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16. Abstract

This report provides a policy-level review of the costs and funding issues associated with Intelligent Transportation Systems/Advanced Traffic Management Systems (ITS/ATMS) operations and maintenance (O&M). Through this research project, a practical methodology has been developed for estimating annual O&M expenses and allocating operating funds. The report includes estimated O&M costs for over 60 ITS elements.

Also reviewed in this report are a number of issues related to departmental policies, procedures, and practices that affect the ability to adequately and consistently fund ITS/ATMS operations and maintenance. These include the source and availability of funds, the budgeting process, the impact of legislative mandates, the increased use of outsourcing, the development of public and private partnerships, and the implications of system design and replacement on O&M costs.

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GUIDELINES FOR FUNDING OPERATIONS AND MAINTENANCE OF ITS/ATMS

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Research Report
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Sponsored by the
Texas Department of Transportation

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TEXAS TRANSPORTATION INSTITUTE
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IMPLEMENTATION RECOMMENDATIONS

This report was sponsored by the Texas Department of Transportation to provide a policy-level analysis of the costs and funding issues associated with the operation and maintenance of Intelligent Transportation Systems (ITS), and more specifically Advanced Traffic Management Systems (ATMS) in Texas. Cost figures and funding guidelines were developed using data from systems currently under operation in Texas, as well as information obtained from a literature review and a survey of other states. The results of this research effort are expected to increase awareness of ITS/ATMS operations and maintenance issues and concerns, and improve the long-term effectiveness of these systems through systematic budget development and funding allocation.

The recommendations for implementation are summarized below:

1. Estimate ITS/ATMS operation and maintenance costs using the Cost Estimate Table developed in this study. The Operations and Maintenance (O&M) Cost Estimate Table developed through this study is based on actual and documented costs, and is flexible enough to apply to each district's operating environment.

2. Allocate ITS/ATMS maintenance and operations funds using the O&M Cost Estimate Table. Each district can project costs from the same basis using the table, and the combined total can be used for annual budget requests. If funding is not available for the full amount, then the available funds can be distributed on a percentage basis using the district totals to determine the proportions.

3. Track O&M costs over the long term to maintain validity and usefulness of the O&M Cost Estimate Table. This includes and annual reconciliation of projected and annual costs, updates to the O&M Cost Estimate Table as necessary, and an assessment of personnel allocation to traffic management system O&M.

4. Examine the source and level of funding of ITS/ATMS operation and maintenance to ensure a balance of funding is achieved between all maintenance and operation activities. This can be accomplished by: identifying and documenting the benefits of ITS O&M to provide decision-makers with objective criteria for balancing funding demands; considering a departmental policy that acknowledges increased funding requirements for maintenance and operation of all transportation system expansions; and taking advantage of federal funding available for traffic management system operations and operational support activities. Alternatively, if additional O&M funding is not forthcoming, consideration should be given toward refraining from building new infrastructure if it cannot be adequately operated or maintained.

5. Improve budgeting and tracking of O&M expenses by developing separate budget accounts for maintenance and operations, and funding both accounts from the maintenance appropriations strategy to allow maximum flexibility. Furthermore, renaming the

maintenance appropriations strategy to include the operational component would provide recognition of transportation system operation while maintaining budget flexibility.

6. Modify departmental processes and approaches in order to stretch current funding. Specific processes that can be modified include increasing outsourced maintenance using funds designated for contracting, strengthening the third-party damage claims recovery process to increase collections, and building upon the success of the catalog procurement process for information resources.

7. Provide direction and guidance for districts to effectively pursue partnerships and ultimately share operating expenses. The basis for developing policy direction on this issue can be the successes TxDOT has achieved to date in public/public and public/private partnerships, as well as ITE recommended practices for joint operations.

8. Continue to support the NTCIP development process and incorporate standards into procurement specifications. Procurement specifications requiring devices to be NTCIP compliant will ensure interoperable and interchangeable devices, which will lead to compatibility and reduced O&M costs in future years.

9. Emphasize lifetime operations and maintenance costs in the system design process. Consider all opportunities for reducing O&M costs during system planning and design. By examining long-term system O&M costs, TxDOT will be in a better position to take a life cycle approach to ITS project development.

10. Improve planning efforts for system reinvestment. Increase funding in existing budget categories that are used to upgrade and rehabilitate current systems.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification or regulation. This report was prepared by Ginger Daniels, P.E. # 64560, Tim Starr, P.E. # 80685, and Bill Stockton, P.E. # 41188.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

The ability of state and local agencies to effectively operate and maintain Intelligent Transportation Systems (ITS) is vitally important to the success of traffic management efforts. The federal government, through the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), has contributed financial resources to deploy new systems and provide start-up assistance with the understanding that state and local agencies will provide for ongoing maintenance and operation. However, existing state and local funding sources are strained. Not only are the current revenue levels in Texas unable to fund needed construction projects, but the demands for maintenance and operation of the transportation infrastructure as a whole are increasing as new projects are constructed.

In some physically constrained corridors where the financial and environmental costs of highway expansion are too high, improvements in the operation of existing facilities may be the only way to improve mobility, making the effectiveness and reliability of traffic management systems critical. Yet the provision of stable, sustained funding for operation and maintenance (O&M) of these systems is uncertain under the current revenue predicament. The problem is compounded by the fact that the costs for operating and maintaining ITS systems are not well-documented.

The purpose of this study is to provide TxDOT with a method for determining the costs associated with the operation and maintenance of ITS and Advanced Traffic Management Systems (ATMS), and to assess the implications of funding issues, budgeting efforts, departmental policies and procedures, and joint operations with outside entities on traffic management O&M. The results and implementation guidelines have been developed based on the experience of those TxDOT districts that currently have substantial ATMS in place, in addition to information gathered from documented studies and the experiences of other state and local transportation agencies.

Through this research effort, a methodology has been developed for implementation which provides a means for estimating annual ATMS maintenance and operational expenses and allocating statewide funds. In addition, recommendations have been presented for review and evaluation of current departmental polices, procedures and practices related to ATMS maintenance and operations, including budgeting, funding, outsourcing, public and private partnerships, system design, and system upgrading.

CHAPTER ONE

INTRODUCTION

INTRODUCTION

The construction of new highways cannot match the growth in travel demand for the foreseeable future; consequently, getting the most mobility from the available system is crucial. Traffic management efforts in many states, including Texas, have resulted in the development of new technologies and management techniques to improve mobility, with demonstrated success in reducing accidents and improving travel time.

As Texas moves forward with the deployment of Intelligent Transportation Systems (ITS) technologies throughout the state, the issue of sustaining and supporting traffic management systems after they have been implemented becomes an increasingly critical one. In the midst of limited funding, undocumented costs, competing maintenance needs, "aging" systems, and institutional barriers, the systems already under operation are struggling to meet the expectations extolled during implementation. Planning for the day-to-day performance and upkeep, despite its necessity, has been a secondary consideration in the ITS implementation process. Although, the entire transportation infrastructure continues to expand as the state's population grows, the Texas Department of Transportation's (TxDOT) funding to operation and maintain the infrastructure has not expanded to meet the demands.

Operation and maintenance (O&M) of ITS and Advanced Traffic Management Systems (ATMS) are those tasks required to allow an existing system to continuously accomplish the goals and objectives for which it was designed and to respond to changing technologies and transportation system demands.

"Operations" involves

- overseeing the day-to-day function of control and management equipment,
- collecting real-time traffic flow data and reacting with traffic flow and incident management strategies,
- communicating and coordinating with related transportation and emergency response agencies,
- disseminating information to the media and public,
- monitoring systems performance criteria,
- updating system databases,
- notifying maintenance personnel of system malfunctions, and
- administering operations contracts and monitoring the performance of operations contractors.

"Maintenance," also referred to as "operational support," involves

- performing preventative maintenance,
- monitoring hardware and software components for required performance levels,
- repairing and/or replacing equipment, components, and modules,
- diagnosing and resolving software inconsistencies, and
- administering maintenance contracts and monitoring the performance of maintenance contractors.

TxDOT recognizes that while most traffic management improvements have a relatively low capital cost as compared to highway expansion, virtually all operational improvements require real-time attention to ensure that they are providing optimal service, particularly in an environment of rapidly changing technology. TxDOT further acknowledges that stable funding of operational improvements is the only way to continue to receive the benefits these kinds of services can provide to the public. A well-run and well-maintained ITS system not only serves the transportation system users as intended but boosts the credibility of the program with the public. Conversely, systems that are plagued with inadequate staffing, persistent software bugs, and inoperable field devices will fail to provide high-performance services, increase liability, and ultimately tarnish the ITS initiative and the credibility of all transportation service providers.

This research project provides a policy-level view of the O&M requirements and associated costs of the traffic management systems that are a part of ITS. Quantifying the funding necessary to adequately operate and maintain ITS/ATMS is the first step toward sustaining system performance, yet very little documentation is available to assist TxDOT in that effort. A process for estimating O&M costs has been developed through this research project.

In addition, several meetings were held with TxDOT staff who currently operate and maintain ITS/ATMS. As indicated during the meetings, the staff is struggling with the lack of stable O&M funding and the procedural issues that create barriers to adequate O&M. The forces that impede the O&M effort are illustrated in Figure 1. The "hindering forces" are examined in this study, and implementation guidelines are presented to address the funding of O&M and the kinds of problems that compound the funding issue.

The purpose of this study, therefore, is twofold: first, to provide a mechanism to estimate the costs required to adequately operate and maintain ITS elements; and second, to examine the funding issues and provide guidelines to address the obstacles that prevent adequate funding of traffic management in Texas. This study examines the O&M funding "pie": getting a handle on the size of the pie, assembling the ingredients, making the pie bigger, slicing the pie, and what to do about "unexpected guests for dinner."

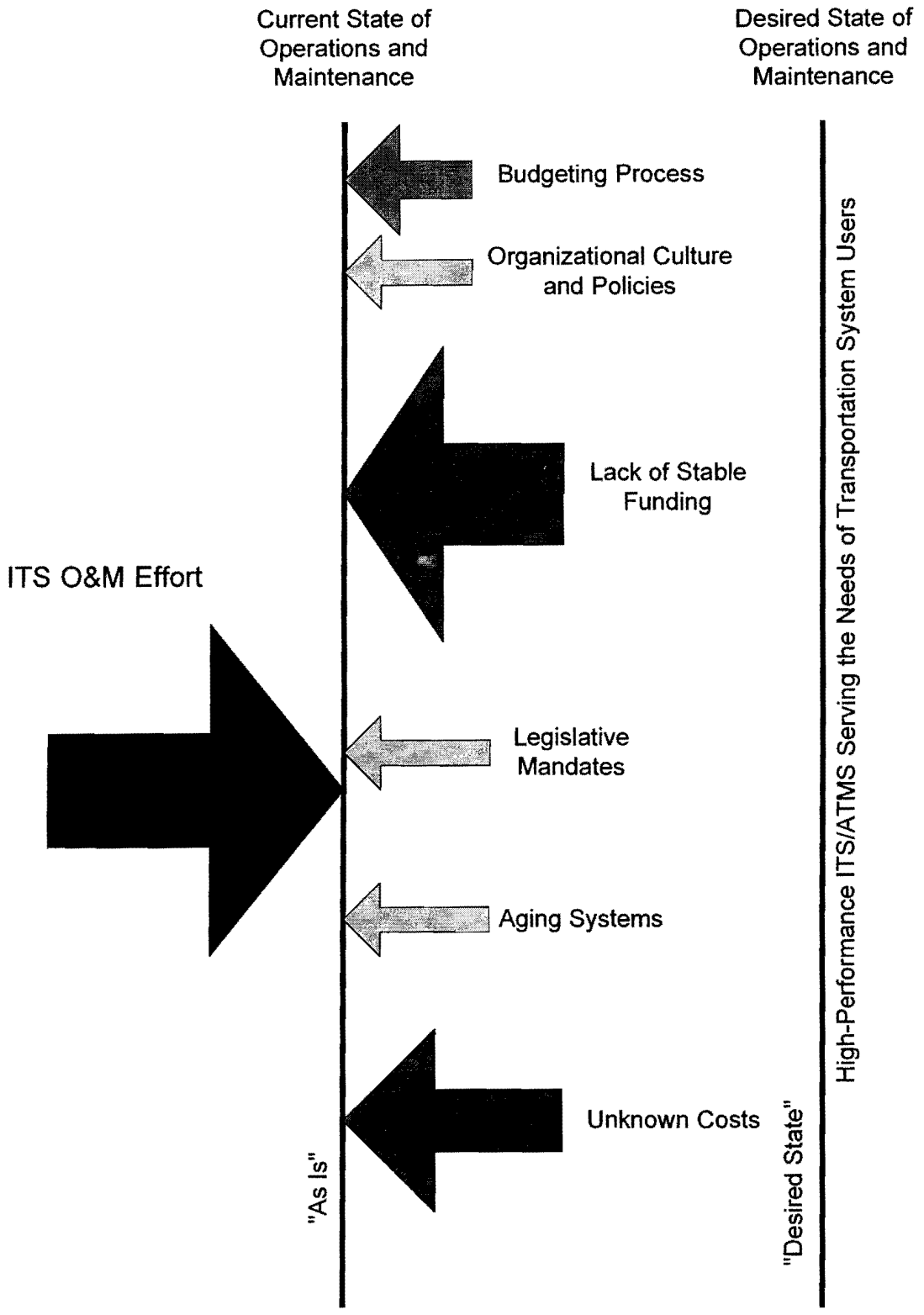


Figure 1. Hindering Forces Affecting ITS O&M

CHAPTER TWO

BACKGROUND

BACKGROUND

LITERATURE SEARCH

Researchers conducted an extensive literature search for this study, but no substantive documented ITS or ATMS operation and maintenance costs were found. Although much reference is made to the issue in a number of publications, very little research has been performed regarding hard data on costs and specific approaches to funding.

The cost figures developed in this study were primarily derived using data from TxDOT metropolitan districts with substantial ITS deployment. In the absence of data from actual expenditures, several other sources were used, including the Institute of Transportation Engineers (ITE) report, "Operation and Maintenance of Electronic Traffic Control Systems" *(1)*.

In addition to the cost data, the ITE report includes a survey of transportation agencies, which experience similar concerns regarding funding for O&M. Some of the concerns include

- an anticipated 20 percent shortfall in both funding and staffing for traffic control systems,
- an increase of 300 to 400 percent in new and expanded ATMS (such as service patrols, closed circuit television [CCTV], detectors and variable message signs [VMS], and
- an estimate by 50 percent of the responding states that rates their current ability to operate ATMS as "fair" to "poor," while almost 70 percent expect their future maintenance levels for ATMS to be "fair" to "poor."

In September, 1996, ITE sponsored the "National Conference on Operating and Maintaining Advanced Traffic Management Systems (ATMS) Centers," which was attended by over 90 professionals involved in one or more aspects of operating and maintaining traffic management centers. The purpose of this conference was to discuss and develop proposed recommended practices on the key elements for successfully operating and maintaining traffic management centers, using a series of white papers as the basis for discussion. The key elements identified were

- Administration,
- Joint Operations,
- Funding,
- Staffing,
- Standards,

- Training,
- Liability, and
- Computer Systems.

The draft recommended practices developed by conference participants for each of these key elements are included in Appendix A. The recommended practices will be further refined and implemented on a test basis at several locations prior to the final publication by ITE in late 1997.

In a paper from the Proceedings of the 1995 Annual Meeting of ITS America entitled, "ITS Operations and Maintenance Issues"*(2)*, author Raman Patel states that in the face of severe state and local budget deficits, federal support of O&M is critical. FHWA has been flexible in the use of federal funds for maintenance and operations and will likely continue to move toward greater flexibility. Also provided in the article is information related to the practices in other countries regarding their policies of not distinguishing between construction, operations, or maintenance when it comes to funding sources. He points to the practice of toll authorities, private sector organizations, and European governments that allocate sufficient funding money for O&M. The private sector in particular operates and maintains complex information exchange networks, such as financial and telecommunications networks, with sufficient funding and without distinction between construction, operations, or maintenance when considering funding sources.

SURVEY OF OTHER STATES

A survey of state transportation agencies was conducted to identify budget structure, funding allocation, and participation by other entities in the operation and maintenance of traffic management systems. The survey confirmed that the challenges facing TxDOT are common nationwide. Twenty-one responses were received and are summarized in Appendix B. Seventeen of the 21 respondents have a wide variety of traffic management systems in place, ranging from traffic signals and variable message signs to ATMS. The budgeting and funding approaches are also as diverse. Of the remaining four responses, two reported no traffic management systems in operation. Two others reported systems that are operated, maintained, and funded exclusively by local agencies.

Five of the 17 respondents who operate and maintain traffic management systems reported an adequate level of funding for operations and maintenance. Four of these five indicated that they have specific categories for budgeting traffic management O&M or utilize other funding sources, such as Federal Congestion Mitigation and Air Quality (CMAQ) funds.

The majority of the remaining 17 states reported inadequate funding for O&M. They have no specific budget category for traffic management O&M and are subject to state-level allocation of maintenance funds, typically in competition with other maintenance functions. Several reported obtaining short-term O&M funding through project construction for a one-year start-up or warranty period, but expressed concern about long-term O&M costs and the lack of an available funding

mechanism.

Twelve of the respondents reported that other agencies are involved in the operations and maintenance of traffic management systems. According to those responding, the most common participants are cities, counties, transit agencies, and public safety agencies. These entities provide some or all of the O&M funding depending on their involvement. The respondents also indicated that, with the exception of consultants and product suppliers, there was limited involvement by the private sector in ITS O&M. Two responded that commercial broadcasters are involved in disseminating information, and one indicated involvement with a private utility in providing fiber optic service.

The State of California, which is one of the states that indicated a sufficient level of funding for operation and maintenance of field elements, takes a life-cycle approach to infrastructure maintenance through a legislative directive. The legislation establishes a ten-year funding plan, and specifically states that the department's annual estimate of expenditures for maintenance, operations, and administration may be adjusted in order to "reflect increases to maintenance inventories caused by newly completed state highway projects...necessary to maintain the current overall level of services" *(3)*. Although not all budget change proposal for increased inventory are approved, California has been able to balance most new operational and maintenance demands without increasing annual funding. This has been achieved because of a combination of dwindling inventory increases over the last ten years, the reduction in new construction due to the construction and right-of-way costs and environmental impacts, and a switch in emphasis from construction of new facilities to operating and maintaining existing facilities *(4)*. While ITS field elements have been fairly easy to define in terms of expanded inventory, Caltrans is currently working on a method to define Traffic Management Center (TMC) for O&M budget change proposals.

From the survey results and interview with several of the respondents, it is apparent that state DOTs are experiencing common difficulties in funding and budgeting for O&M. The following observations illustrate approaches taken by other states in an effort to bridge the funding gap:

- Federal funding sources, including CMAQ, National Highway System (NHS), and Surface Transportation Program (STP) funds are increasingly utilized for traffic management O&M.

- While system operation is predominately an in-house function, contract maintenance is being utilized more frequently in an effort to (1) utilize contracting dollars, which seem to be more available, and save maintenance dollars, and (2) perform necessary maintenance in the midst of hiring freezes and restrictions to adding positions.

- Spare parts are included in construction or maintenance contracts to avoid complications with procurement, compatibility, and funding after the system becomes operational.

- Identifying ITS O&M as a distinct budgeting element is vitally important, even if it competes with other maintenance functions. If nothing else, it acknowledges traffic management

O&M as an ongoing expense and provides a means of tracking costs. However, the use of multiple detailed ITS budget accounts have proven to be inflexible and cumbersome.

- None of the respondents indicated deliberate efforts to budget for replacing or upgrading current systems; several are attempting to upgrade in conjunction with other construction projects.

The results of the survey demonstrate that many states have struggled with the O&M funding issue and have endeavored to look beyond the traditional boundaries of the organization for innovative and creative ways to meet their needs.

CHAPTER THREE

ESTIMATING OPERATION AND MAINTENANCE COSTS

ESTIMATING OPERATION AND MAINTENANCE COSTS

Getting a Handle on the Size of the Pie

ISSUES

While some documented O&M cost data exist for traffic signal systems, very little documented O&M cost data exist for the relatively new and rapidly evolving freeway ITS elements, such as freeway Traffic Management Centers (TMC) and their related field components. In the absence of actual documented O&M cost data, O&M cost projections for ITS/ATMS are typically based on a traditional "rule-of-thumb" that estimates annual O&M costs to be ten to fifteen percent of capital costs.

A methodology is needed to enable TxDOT to establish and project O&M costs for existing and planned ITS/ATMS deployment. TxDOT's ability to accurately establish and project ITS/ATMS operations and maintenance costs is critical to ensuring that ITS systems continue operating at their maximum performance capability. Accurate O&M cost estimates can be used to determine how big the funding "pie" should be.

FINDINGS

Development of Estimation Process

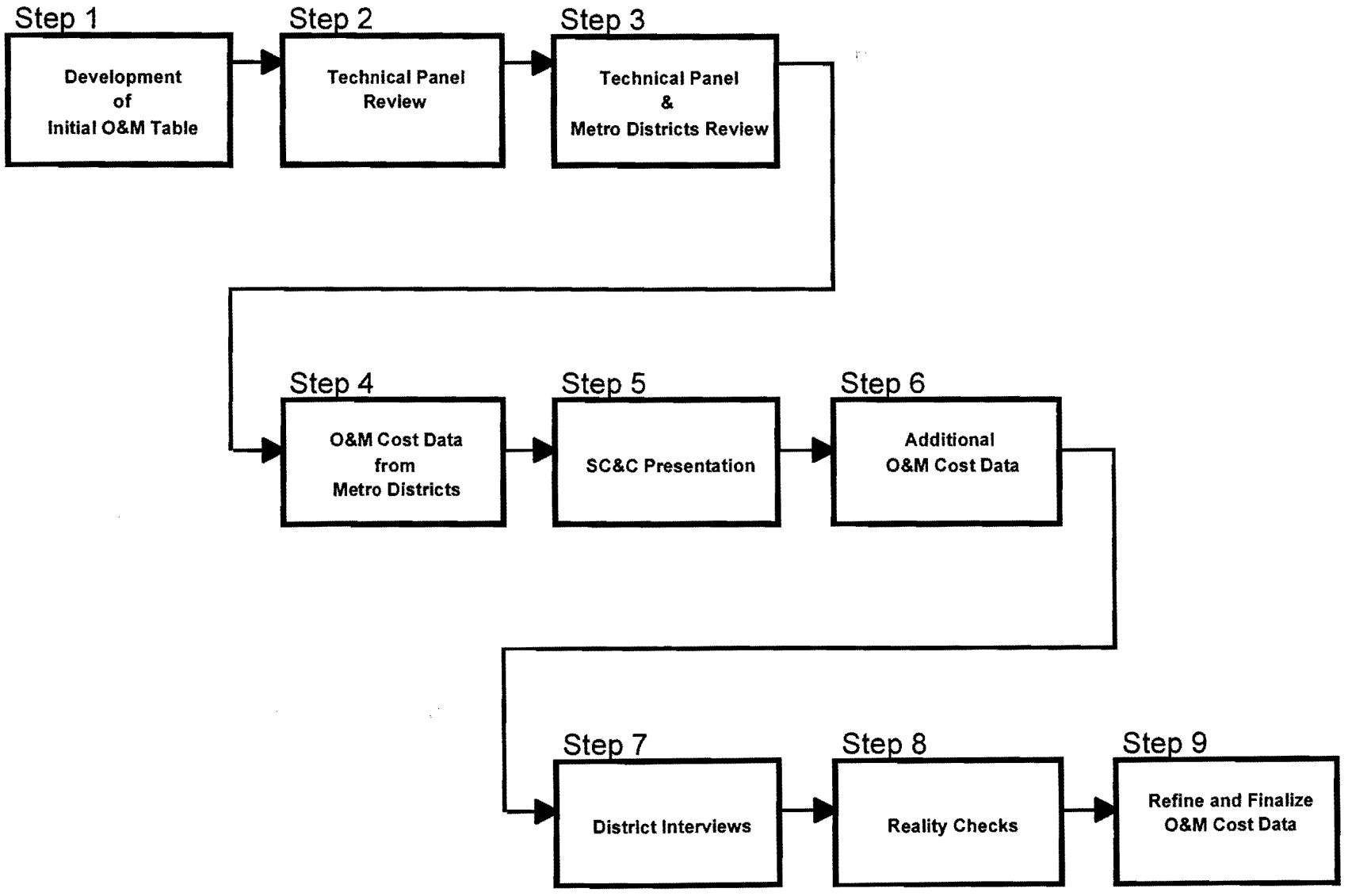
One of the most important products of this research is the O&M Cost Estimate Table. The table uses several sources, including heavy emphasis on TxDOT's actual experience, to document a methodology for estimating and projecting costs. The key sources used were the TxDOT metropolitan districts with substantial ITS deployment, the ITE report, "Operation and Maintenance of Electronic Traffic Control Systems" *(1)*; the FHWA report, "Cost Estimates and Assumptions for the Core Infrastructure" *(5)*; Texas municipalities and transit agencies; technical journals; and equipment suppliers. TxDOT personnel on the project's technical panel, as well as additional personnel from the metropolitan districts, participated extensively throughout the development of the O&M Cost Estimate Table. The flowchart shown in Figure 2 graphically summarizes the table development process.

Each step in the development process illustrated in Figure 2 is described below,

Step 1: Develop table for core elements and basic units of measure - An initial O&M table was developed listing core ITS elements, along with each element's corresponding basic unit of measure.

Step 2: Refine table through Technical Panel review - The initial O&M table was presented to the technical panel for review and comments regarding the essential core ITS elements and corresponding appropriate units of measure.

Development of O&M Cost Estimate Table



Step 3: Revise table and submit for Technical Panel and metropolitan district review - After incorporating comments from the technical panel's initial review, an updated O&M table listing essential or "core" ITS elements and corresponding basic units of measure was sent to the technical panel members, as well as the metropolitan districts for their review and comment.

Step 4: Obtain O&M cost data from metropolitan districts - From comments received, a consensus O&M table listing the essential ITS elements, along with corresponding basic units of measure, was developed and sent to the metropolitan districts requesting they provide any available O&M cost data.

Step 5: Review project status with SC&C Committee - The O&M table, which includes essential elements, corresponding basic units of measure, and available TxDOT O&M cost data, was presented to TxDOT's Surveillance, Communication and Control (SC&C) Committee for review and comment.

Step 6: Obtain additional O&M data - O&M cost data were obtained for those ITS elements for which no TxDOT cost data were available. Various sources used include FHWA reports, Texas municipalities and transit agencies, technical journals, research reports, and equipment suppliers.

Step 7: Interview metro districts - Metro districts with substantial ITS deployment were interviewed. Information obtained from the interviews included each District's existing inventory of deployed ITS elements and annual traffic management O&M budget.

Step 8: Conduct "reality checks" - Using each district's inventory of deployed ITS elements and annual budget, "reality checks" were conducted to compare each district's actual traffic management O&M budget to the total O&M cost estimates calculated using the O&M table developed.

Step 9: Refine and finalize O&M cost data - Working with the metro districts previously interviewed, O&M costs were refined where the reality checks showed cost estimated to be too high or too low without reasonable explanation.

Using the O&M Cost Estimate Table

Elements included within the O&M Cost Estimate Table, which begins on Page 22, are separated by their corresponding ITS/ATMS function. Similar to the FHWA's report, "Cost Estimates and Assumptions for the Core Infrastructure" *(5)*, individual elements are categorized in the table using the following ITS/ATMS functions: Traffic Management Center (TMC), Field Communications/Processing, Surveillance, Traffic Control, Traveler Information, and Incident/Emergency Response. Figure 3 depicts the six separate functional categories as defined for this project. A description of each follows.

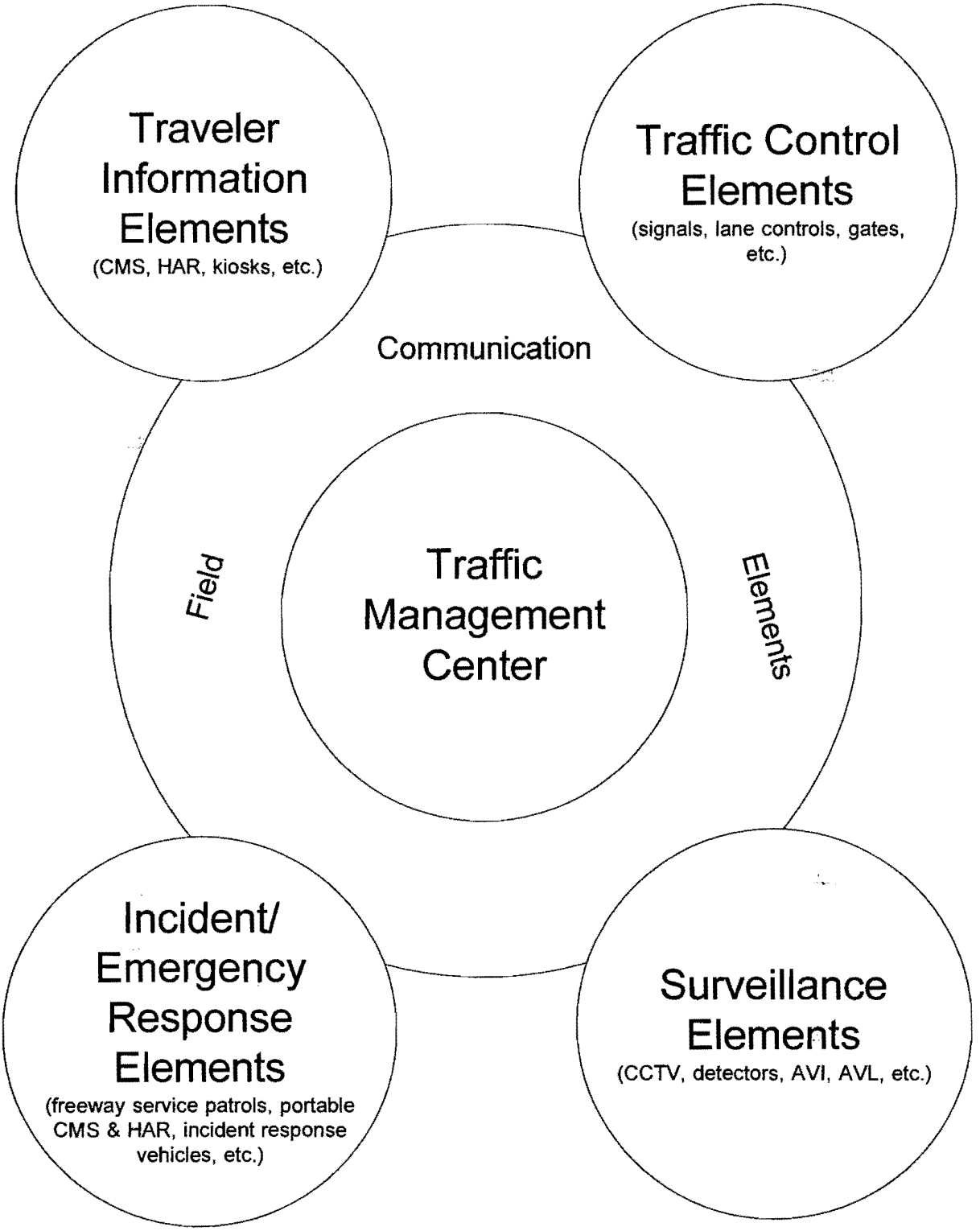


Figure 3. ITS/ATMS Functional Categories

- The *Traffic Management Center (TMC)* functional category shown on pages 22 and 23 includes all elements associated with TMCs, such as facility utilities and security, all computers, transmission and multiplexing equipment, as well as associated hardware and software, and closed circuit television (CCTV) video display systems. Vehicles used to support the TMC and the operations personnel required to operate the TMC are also included under this category.

- The *Field Communications/Processing* functional category shown on pages 24 and 25 includes the communications media, both wireline and wireless, used to transport data and video from the field to the TMC, and control signals from the TMC to the field equipment. Also included in this category are processing satellites, communication hubs, and controller cabinets.

- The *Surveillance* functional category shown on pages 26 and 27 includes all elements used to monitor freeway conditions, such as CCTV cameras, vehicle pavement and non-intrusive detectors, and automatic vehicle identification (AVI) and automatic vehicle location (AVL) components. Also included under this category are weather and environmental sensors.

- The *Traffic Control* functional category shown on pages 28 and 29 includes all elements associated with traffic control, such as traffic signals, ramp meters, lane control signals, and automated gates (access control).

- The *Traveler Information* functional category shown on page 30 includes all elements used to convey traveler information to motorist, such as changeable message signs, highway advisory radio (HAR), and kiosks.

- The *Incident/Emergency Response* functional category shown on page 31 includes all mobile elements used to monitor and manage freeway incidents, such as freeway service patrols, portable HAR stations, portable changeable message signs, portable CCTV trailers, and specialized incident management vehicles.

The O&M Cost Estimate Table presented on the following pages lists the ITS/ATMS elements and each element's corresponding basic unit of measure. Also provided in the table are each element's estimated unit operations cost, estimated unit maintenance cost, the combined unit O&M cost, and the assumptions related to factors included in each of the costs. As mentioned previously, the elements are subdivided by functional categories, with each category shown on separate pages. Using quantities measured in terms of the base units shown in the table, TxDOT can project traffic management O&M costs for existing and/or planned deployment by multiplying these quantities by their corresponding unit operational and maintenance costs.

For example, the projected O&M costs for 10 LED changeable message signs can be calculated as follows:

O&M Cost for 10 LED Changeable Message Signs (CMS) =

	annual operating costs (from page 30)	$ 1,000
+	annual maintenance cost (from page 30)	$ 2,000
=	unit O&M costs	$ 3,000
x	number of units	x 10
=	total annual O&M cost for 10 LED CMSs	$30,000

Personnel Allocation

Many of the table's ITS/ATMS elements show a range of estimated O&M costs. These cost ranges are a result of varied O&M costs being experienced by the TxDOT districts. Factors contributing to the variance in O&M costs from some of the elements include age and quality of equipment, personnel skill levels, and system design. Other factors relating to specific elements are listed in the table under the "Cost Assumptions" column.

It should be noted that maintenance personnel costs are accounted for in the estimated maintenance costs shown for each element. However, with the exception of freeway service patrols, operations personnel costs are not accounted for in the estimated operations cost shown for each element. Rather, operations personnel costs are shown as a separate line item due to, (1) the interrelatedness of operating many of the various ITS elements, including the fact that many of the ITS/ATMS elements are operated simultaneously by the same operator; and (2) the difficulty associated with distributing administration costs among the various ITS/ATMS elements. The table does not provide guidelines for determining appropriate operations or maintenance staffing levels, only the estimated cost per employee.

O&M Cost Estimates Table shown on the following pages.

TRAFFIC MANAGEMENT CENTER

ATMS/ITS Element Description	Base Unit	Estimated Annual Unit Costs per Unit			Cost Assumptions	Cost Origin
		Operations[1]	Maintenance[2]	Combined O&M		
Facility maintenance/power/ utilities/security	per sq. meter	$75	$25	$100	*Operations:* all utilities (e.g. power, water, telephone, etc.), security, building insurance, janitorial services; *Maintenance:* all routine building maintenance	TxDOT/ ITE
	per sq. feet	$7.50	$2.50	$10		
TMC Computer/Communications Room - equipment (including all associated hardware and software)	per km	$0	$900 to $1,300	$900 to $1,300	Costs include computer hardware/software maintenance contracts and equipment replacement[3]. The low and high ends of the cost range represent the estimated cost/unit length for a TMC/freeway system with distributed and centralized processing system architectures respectively. An additional factor influencing cost is interjurisdictional complexity	TxDOT
	per mile of freeway system coverage capability	$0	$1,400 to $2,000	$1,400 to $2,000		
TMC Support Vehicles	each	$5,600	$800	$6,400	*Operation*: fuel and administrative overhead; *Maintenance*: routine, preventive, and corrective vehicle maintenance	TxDOT/ ITE

1. Operations personnel costs for each element are listed separately under the TMC functional category.
2. Maintenance personnel costs are included in the cost/unit for each individual ITS/Traffic Management element.
3. Power costs are accounted for under **Facility Maintenance/Power/Utilities/Security**.

TRAFFIC MANAGEMENT CENTER

ATMS/ITS Element Description	Base Unit	Estimated Annual Unit Costs per Unit			Cost Assumptions	Cost Origin
		Operations[1]	Maintenance[2]	Combined O&M		
Operations Personnel	each	$45,000	$0	$45,000	Salary and benefits (e.g. retirement, health insurance, etc.)	TxDOT
Traffic Control Room Floor:						
Console Equipment (including CCTV video display equipment)	per console	$0	$1,200	$1,200	Replacement parts and contract maintenance[3]	TxDOT
CCTV Video Display System						
Video Wall	per TMC	$0	$30,000	$30,000	Replacement parts and contract maintenance	TxDOT
Front Projection Video Display Unit	each	$0	$7,500	$7,500	Replacement parts and contract maintenance	TxDOT/ TTI
Rear Projection Video Display Unit	each	$0	$7,500	$7,500	Replacement parts and contract maintenance	TxDOT/ TTI

1. Operations personnel costs for each element are listed separately under the TMC functional category.
2. Maintenance personnel costs are included in the cost/unit for each individual ITS/Traffic Management element.
3. Power costs are accounted for under **Facility Maintenance/Power/Utilities/Security**.

FIELD COMMUNICATIONS/PROCESSING

ATMS/ITS Element Description	Base Unit	Estimated Annual Costs per Unit			Cost Assumptions	Cost Origin
		Operations[1]	Maintenance[2]	Combined O&M		
Wireline Media:						
Owned Fiber	per km	$0	$500	$500	Maintenance of fiber and conduits[3]	TxDOT
	per mile	$0	$800	$800		
Leased Fiber:						
DS1 or DS3	per km	$1,250	$0	$1,250	*Operations:* lease cost, which is sensitive to the number of customers sharing installation costs; *maintenance:* provided by the fiber provider	TTI
	per mile	$2,000	$0	$2,000		
Coax Cable	per km	$0	$500	$500	Maintenance of coax cable and conduits[4]	TxDOT
	per mile	$0	$800	$800		
Twisted Pair	per km	$0	$100	$100	Maintenance of twisted pair wires and conduits[4]	TxDOT
	per mile	$0	$150	$150		
Leased telephone lines:						
ISDN (BRI - basic rate interface)	per location	$700	$0	$700	*Operations:* lease cost and includes local calls only; *maintenance*: provided by the ISDN provider	TxDOT
ISDN (PRI - primary rate interface)	per location	$14,400	$0	$14,400	*Operations:* lease cost; *maintenance*: provided by the ISDN provider.	TxDOT
T-1	per link	$5,000 to $15,000	$0	$5,000 to $15,000	Lease rate is distance sensitive; longer distance = higher rate; *maintenance:* provided by the ISDN provider	TxDOT

1. Operations personnel costs for each element are listed separately under the TMC functional category.
2. Maintenance personnel costs are included in the cost/unit for each individual ITS/Traffic Management element.
3. Power consumption is absorbed under **Processing Satellites** and/or **Communications Hubs**.
4. Power consumption is absorbed under **Controller Cabinets**.

FIELD COMMUNICATIONS/PROCESSING

ATMS/ITS Element Description	Base Unit	Estimated Annual Unit Costs per Unit			Cost Assumptions	Cost Origin
		Operations[1]	Maintenance[2]	Combined O&M		
Wireless Media (including associate end equipment)						
Microwave	per hop	$300	$1,000	$1,300	*Operations:* Power consumption and FCC license renewal fees; *Maintenance:* routine	TxDOT
Spread Spectrum	per hop	$0	$300	$300	Routine maintenance	TxDOT
Two-way Radio	per channel	$0	$500	$500	Routine maintenance	TxDOT
Low Power TV	each	$1,500	$7,500	$9,000	*Operations:* Power consumption; *Maintenance:* routine	TxDOT
Processing Satellites:						
Facility Maintenance/power/ utilities/security	each	$7,000	$1,500	$8,500	*Operations:* Security, utilities; *Maintenance:* routine	TxDOT
Computer/transmission/ multiplexing equipment	each	$0	$2,000	$2,000	Routine maintenance and replacement parts	TxDOT
Communication Hubs:						
Facility Maintenance/power/ utilities/security	each	$5,000	$1,000	$6,000	*Operations:* Security, utilities; *Maintenance:* routine	TxDOT
Transmission/multiplexing equipment	each	$0	$1,500	$1,500	Routine maintenance and replacement parts	TxDOT
Controller Cabinets	each	$0	$400	$400	Routine maintenance, replacement parts[3,4]	TxDOT

1.Operations personnel costs for each element are listed separately under the TMC functional category.
2. Maintenance personnel costs are included in the cost/unit for each individual ITS/Traffic Management element.
3. Includes local control units for detectors, CMS controllers, and LCS controllers.
4. Power consumption costs are accounted for under **Lane Control Signals** and **Changeable Message Signs**.

SURVEILLANCE

ATMS/ITS Element Description	Base Unit	Estimated Annual Unit Costs per Unit			Cost Assumptions	Cost Origin
		Operations[1]	Maintenance[2]	Combined O&M		
AVI:						
Transponders	each	$0	$10 to $15	$10 to $15	Routine maintenance and replacement	TTI
Readers	each	$0	$500	$500	Routine maintenance	TTI
AVL:						
Leased transceivers/antennae	per vehicle	$750 to $1,200	$0	$750 to $1,200	*Operations:* lease cost of the transceivers and antennae, and cellular airtime; *maintenance:* by the provider	TTI
Owned transceivers/antennae	per vehicle	$250 to $500	$100 to $200	$350 to $700	*Operations:* cellular airtime; *maintenance:* routine and replacement	TTI
CVO:						
WIM (weigh-in-motion)	per lane	$0	$500 to $3,000	$500 to $3,000	Routine maintenance and calibration of WIM detectors, repairs to pavement failure surrounding detectors	TTI
Weather/Environmental Sensors (e.g. Flood control/pump monitors)						
Leased Weather/ Environmental Sensors	per station	$750	$0	$750	*Operations:* lease cost of sensors; *Maintenance:* by the provider	TxDOT
Owned Weather/ Environmental Sensors	per station	$0	$500 to $1,000	$500 to $1,000	Routine maintenance and calibration of detectors	TxDOT/ TTI

1. Operations personnel costs for each element are listed separately under the TMC functional category.
2. Maintenance personnel costs are included in the cost/unit for each individual ITS/Traffic Management element.

SURVEILLANCE

ATMS/ITS Element Description	Base Unit	Estimated Annual Unit Costs per Unit			Cost Assumptions	Cost Origin
		Operations[1]	Maintenance[2]	Combined O&M		
CCTV:						
CCTV cameras	each	$0	$500 to $1,300	$500 to $1,300	Routine maintenance for camera, camera controls, housing and/or support pole[3]	TxDOT
CCTV cameras with VIP capability	each	$0	$700 to $1,800	$700 to $1,800	Routine maintenance for camera, camera controls, housing and/or support pole, and VIP calibrations[3]	TxDOT/ TTI
Pavement Vehicle Detectors:						
Inductive Loop	per station	$0	$200 to $300	$200 to $300	Contract maintenance and replacement of loops; 4 lanes per station; loop failure rates of 4% to 6% per year; power costs negligible	TxDOT
Non-intrusive Loop Detectors:						
Microwave-Radar/Sonic/ Acoustic/Lasers	per station	$0	$200 to $300	$200 to $300	Routine maintenance and calibration of detectors; 4 lanes per station, with 1 detector per lane; power consumption negligible	TxDOT
Video Imaging Detectors	per station	$0	$500	$500	Routine maintenance and calibration of detectors; 1 video imaging detector per station; power consumption negligible	TTI

1. Operations personnel costs for each element are listed separately under the TMC functional category.
2. Maintenance personnel costs are included in the cost/unit for each individual ITS/Traffic Management element.
3. Power consumption costs are accounted for under **Processing Satellites** and **Communications Hubs**.

TRAFFIC CONTROL

ATMS/ITS Element Description	Base Unit	Estimated Annual Unit Costs per Unit			Cost Assumptions	Cost Origin
		Operations[1]	Maintenance[2]	Combined O&M		
Traffic Signals (includes all traffic signals with central monitoring and control capability):						
Traffic Signal Equipment/Hardware	per controller	$1,000 to $1,500	$1,500 to $2,500	$2,500 to $4,000	*Operations:* power consumption; *Maintenance:* routine on signal poles and heads and traffic signal controller cabinets. High end represents diamond interchanges controlled by a single controller	TxDOT/ ITE
Intersection Pavement Detectors	per controller	$0	$500 to $1,000	$500 to $1,000	Contract maintenance/ replacement of loop detectors[3]	TxDOT
Traffic Signal Timing Plans	per controller	$0	$500 to $1,000	$500 to $1,000	Contract engineering for maintaining current traffic signal timing plans	ITE
Traffic Signal Pre-emption System	per controller	$0	$500	$500	Routine maintenance	TTI
Railroad Signal Pre-emption system	per crossover intersection	$0	$500	$500	Routine Maintenance	TTI
Ramp Meters:						
Ramp Metering Equipment/Hardware	per station	$0	$2,000	$2,000	*Operations:* power consumption; *Maintenance:* routine	TxDOT/ FHWA
Ramp Metering Timing Plans	each	$0	$500 to $1,000	$500 to $1,000	Contract engineering for maintaining current timing plans	ITE

1. Operations personnel costs for each element are listed separately under the TMC functional category.
2. Maintenance personnel costs are included in the cost/unit for each individual ITS/Traffic Management element.
3. Power consumption accounted for under **Traffic Signal Equipment Hardware**.

TRAFFIC CONTROL

ATMS/ITS Element Description	Base Unit	Estimated Annual Unit Cost per Unit			Cost Assumptions	Cost Origin
		Operations[1]	Maintenance[2]	Combined O&M		
Lane Control Signals:						
Freeway Lane Control Signals	station	$250 to $500	$750 to $1,000	$1,000 to $1,500	*Operations:* power consumption; *Maintenance:* routine and bulb replacements; 4 lanes per station	TxDOT
HOV Lane Control Signals	station	$250	$500	$750	*Operations:* power consumption; *Maintenance:* routine and bulb replacements	TTI
Automated Gate or Access Control:						
HOV Facility	per site	$500	$5,000	$5,500	*Operations:* power consumption; *Maintenance:* routine and repair of vehicle collision damage to gate	FHWA/ TTI
Median Barrier	per site	$500	$5,000	$5,500	*Operations:* power consumption; *Maintenance:* routine and repair of vehicle collision damage to gate	TTI
Dynamic Lane Assignment Signs	each	$100	$200 to $400	$200 to $400	*Operations:* power consumption; *Maintenance:* routine and bulb replacement	TTI

1. Operations personnel costs for each element are listed separately under the TMC functional category.
2. Maintenance personnel costs are included in the cost/unit for each individual ITS/Traffic Management element.

TRAVELER INFORMATION

ATMS/ITS Element Description	Base Unit	Estimated Annual Unit Costs per Unit			Cost Assumptions	Cost Origin
		Operations[1]	Maintenance[2]	Combined O&M		
Changeable Message Signs:						
LED	each	$1,000	$2,000	$3,000	*Operations:* power consumption; *Maintenance:* routine and LED replacements	TxDOT
Flip Disk Hybrid	each	$1,000	$3,000	$4,000	*Operations:* power consumption; *Maintenance:* routine and bulb replacements	TxDOT
Fiber	each	$1,000	$3,000	$4,000	*Operations:* power consumption; *Maintenance:* routine and bulb replacement	TxDOT
Highway Advisory Radio (HAR)	each	$0	$500 to $1,000	$500 to $1,000	Routine maintenance	TxDOT/ FHWA
Kiosks	each	$0	$5,000	$5,000	*Operations:* power consumption; *Maintenance:* routine and repairs to vandalized kiosks	TxDOT/ TTI/ FHWA

1. Operations personnel costs for each element are listed separately under the TMC functional category.
2. Maintenance personnel costs are included in the cost/unit for each individual ITS/Traffic Management element.

INCIDENT/EMERGENCY RESPONSE

ATMS/ITS Element Description	Base Unit	Estimated Annual Unit Costs per Unit			Cost Assumptions	Cost Origin
		Operations[1]	Maintenance[2]	Combined O&M		
Freeway Service Patrols	each	$70,000 to $75,000	$10,000 to $15,000	$80,000 to $90,000	*Operations:* fuel, administrative overhead, salary and benefits for two operators per vehicle; *Maintenance:* preventive and corrective; funds to replace vehicles every few years	TxDOT
Incident Management Timing Plans	per controller	$0	$500 to $1,000	$500 to $1,000	Cost includes contract engineering to update incident management timing plans	ITE
Portable HAR	each	$0	$2,000	$2,000	Routine maintenance to HAR unit and the trailer housing	FHWA
Portable CMS	each	$500	$1,500 to $3,000	$2,000 to $3,500	*Operations:* diesel to run generator; *Maintenance:* routine and bulb replacement	TxDOT
Portable CCTV	each	$0	$2,000	$2,000	Routine maintenance to CCTV and trailer/pole housing	TTI
Specialized Incident Management Vehicles:						
Portable Command Center Vehicle	each	$5,000	$10,000	$15,000	*Operations:* fuel, communications, cellular airtime and vehicle insurance; *Maintenance:* routine, preventative and corrective to vehicle and communications equipment within vehicle	TTI
"Microblaze" Trailer	each	$5,000	$1,000	$6,000	*Operations:* microbe solution costs; *Maintenance:* routine, preventative and corrective maintenance to the trailer	TTI
Call Boxes	each	$500	$500	$1,000	*Operations:* telephone, including cellular airtime; *Maintenance:* routine and repairs due to vandalism	FHWA/ TTI

1. Operations personnel costs for each element are listed separately under the TMC functional category.
2. Maintenance personnel costs are included in the cost/unit for each individual ITS/Traffic Management element.

RECOMMENDATIONS

Estimate ITS/ATMS operation and maintenance costs using the Cost Estimate Table

It is recommended that TxDOT use the O&M Cost Estimate Table for projecting ITS/ATMS operation and maintenance costs and for determining funding needs.

Allocate funds using the O&M Cost Estimate Table

Current methods of allocating program funds by formula cannot account for the vast differences in systems across the state. Formula components such as mile of freeway system on-line and system complexity do not account for factors such as the age of the system and the configuration of the various field elements. The O&M Cost Estimate Table provides an element-by-element estimation of costs with distinct ranges so that different levels of sophistication and ages for individual elements can be considered.

The table not only provides a means of getting a handle on the size of the pie, but offers a means of slicing the pie. Each district could project O&M costs from the same base using the table, and the combined total could be used for annual budget requests. If funding is not available for the full amount, then the available funds could be distributed on a percentage basis using the district totals to determine the proportions.

Track O&M costs over the long term

TxDOT should establish a mechanism within the budget and financial accounting system to monitor the following areas and use the information to continually improve the O&M funding process.

Annually reconcile projected and actual costs, including updates of O&M cost estimating tables as necessary.

The vast majority of TxDOT's ITS deployment is relatively new and thus is still under warranty. In the coming years, as systems age and warranties expire, O&M costs will increase. TxDOT budget planners need to be cognizant of this fact. To what extent ITS O&M costs will increase is uncertain. The costs estimates shown in the Cost Estimate Table represent cost estimates for the year 1996 assuming no elements are under warranty, and reflect only "tolerable" levels of maintenance and operations. Realizing this, it is recommended that TxDOT annually refine the O&M cost estimates. By documenting their traffic management O&M costs, TxDOT districts can help refine the existing O&M Cost Estimate Table for years to come, thus ensuring that this document remains a current and useful resource. Furthermore, the table should ideally reflect "desirable" levels of maintenance and operation, as opposed to "tolerable."

Refine personnel allocation to traffic management systems O&M.

The methodology used in this report to account for personnel costs was to distribute maintenance personnel costs among the individual core ITS/ATMS elements and to provide a separate line item for operations personnel costs under the TMC functional category. It was the general consensus of the project's technical panel that the ideal methodology would handle operations personnel costs in the same manner as maintenance personnel costs. But due to the difficulty of assigning operations personnel to individual core ITS elements for the reasons mentioned previously, operations personnel costs are listed as a separate line item with a base cost unit per employee. Tracking of personnel allocation to ITS/ATMS activities will demonstrate whether this approach is the most meaningful in determining O&M costs.

One significant consideration not addressed by the proposed cost estimating methodology is the appropriate staffing level necessary to adequately operate and maintain ATMS. The ITE-sponsored, "National Conference on Operating and Maintaining Advanced Traffic Management Systems (ATMS) Centers," considered the issue of staffing as a key element of TMC operation and developed draft recommended practices (see Appendix A). The conference suggested that staffing levels should be determined based on the functional requirements of the TMC, and recommended the development of a matrix of staffing needs by function. This tool would provide assistance to agencies for determining appropriate staffing levels.

CHAPTER FOUR

FUNDING OF OPERATIONS AND MAINTENANCE

FUNDING OF OPERATIONS AND MAINTENANCE

Assembling the Ingredients

ISSUES

New traffic management infrastructure is being added to the transportation system with each new ITS/ATMS project. That requires operations staffing and specialized maintenance needs. Stable and consistent funding is needed to provide desirable levels of maintenance and operation for these systems, as well as for all new transportation infrastructure.

Maintenance and operation of ITS elements compete for funding with pavements, bridges, traffic control devices, vegetation management, and all other maintenance and operation activities. The demand for O&M for these activities also continues to increase as the infrastructure expands and ages. Unfortunately, the maintenance and operation funding "pie" is not growing at the same rate as combined maintenance needs.

FINDINGS

Financing from sources outside of TxDOT for the development and construction of new systems has been more readily available than has internal state funding sources to operate and maintain the systems once they are built. The planning necessary for continued funding of operation and maintenance has been insufficient. ITS implementation plans, which are prepared for federally-funded deployment and outline the department's commitment for sustained O&M funding, have not been followed. And as systems have come on line, the competition with other maintenance functions for O&M funding has intensified.

TxDOT currently funds traffic management O&M from two state-funded sources: Routine Maintenance funds, and Rehabilitation of Traffic Management Systems funds, also known as Category 10B funds. Figure 4 illustrates these funding sources in relation to TxDOT's total budget for highway-related funding.

Routine Maintenance and Operations funding is approximately $500 million annually and is allocated by formula to the districts each year for all maintenance and operations activities. The local districts determine how much of their allocation goes to traditional maintenance functions and how much goes to traffic management functions. For fiscal year 1997, $8.7 million of this money was requested for operating and maintaining traffic management systems. However, final budget figures provided to the districts do not distinguish between ITS/ATMS operation and maintenance and other maintenance functions. Furthermore, because there is no required separation by function code, determining the final amount being dedicated to traffic management systems in FY 1997 becomes a complex task.

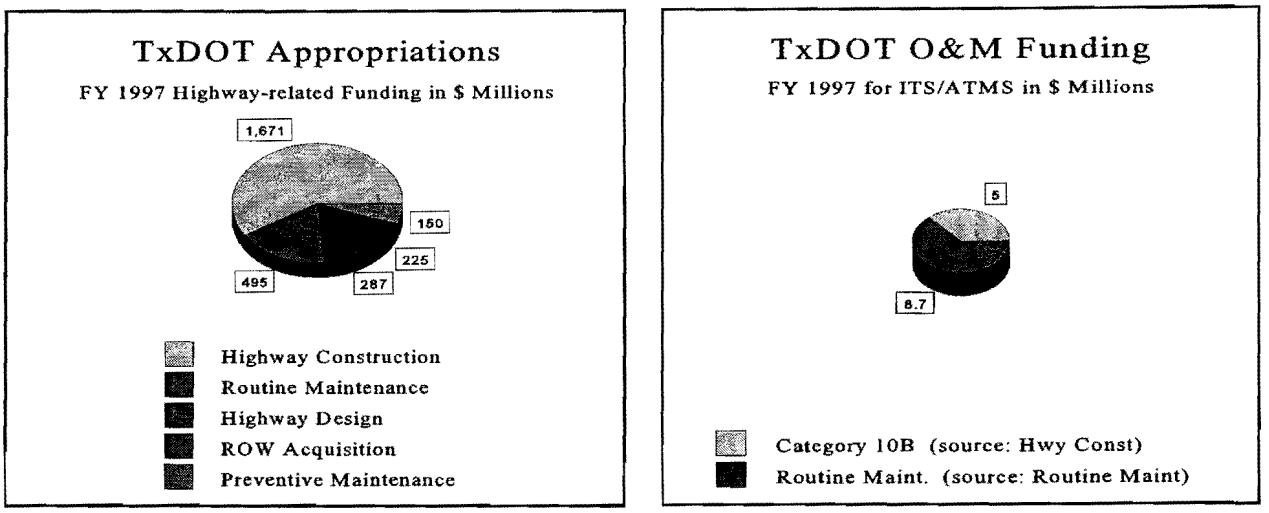


Figure 4. ITS/ATMS O&M Funding Sources *(6)*

Category 10B funding is also a state-funded program category used for contracted rehabilitation and maintenance of traffic management systems. It supplies approximately $5 million annually, which is allocated to the districts using a formula based on the number of freeway and arterial miles operated using ATMS. A new allocation formula has been developed to factor in the complexity of the districts' ATMS. Category 10B funds may be used only on contracted work, and thus far have primarily been used for upgrading variable message signs and maintaining loop detectors. Federal funding is not currently being used for ATMS operations and maintenance activities.

One of the greatest difficulties in providing adequate O&M funding for ITS/ATMS is the fact that there is insufficient funding for current maintenance and operation needs. With the implementation of pavement and bridge management systems, and the ability of those systems to project the long-term costs for under-funded maintenance, it is much easier to justify funding for those activities than for traffic management systems when funds are scarce.

The ITE recommended practices for ATMS center operation and maintenance will address funding as a critical element in sustaining TMC's *(17)*. Based on the discussion at the ITE national O&M conference, the dominant focus on the national level for ITS O&M is the use of federal funds for operations and maintenance, with an emphasis on funding flexibility in future legislation. Also emphasized was the dissemination of more information to state and local agencies about federal funding opportunities for O&M. Pursuit of public and private partnerships and other cost-sharing arrangements was also recommended, but with less emphasis than federal funding options. Interestingly, the emphasis on federal funding for long-term O&M is counter to prior federal direction on this issue. The appropriate role of the federal government in infrastructure investment and preservation, and the funding share available for federal discretionary spending, has been and will continue to be the subject of public policy debate *(7)*. Consequently, it is a factor to be considered regarding long-term reliance on federal funding for ITS O&M.

RECOMMENDATIONS

Work toward achieving an equitable balance of funding between all maintenance and operation activities.

Until the maintenance and operation funding "pie" is increased, a balanced approach to funding O&M activities should be taken, with consideration for safety factors, benefits to the transportation system users, and life-cycle costs. The guidelines listed below could help facilitate a balanced funding approach.

Identify and document the benefits of ITS O&M.

Without clear benefits/cost data demonstrating the effectiveness of traffic management systems, O&M for traffic management will have difficulty competing for an appropriate share of the pie. Much of the difficulty relates to the perceptions derived from transportation system needs that can be "seen" versus those that are "unseen". For example, most individuals can appreciate the necessity of resurfacing a rutted highway or repairing a damaged guardrail section because these are needs they can actually see. However, many cannot immediately perceive the need for preventative maintenance resurfacing on a section of pavement that visually appears sufficient, until that activity is placed in the context of preserving an expensive investment that will continue to have viable, long-term operability. The department's Pavement Management Information System (PMIS) assists by assessing long-term costs to the lack of adequate maintenance. Likewise, the costs and benefits of good ITS/ATMS operation and maintenance and the consequences of poor O&M on long-term operability and on the mobility of system users should be documented in order to provide decision-makers with a comparable tool to balance the funding between competing maintenance needs. As a result, the total transportation infrastructure investment can be protected to the greatest extent possible with available funding.

Consider a departmental policy that acknowledges increased funding requirements for maintenance and operation of transportation system expansions.

A policy directive should be considered that provides for expected budget increases to support maintenance and operation of all newly completed projects, with a goal of maintaining and operating at a specified level of service. This strategy adopts a long-term, life-cycle cost approach to preserving the transportation infrastructure. It would ensure that as the inventory is expanded, including the addition of ITS elements, the funding needed to sustain it at an acceptable level of service is automatically included in the budgeting process.

If current funding levels do not support the existing maintenance needs, then this direction could be undertaken in conjunction with the inception of other funding sources or approaches currently being pursued by TxDOT. Alternatively, if additional O&M funding is not forthcoming, then consideration should be made to refrain from building new infrastructure if it cannot be adequately maintained and operated. The life-cycle approach is currently used by the State of California and

is described in more detail in Chapter 2.

Take advantage of federal funding available for traffic management system operations and operational support activities.

Federal funds are allowed for operations under several categories: Surface Transportation Program (STP), National Highway System (NHS), and Congestion Mitigation and Air Quality Program (CMAQ) for non-attainment areas. STP is available for operations on eligible routes with no time limit and with an 80% federal share and 20% state/local share for operations. On November 28, 1995, the passage of the NHS Act made ongoing operations costs for traffic management systems eligible for both NHS and CMAQ funding *(7)*. The substitution of the term "operating costs" for "start-up costs" removed the previous time limitation of two years. An 80/20 federal/local funding participation is required. Because project constructed with NHS funds allow appropriation of operating funds within the initial project scope, emphasis should be placed on using NHS funding for construction projects. CMAQ funding for operations may be used beyond an initial three-year "start-up," provided the project continues to demonstrate air quality benefits.

The use of federal funding for maintenance activities, while officially disallowed, is interpreted differently across FHWA regions. Defining maintenance activities as "operational support" (since these tasks are required in order for the system to operate effectively) has led to the use of federal funding for activities traditionally defined as "maintenance."

The federal funding approach to O&M is not necessarily a means of making the pie bigger, but making sure that federal funds available are utilized to the greatest benefit of the transportation system users. Although the use of federal funds for operations is a common practice in a number of other states, it is a different approach than TxDOT's traditional view of using federal funding exclusively for construction. Justifying a different approach to using federal funding is difficult given that current funding levels are only able to finance 33 percent of the construction of transportation projects needed over the next ten years. TxDOT will have to weigh the benefits of lane-adding capacity versus operational capacity, as well as other federally funded project demands, in determining whether to pursue eligible federal funding for operations. An evaluation methodology that assures maximum benefit to the users for the resources available is needed in order to effectively make this determination *(8)*. If federal funding for in-house operations is pursued, then corresponding administrative and budgeting procedures must be implemented to facilitate its use. For example, the accounting system is not equipped to handle federal dollars as in-house operational funds since all federal funding is considered by TxDOT as contracting dollars.

Because the metropolitan planning organizations (MPOs) have a pivotal role in the allocation of federal funds, TxDOT will have to take a more proactive and cooperative approach with the MPOs in recommending the use of federal funds for traffic management operations should this approach be pursued. It is recommended that TxDOT strongly encourage the use of CMAQ funds in particular for traffic management O&M in non-attainment areas whenever possible. Federal funding allocated by an MPO for a specific ITS/ATMS operation should not have to be declined due to staffing or

procedural issues. As stated above, using CMAQ funds for in-house operational expenses will require internal changes made to the accounting system.

CHAPTER FIVE

BUDGETING AND TRACKING OF O&M EXPENSES

BUDGETING AND TRACKING OF O&M EXPENSES

Clarifying How to Slice the Pie

ISSUES

As with many of the states responding to the survey, TxDOT has no specific, separate budget account for O&M of traffic management systems. Budgeting for traffic management is handled as O&M for traffic control devices has historically been budgeted, which is through the routine maintenance budgets of the individual districts. The O&M expenses for new systems have not been effectively conceptualized in relation to the budgeting process. Consequently, the funding "pie" has not grown but has simply been sliced into smaller pieces.

As the funding pie is further sliced, traffic management O&M continues to struggle with insufficient funding while traditional maintenance functions, such as pavements and bridges, suffer as well from a shrinking slice of the pie. In the face of steadily declining maintenance levels of service for these traditional functions, slicing the pie differently to accommodate traffic management needs only creates further obstructions to adequately preserving the transportation infrastructure.

FINDINGS

The TxDOT operating budget process, which is similar to that used in several other states, emphasizes traditional maintenance functions. Traffic management programs are imbedded within district maintenance and operations budgets, over which the district maintenance engineers have primary discretion. Traffic management O&M budgets are combined with traditional routine maintenance budgets when funds are requested. When funds are allotted from the state level to the local districts, the figures do not distinguish traffic management O&M from other maintenance functions. The final allocation is handled at the district level, under the direction of the district maintenance engineer, who may or may not have the same accountability for and commitment to traffic management as compared to other maintenance activities. As a result, the final amount allocated to ITS/ATMS O&M depends on the district leadership and the individual working relationships between managers at the district level.

The metropolitan districts that are heavily involved in ITS/ATMS are seeking creative ways to fund their programs, particularly their personnel. The metropolitan district operations engineers interviewed for this study have some traffic management personnel budgeted in district programs other than maintenance, such as design or construction. Budgeting for administrative and public affairs personnel is extraordinarily difficult under this scenario. Furthermore, the traditional job classifications and salary levels of operations and maintenance personnel are not always consistent with the skills required for new technologies, which create difficulties in attracting and retaining competent employees.

While the diffusion of staff resources to various accounts mitigates the immediate need to fund O&M for traffic management, it makes it virtually impossible to systematically track expenses for

the traffic management system itself. The TxDOT accounting system provides a means to track these diffused resources, but only if the district staff intentionally separate traffic management into a separate function code. Otherwise, the true operation and maintenance costs of the system under the department's standard accounting configuration are not readily available without extensive staff time to compile the data.

RECOMMENDATIONS

Improve budgeting and tracking of O&M expenses.

Develop separate budget accounts for maintenance and operations, funding both accounts from the maintenance appropriations strategy to allow maximum flexibility. Strong consideration should be given to renaming the maintenance strategy to the, "Maintenance and Operation Strategy," or a similar name to recognize the operational component in addition to the maintenance aspect. Some districts are already separating traffic operations from other maintenance functions using internal account procedures. This should be applied consistently throughout TxDOT.

This department-wide action would be the first step in elevating the importance of operations in the overall transportation system function. Currently the policy and budget decisions regarding maintenance reflect an emphasis on pavements. While pavements comprise the most significant portion of the transportation infrastructure, the operational aspects should be given appropriate recognition in the budgeting process as a vital function and considered on a similar footing. Not only would this action increase the visibility and importance of operations, but it would also provide a better mechanism for tracking actual expenses. To work effectively, all costs associated with traffic management O&M, including personnel, should be accurately charged to the established function code.

Special attention should be made to budgeting in multi-agency funding arrangements. During the development of the interagency agreement, each agency's monetary participation, including any obligation for contingency budgeting, should be clearly detailed. By using the Cost Estimate Table, the entities involved will have a means of estimating annual operating expenses and dividing expenses according to responsibility and accountability. In a multi-agency operation where funds are combined for a particular function, such as administration, public relations, or TMC operation, any unexpected overages or other unplanned expenses in that function should not be the sole responsibility of one participant but should be shared proportionately.

CHAPTER SIX

POLICIES AND PROCEDURES AFFECTING OPERATIONS AND MAINTENANCE

POLICIES AND PROCEDURES AFFECTING OPERATION AND MAINTENANCE

Making the Pie Go Farther

ISSUES

Legislative mandates, departmental policies, and internal departmental processes all have an impact on how new services, including ITS/ATMS O&M, are provided. In the face of these limited revenues, the department is struggling to find the best approaches to performing services within a changing organizational culture. The issues examined in this chapter include: (1) limitation to adding staff, (2) requirements for minimum contracting levels, (3) recovery of third-party damage claims, and (4) procurement of commodities needed to sustain system operation and maintenance.

FINDINGS

Figure 5 illustrates the flexibility TxDOT has to make decisions regarding staffing and contracting in light of legislative directives. The issues are described in detail below.

Staffing and Contracting Mandates

Legislative mandates, such as the full-time equivalent (FTE) employee cap and minimum contracting requirements *(6)*, limit a district's ability to provide new services in-house. Contracting certain ITS operations and maintenance functions might be the most efficient approach, while for other activities it may be the most costly in the long term, resulting in a loss of in-house expertise as well as accountability problems with multiple vendors performing interrelated functions. The Report of the Optimum Department Staffing Task Force *(9)* recommends holding district FTE allocations at current levels, although it states that, "traffic management systems and ITS will have a yet-to-be-determined effect on staffing," and suggests a review of the Maintenance/Traffic Operations Staffing Model to incorporate, "contemporary work practices such as traffic management staff." The current TxDOT and legislative policies allow very limited flexibility to add operations personnel, even if additional CMAQ funding is available to implement operational activities. Although most agencies provide operational support in-house, there are examples of successful privatization of operational activities *(10,11)*.

One of the more frustrating problems for the districts wanting to initiate or expand freeway service patrol programs has been the inability to add FTEs to the payroll. To overcome this constraint, the program can be accomplished indirectly through the use of a third-party contractor. Concerns about control over performance of a contractor for this service have been expressed. Given the nature of the service, the most appropriate approach in procuring these services would be through the use of a Request for Proposal (RFP), in which various evaluation factors in addition to price would be used to select the most qualified provider.

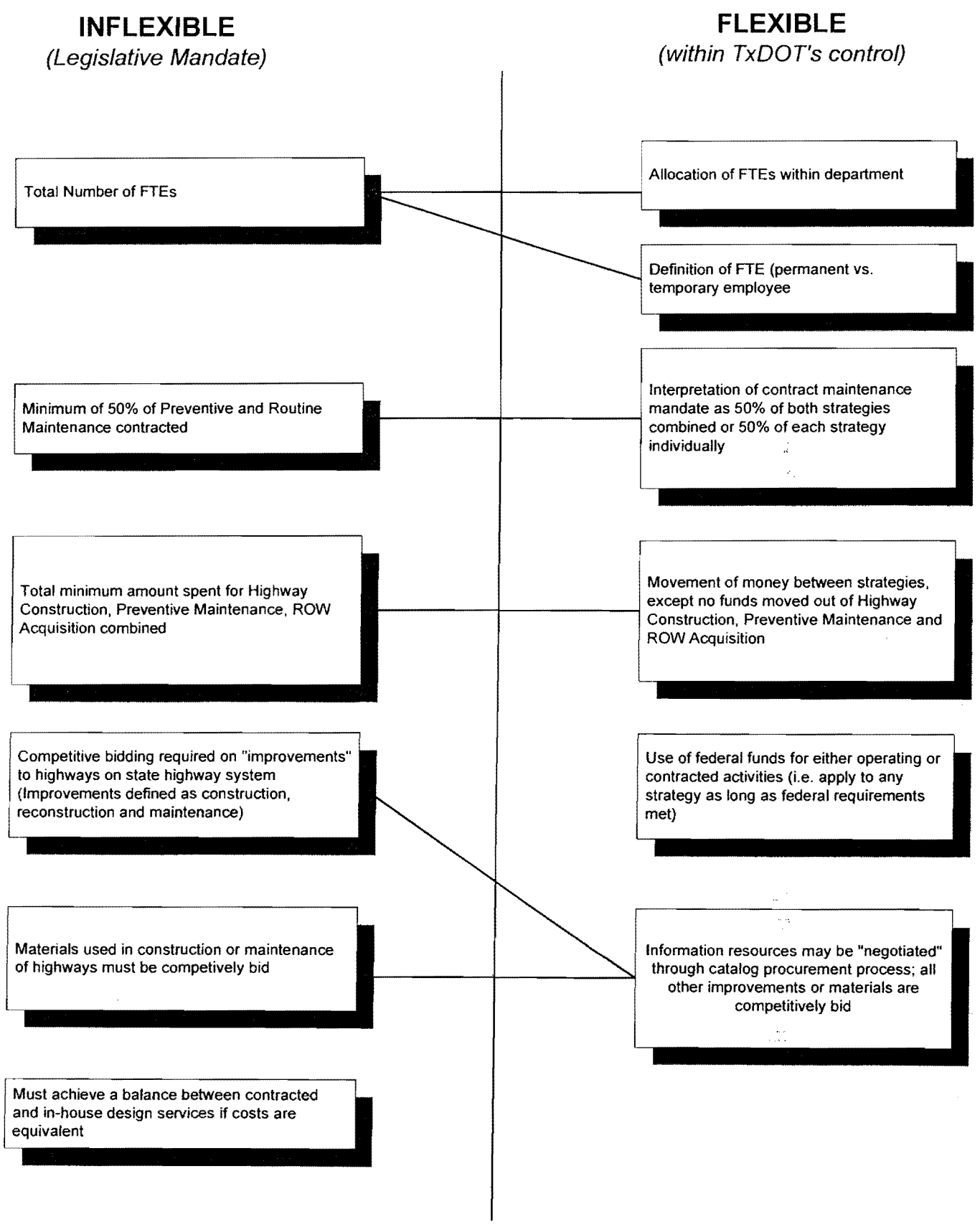


Figure 5. TxDOT's Budgeting Flexibility

Some evaluation factors to be considered include:

- assessment of the personnel recruitment and training program,
- financial capacity to afford a fleet of vehicles and appropriate equipment to service the public's need,
- adequacy of insurance coverages,
- experience in providing these services in other locations, and
- satisfaction of other clients with the services provided.

Also critical to using a contractor for these services is the ability to monitor the service provided and assess the quality of work on an ongoing basis, with performance standards clearly understood by the parties. The performance standards should be included in the RFP as a minimum requirement. A draft of the contract should be included in the RFP, and thoughtful attention should be paid to structuring actions against the vendor for unsatisfactory performance. It should be noted that the largest freeway service patrol in the U.S., which is located in Los Angeles, California, is accomplished through contracts managed by the Metropolitan Transportation Authority *(11)*.

Concerns regarding liability related to non-TxDOT employees performing operations functions on the highway system are not supported by law. TxDOT faces no liability for the negligent acts of the employees of an independent contractor. The Texas Tort Claims Act liability cap applies only to the acts of TxDOT personnel *(12)*. TxDOT liability exposure would be reduced by using appropriately insured third-party contractors and a well-structured contract, given that tort liability and workers compensation issues would not be TxDOT's responsibility. Another alternative would be contracting with local enforcement agencies to provide the service via an interlocal agreement; however, tort liability exposure would exist because the service providers would be the employees of a governmental unit covered by the Texas Tort Claims Act. Based on research performed on establishing freeway service patrols, the fears related to liability have been "overestimated" *(11)*.

If costs or other difficulties make contracting impractical, then the FTE restriction should be reexamined. The source of the problem may be TxDOT's interpretation of the Legislature's FTE cap. There is no explanation in the appropriations bill as to how FTEs are counted, and there is no accounting principle governing how to count FTEs. TxDOT defines and counts an FTE as anyone employed by the department, including temporary or part-time personnel, as opposed to counting permanent employees only. The relationship between the employer and the employee, such as the provision of benefits, the basis of pay, and the extent of supervision dictates whether a person is considered an employee and thus counted as an FTE. An entity would not count as an FTE someone with whom is does not have an employment relationship. It is possible that a job classification can be structured for service patrol operations personnel that does not compromise the Legislature's intent or any accepted accounting principle.

Recovery of Third-Party Damage Claims

Due to a lack of incentive for collection at the local level, recouping from third parties the damages caused to field equipment is inconsistent, resulting in a lost opportunity to recover maintenance expenses. There is currently no connection in the financial accounting system between budgeted damage expenses and actual collection amounts. Damages are budgeted on an annual basis, with any money collected going back to the general highway fund; as a result, the absence of any benefit or penalty in the collection process at the district level can make this task a low priority.

Procurement

The experience of the various district in procuring the hardware, spare parts, software, and equipment needed to sustain their operations is very diverse. It appears to be more a function of the individuals directly involved in procurement than the procedures themselves. The catalog procurement process for information resources has greatly improved the ability to quickly purchase needed commodities at good prices. However, not all districts are utilizing the process to its full potential, including the negotiation aspects and catalog updating features.

RECOMMENDATIONS

Increase outsourced maintenance using contracting dollars.

The use of maintenance outsourcing can be increased to take advantage of funding for contracted work instead of using in-house routine maintenance funding, and to achieve necessary maintenance work while under restrictions to adding FTEs. There are two areas where this is especially advantageous:

- Establishing multi-year maintenance agreements with suppliers in conjunction with contracts for labor and materials (including spare parts), especially for software maintenance. For example, federal funding has extended beyond the construction phase in New York City for costs associated with TMC computer systems maintenance over extended periods by using a separate line item in the procurement contract.

- Taking opportunities to upgrade systems in conjunction with related construction contracts. For example, one state agency justified system upgrades as part of a major reconstruction project by showing that better traffic flow would be provided during construction.

District traffic management personnel who have performed limited outsourcing will require orientation in outsourcing procedures specific to information resources. Phase 4 of the Retooling TxDOT effort for Information Services, which is scheduled for completion in 1997, will provide an outsourcing strategy that should contain guidelines adaptable to traffic operations functions *(13)*.

Contracting of freeway service patrols should also be pursued where FTE restrictions limit the

opportunities to provide this service in-house. Flexibility in the FTE restriction should be considered if the costs or difficulties with contracting this type of operation prove to be too great. Using the Request for Proposal (RFP) process, described earlier in this chapter, fears related to performance, accountability and liability can be addressed. Other agencies have established successful freeway service patrols through third-party contracts. However it is accomplished, the freeway service patrol programs have been one of the most well-received programs in Texas and throughout the country because of the direct benefit to the taxpayer. From an operational as well as public relations standpoint, TxDOT cannot afford to pass up federal funding allocated for this type of program.

Strengthen damage claims recovery process.

The inconsistent recovery of third-party damage claims across the state has resulted in lost recovery of maintenance expenses. TxDOT should implement policies and procedures to aggressively pursue claims for third-party damages to field equipment. An incentive program should be put in place whereby districts can receive a credit for their collections over established budgetary levels.

The current appropriations bill does not prevent TxDOT from establishing a special allocation for damage recovery funds, in which the district recovering the funds and headquarters would share in the receipts. Such an innovative, incentive-oriented approach to budgeting would be consistent with the Transportation Commission's statutory mandate to enhance existing revenue sources. However, because of restrictions to adding FTEs, hiring a private collection agency on a commission basis may be the only alternative presently available for addressing this deficiency.

Build upon successful procurement approaches.

The catalog procurement process for information resources has proven to be an effective tool for purchasing commodities, but is not consistently being utilized to its full potential. A refresher course provided by the General Services Division would help improve the use of this process, as well as the proprietary purchase process for non-catalog items.

CHAPTER SEVEN

PUBLIC AND PRIVATE PARTNERSHIPS AND O&M

PUBLIC AND PRIVATE PARTNERSHIPS AND O&M

Making The Pie Bigger

ISSUES

Joint efforts in the operation of traffic management systems can take advantage of economy of scale, reduce redundancies and discrepancies, and help achieve overall transportation objectives for a community. Whether agencies share an operations facility, surveillance data, communications infrastructure or a signal maintenance effort, there is an obvious savings to TxDOT, and ultimately the taxpayer, when expenses are shared, resources are jointly used, and similar functions of multiple entities are jointly contracted. As a result, the size of the pie is increased.

However, barriers to interagency coordination are created by: (1) the traditional organization culture that defines boundaries between jurisdictions and other transportation modes, and between the agency and the private sector; (2) the lack of communications standards for data transmission; and (3) the multitude of unique operating circumstances from district to district across the state, including some that face more challenges to forging interagency alliances than others.

FINDINGS

Within the institutional framework of TxDOT, there is limited guidance provided as it relates to public and private partnerships. The presence of interagency and private sector participation in O&M, where it is now occurring, is more the result of individual efforts at the district level and less to a consistent departmental policy.

Public Agency Partnerships

Each district has a unique operating environment with a diversity of local entities, enforcement, and transit authorities, each with varying levels of resources and commitment. In some districts the development of interagency coordination will be more of a challenge than it is in others simply because of the shear number of overlapping jurisdictions.

The TxDOT *ITS Deployment Strategy (8)* provides recommended areas for ITS deployment and the roles TxDOT should consider playing in forging public partnerships. In some cases, a lead role is essential; in others, a supporting role is more appropriate. The *ITS Strategy* recommends that policy direction be provided as it relates to achieving seamless integration of the transportation system across jurisdictional lines, with expenses shared proportionately. This is true not only for ITS/ATMS deployment but also for sustained operation and maintenance of systems. Further attention should be directed at the budgeting process as it relates to interagency agreements to ensure that funding participation by all parties is fair and reasonable.

Information sharing across traditional boundaries creates a whole new set of challenges related to compatibility, interfacing, and control. The National Transportation Communications for ITS

Protocol (NTCIP) is an ongoing initiative to provide a communications standard that ensures interoperability and interchangeability among traffic control and ITS devices, and to do so by utilizing existing communications standards and models to the greatest extent possible. FHWA supports the NTCIP as the communications protocol for the transmission of data between the roadways and traffic management centers. The ongoing NTCIP initiative is being directed by a joint AASHTO/ITE/NEMA committee.

Interoperability and interchangeability among traffic control and ITS devices will provide many O&M benefits including *(12)*:

- Improved interjurisdictional coordination and integration. Equipment that is compatible across agency boundaries will provide improved operations.

- Enhanced opportunities to share communications costs with other agencies. Standards will allow multiple agencies to share communication systems.

The ITE-sponsored "National Conference on Operating and Maintaining ATMS Centers" identified joint operations as a key element. The draft recommended practices from that effort, which emphasized interagency partnerships, are included in Appendix A. A number of strategies are listed, which can facilitate and enhance joint operation of systems.

Private Sector Participation

The *ITS Strategy* also recommends that TxDOT develop policy direction related to the development of long-lasting, workable partnerships with the private sector, because this is distinctly different than hiring a private contractor to perform work on behalf of the department. The "long-lasting" aspect of the policy development is particularly important as it relates to operations and maintenance activities.

One issue discussed in other areas of the country and considered a means of "making the pie bigger" is charging for information generated by a traffic management system. This is a controversial topic with differing viewpoints on whether expenses should be recovered through charging outside entities or whether the goodwill promoted by providing free information reaps greater long-term benefits.

In Texas, the Texas Public Information Act *(15)*, formally known as the Open Records Act, limits the ability of TxDOT to charge for information generated from a traffic management system. It does, however, grant a governmental agency the ability to charge the cost of reproducing the information, as opposed to recovering the costs of original collection or maintenance of the data. Certain ITS elements that are developed for the sole purpose of transmitting collected information to outside sources, should be considered as providing "reproduced data" and charged according to the actual cost to provide the information. In one TxDOT district, the licensing fee for low power TV is paid by outside sources to a consortium that includes TxDOT, and this covers upgrades to the software that accesses the system. TxDOT employees also use the low power TV to access the

system from remote sites. However, if this service was offered solely for the use of outside sources, there would be a legal basis to charge O&M expenses, such as electrical power consumption and routine maintenance costs.

RECOMMENDATIONS

Direction and guidance are necessary in order for the districts to effectively pursue partnerships and ultimately share operating expenses.

TxDOT should provide policy direction related to public and private partnerships, highlighting and building upon the successes to date. Specific issues to be addressed are the seamless integration of the transportation system to achieve community objectives, and the development of private sector partnerships, with special attention to operation and maintenance coordination and funding. The draft recommended practices for the ITE-sponsored, "National Conference on Operating and Maintaining ATMS Centers," (see Appendix A), provide a basis for development of an internal policy on promoting joint operations at the district level.

Two additional issues could be addressed in the policy. First, direction could be provided on the question of whether the department should pursue charging outside sources for reproduction of data, within the boundaries of the law, as a means of recouping operational expenses. Second, special attention should be directed to the clarification of budgeting multi-agency funding arrangements. During the development of the interagency agreement, each agency's monetary participation, including any obligation for contingency budgeting, should be clearly detailed.

By using the O&M Cost Estimate Table, the entities involved will have a means of estimating annual operating expenses and dividing expenses according to responsibility and accountability. In a multi-agency operation where funds are combined for a particular function, such as administration, public relations, or TMC operation, any unexpected overages or other unplanned expenses in that function should not be the sole responsibility of one participant but should be shared proportionately.

Continue to support the NTCIP development process and incorporate standards into procurement specifications.

As communications standards are developed, it is recommended that TxDOT's procurement specifications require roadway devices to be NTCIP compliant where applicable. A consortium of standards agencies (AASHTO, ITE, and NEMA) are actively pursuing the development and maintenance of NTCIP standards for roadside devices. These devices include: actuated traffic signal controllers, variable message signs, ramp meters, video camera controls, highway advisory radio, environmental sensors, weigh-in-motion devices, and vehicle detection (including video detection) and classification devices *(14)*. Procurement specifications requiring devices to be NTCIP compliant will ensure interoperable and interchangeable devices, which will lead to compatibility and reduced O&M costs in future years.

CHAPTER EIGHT

SYSTEM DESIGN AND REPLACEMENT IMPLICATIONS RELATED TO OPERATION AND MAINTENANCE COSTS

SYSTEM DESIGN AND REPLACEMENT IMPLICATIONS RELATED TO O&M COSTS

Unexpected Guests for Dessert

ISSUES

Although this study does not specifically address system design, no discussion of operations and maintenance funding would be complete without mentioning the effect system design plays on O&M costs. The lack of attention to long-term operations and maintenance costs during system design has implications on the ability to sustain, coordinate, and upgrade systems. In addition, upgrading and replacing systems can affect routine O&M budgets if there is not adequate planning for capital costs in the budgeting process. This section is subtitled, "unexpected guests for dessert," because the issue of funding the replacement or upgrading of ITS/ATMS systems is rarely discussed in ITS literature and is seldom considered when planning for transportation infrastructure expansion. The O&M funding pie, as it is currently structured, cannot adequately fund O&M, much less system improvements.

FINDINGS

Design decisions are often influenced more by initial implementation costs rather than lifetime costs that include O&M. Initial system implementation costs and anticipated O&M costs should be given appropriate weight in the analysis, with particular attention being given to total lifetime costs. Caution should be taken in investing a large sum of capital funds to build more ITS capability at the expense of O&M requirements *(2)*.

The lack of a common, open communications standard for the transportation industry is forcing many agencies to choose between competing proprietary alternatives when installing ITS/ATMS infrastructure *(14)*. The procurement of proprietary equipment leads to increased O&M costs resulting from the deployment of various non-interchangeable equipment for similar functions. The deployment of a variety of equipment for similar functions requires increased personnel training to operate and maintain the equipment, as well as increased spare parts inventories. The NTCIP initiative described in the previous chapter will provide a communications standard that facilitates interchangeability among traffic control and ITS device and results in O&M benefits, including the following:

- Reduced personnel training requirements. Since components will be more interoperable and interchangeable, there will be less need to preserve O&M skills associated with a large product mix.

- Reduced replacement parts costs. Interoperable and interchangeable equipment will result in a more competitive procurement process.

- Smaller equipment inventories. Since equipment will be interoperable and interchangeable, a smaller diversity of spares will be required.

The provision of routine replacement and upgrading of aging and outdated ITS/ATMS equipment is critical to ensuring high system performance over the years. With the exception of a few elements, such as freeway service patrol vehicles and pavement loop detectors, TxDOT is not budgeting for the replacement and upgrading of many of its new ITS/ATMS components being deployed. Currently, the cost of replacing and upgrading within TxDOT is most often being absorbed through state-funded Traffic Management System Rehabilitation (Category 10B) and routine maintenance budgets. However, the revenue needs assessment submitted for FY 1997 budgeting process indicated that the current annual allocation of $ 5 million in traffic management rehabilitation money is causing the O&M effort to "lose ground," and will require an additional $ 7 million annually to achieve desirable O&M levels.

TxDOT's existing ITS/ATMS is relatively new and the impact from failing to budget for equipment replacement and upgrades has been minimal. However, as systems age and warranties expire, replacement and upgrade costs will continue to increase. Based on interviews with other states, there is no process underway to systematically and intentionally address the issue of reinvestment in existing ITS/ATMS systems.

The issue of information resource asset management coupled with dramatic increases in growth of applications, which create incredible demands on systems, is an issue the information resource industry is also struggling with. The Gartner Group, an international information technology advisory service, states that enterprise executives are increasingly concerned with the rising costs of network communications driven by the deployment of many new client/server applications. They describe their clients as being, "...so overwhelmed with fulfilling their day-to-day networking needs that they have not had the time to focus on huge planning, design, implementation, operation, and especially, the business implication of such dramatic network dependence and expense growth" *(16)*.

RECOMMENDATIONS

Emphasize operations and maintenance costs in system design.

Close examination and assessment of lifetime O&M costs should be a critical factor in the design process. TxDOT should take advantage of all opportunities to include O&M cost-reducing measures in design. For example, built-in diagnostics to identify and repair system problems should be given strong consideration on all new and upgraded systems in order to reduce long-term O&M costs.

Continue to support the NTCIP development process and incorporate standards into procurement specifications.

As discussed in detail in the previous chapter, TxDOT should continue to support and incorporate NTCIP standards in its specifications. Procurement specification requiring devices to be NTCIP

compliant will ensure interoperability and interchangeable devices, which will lead to compatibility and reduced O&M costs in future years.

Improve planning efforts to upgrade existing systems.

The establishment and use of state Traffic Management System Rehabilitation Funds (Category 10B) is a good initial approach to addressing the upgrading needs, although the current level of funding is insufficient. TxDOT's Information Services (IS) "Retooling" effort, to be completed in 1997, will explore these issues and recommend department-wide guidelines related to information resource asset management and budgeting *(13)*. To avoid draining future routine maintenance dollars, it is recommended that TxDOT begin planning efforts to fund ITS/ATMS capital projects that upgrade existing systems using life-cycle based principles and IS Retooling recommendations. TxDOT should also aggressively seek out opportunities to upgrade and replace systems in conjunction with related construction projects.

REFERENCES

1. Institute of Transportation Engineers, *Operations and Maintenance of Electronic Traffic Control Systems*, June 1995.

2. Patel, Raman K., *ITS Operational and Maintenance Issues: Intelligent Transportation Serving the User Through Deployment*, Proceedings of the 1995 Annual Meeting of ITS America, Atlanta, Georgia, 1995, pp. 371-384.

3. Ten-year state transportation funding plan, Section 164(c), California Streets and highways Code.

4. L.G. Kubel, Telephone interview, Caltrans, Sacramento, California, August 28, 1996.

5. Federal Highway Administration, Office of Traffic Management and Intelligent Transportation System Applications (HTV-10), *Cost Estimates and Assumptions for the Core Infrastructure*, June 1995.

6. Article VII, Chapter 1063, 74th Texas Legislature, Regular Session; appropriations legislation for the Texas Department of Transportation.

7. Lancaster, H.M., and Genegas, S.G., "The Paradox of Federal Infrastructure Programs: Aging Infrastructure and Constrained Budgets," *Public Works Management and Policy*, v. 1, n. 2, October, 1995, pp. 107-119.

8. Texas Department of Transportation, *Intelligent Transportation Systems Deployment Strategy*, May 1996.

9. Texas Department of Transportation, *Report of the Optimum Department Staffing Task Force*, October 1995.

10. Yermack, Lawrence, "Privatizing Traffic Operations," *ITS World*, July/August 1996, pp. 16-17.

11. Fenno, David, et al, "Guidelines for Establishing Freeway Service Patrols, *Compendium of Technical Papers for the 66th Annual Meeting of the Institute of Transportation Engineers*, September 1996, pp. 54-61.

12. Texas Tort Claims Act, Section 101.021, Texas Civil Practice and Remedies Code.

13. Texas Department of Transportation, *Information Services Business Process Retooling, Phase 3: Initial Design and Implementation Strategy*, October, 1995.

14. Seymour, Edward J., "NTCIP Standards for Operations and Maintenance of Traffic Management Centers", White paper presented at the Operating and Maintaining ATMS Centers conference, Minneapolis, Minnesota, September 14-15, 1996.

15. Texas Public Information Act, Chapter 552, Texas Government Code.

16. Cooperman, J., Gartner Group, Inc., "Network Budgets are Increasing," Research Note, May 1996.

17. Institute of Transportation Engineers, unpublished document, *White Papers for the National Conference on Operating and Maintaining Advanced Traffic Management Systems (ATMS)Centers*, Minneapolis, Minnesota, September 14-15, 1996.

APPENDICES

APPENDIX A

SUMMARY OF DRAFT RECOMMENDED PRACTICES FOR OPERATING AND MAINTAINING ATMS CENTERS

Provided below is a summary of the recommended practices drafted at the ITE National Conference on Operating and Maintaining Advanced Traffic Management System (ATMS) Centers, in Minneapolis, Minnesota on September 14-15, 1996. The conference was attended by over 90 professionals who are involved in one or more aspects of operating and maintaining ATMS Centers.

White papers addressing each of the following key elements of ATMS Center operation and maintenance were presented at the following plenary sessions:

- Administration,
- Joint Operations,
- Funding,
- Staffing,
- Standards,
- Training,
- Liability, and
- Computer Systems.

Workshops were then formed for each of these areas wherein participants discussed the issues and further refined the draft recommended practices. The draft recommended practices will be refined and compiled for peer review through ITE, followed by testing at several sites. The completed recommended practices will be published by ITE in late 1997 following the peer review and testing process.

ADMINISTRATION

1. The TMC function should reside in the Traffic Operations segment of the responsible agency at as high a level as possible.

2. To obtain necessary maintenance support of field equipment linked to the TMC, either move the personnel necessary for maintaining the TMC field equipment from the Agency's Maintenance Division to a position under the TMC Head or dedicate the necessary personnel within the Maintenance Division to TMC related functions.

3. The TMC should be networked with other TMCs to provide regional coverage of freeways, surface streets and transit.

4. A typical Operations Manual should be developed and cover three basic areas - general

information about the TMC, policies and procedures on the internal operations and maintenance of the TMC, and policies and procedures involving the management of traffic.

5. Regional TMCs operated by State DOTs or Regional Governments should follow a policy of 24 hours a day, 7 days a week operation.

6. Conduct tours for the general public, transportation professionals and VIPs. Different provisions should be made for each type of tour. Video tapes describing the TMC operations should be produced. A demonstration Work Station should be provided in a designated observation area.

7. Information distributed to the media, value added re-packagers, and the general public should be free. Charge private companies only for the cost of connections to the date base.

8. Incidents reported by automated detection algorithms, the general public, or radio/TV traffic reporters should be subject to a verification procedure prior to activating response plans and broadcasting the incident from the TMC.

9. Pre-designed response plans should be developed for different levels of incidents, congestion, and planned events.

10. Provide computer to computer communication network links between TMCs and other types of control centers for real-time coordination of transportation operations. Establish a Policy Steering Committee, Technical Committee, and User's Groups to foster longer term coordination, cooperation, and "buy-in ".

11. In-house vs. outsourced staffing depends on the local situation. If certain conditions exist, such as downsizing or difficulty filling highly technical positions, then outsourcing should be seriously considered.

12. TMCs should be designed to facilitate the exchange of information between participating jurisdictions.

13. Regional systems should be designed to allow one jurisdiction to take control of another jurisdictions' traffic signals.

JOINT OPERATIONS

1. Identify group members including a diverse set of functional disciplines in the initial stages of projects and program development to meet local needs. Consider joint operations either through co-location or connected through communication.

2. Identify individual operational needs then assess operational commonalities.

3. Adopt mission statements, goals, and objectives by participating agencies and identify benefits of joint operations.

4. Approach joint operations with an open attitude of how overall results can be enhanced by sharing resources.

5. Identify and establish potential soft and hard financial resources to accomplish joint operation activities.

6. Grow the joint operations process at a manageable rate through the sharing of small initial resources and operational capabilities such that they build larger and long term capabilities.

7. Encourage the development of joint operations and control in all phases of system development, planning, design, construction, operations and maintenance.

8. Adopt an open system architecture such that new systems and changes in hardware and operating procedures can be accommodated easily.

9. Consider a common communication system for coordinated traffic signal systems and other devices among multiple jurisdictions.

10. Provide the ability to access CCTVs by agencies and disciplines other than the legal owner or external to the central control facility by sharing images, selecting cameras and camera control.

11. Provide the ability to allow operation of variable message signs by other agency staff or disciplines initially using stored messages.

12. Train agency staff such that they can perform the operations of other agency staff and systems such as VMS/CMS and CCTV.

13. Establish user groups to positively review or debrief operations on a regular basis, such that overall performance is improved.

FUNDING

1. When Federal gas tax funds are used for capital projects there must be a condition for commitment to fund operations and maintenance activities by state and local agencies prior to design approval.

2. Use NHS Funds in addition, to other federal funding sources, for new TMCs operation and traffic system support activities.

3. Make an amendment to ISTEA with language that will recognize maintenance costs of advanced traffic control systems to be eligible for reimbursement as is the case for operational costs.

4. Include life cycle-based costs in the initial capital project to provide greater stability in the funding process.

5. Develop a position on replacing existing funding sources used by state and local agencies for operations and maintenance costs with a dedicated allocation using Federal gas tax funding.

6. Develop a funding allocation model for operations and system support for ATMS based on reasonable standards or prevailing methods.

7. Funding for costs associated with TMC computer system maintenance programs over extended periods is permitted as operations support, and should be included in purchase or procurement contracts.

8. A manual that contains the latest uniform funding guidelines and requirements for a System Implementation Plan should be developed for use by state and local agencies.

9. Make federal funds available to state and local agencies without making a distinction between capital funds and O&M funds.

10. Education of the local MPO, budget officials, and management is required to increase support for ITS in general and funding for O&M in particular.

11. State and local jurisdictions should explore innovative funding sources for implementation and operation of advanced traffic management systems, such as: public/public and public/private cost sharing, and local share credit for dedication of right of way.

STAFFING

1. Staffing levels must support the needs and intent of the TMC.

2. There should usually be two operators per shift depending on functional requirements.

3. An adaptable staffing policy and Employment Plan should be developed to allow the TMC to operate successfully. An Operations Manual should define functional requirements - an essential step to staffing and planning.

4. Classify Technical and support staff properly with minimum skill requirements.

5. Obtain feedback for the operators themselves.

6. Maintain a core staff of sufficient size to cover all required seats on all shifts.

7. Utilize private sector outsourcing to round out minimal staff.

STANDARDS - NTCIP

1. Infrastructure agencies should procure NTCIP compliant roadside devices where there are applicable, approved standards for those devices.

2. Infrastructure agencies should consider adding a procurement option for conversion to NTCIP communications as part of their procurement specification for roadside devices that have been identified in the AASHTO/ITE/NEMA work plan for NTCIP but that have not yet been standardized.

3. Infrastructure agencies with large TMCs and private sector integrators should continuously work with the AASHTO/ITE/NEMA SDO Consortium to standardize center to center communications as part of NTCIP. The infrastructure agencies and consultants should allocate some of their work effort to assist in the development of an NTCIP ITS architecture and in agreement with evolving data dictionaries.

4. The FHWA should continue to augment funding for the development and maintenance of the NTCIP standard.

5. The FHWA, states, and MPOs should work together to implement conversion to NTCIP in large scale Traffic Management Centers.

6. The FHWA, states, and MPOs should work to implement dedicated funding to augment the replacement of limited sized, closed-loop traffic signal systems in medium to smaller sized agencies where further ITS service deployment is likely to be implemented.

7. Legislative mandates that require NTCIP deployment are not needed since NTCIP is in advanced stages of development.

8. The FHWA should take the lead in developing and conducting training courses pertinent to NTCIP. States and professional organizations should encourage training in NTCIP through seminars and professional development activities.

9. The NTCIP effort should be coordinated with other relevant international standards activities including the International Standards Organization (ISO). The United States should seek international adoption of NTCIP through ISO program TC204.

10. Review the NTCIP development process so that other standards development effort could benefit from the "lessons learned" from the development of NTCIP.

11. Infrastructure agencies should employ NTCIP to the maximum extent possible even where the physical media is not defined, especially for message definitions.

TRAINING

1. Provide cross training for staff.

2. Involve operations and maintenance personnel in the development of specification and procurement of material.

3. Provide continuous training.

4. Training should include visits to other centers.

5. Provide an effective rotating operator training program for alternates.

6. Conduct simulated events or table top exercises.

7. Create a career ladder for operations and maintenance personnel.

8. Create a listing of existing training programs for ATMS centers.

9. Work with educational institutions to develop or update curricula to reflect the training needs of center operators.

10. Identify a training coordinator for the TMC to develop cross-training programs and coordinate training activities.

11. Develop a training matrix for agency classifications with a continuous training emphasis.

12. Work with stakeholder organizations to include applicable issues in training programs.

LIABILITY

Planning

1. Include liability issues in the strategic planning process for traffic management programs.

2. Address liability issues in developing business planning initiatives for traffic management programs.

3. Give emphasis to program evaluation, market research and users.

Design

4. Include liability concerns in the preliminary design and final design of traffic management projects and services. System maintenance should be given a high priority to minimize liability risks.

Construction

5. Establish an adequate CI program staffed by appropriately trained inspectors to ensure compliance with specifications.

6. Appropriate field inspection and testing reports should be kept throughout construction.

7. Acceptance testing of control center software should be in compliance with pre-established test procedures.

Operations

8. Liability issues should be considered in all aspects of traffic management operations.

9. When no longer required in their original form, records should be discarded or consolidated in a macro approach for use by other agencies.

10. Unplanned diversions should be treated in the same manner as planned diversions and carried out in accordance with the MUTCD.

11. If a diversion route belongs to another agency then a pre-establish incident management agreement should be developed.

12. Records produced by ATMS as defined by agency should be retained in their original form for the period prescribed by the agency's legislative requirements.

13. Focus on liability concerns in overall traffic management program administration.

14. CCTV/Video should be used only in accordance with established procedures.

15. Make Quality Improvement a continuous focus area.

Maintenance

16. Preventive inspection and maintenance programs should be developed and followed.

17. Trouble-call response thresholds should be established and maintained.

18. Additional maintenance functions need to prioritized based on severity and degree of exposure to tort liability, as determined by risk assessment.

COMPUTER SYSTEMS

1. Management of the organization operating the ATMS center must commit adequate funding and staffing resources for effective software maintenance. The system operator has a responsibility to communicate this to management.

2. Provide sufficient, qualified staff to work in the ATMS center for both operation of systems and maintenance of software.

3. As operating ATMS systems are modified over time, an effort should be made to document the migrating system design.

4. Establish coding standards for software enhancements and for the generation of new programs.

5. Establish a documentation standard to be used as a guide for both in-house and contract programmers. Include the standard in any contracts for software development.

6. Obtain an annual maintenance contract on all computers and other hardware that is not easily supported by the agency staff, include spare parts and commercial off-the-shelf application software.

7. Newly modified or developed software must be tested for consistency with the documentation and with the required operational enhancement intended.

8. The complete ATMS system (all software elements) should be backed up on a regular schedule. The hard disk drives should have copies "mirrored" onto another physical hard disk on the same system. Copies of the back up should be stored off site to ensure regeneration of the system in case of a disastrous failure such as sever equipment damage. This should include hardware configuration information for replacement equipment.

9. Build a firewall into ATMS systems that are accessible by users outside of the operating agency. Also include "levels of access" for agency staff to prevent inexperienced operators from damaging critical system databases and software.

10. Appropriate process should be developed for procurement of hardware/software in complex systems and licensing/software rights should be addressed.

11. Good procurement procedures are needed to address the software development process, including frame of reference and good communication/cooperation.

APPENDIX B

		Signal Control	computerized signal control	VMS	Surveillance	Radar Detectors	Fixed Message Fiber Optic Signs	Advanced Traffic Management Systems	Ramp Meters	Highway Advisory Radio	Freeway Service Patrols	Closed Loop Signal Systems	Machine Vision Detection Systems	Long Vehicle Speed Analysis Units	Weather and Surface Condition Monitoring Systems	Motorist Aid Call Boxes	HOV Lanes	Incident Management on Construction Projects
Arkansas	Metro	X																
	Rural																	
Wyoming	Metro	X																
	Rural			X														
Connecticut	Metro		X	X	X	X	X	X		Design	X	X			X		X	
	Rural																	
North Carolina	Metro		X		design			under contract										
	Rural			X			X						X	X				
North Dakota	Metro																	
	Rural																	
California	Metro	X	X	X	X			X	X	X	X					X	X	
	Rural	X		X											X	X		
Maryland	Metro	X	X	X	X	X	X	X		X	X	X			X		X	X
	Rural	X	X	X						X		X			X			X
West Virginia	Metro	X	X									X						
	Rural			design											X			
Rhode Island	Metro																	
	Rural																	
New Jersey	Metro	X	under contract	X	X				X	X	X	X	design		X	X		X
	Rural	X	under contract	X						X					X	X	X	X
Florida	Metro		X	X	X			under contract		X	X	X						
	Rural															X		
Mississippi	Metro	X				X		X				X				X		X
	Rural					X						X				X		

		Signal Control	computerized signal control	VMS	Surveillance	Radar Detectors	Fixed Message Fiber Optic Signs	Advanced Traffic Management System	Ramp Meters	Highway Advisory Radio	Freeway Service Patrols	Closed Loop Signal Systems	Machine Vision Detection Systems	Long Vehicle Speed Analysis Units	Weather and Surface Condition Monitoring Systems	Motorist Aid Call Boxes	HOV Lanes	Incident Management on Construction Projects
Georgia	Metro	X	X	X	X	X	X	X	X	X	X	X	X				X	X
	Rural			X								X			X			
Minnesota	Metro		X	X	X			X	X	X	X	X				X	X	X
	Rural	X																
Iowa	Metro	X		X				X										
	Rural	X																
Nevada	Metro		X					X				X						
	Rural														X			
Virginia	Metro	X	X	X	X		X	X	X	X	X	X			X		X	X
	Rural																	
Idaho	Metro											X						
	Rural	X										X						
Kentucky	Metro	X	X	X	X	X	X	Being Built		X	X	X	X		X			X
	Rural	X	X							X								X
Michigan	Metro		X	X	X			X	X		X	X						
	Rural																	
Louisiana	Metro	X		X														
	Rural	X																

	Are sufficient funds allocated to O&M of TM systems?	Is the allocation of TM systems funds made at state or local headquarters?	How are statewide resources to support O&M allocated?	Are O&M of TM Systems a specific budget category?	If O&M is not a specific category, then how is it budgeted?	Is O&M funding considered in the planning for construction	Do you have to allocate in multiple metro areas?	If yes, how are funds allocated among the areas?
Arkansas	Funded by local government	Both	State resources not used	No	N/A (funded locally)	Yes	N/A	N/A*
Wyoming	Yes, at present	Both	Informal agreement between district and Hdqtrs	Yes for in-house traffic signal maint. & upgrades only	contract O&M and timing upgrades in separate categories	Not consistently	No	N/A
Connecticut	Yes, thru projects, Long-term Questionable	NA	NA	No	Thru funded projects	Yes, more on future projects	NA	N/A
North Carolina	No	Both	Maint. allocation in competition with maint. functions	No	Included in general traffic services maint., competing with pavements & bridges	No	Yes	Funds are allocated from the statewide maintenance budget prior to budget being dispersed amoun divisions
North Dakota	Doesn't have any TM systems	N/A	N/A	N/A	N/A	N/A	N/A	N/A
California	Yes for field elements, no for central TMC equipment	State	O&M Program managers	Yes, O&M are in separate categories	N/A	Not sufficiently	Yes	Program Managers at Hdqrts
Maryland	Yes	State	Through annual maintenance budget	No	N/A	Yes, more on future projects	No	N/A
West Virginia	No	State	By the Traffic Engineering Division based on needs and local pressure	No	N/A	Yes	No	N/A
Rhode Island	Does not currently have any TM systems	None done yet but will be at state level	N/A	No	N/A	No	No	N/A
New Jersey	Still under warranty; preparing contract for maint.	State	Through NJDOT	CMAQ funding used for O&M	State pays O&M, FHWA reimburses	Yes, 10% of construction costs	Yes	Project Specific
Florida	No	Local	By district, investigating off-the-top distribution	N/A	Yes, district inputs $ amount in work program	Yes	Yes	State formula

*Not Applicable

	Are sufficient funds allocated to O&M of TM systems?	Is the allocation of TM systems funds made at state or local headquarters?	How are statewide resources to support O&M allocated?	Are O&M of TM systems a specific budget category?	If O&M is not a specific category, then how is it budgeted?	Is O&M funding considered in the planning for construction?	Do you have to allocate in multiple metro areas?	If yes, how are funds allocated among the areas?
Mississippi	Yes	Yes	Central Office Traffic Engineering & District Offices	No	Admin. & District maint.	Yes	Yes	Population
Georgia	No	State	to organizational units	Yes	N/A	Yes	Yes	Population, Congressional/ Highway District, congestion mitigation, etc..
Minnesota	Yes	Local	Operations by district and maintenance by Central Office Traffic Engineering	Yes	N/A	generally, but it is not always followed thru	Yes	District budgeting based on TM needs
Iowa	Yes	Local for O&M	Normal budget process	Yes	N/A	Yes	Yes	Part of construction project funds
Nevada	Yes, generally	State	No state funds currently being used	Yes	N/A	Yes, as required by FHWA	N/A	N/A
Virginia	No, plus there are institutional barriers	Local districts	9 major budget categories for 3 TMCs	Yes by activity	Budget is being re-engineered to separate TMCs into "Special Facilities" cat.	Yes, but O&M personnel not involved	Yes	Lump sum by county based on need
Idaho	No	Maintenance - local, Operation - state	As needed basis	Yes	N/A	Yes	Yes	State billed based on number of approaches on state highway system
Kentucky	No	State	As needed	No	Funded thru Highway Plan	Yes	Yes	Need and availability
Michigan	Yes	State	Budget Process - Competes with everything else	N/A	N/A	No	Yes	Needs and availability of funds
Louisiana	No	State	Based on funding available and distributed throughout districts and hdqrts sections	No	N/A	Considered to a very limited extent	No	N/A

	What other agencies aid in operation of TM systems?	What other agencies aid in funding O&M of TM systems?	Is there any private sector involvement in operations of TM systems?	Have you been able to secure any other funding sources to support O&M?
Arkansas	Local jurisdictions	Local jurisdictions	N/A	N/A
Wyoming	None	None	No	No
Connecticut	None	None	Yes, contract for operation of Highway Operations Center	FHWA funding for start-up costs
North Carolina	municipalities assist with O&M of computerized traffic signal systems	None	No	No, but pursuing CMAQ funds
North Dakota	N/A	N/A	N/A	N/A
California	Local and regional transportation agencies	Local and regional transportation agencies	Minimal; motorist information dissemination	No
Maryland	Toll Authority and Montgomery County	None	Yes, 86 miles of fiber optics by MCI	No
West Virginia	Several larger cities	Larger cities pay for O&M	No	No, other than construction funds for initial (1 yr.) O&M
Rhode Island	None	None	No	Not yet
New Jersey	TRANSCOM-information clearing house involving multiple agencies	None	No	No

Florida	Florida Highway Patrol	MPO	No, being considered	No
Mississippi	Larger Cities	Cities	No	No
Georgia	City, county, federal gov't., transit systems, GEMA	City, county, federal gov't., transit systems, GEMA	Consultants aid in planning, training and design	No
Minnesota	Cities, counties, State patrol, transit agencies, state maintenance	None, except share traffic signal O&M	Yes, via a partnership with commercial broadcasters	Generally no, but have received federal funding for 1 year after construction, and CMAQ funding
Iowa	Cities,. counties and public safety	Cities and counties	Only for contract system maintenance	No
Nevada	City of Las Vegas, North Las Vegas, Henderson and Clark counties	City of Las Vegas, North Las Vegas, Henderson and Clark counties	Not at this time	No
Virginia	Virginia State Police and urban localities in adjacent states	Generally none, except in No.VA with Tri-State Agreement	No	"Smart Highway" project with automatic tolls
Idaho	None	Highway districts, cities	No	No
Kentucky	Lexington MPO and Cincinnati area MPO	Any city, county or other jurisdictional authority has the opportunity to partner with KDOT	Yes, partnership with TRW for 2 years of operation of ARTIMIS in No. Kentucky/Cincinnati	No
Michigan	None	None	No	No
Louisiana	None	None	No	No