100%	20%	100%	27%	100%	100%	100%

→ Percentage comparison across TOA Systems  
 ↓ Percentage comparison across formal procedures

## **TOA Management Data**

Five types of data inventories were specified. They were:

- Characteristics / Capabilities data inventory,
- Maintenance Requirements data inventory,
- Maintenance Cost History data inventory,
- Repair / Failure History data inventory, and
- Age / Condition data inventory.

Table 3.8 summarizes the responses for TOA data inventory kept by state transportation agencies. For 511 telephone dial-in service, 42 percent of the responses managed characteristics/capabilities data inventory, and 17 percent mentioned maintenance requirements data inventory, maintenance cost history data inventory, and age/condition data inventory. Eight percent of the respondents reported to manage repair/failure history data inventory.

For CCTV cameras, 25 percent of the responses indicated repair/failure history data inventory, 22 percent managed age/condition data inventory, and 19 percent kept characteristics/capabilities data inventory and maintenance cost history data inventory. The remaining respondents indicated that they managed maintenance requirements data inventory (14 percent).

For loop detectors, the primary data kept is repair/failure history data inventory (26 percent). Maintenance cost history data inventory and age/condition data inventory were also given significant importance (22 percent). Nineteen percent of the responses indicated characteristics/capabilities as another major data inventory managed, followed by maintenance requirements data inventory at 11 percent.

For pavement sensors, 30 percent of the respondents indicated managing characteristics/capabilities data inventory. Twenty percent reported maintenance cost history, repair/failure history, and age/condition as another set of major data inventory managed. Only 10 percent reported maintenance requirements data inventory was kept for this particular asset.

For signal systems, the primary data inventory managed were characteristics/capabilities and repair/failure history data, both indicated by 27 percent of the responses. Twenty-three percent of respondents reported age/condition as another important data inventory managed. The remaining respondents indicated maintenance cost history data inventory (15 percent) and maintenance requirements data inventory (8 percent).

For VMS controllers, five data inventories were almost equally managed. Twenty-three percent of the respondents reported repair/failure history and age/condition as the most significant data inventory to be managed. Twenty percent indicated maintenance cost history data inventory, while 18 percent indicated characteristics/capabilities data inventory and age/condition data inventory.

Similar for Advanced Traffic Management Systems, 22 percent of the respondents reported to manage characteristics/capabilities and age/condition data inventory. Nineteen percent of the respondents indicated to manage maintenance requirements, maintenance cost history, and repair/failure history data inventory.

For Advanced Traveler Information Systems, characteristics/capabilities, maintenance cost history, repair/failure history, and age/condition were considered to be the primary data inventory managed by 21 percent of the respondents. While maintenance requirements data inventory data were indicated by 14 percent responses.

There was no response received for Automated Crash Notification Systems. For Incident Management Systems, repair/failure history data inventory was the primary data managed with 33 percent responses. Characteristics/capabilities, maintenance requirements, maintenance cost history, and age/condition data inventory were equally reported at 17 percent of total responses.

For RWIS, among the primary data inventory indicated were age/condition (27 percent), characteristics/capabilities (23 percent), and maintenance cost history (23 percent). Another major data inventory managed for this TOA systems was repair/failure history data inventory (18 percent). There was only 9 percent of the responses indicated the importance of maintenance requirements data inventory for this systems.

The responses to characteristics/capabilities data inventory varied considerably, with the highest for CCTV cameras, signal systems, and VMS controllers (13 percent) and the lowest for Incident Management Systems (4 percent). The responses to maintenance requirements data inventory varied from 22 percent for VMS controllers to 6 percent for 511 telephone dial-in service, pavement sensors, signal systems, Advanced Traveler Information Systems, Incident Management Systems, and RWIS. The responses to maintenance cost history data inventory varied from 17 percent for VMS controllers to 4 percent for 511 Telephone Dial-In Service and Incident Management Systems. The responses to repair/failure history data inventory varied from 17 percent for CCTV cameras, VMS controllers to 2 percent for 511 Telephone Dial-In Service. The responses to age/condition data inventory varied from 17 percent for VMS controllers to 4 percent for both 511 Telephone Dial-In Service and Incident Management Systems. No response was consistently obtained for Automated Crash Notification Systems on all types of data inventory.

In total, characteristics/capabilities, repair/failure history, and age/condition were reported as the primary asset management data inventory for TOA by 22 percent of the respondents. Nineteen percent reported maintenance requirements as another major data inventory. 14 percent of respondents indicated the importance of maintenance cost history data inventory.

**Table 3.8 TOA Management Data**

	Characteristics / Capabilities		Maintenance Requirements		Maintenance Cost History		Repair / Failure History		Age / Condition		Total	
511 Telephone Dial-in Service	5		2		2		1		2		12	
	42%	9%	17%	6%	17%	4%	8%	2%	17%	4%	100%	5%
CCTV Cameras	7		5		7		9		8		36	
	19%	13%	14%	16%	19%	15%	25%	17%	22%	15%	100%	15%
Loop Detectors	5		3		6		7		6		27	
	19%	9%	11%	9%	22%	13%	26%	13%	22%	12%	100%	11%
Pavement Sensors	6		2		4		4		4		20	
	30%	11%	10%	6%	20%	9%	20%	8%	20%	8%	100%	8%
Signal Systems	7		2		4		7		6		26	
	27%	13%	8%	6%	15%	9%	27%	13%	23%	12%	100%	11%
VMS Controllers	7		7		8		9		9		40	
	18%	13%	18%	22%	20%	17%	23%	17%	23%	17%	100%	17%
Advanced Traffic Management Systems	6		5		5		5		6		27	
	22%	11%	19%	16%	19%	11%	19%	9%	22%	12%	100%	11%
Advanced Traveler Information Systems	3		2		3		3		3		14	
	21%	6%	14%	6%	21%	7%	21%	6%	21%	6%	100%	6%
Automated Crash Notification Systems	0		0		0		0		0		0	
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Incident Management Systems	2		2		2		4		2		12	
	17%	4%	17%	6%	17%	4%	33%	8%	17%	4%	100%	5%
Road Weather Information Systems	5		2		5		4		6		22	
	23%	9%	9%	6%	23%	11%	18%	8%	27%	12%	100%	9%
Total	53		32		46		53		52		80	
	22%	100%	14%	100%	19%	100%	22%	100%	22%	100%	100%	100%

→ Percentage comparison across data inventory  
 ↓ Percentage comparison across TOA

## TOA Maintenance Policies

Four types of maintenance policies were specified in the survey as follow:

- Preventive maintenance – a replacement maintenance is performed because staffs experience some issues that can lead to failures,
- Corrective maintenance – a replacement maintenance is performed because a failure occurs,
- Inspection maintenance – a replacement maintenance is performed when an inspection reveals problems, and
- Replacement – a replacement maintenance is performed when component is found obsolete.

Table 3.9 summarizes the responses for maintenance policies implemented for TOA. For 511 telephone dial-in service, corrective maintenance was reported as the primary policy by 54 percent of responses. Twenty-three percent of responses indicated inspection maintenance and replacement as major policies. There was no response indicated the importance of preventive maintenance for the asset.

For CCTV cameras, the primary policy performed was corrective maintenance (38 percent) and inspection maintenance (25 percent). Nineteen percent responded of performing both preventive maintenance and replacement.

For loop detectors, 50 percent of the responses indicated that corrective maintenance was the primary policy implemented. Inspection maintenance and preventive maintenance were considered as major policies, indicated by 21 percent and 17 percent of the responses consecutively. Thirteen percent of respondents reported replacement as another major policy for this asset.

For pavement sensors, 78 percent of the respondents reported corrective maintenance as a significantly important policy for this asset. Inspection maintenance (11 percent) and replacement (11 percent) received relatively low responses as maintenance policies. There was no response reported implementing preventive maintenance policy for this asset.

For signal systems, corrective maintenance (44 percent) was indicated as the primary policy. Following this policy was preventive maintenance (24 percent) and inspection maintenance (20 percent). Twelve percent reported replacement as a preferred maintenance policy for this asset.

For VMS controllers, corrective maintenance was reported by 37 percent of the responses as the primary maintenance policy. Following this policy were inspection maintenance (27 percent), preventive maintenance (20 percent), and replacement (17 percent).

For Advanced Traffic Management Systems, corrective maintenance (36 percent) was indicated as the primary maintenance policy. Inspection maintenance (27 percent), preventive maintenance (18 percent), and replacement (18 percent) were stated as major maintenance policies implemented for the systems.

For Advanced Traveler Information Systems, the primary maintenance policy reported was corrective maintenance (38 percent). Twenty-three percent of the respondents stated inspection maintenance and replacement as major maintenance policies. Only 15 percent of the respondents reported implementing preventive maintenance policy.

For Incident Management Systems, the main maintenance policy was corrective maintenance (35 percent). Following corrective maintenance, there were inspection maintenance (24 percent) and preventive maintenance (24 percent). Eighteen percent stated performing replacement policy for this systems.

For RWIS, the primary maintenance policy reported was corrective maintenance (44 percent). Twenty-two percent of the responses reported inspection maintenance and replacement as significant policies. Relatively low responses reported preventive maintenance policy (11 percent) for this systems.

In general, the highest response rate to maintenance policies for individual asset or system was 78 percent (corrective maintenance for pavement sensors). Further, the lowest responses rate was 11 percent (preventive maintenance for RWIS, inspection maintenance for pavement sensors, and replacement for pavement sensors). The responses to preventive maintenance policy varied, with highest for signal systems and Incident Management Systems (24 percent) and lowest for RWIS (11 percent). The responses to corrective maintenance varied considerably, from 78 percent for pavement sensors to 35 percent for Incident Management Systems. The responses to inspection maintenance varied from 27 percent for VMS controllers and Advanced Traffic Management Systems to 11 percent for pavement sensors. The responses to replacement varied from 23 percent for 511 telephone dial-in service and Advanced Traveler Information Systems to 11 percent for pavement sensors. No response was obtained for Automated Crash Notification Systems on all maintenance policies.

To sum, corrective maintenance was reported as the primary maintenance policy for traffic operations by 43 percent of the respondents. Twenty-three percent reported inspection maintenance another maintenance policy implemented. Seventeen percent was reported to both preventive maintenance policy and replacement.

**Table 3.9 TOA Maintenance Policies**

	Preventive		Corrective		Inspection		Replacement		Total	
511 Telephone Dial-in Service	0		7		3		3		13	
	0%	0%	54%	8%	23%	6%	23%	9%	100%	6%
CCTV Cameras	6		12		8		6		32	
	19%	18%	38%	14%	25%	17%	19%	17%	100%	16%
Loop Detectors	4		12		5		3		24	
	17%	12%	50%	14%	21%	11%	13%	9%	100%	12%
Pavement Sensors	0		7		1		1		9	
	0%	0%	78%	8%	11%	2%	11%	3%	100%	4%
Signal Systems	6		11		5		3		25	
	24%	18%	44%	13%	20%	11%	12%	9%	100%	12%
VMS Controllers	6		11		8		5		30	
	20%	18%	37%	13%	27%	17%	17%	14%	100%	15%
Advanced Traffic Management Systems	4		8		6		4		22	
	18%	12%	36%	9%	27%	13%	18%	11%	100%	11%
Advanced Traveler Information Systems	2		5		3		3		13	
	15%	6%	38%	6%	23%	6%	23%	9%	100%	6%
Automated Crash Notification Systems	0		0		0		0		0	
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Incident Management Systems	4		6		4		3		17	
	24%	12%	35%	7%	24%	9%	18%	9%	100%	8%
Road Weather Information Systems	2		8		4		4		18	
	11%	6%	44%	9%	22%	9%	22%	11%	100%	9%
Total	34		87		47		35		203	
	17%	100%	43%	100%	23%	100%	17%	100%	100%	100%

→ Percentage comparison across maintenance policies  
 ↓ Percentage comparison across TOA

## TOA Assessment Methods

Three assessment methods were specified for TOA:

- Monitoring systems – as assessment that is made based on data and information collected from monitoring systems,
- Field survey – as assessment that is made based on data and information collected from field survey, and
- Customer complaint – as assessment that is made based on data and information collected from customer complaint.

Table 3.10 summarizes how the three assessment methods were used by state transportation agencies in making assessments on the performance of TOA. For 511 telephone dial-in service, monitoring systems (78 percent) was the primary method used to determine this asset's performance. Customer complaint (22 percent) was also given significant importance. There was no response received for field survey method.

For CCTV cameras, 92 percent of the responses indicated using monitoring systems method in determining the asset's performance. Significantly lower at 8 percent, customer complaint method was used. There was no response received for field survey method for this asset.

For loop detectors, the primary method performed was monitoring systems (73 percent). Twenty percent of the responses indicated using customer complaint method, while no response for field survey method.

For pavement sensors, all of responses indicated that state transportation agencies using monitoring systems method in assessing this asset's performance. There was no response received for field survey as well as customer complaint method.

For signal systems, the primary method performed was customer complaint (45 percent). Monitoring systems method and field survey method were equally reported by 27 percent of total responses.

For VMS controller, 77 percent of the respondents indicated using monitoring systems as the primary assessment method. Customer complaint and field survey method were reported by 15 percent and 8 percent from total responses consecutively.

For Advanced Traffic Management Systems, monitoring systems (89 percent) was stated as the most implemented method in assessing the systems performance. In a significantly lower rate of response, customer complaint method was reported by 11 percent of respondents. There was no response received for field survey method.

For Advanced Traveler Management Systems, the primary method performed was monitoring systems (83 percent). Seventeen percent responded relying customer

complaint for this systems' assessment. There was no response received for field survey method.

For Incident Management Systems, the primary method performed was monitoring systems (78 percent). Equally reported by 11 percent of the respondents were field survey and customer complaint method.

For RWIS, the primary method performed was monitoring systems (78 percent). Twenty-two percent responded using customer complaint for this systems' assessment. There was no response received for field survey method.

Monitoring systems method was generally performed as the primary method for assessing TOA, except for signal systems (27 percent response rate). The response rate for monitoring systems was as high as 73 percent for loop detectors to 100 percent for pavement sensors. Field survey was not performed but signal systems (27 percent) and Incident Management Systems (11 percent). Customer complaint method was performed between 8 percent (CCTV cameras) and 45 percent (signal systems).

In total percentage of total responses, monitoring system methods were performed by 77 percent, customer complaint notification was noted by 18 percent, and a field survey method was performed by only 5 percent of total respondents.

**Table 3.10 TOA Assessment Methods**

	Monitoring Systems		Field Survey		Customer Complaint		Total	
511 Telephone Dial-in Service	7		0		2		9	
	78%	9%	0%	0%	22%	11%	100%	9%
CCTV Cameras	12		0		1		13	
	92%	16%	0%	0%	8%	6%	100%	13%
Loop Detectors	8		0		3		11	
	73%	11%	0%	0%	27%	17%	100%	11%
Pavement Sensors	9		0		0		9	
	100%	12%	0%	0%	0%	0%	100%	9%
Signal Systems	3		3		5		11	
	27%	4%	27%	60%	45%	28%	100%	11%
VMS Controllers	10		1		2		13	
	77%	13%	8%	20%	15%	11%	100%	13%
Advanced Traffic Management Systems	8		0		1		9	
	89%	11%	0%	0%	11%	6%	100%	9%
Advanced Traveler Information Systems	5		0		1		6	
	83%	7%	0%	0%	17%	6%	100%	6%
Automated Crash Notification Systems	0		0		0		0	
	0%	0%	0%	0%	0%	0%	0%	0%
Incident Management Systems	7		1		1		9	
	78%	9%	11%	20%	11%	6%	100%	9%
Road Weather Information Systems	7		0		2		9	
	78%	9%	0%	0%	22%	11%	100%	9%
Total	76		5		18		99	
	77%	100%	5%	100%	18%	100%	100%	100%

→ Percentage comparison across methods  
 ↓ Percentage comparison across TOA

### The Use of TOA for Level of Service Monitoring

Three mechanisms to monitor roadway level of service (LOS) and intersection LOS are specified: CCTV cameras, loop detectors, and manual data collection program. Of these three mechanisms, state transportation agencies indicated how they are implemented in LOS monitoring.

As can be seen in Table 3.11, 30 percent of total responses stated not using CCTV cameras, loop detectors and manual data collection program for LOS monitoring. For each asset or program that was not performing LOS monitoring, CCTV cameras were reported by 42 percent, loop detectors were reported by 27 percent, and manual data collection program was reported by 23 percent.

Further, CCTV cameras were used to monitor roadway LOS (42 percent) and intersection LOS (17 percent). Loop detectors were indicated for monitoring roadway LOS (40 percent) and intersection LOS (33 percent). Manual Data Collection Program was stated for monitoring roadway LOS (38 percent) and intersection LOS (38 percent).

**Table 3.11** The Use of TOA for Level of Service Monitoring

	Roadway LOS		Intersection LOS		Not Used (N/A)		Total	
CCTV Cameras	5		2		5		<b>12</b>	
	42%	31%	17%	17%	42%	42%	100%	30%
Loop Detectors	6		5		4		<b>15</b>	
	40%	38%	33%	42%	27%	33%	100%	38%
Manual Data Collection Program	5		5		3		<b>13</b>	
	38%	31%	38%	42%	23%	25%	100%	33%
Total	16		12		12		<b>40</b>	
	40%	100%	30%	100%	30%	100%	100%	100%

→ Percentage comparison between roadway LOS, intersection LOS, and N/A  
 ↓ Percentage comparison across mechanism

### Issues and Priorities

A total of 10 primary operational issues on TOAMS were specified. State transportation agencies were asked to rate these operational issues’ importance—level 1 being very important and level 5 being not important. The issues are:

- Conduct trainings to enhance technical maintenance skills
- Contracting for systems maintenance
- Improve contractor responsiveness
- Physical condition assessment
- Reallocate staff to improve efficiency of operation
- Reduce repairment or replacement costs
- Repair / Replace equipment
- Standardize components
- Upgrade central systems
- Upgrade individual systems

The rate of importance of TOAMS operational issues were reported on Table 3.12. The following assessments were made based on the highest responses received for corresponding issues. Among the most important operational issues (level 1 of importance) were repairing/replacing equipment (54 percent), reducing repairment of replacement cost (50 percent), standardizing components (46 percent), and conducting trainings to enhance technical maintenance skills (31 percent). Among the high important operational issues (level 2 of importance) were contracting for systems

maintenance (46 percent) and assessing physical condition (38 percent). Among the medium important operational issues (level 3 of importance) were upgrading individual systems (62 percent), reallocating staff to improve efficiency of operation (54 percent), upgrading central systems (46 percent), improving contractor responsiveness (38 percent), and improving contractor responsiveness (38 percent).

Furthermore, a total of 9 primary initiatives on TOAMS were specified. State transportation agencies were asked to rate these initiatives' importance—level 1 being very important and level 5 being not important. The initiatives are:

- Adjust / Upgrade existing infrastructure systems
- Coordinate agencies across jurisdictions
- Deploy more systems management on ITS facilities
- Develop a computerized systems management module
- Expand systems capabilities
- Improve technology interaction of ITS systems technology
- More infrastructure systems installation
- Multi agencies coalition, both transportation and non-transportation agencies
- Prioritizing and scheduling maintenance of ITS systems and components

As can be seen in Table 3.13, among the most important initiatives were adjusting/upgrading existing infrastructure systems (54percent), coordinating agencies across jurisdictions (46 percent), expanding systems capabilities (46 percent), improving technology interaction of ITS systems technology (38 percent), and multi agencies coalition, both transportation and non-transportation agencies (38 percent). Among the high important initiatives (level 2 of importance) were adjusting more infrastructure systems installation (46 percent), deploying more systems management on ITS facilities (38 percent), and prioritizing and scheduling maintenance of ITS systems and components (38 percent). Among the initiatives of medium importance (level 3 of importance) was developing a computerized systems management module (38 percent).

**Table 3.12** Importance of TOAMS Operational Issues

	1		2		3		4		5		Total	
Conduct trainings to enhance technical maintenance skills	4		4		2		3		0		13	
	31%	11%	31%	11%	15%	4%	23%	50%	0%	0%	100%	10%
Contracting for systems maintenance	3		6		4		0		0		13	
	23%	8%	46%	16%	31%	9%	0%	0%	0%	0%	100%	10%
Improve contractor responsiveness	4		4		5		0		0		13	
	31%	11%	31%	11%	38%	11%	0%	0%	0%	0%	100%	10%
Physical condition assessment	2		5		5		1		0		13	
	15%	5%	38%	13%	38%	11%	8%	17%	0%	0%	100%	10%
Reallocate staff to improve efficiency of operation	1		3		7		2		0		13	
	8%	3%	23%	8%	54%	15%	15%	33%	0%	0%	100%	10%
Reduce repairment or replacement costs	6		4		2		0		0		12	
	50%	16%	33%	11%	17%	4%	0%	0%	0%	0%	100%	9%
Repair / Replace equipment	7		3		3		0		0		13	
	54%	18%	23%	8%	23%	6%	0%	0%	0%	0%	100%	10%
Standardize components	6		2		5		0		0		13	
	46%	16%	15%	5%	38%	11%	0%	0%	0%	0%	100%	10%
Upgrade central systems	3		4		6		0		0		13	
	23%	8%	31%	11%	46%	13%	0%	0%	0%	0%	100%	10%
Upgrade individual systems	2		3		8		0		0		13	
	15%	5%	23%	8%	62%	17%	0%	0%	0%	0%	100%	10%
Total	38		38		47		6		0		129	
	29%	100%	29%	100%	36%	100%	5%	100%	0%	0%	100%	100%

→ Percentage comparison across rate of importance  
 ↓ Percentage comparison across operational issues

**Table 3.13** Importance of TOAMS Initiatives

	1		2		3		4		5		Total	
Adjust / Upgrade existing infrastructure systems	7		5		1		0		0		13	
	54%	16%	38%	13%	8%	4%	0%	0%	0%	0%	100%	11%
Coordinate agencies across jurisdictions	6		4		3		0		0		13	
	46%	14%	31%	11%	23%	13%	0%	0%	0%	0%	100%	11%
Deploy more systems management on ITS facilities	3		5		4		1		0		13	
	23%	7%	38%	13%	31%	17%	8%	8%	0%	0%	100%	11%
Develop a computerized systems management module	3		2		5		2		1		13	
	23%	7%	15%	5%	38%	22%	15%	17%	8%	100%	100%	11%
Expand systems capabilities	6		5		0		2		0		13	
	46%	14%	38%	13%	0%	0%	15%	17%	0%	0%	100%	11%
Improve technology interaction of ITS systems technology	5		2		5		1		0		13	
	38%	12%	15%	5%	38%	22%	8%	8%	0%	0%	100%	11%
More infrastructure systems installation	4		6		0		3		0		13	
	31%	9%	46%	16%	0%	0%	23%	25%	0%	0%	100%	11%
Multi agencies coalition, both transportation and non-transportation agencies	5		4		2		2		0		13	
	38%	12%	31%	11%	15%	9%	15%	17%	0%	0%	100%	11%
Prioritizing and scheduling maintenance of ITS systems and components	4		5		3		1		0		13	
	31%	9%	38%	13%	23%	13%	8%	8%	0%	0%	100%	11%
Total	43		38		23		12		1		117	
	37%	100%	32%	100%	20%	100%	10%	100%	1%	100%	100%	100%

→ Percentage comparison across rate of importance  
 ↓ Percentage comparison across initiatives

## **OBSERVATIONS**

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*TOA Implementation*; the survey indicates that all state transportation agencies manage closed-circuit television (CCTV) cameras and road weather information systems (RWIS). The survey also reveals that most of state transportation agencies manage pavement sensors, loop detectors, variable message sign (VMS) controllers, and signal systems. In addition, only a few state transportation agencies manage Automated Crash Notification Systems.

*Formal Procedures*; on the benefits of implementing formal procedures for TOAMS, state transportation agencies indicated that these procedures were needed for estimating personal needs, managing maintenance records, assessing systems deficiencies, life cycle cost analysis, performance monitoring, and managing the spare parts inventory.

*Data Inventory*; five types of inventory data were asked whether state transportation agencies keep inventory data on their traffic operations assets. These inventory data are characteristics/capabilities, maintenance requirements, maintenance cost history, repair/failure history, and age/condition. The survey suggest that less than a half of the state transportation agencies keep these inventory data on their traffic operations assets.

*Strategy on Maintenance*; the survey reveals that corrective maintenance type of strategies is commonly used by state transportation agencies, rather than preventive, inspection or replacement strategies.

*Assessment Methods*; the survey shows that the functioning condition of traffic operations assets is mostly assessed through systems monitoring, rather than field inspection or customer complaints.

*Operational Issues*; State transportation agencies indicated a number of operational issues associated with TOAMS. Most of these operational issues are associated with conducting training to enhance technical maintenance skills, improving contractor responsiveness, reducing repair or replacement costs, repairing/replacing equipment, and standardizing components.

*Systems Initiatives*; State transportation agencies also indicated that systems initiatives should address on the issues of expanding systems capabilities, coordinating agencies across jurisdiction, and adjusting/upgrading existing infrastructure systems.

Table 3.14 summarizes observations based on survey results. The table lists components of each category that were mostly implemented by State DOTs. None is listed under data inventory category since the survey reports that only less than a half of the state DOTs keep data inventory on their traffic operations assets. That is, this suggests an urgent need in integrating data inventory mechanism for TOAMS

**Table 3.14** Preferences indicated by State Transportation Agencies on TOAMS

Categories	Mostly implemented by State DOTs
TOA Implementation	Closed-circuit television (CCTV) Road weather information systems (RWIS) Pavement sensors Loop detectors Variable message sign (VMS) controllers Signal systems
Formal Procedures	Estimating personal needs Managing maintenance records Assessing systems deficiencies Life cycle cost analysis Performance monitoring Managing the spare parts inventory
Data Inventory	-
Strategy on Maintenance	Corrective maintenance
Assessment Methods	System monitoring
Operational Issues	Conducting training to enhance technical maintenance skills Improving contractor responsiveness Reducing repair or replacement costs Repairing/replacing equipment Standardizing components
System Initiatives	Expanding systems capabilities Coordinating agencies across jurisdiction Adjusting/upgrading existing infrastructure systems

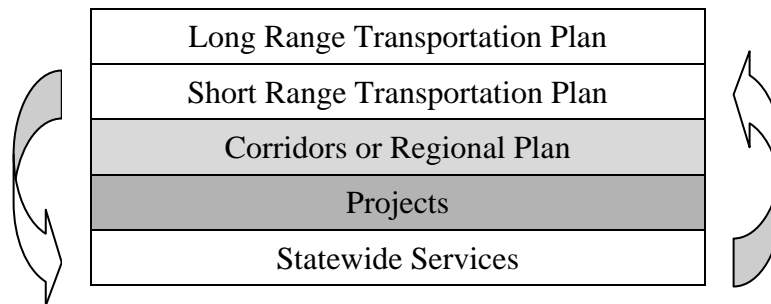


## Chapter 4 FRAMING THE NEXT GENERATION OF TOAMS

### ***INTRODUCTION***

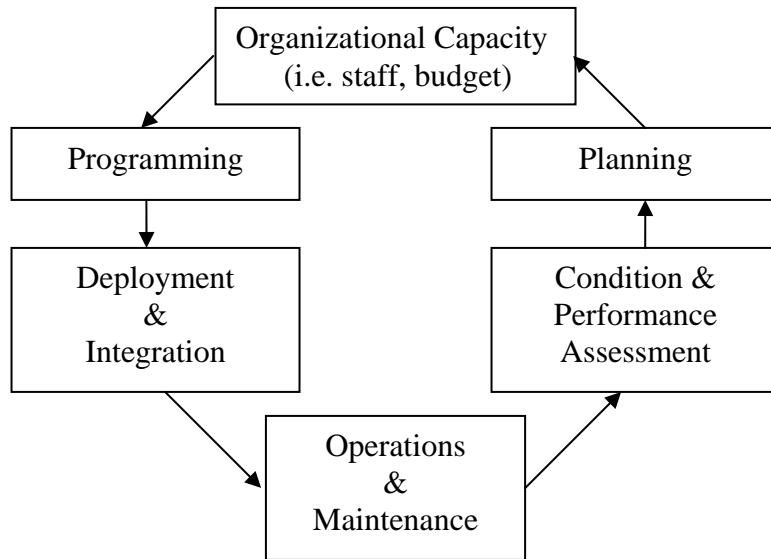
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It is recognized that the key challenge for traffic operations is to interpret a short range transportation plan (SRTP; 5-8 year plan) into statewide services (figure 4.1). A number of different specializations and expertise requires attention during these processes. A lack of organized mechanisms to capture this expertise belies state transportation agencies. As a result, some outputs emerging from the peer exchange and research efforts did not completely address implementation issues related to TOA.

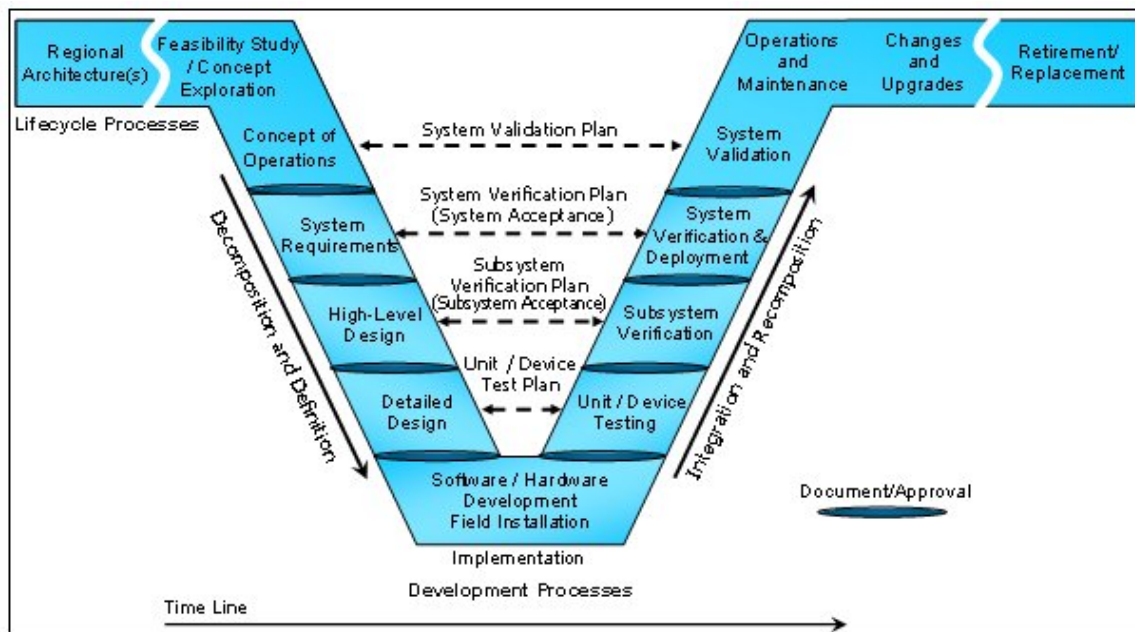


**Figure 4.1** General Planning Framework

The framework offered by asset management principles, therefore, allows practitioners to guide the processes. Considering the traffic operations life cycle specified during the peer exchange (figure 4.2), it overlaps, at several parts, with the generic asset management components (figure 2.1). The operations & maintenance, condition & performance assessment, planning, programming, and deployment & integration in traffic operations life cycle (figure 4.2) are in the same sequence as condition assessment & performance modeling, short- and long-range plans (project selection), program implementation, and performance monitoring in asset management components (figure 2.1). Further, the traditional system engineering “V” diagram should also be considered for continued adoption of TOA (figure 4.3).



**Figure 4.2** Traffic Operations Life Cycle

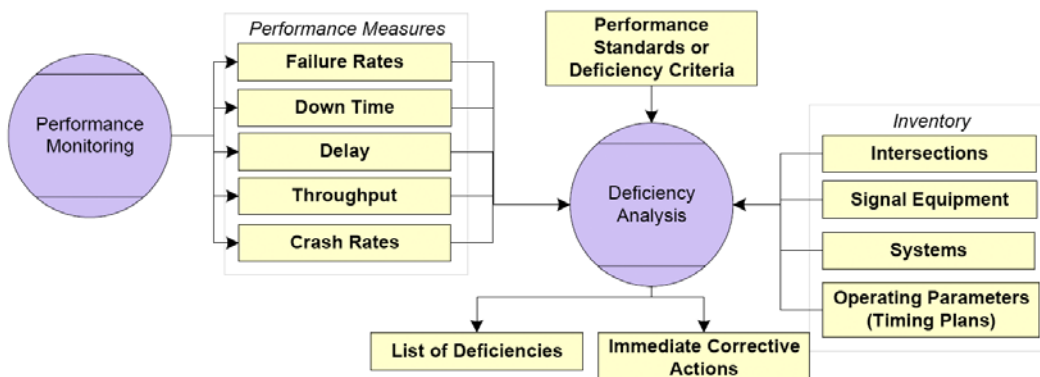


**Figure 4.3** System Engineering “V” Diagram (Office of Operations, FHWA)

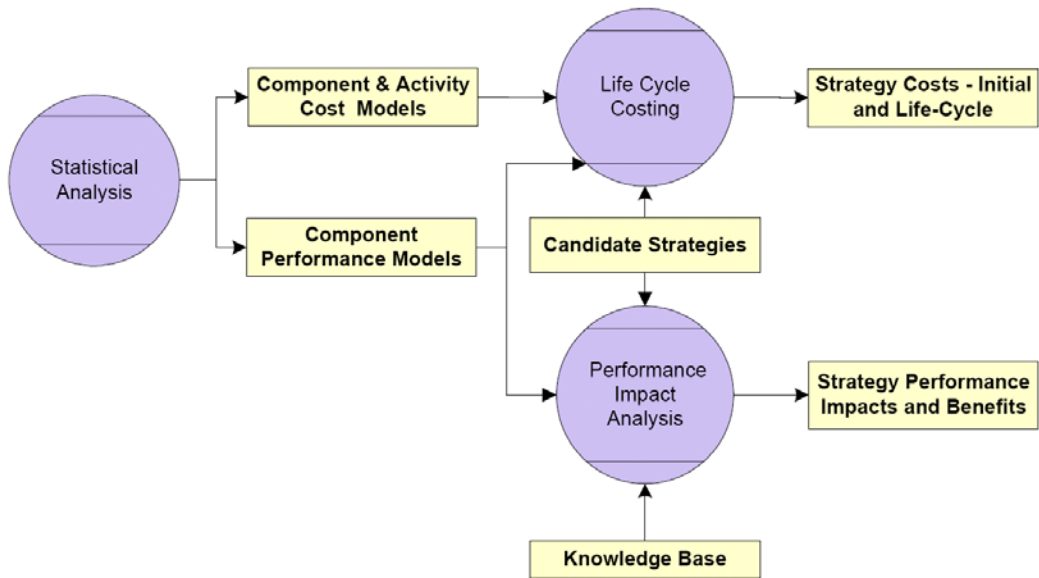
In addition, another framework for decision processes unique to TOAs has been recognized by FHWA. Consideration on these processes can be an important input in adopting asset management principles for TOAMS. This particular study addresses signal systems asset management systems, which identifies four decisions processes as the signal systems asset management (SSAM) architecture (FHWA, 2004a). The four decision processes are:

- *Daily operations and management.* In this process, decisions making will address issues on staff hiring and training, work prioritization and scheduling, and staff deployment. It also responses to urgent work requests and equipment failures and makes adjustments to operating parameters in response to special events or incidents.
- *Identification and systems' deficiencies.* Key process elements considered in this process are problem areas identification (as related to poor performance) and deficiencies prioritization (based on severity of problems, impacts on customers and other established criteria).
- *Development and evaluation of preservation and improvement options.* In general, key process elements include specification of policies and procedures on different types of maintenance, while minimizing the use of major capital investments (figure 4.4 [c]).
- *Resource allocation and budgeting.* Key process elements are allocating a fixed budget across competing needs; making best use of available funding sources; selecting the best mix of preservation and improvement work and necessary investment; estimating resource requirements based on a set of target activities including funding assessments (figure 4.4 [d]).

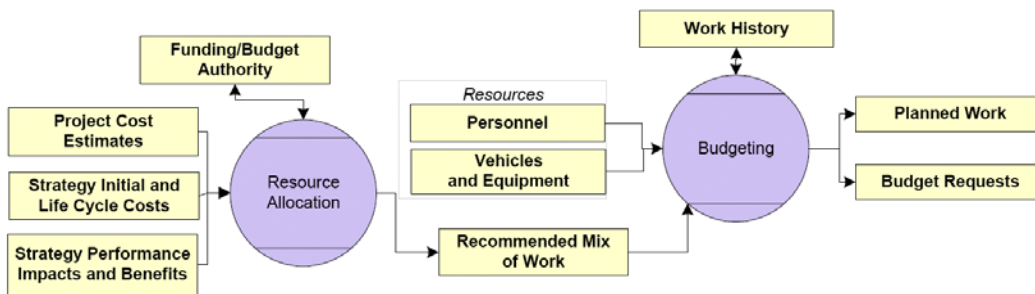
Each process integrates a number of functional components, which requires different data sets as inputs in order for functional components to work. System architectures of each process are shown in figure 4.4 below.



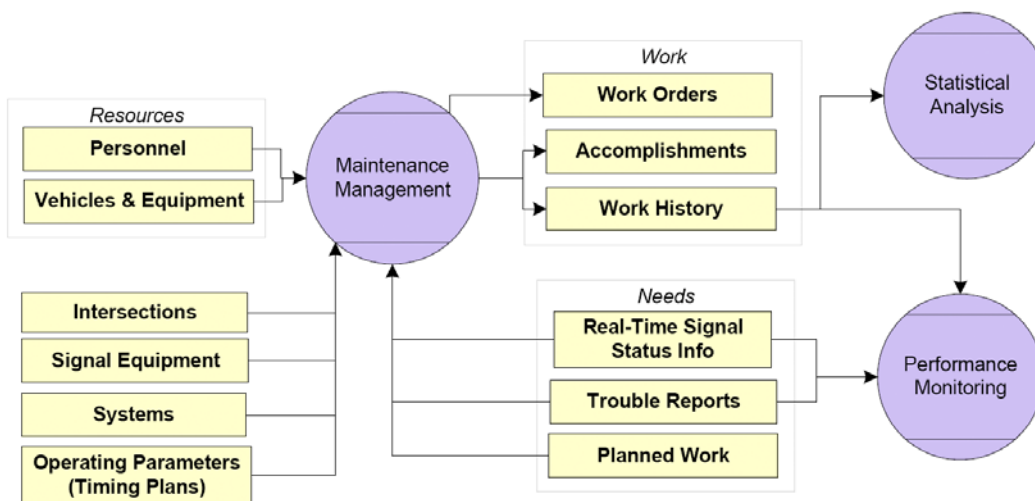
(a) System Architecture on Daily operations and management.



(b) System Architecture on Identification and system deficiencies.



(c) System Architecture on Development and evaluation of preservation and improvement options.



(d) System Architecture on Resource allocation and budgeting.

**Figure 4.4** System Architectures on SSAM Systems (FHWA, 2004a)

Considering previous discussions in chapter 3, state transportation agencies face great challenges in delivering the TOA decision processes. Particularly, the functional components required in each step mirror these formal procedures that state transportation agencies reported lacking in their implementation efforts. Further, as noted in previous chapters, significant improvement in TOA data inventory is mandatory in providing required information for the functional components to work. These challenges are consistent with what FHWA noted about some of the lacking on operations asset management current practices discussed earlier in the literature review section.

Following results of the survey and conversation during the peer exchange, three topic areas were identified to frame further discussions on a next generation of TOAMS. The topic areas were:

- *Obsolescence Planning.* Both conditions and environments change quickly causing TOAs to become obsolete. While there are a number of factors influencing obsolescence, obsolescence planning is critical for TOAMS.
- *Software Systems.* User needs on standard capabilities are often found unmet by either proprietary or in-house software. The active collaboration between users and software vendors in developing the software is as important as the availability of source code to make the software customizable. Addressing these issues is crucial for TOAMS since it connects and controls a number of different TOAs within the communication networks.
- *Maintenance Contracting and Labor Expertise.* The traditional traffic operations workforces has neither the training nor skill set for systems maintenance. Highway maintenance contractors also do not. Cross-training is an option that should be explored more further. Another is efficiently and effectively managing a number of different specialized skills.

## ***OBSOLESCENCE PLANNING***

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Obsolescence is a condition of being antiquated and, thus, unable to meet performance requirements that are changing. Four broad aspects influencing obsolescence are (Lemer, 2008):

- *Technological changes:* previously installed systems are incompatible with new technology.
- *Regulatory changes:* previously installed systems no longer meet the new regulations.
- *Economic or social changes:* system expansions are needed for accommodating new urban areas.
- *Values or behavior changes:* societal commitment to private auto travel requires more sophisticated systems.

In addition to asset management principles that offer solutions for obsolescence planning through systematic performance monitoring,

Considering previous discussions, it is safe to assume that a systematic performance monitoring within asset management principles offers a potential solution for obsolescence planning. Beyond that, however, a number of factors unique to TOA must be considered too. First, the terminology of service life may not be easily translated to TOA. Because of incompatibilities and advances in other technologies, incremental replacement over a designated time period may not be an option. Thus, instead of using service life, TOA maintenance and replacement should be based on technology trends. Practitioners must address how much replacements are likely to cost, and how these needs fit into a maintenance program.

Second, the uncertainty of useful service life makes long range planning for TOA replacement difficult to estimate. The long range plan must be flexible to facilitate obsolescence planning for traffic operations, especially because of uncertainties in determining the type of technologies that will become available in the next 20 years—a time horizon traditionally used for a long range plan. A 10 year time horizon may be more appropriate for traffic operations technology, considering more predictability in advancements of related technology.

The next factor is compatibility and interoperability. New technology in a highly competitive industry is vulnerable to business failures, takeovers, and buy-outs. Furthermore, software or technology upgrades may not be compatible with previous systems, and vendor components are often not interoperable. In order to address this situation, industries should be encouraged to work together to develop standardized compatibility for devices or systems throughout the ITS. Not only does this partnership solve interoperability issues, but it also ensures backwards compatibility in traffic operations assets/systems.

The fourth factor is related to TOA maintenance. For most transportation assets, preventive maintenance is more desirable than corrective maintenance because continuity in meeting the expected LOS is desirable. We know that in the long run it costs less to have transportation assets in good condition than in bad condition. This may not be true for TOA. What may be most important for TOA is the ability to quickly diagnose and correct systems, predictive and reactive maintenance. We may need further economic analysis on the benefits between preventive and corrective maintenance for TOA, including the development of historical data on replacement (technology advancement and replacement cycles).

## **SOFTWARE SYSTEMS**

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Software systems are usually designed for controlling TOA and collecting data using TOA for further decision-making analysis and real time system management. Three dimensions of software systems in order of importance are:

- *Operating Systems (OS) for central systems and Wide Area Network (WAN).* Software systems should support the operation of a central hub. Not only is it important for ensuring reliability of the central systems, but it is also about ensuring the performance monitoring for meeting standard operations. In

addition, communication with other agencies relies on the central hub. Thus, managing the central hub at a reliable level is a key.

- *Communication fiber optics fields to a Traffic Management Center (TMC).* Software systems should facilitate systems communication linking all field devices to TMC.
- *Field devices as input and output.* Software systems should optimize the operation of field devices as both the input devices (recording field information) and the output devices (sending information from central hub).

Following a software systems development process, it is crucial to ensure that software systems satisfy expected functional capabilities. Agencies cannot assume their software developer knows traffic operations and vice-versa. Thus, the development of both proprietary and in-house software has to closely involve potential users so that software solutions meet actual expectations. Despite invaluable general usability of such products, this situation will require software customization.

Further, if customization is needed, the source code becomes crucial for users in software customization. Thus, the source code ownership needs to be regulated. There are two benefits the users can find from this customization. First, software replacement becomes unnecessary since the software is customizable in meeting specific users or projects needs. Second, the absence of a software vendor does not prevent users from customizing the software.

Issues on data stewardship are becoming apparent from both a technical and business perspective. Several states noted that comprehensive plan development within operations has included issues on data stewardship. The concern is how to optimize the use of archived data in identifying any failure in the systems.

Related to workforce, the relationship between an ITS group and information technology (IT) group in a state transportation agency has been an issue. It is recognized that dedicated IT staffs are necessary in the ITS groups to handle software-related issues. However, the unclear organization structure within state agencies leads to ineffective collaboration between the two groups. Part of the national discussion needs to include debate on the role of the agency's IT professionals, and how they should be coordinated in TOAMS. Agencies face similar overlap with IT and mapping geographic information management. Problems can occur not only in the relatively small scope of the traffic operations business area, but also in a larger scope, in some cases, where ITS is considered a part of the state IT strategic plan. In this case, the state strategic plan is unable to identify the unique roles of ITS relative to IT, causing the strategic plan's inability to address immediate needs of IT in a transportation sector.

## ***MAINTENANCE CONTRACTING AND LABOR EXPERTISE***

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Asset availability and reliability become critical issues in capital-intensive activities, leading to the necessity of strategic maintenance to become a standard procedure. The increasing demand for a robust transportation system puts TOA maintenance in a similar situation. Type of service delivery is one of four strategic dimensions of maintenance (Tsang, 2002). In addition to in-house maintenance, outsource maintenance is another option in service delivery type. Outsource maintenance is typically conducted for three different reasons (Tsang, 2002):

- In-house maintenance provider does not have sufficient capability to meet high demand. In this situation, a short period of outsourcing can be useful to fill the gaps.
- Specialization skills in maintenance are too wide while maintenance works are too specific resulting difficulty in having an in-house expert.
- Outsourcing maintenance is a cost-effective service delivery option when in-house expertise and specific facilities are unavailable.

Following these reasons, it is safe to assume the close relation between maintenance and labor expertise. The needs of specific skills and facilities for maintenance require public agency to conduct outsource maintenance. That is, a collaboration between public agencies and private sectors. Normally, a contracting agreement is needed in order to ensure a proper service delivery from private sector in maintenance.

Further discussion on maintenance contracting and labor expertise in the area of transportation can be referred to the concept of public private partnerships (PPPs). FHWA defines PPPs as a contractual agreement between a public agency and a private sector institution, allowing for greater participation from private sector in the transportation projects delivery (FHWA, available online). Under PPPs, it is expected that private sectors can participate in sharing their resources in technical, management and financial areas.

In addressing these issues in the context of TOAMS, the peer exchange and research efforts revealed a number of frustrations faced by state agencies in the inability to contract maintenance and to compete for and hire certain labor expertise. It is especially still unclear how collaboration between a public agency and a private company in delivering transportation-related services should be conducted and in what area.

A total of 8 types of activities and 4 potential groups involve in TOAMS were specified. The peer exchange identified typical interactions of the groups in executing TOAMS activities (Table 4.1). As can be seen, the state is expected to have more leading roles in 5 TOAMS activities. Three other activities are expected to be led by three other groups: contractor vendor for application development, contractor on-site for TOAMS training, and a university or other agency for performance monitoring. A few supporting roles are indicated as well for 3 TOAMS activities.

**Table 4.1** Group Interactions within TOAMS Activities

Activities	State	Contractor Vendor	Contractor On-Site	Other Agency (University, State IT, etc)
Planning and Programming	<b>L</b>			<b>S</b>
TOAMS Design / Project Management	<b>L</b>	s	<b>S</b>	s
Application Development	<b>S</b>	<b>L</b>		
Database Development	<b>L</b>			<b>S</b>
Software Administration/Maintenance	<b>L</b>		<b>S</b>	
TOAMS Training	s		<b>L</b>	<b>S</b>
TOAMS users	<b>L</b>			
Performance Monitoring	s			<b>L</b>

*\*) Please note that leading roles are indicated by a letter of “L” and supporting roles are indicated by a letter of “S” or “s.” The two supporting role letters specify the level of support to particular activities.*

Despite the involvement of a number of different groups in PPPs, it is recognized that public agencies are still taking leading roles. The private sector, which has more specialized skills and offers better technology innovations, still needs political and funding support in order to move forward.

Furthermore, the presence of leading or supporting role does not indicate that one party has more benefits than the other. As a matter of fact, the contribution of private sector under PPPs is intended to supplement—instead of to substitute for—public investment in transportation improvements. Therefore, it is critical that collaboration between a public agency and a private company needs further examination to ensure more efficient and effective TOAMS. The conflicting issues are how public interests are fulfilled, while at the same time private interests are served?

Following FHWA guidelines and considering the position paper released by Oberstar and DeFazio in 2007 about public interest concerns of PPPs, there are at least 3 issues need to be addressed in conducting PPPs for TOAMS:

- PPPs allow an improved quality and systems performance from the use of innovative materials and management techniques. It is noted earlier that product incompatibilities have been an issue in the area of traffic operations. By encouraging private sectors to address the issue of compatibility, potential monopolistic production of TOAs by private sectors can be avoided.

Since TOAs service life is unpredictable, maintenance contract should address technological trends. There are two possible ways. First, maintenance contact should be made as short as possible so that public agency has the flexibility to

meet technological trends. Alternatively, maintenance contract should not limit to standard maintenance activities (preventive, corrective, inspection, and replacement). Once the most advanced technology becomes available during the life of the contract, its implementation should be prioritized.

- PPPs allow substitution of private resources and personnel for constrained in-house resources. However, a state transportation agency should develop and maintain its competency and its capabilities to negotiate with private sector companies to the public's best interests.
- PPPs allow a public agency to access new sources of private capital, resulting project cost savings. Not only is it critical to ensure a reasonable return of private sector investment, but also it is critical to have all needed maintenance services delivered throughout the life of the contract.

Maintenance contracting is not limited to physical-based maintenance as discussed earlier. Performance-based maintenance contracting is also present. In this case, private sectors are expected to measure and to report on performance of transportation assets. In this way, specific information on the needs on maintenance is gathered. Related work of the National Cooperative Highway Research Program (NCHRP) is currently investigating performance-based contracting for maintenance (NCHRP Project 20-5).

## Chapter 5 SUMMARY AND RECOMMENDATIONS

### **SUMMARY**

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Up-to-date asset management tools are needed for TOA especially considering the increasing financial commitments to support the operations of roadway networks. When following asset management approaches developed over 50 years for pavement and bridges, the unique characteristics of TOA have not been studied, and have challenged public officials in developing the most effective strategies or policies at each deployment stage from planning to statewide implementation.

Based on previous discussions, the critical issues of TOAMS can be categorized in three key themes:

#### **1. Connecting investment and performance.**

The lack of a measurable indicator in current system management for TOAs causes a weak link between investment strategies and systems performance. Since limited budget will always be an issue, a strategic budget allocation is important. However, a justifiable budget assessment is challenging to make without adequate data reporting system performance. Therefore, improvement in data inventory is critical, including data inventory from LOS monitoring. The completeness of data inventory will ensure a robust performance indicator, leading to a much better assessment for investment strategies and overall systems reliability.

#### **2. Improving configuration planning.**

A strategic assessment will only emerge from effective planning processes. While data processing is important in producing convincing information, it is more critical to manage how the information is used and reproduced during planning processes. As discussed earlier, TOAMS involve a number of different groups of people with various competencies. Current confusion in what roles and how they should communicate with each other cause ineffective planning processes. Responsibilities of each group are not clearly defined resulting improper executions of traffic operations tasks. Therefore, it is critical to enhance the collaboration among groups involved within TOAMS activities, which involves, but not limited to, planner, traffic engineer, IT and ITS official.

#### **3. Promoting public-private partnerships (PPPs)**

In theory, PPPs will give significant benefits to TOAMS. Guidelines in implementing PPPs are widely available, including a number of concerns to be anticipated. Part of the efforts should include documenting state best practices in transportation management, which current discussions on PPPs are limited found. This causes only a few lessons could be learned from other states transportation agencies in how PPPs were implemented. In addition, a special attention should be given on the implementation of PPPs in the area of traffic operations since it is

relatively new. Most PPPs implementation is done in traditional areas such as pavements, bridges, and highways.

## ***RECOMMENDATIONS***

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The detailed recommendations presented in the following sections should be useful for further development of TOAMS on a national as well as state level.

### **1. Develop maintenance procedure standards including maintenance contracting**

This recommendation addresses the life-span for traffic operations and operational performance. It is intimately related to the establishment of an historical database of TOA replacement and a minimum LOS of TOA. These establishments will help ensure more effective decision making processes in TOA maintenance.

### **2. Develop configuration standards**

Having a national standard for configurations provides at least four benefits. First, problems faced by users will be similar and efforts in finding solutions will be much more effective and efficient. Second, industries can be leveraged where manufacturing components have obvious markets. Third, components available in the market will have high compatibility and, therefore, agencies have interoperably to use components from any manufacturing company. Last, the advancement of technology will be much more predictable, leading to a more effective planning process.

### **3. Develop a traffic operations guide under the auspices of AASHTO**

From the perspective of DOT officials, it is helpful to have a single comprehensive TOAMS synthesis that can be used in an executive decision environment as a tool for traffic operations. This is essential since there are a lot research reports available, sometimes causing DOT officials overwhelmed. The guidance will include:

- Scan and synthesis of preferred practices including contracting approaches and management skills
- Self assessment and/or peer review on processes or programs conducted
- Set of guidance “brochures”

### **4. Forecast technological advancement and analyze possible impacts**

While it is challenging to predict the availability of technologies, it is worth the effort when such information is available, especially for obsolescence planning. In addition, further analysis would be necessary to determine how these predicted technologies could impact both operational and organizational aspects of TOAMS.

**5. Improve the implementation of analytical procedures**

Further analysis on data collected is crucial in devising strategies and policies geared toward TOA systems reliability. The implementation of formal procedures specific to TOAMS needs to go beyond basic operational procedures. Significant improvement in the area of analytical procedures is crucial considering the relatively little attention it has received from state transportation agencies. This is especially because most analytical tools currently available are oriented toward traditional infrastructure. Some analytical procedures are especially important considering current limited implementation in state transportation agencies. They are life-cycle cost analysis; performance analysis including a robust indicators development based on data monitoring; and budget allocation analysis in consideration with tasks' prioritization.

**6. Explore comparable industries in the management of traffic operations asset**

Although TOA is specific to transportation management, in this case surface transportation, some specific components within TOA can be found in other industries. Particularly in the communication configuration of software systems (OS central systems and WAN, communication fiber optics fields to TMC, and field devices as input or output), looking at best practices from the military or the Federal Aviation Administration (FAA) could help advance the implementation of TOAMS.



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**Appendix A**  
**Survey Questionnaire**

## Agency Profile

1. Location of the agency \* required

2. Name of your agency \* required

3. Type of Agency

- Federal  
 State  
 Local

4. Does your agency use proprietary software for TOAMS?

- No  
 If Yes, How important is the software? (1=High, 5=Low)

5. Does your agency use in-house developed software for TOAMS?

- No  
 If Yes, How important is the software? (1=High, 5=Low)

6. Check all the components your agency manages

	Manages	Don't have
511 Telephone Dial-in Service	<input type="checkbox"/>	<input type="checkbox"/>
Advanced Traffic Management System	<input type="checkbox"/>	<input type="checkbox"/>
Advanced Traveler Information System	<input type="checkbox"/>	<input type="checkbox"/>
Automated Crash Notification System	<input type="checkbox"/>	<input type="checkbox"/>
CCTV Cameras (traffic surveillance)	<input type="checkbox"/>	<input type="checkbox"/>
Incident Management System	<input type="checkbox"/>	<input type="checkbox"/>
Loop Detectors (traffic count, occupancy and speed)	<input type="checkbox"/>	<input type="checkbox"/>
Pavement Sensors (temperature)	<input type="checkbox"/>	<input type="checkbox"/>
Road Weather Information System	<input type="checkbox"/>	<input type="checkbox"/>
Signal System (signal heads, controllers)	<input type="checkbox"/>	<input type="checkbox"/>
VMS Controllers	<input type="checkbox"/>	<input type="checkbox"/>



8. Does your agency have any of the following formal process applied to the components listed? Check all that apply

	Automated Crash Notification System	Advanced Traveler Information System	Advanced Traffic Management System	Incident Management System	Road Weather Information System
Budget planning for maintenance and replacement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Communications Network Management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dedicated staff	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Estimate personnel needs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Field equipment inventory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Maintenance record and management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Make assessment on deficiencies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Make purchase decision(s)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Perform life-cycle cost analysis	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Performance monitoring	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Propose new improvement project	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Schedule maintenance repair and/or replacement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Spare parts inventory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Written Guidelines	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Others	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

## Asset Use and Data Collected

9. For each asset, what data do you keep on your inventory? (check all that apply)

	Characteristics / Capabilities	Maintenance Requirements	Maintenance Cost History	Repair / Failure History	Age / Condition
511 Telephone Dial-in Service	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Advanced Traffic Management System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Advanced Traveler Information System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Automated Crash Notification System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
CCTV Cameras (traffic surveillance)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Incident Management System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Loop Detectors (traffic count, occupancy and speed)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pavement Sensors (temperature)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Road Weather Information System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Signal System (signal heads, controllers)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
VMS Controllers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

10. How frequently your agency use the following components and systems (1 = Daily , 5 = Yearly or Never)

	1	2	3	4	5
511 Telephone Dial-in Service	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Advanced Traffic Management System	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Advanced Traveler Information System	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Automated Crash Notification System	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	1	2	3	4	5
CCTV Cameras (traffic surveillance)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Incident Management System	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Loop Detectors (traffic count, occupancy and speed)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pavement Sensors (temperature)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Road Weather Information System	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Signal System (signal heads, controllers)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
VMS Controllers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### System Monitoring

11. What maintenance policies are used for the following components and systems? (check all that apply)

	Preventive Maintenance (Replacement due to experience)	Corrective Maintenance (Replacement when a failure occurs)	Inspection Maintenance (Replacement when an inspection reveals problems)	Replacement (When component is obsolete)
511 Telephone Dial-in Service	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Advanced Traffic Management System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Advanced Traveler Information System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Automated Crash Notification System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
CCTV Cameras (traffic surveillance)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Incident Management System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Loop Detectors (traffic count, occupancy and speed)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Preventive Maintenance (Replacement due to experience)	Corrective Maintenance (Replacement when a failure occurs)	Inspection Maintenance (Replacement when an inspection reveals problems)	Replacement (When component is obsolete)
Pavement Sensors (temperature)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Road Weather Information System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Signal System (signal heads, controllers)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
VMS Controllers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

12. What is your method for determining if the following systems are working?

	Monitoring System	Field Survey	Customer Complaint
511 Telephone Dial-in Service	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Advanced Traffic Management System	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Advanced Traveler Information System	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Automated Crash Notification System	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
CCTV Cameras (traffic surveillance)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Incident Management System	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Loop Detectors (traffic count, occupancy and speed)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pavement Sensors (temperature)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Road Weather Information System	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Signal System (signal heads, controllers)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
VMS Controllers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

13. Does your agency use any of the following components to monitor level of service (LOS) ?

	Roadway LOS	Intersection LOS	Not Used (N/A)
CCTV Cameras (traffic surveillance)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Loop Detectors (traffic count, occupancy and speed)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Manual Data Collection Program	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

14. Does your agency monitor compliance with MUTCD standards?

- No
- If Yes, please specify how (software, manual, etc)

15. How are customers able to notify the agency about malfunctioning traffic operations assets?

- Phone
- Online
- Mail
- Not Able to Notify

### Issues and Priorities

16. Rate the current importance of these operational issues for your transportation agency?  
(1=Very Important, 5=Not Important)

	1	2	3	4	5
Conduct trainings to enhance technical maintenance skills	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contracting for system maintenance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improve contractor responsiveness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Physical condition assessment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reallocate staff to improve efficiency of operation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduce repairment or replacement costs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	1	2	3	4	5
Repair / Replace equipment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Standardize components	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Upgrade central system	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Upgrade individual systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. How does your agency rate the importance of the following initiatives? (1 = Very Important 5 = Not Important)

	1	2	3	4	5
Adjust / Upgrade existing infrastructure system	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Coordinate agencies across jurisdictions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Deploy more system management on ITS facilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Develop a computerized system management module	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Expand system capabilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improve technology interaction of ITS system technology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
More infrastructure system installation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Multi agencies coalition, both transportation and non-transportation agencies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Prioritizing and scheduling maintenance of ITS systems and components	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## Respondent Information and Interests

18. Who filled out this survey? \* required

Name and title

Email

19. Who filled out this survey?

Phone

Fax

20. Would your state send a representative, if travel is funded, to the Transportation Operations Asset Management Systems Peer Exchange and Workshop in Milwaukee, Wisconsin in February 2008?

- No
- If Yes, please list name, title, address, email, phone, and fax

21. Are you interested in presenting or discussing your states' TOAMS program experiences, successes or challenges?

- No
- If Yes, please indicate topic areas.

22. What has your agency done that others can learn from? (Best Practices?)

## **TOAM Resources**

We are requesting TOAMS tools/resources from all state transportation agencies. We will be compiling all materials onto a website. We will contact you to arrange for the collection of these items.

23. Please indicate the TOAMS tools or documents your agency may share with others (check all that apply)

- Inventory management tools
- System Documentation (research report on system development)
- System performance (charts, tables, graphs to illustrate system performance)
- Training materials
- Other, please specify