Guidelines for Funding Operations and Maintenance of Intelligent Transportation Systems/Advanced Traffic Management Systems

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As the deployment of intelligent transportation systems (ITS) technologies moves forward, the issue of sustaining and supporting traffic management systems after they have been constructed becomes increasingly critical. 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 conveyed during implementation. Planning for day-to-day performance and upkeep, despite the necessity, has been an unglamourous and apparently secondary consideration in the ITS implementation process. A well-run and well-maintained 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 and will certainly tarnish the ITS initiative and the credibility of all transportation service providers. Quantifying and securing the funding necessary to operate and maintain ITS and advanced traffic management systems adequately is the first step, yet very little documentation is available to assist system operators. First, a mechanism is provided for estimating the costs required to operate and maintain ITS elements adequately; second, the funding issues are examined and guidelines are provided to address the obstacles that prevent adequate funding of traffic management operations and maintenance. Although the Texas Department of Transportation costs and procedures are examined, the research and recommendations will be useful to other state agencies.

Operation and maintenance (O&M) of advanced traffic management systems (ATMS) are those tasks required to allow an existing system to accomplish continuously the goals and objectives for which it was designed and to respond to changing technologies and transportation system demands.

Operation 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 the public;
- Monitoring system performance criteria;
- Updating system data bases;
- Notifying maintenance personnel of system malfunctions, and communicating them with related transportation and emergency response agencies; and
- Administering operations contracts and monitoring the performance of operations contractors.

Maintenance involves

- Performing preventive maintenance;
- Monitoring hardware and software components for required performance levels;
- Repairing or replacing equipment, components, and modules;
- Diagnosing and resolving software inconsistencies; and
- Administering maintenance contracts and monitoring the performance of maintenance contractors.

Most agencies recognize that while traffic management improvements have a relatively low capital cost compared with highway expansion, virtually all operational improvements require real-time attention to ensure that they are providing optimal service. It also is recognized that adequate funding of operational improvements is the only way to continue to receive the benefits that these kinds of service provide to the public.

Unfortunately, there is limited information available to agencies related to the expected costs of ongoing O&M for these systems. Through a research effort sponsored by the Texas Department of Transportation (TxDOT), a process has been developed for estimating O&M costs for budgeting purposes. This paper summarizes the results of that effort, presenting O&M costs for more than 60 ITS elements and a discussion of procedural and institutional barriers related to traffic management O&M in Texas.

BACKGROUND

Literature Search

An extensive literature search was conducted for this paper, but no substantive documented ITS or ATMS O&M costs were found. Although much reference is made to the issue in a number of publications, very little research has been performed on hard data on costs and specific approaches to overcoming the funding void. The cost figures developed in this study primarily were derived using data from TxDOT metropolitan districts with substantial ITS deployment.

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In the absence of data from actual expenditures, several other sources were used, including the ITE report *Operation and Maintenance of Electronic Traffic Control Systems* (*1*).

In addition to cost data, the ITE report includes a survey of transportation agencies, which report a 20 percent shortfall in both funding and staffing for traffic control systems. In new and expanded ATMS, the number of major elements [such as service patrols, closed-circuit television (CCTV), detectors, and variable message signs (VMS)] is expected to increase 300 to 400 percent in the next 5 years. Half of the responding states rate their current ability to operate ATMS as fair to poor, and 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 more than 90 professionals involved in one or more aspects of operating and maintaining traffic management centers. The purpose of the conference was to discuss and develop recommended practices on eight key elements that are critical to operating and maintaining traffic management centers, including funding, joint operations, staffing, standards, and administration. The recommended practices will be refined further and implemented on a test basis at several locations before final publication by ITE.

Survey of Other States

A survey of state transportation agencies was conducted to identify the budget structure, funding allocation, and participation by other entities in O&M of traffic management systems. Twenty-one responses were received. Seventeen of the 21 respondents have a wide variety of traffic management systems in place, ranging from traffic signals 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 operated by local agencies.

Five of the 17 respondents who operate and maintain traffic management systems reported an adequate level of funding for O&M. Twelve states reported inadequate funding for O&M. Seven of these 12 respondents say 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 1-year startup or warranty periods, but concern was expressed about long-term O&M costs and the lack of an available funding mechanism.

On the basis of the survey results and interviews with several of the respondents, it is apparent that state transportation agencies are experiencing similar difficulties in funding and budgeting for O&M. The following observations illustrate approaches that several states have taken in an effort to bridge the funding gap:

- Federal funding sources, including Congestion Mitigation and Air Quality (CMAQ), National Highway System (NHS), and Surface Transportation Program (STP) funds are increasingly used for traffic management O&M.
- Whereas system operation is predominantly an in-house function, contract maintenance increasingly is being used in an effort to (*a*) save maintenance dollars and utilize contracting dollars, which appear to be more abundant; and (*b*) 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 budget category is vitally important, even if it competes for funds 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 categories has proven to be inflexible and cumbersome.
- None of the respondents indicated deliberate efforts to budget for reinvestment (replacing or upgrading) for current systems; several are attempting to upgrade in conjunction with other construction projects.

The results of the survey demonstrate that many states that have struggled with providing adequate funding for O&M have tried to look beyond traditional means to innovative ways of meeting their needs.

ESTIMATION OF O&M COSTS

A primary objective of the research effort was to develop a methodology that enables TxDOT to establish and project O&M costs for existing and planned ITS/ATMS deployment. The ability to establish and project accurately ITS/ATMS O&M costs is critical to ensuring that ITSs continue operating at maximum performance capability.

Development of Estimation Process

Actual documented ITS O&M cost data are very limited. Some documented O&M cost data exist for traffic signal systems, but very few exist for the relatively new and rapidly evolving freeway ITS elements, such as freeway traffic management centers and their related field components. In the absence of actual documented O&M cost data, O&M cost projections for ITS/ATMS are based predominantly on the traditional rule of thumb that estimates annual O&M costs to be 10 to 15 percent of the capital costs.

The prevailing methodology adopted for this paper consists of the development of an O&M cost estimate table that uses actual O&M cost data experienced by TxDOT metropolitan districts. TxDOT personnel from various metropolitan districts throughout the state were asked to provide any available ITS O&M cost data. For the ITS elements for which no cost data were available, additional cost data were obtained from the following sources: the ITE report *Operation and Maintenance of Electronic Traffic Control Systems* (*1*); the FHWA report *Cost Estimates and Assumptions for the Core Infrastructure* (*2*); Texas municipalities and transit agencies; technical journals; and equipment suppliers. TxDOT personnel also provided comments pertaining to the structure of the O&M cost estimate table, such as what essential or core elements should be included.

Upon completion of a preliminary O&M cost estimate table, TxDOT personnel from metropolitan districts were contacted again and asked to provide annual traffic management O&M budget figures and ITS deployment quantities for the elements included in the table. Using this information, "reality checks" were conducted to compare each district's actual annual traffic management O&M budget with the total O&M cost estimates calculated using the O&M table. Working with TxDOT personnel, the O&M cost estimates

were refined where the reality checks showed cost estimates to be too high or too low.

O&M Cost Estimate Table

For clarity, the O&M cost estimate table is divided here into six tables by ITS/ATMS function. Similar to the FHWA report, *Cost Estimates and Assumptions for the Core Infrastructure* (*2*), individual elements are categorized by the following ITS/ATMS functions:

- Traffic management center (TMC) (Table 1),
- Field communications/processing (Table 2),
- Surveillance (Table 3),
- Traffic control (Table 4),
- Traveler information (Table 5), and
- Incident/emergency response (Table 6).

Each table gives the element's corresponding basic unit of measure. Also provided in each table are estimated unit operations cost, estimated unit maintenance cost, combined unit O&M cost, and assumptions related to the cost figures. Using quantities measured in terms of the base units shown in the table, agencies can project traffic management O&M costs for existing or planned deployment by multiplying these quantities by their corresponding unit operational and maintenance costs.

Many of the ITS/ATMS elements show a range of estimated O&M costs. These ranges are a result of varied O&M costs being experienced by the TxDOT districts. Factors contributing to the variance in O&M costs for some elements include age and quality of equipment, personnel skill levels, and system designs. Other factors relating to specific elements are listed in the tables under the Costs 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. Instead, operations personnel costs are shown as a separate line item. This approach was taken because of (*a*) 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 (*b*) the difficulty associated with distributing administration costs among the various ITS/ATMS elements. The tables do not provide guidelines for determining appropriate operations or maintenance staffing levels, only the estimated cost per employee. The ITE draft recommended practices for traffic management center staffing suggest that staffing levels be based on the functional requirements of the center.

EVALUATIONS OF PROCEDURES AND PRACTICES AFFECTING OPERATIONS AND MAINTENANCE

Funding of O&M

Issues

New traffic management infrastructure is being added to the transportation system with each new ITS/ATMS project, requiring agencies to increase operations staffing and provide specialized maintenance needs. Stable and consistent funding is needed to provide desirable levels of maintenance and operation for traffic management 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 traditional maintenance and operation activities. The demand for O&M for these activities also continues to increase as the infrastructure expands and ages. Unfortunately, the funding sources are not growing at the same rate as the need.

Findings

As with other states, financing from sources outside 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 commitment for sustained O&M funding, have not been consistently followed. And as systems have come on-line, the competition with other maintenance functions for O&M funding has intensified within an environment of steadily diminishing revenues.

In Texas, the annual ITS/ATMS budget request for fiscal year 1997 (year ending August 31, 1997) consisted of $8.7 million from the routine maintenance strategy and $5 million from the highway construction strategy for contracted traffic management rehabilitation, which includes maintenance as well as upgrades. Figures 1 and 2 show the magnitude of this allocation in relation to TxDOT's total budget for highway-related funding.

One of the greatest difficulties in providing adequate O&M funding for ITS/ATMS is that there is insufficient funding for all 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 underfunded maintenance, it is much easier to justify funding for those activities when funds are scarce.

The ITE-recommended practices for ATMS center operation and maintenance will address funding as a critical element in sustaining traffic management centers. On the basis of discussion at the ITE national conference, the dominant focus on the national level for ITS O&M funding is the use of federal funds for O&M with an emphasis on funding flexibility in future legislation. Also emphasized was the dissemination of more information to state and local agencies, including metropolitan planning organizations (MPOs), about federal funding opportunities for O&M. Federal funds are allowed for operations under several categories: STP, NHS, and CMAQ for nonattainment areas. STP is available for operations on eligible routes with no time limit and with an 80 percent federal share and 20 percent 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. The substitution of the term "operating costs" for "startup costs" removed the previous time limitation of 2 years. An 80/20 federal/local funding participation is also required. Because projects constructed with NHS funds allow the appropriation of operating funds within the initial project scope, emphasis should be placed on using NHS funding for ITS construction projects. CMAQ funding for operations may be used beyond an initial 3-year startup, provided that the project continues to demonstrate air quality benefits.

The use of federal funding for maintenance activities is interpreted differently across FHWA regions. Defining maintenance

TABLE 1 O&M Cost Estimate Table: 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
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**.

TABLE 2 O&M Cost Estimate Table: 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	per km	$9,000	$0	$9,000	*Operations:* lease cost; *maintenance:* provided by the fiber provider	TxDOT
	per mile	$14,500	$0	$14,500		
DS3	per km	$37,000	$0	$37,000	*Operations:* lease cost; *maintenance:* provided by the fiber provider	TxDOT
	per mile	$60,000	$0	$60,000		
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
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 equipement	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. Power consumption is absorbed under **Processing Satellites** and/or **Communications Hubs**, includes local control units for detectors, CMS controllers, and LCS controllers.
4. Power consumption is absorbed under **Controller Cabinets**, power consumption costs are accounted for under **Lane Control Signals** and **Changeable Message Signs**.

TABLE 3 O&M Cost Estimate Table: 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
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**.

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 amount of overall funding available, nonetheless, is finite. Without clear benefits data demonstrating the effectiveness of traffic management systems, O&M for traffic management will have difficulty competing for an appropriate share of funding against growing infrastructure maintenance demands. Documenting 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 would give decision makers 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.

Budgeting and Tracking of O&M Expenses

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 in the same way that O&M for traffic control devices historically has been budgeted, which is through the routine maintenance budgets of the individual local districts. The O&M expenses for new systems have not been conceptualized effectively in relation to the budgeting process. Consequently, the funding sources have not grown but have been further burdened.

As funding becomes more scarce, 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 funding 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 for other maintenance activities. As a result, the final amount allocated to ITS/ATMS O&M depends on the district leadership and the individual working relationship among 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

TABLE 4 O&M Cost Estimate Table: 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**.

(*continued on next page*)

TABLE 4 (*Continued*)

ATMS/TTS 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.

TABLE 5 O&M Cost Estimate Table: 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.

TABLE 6 O&M Cost Estimate Table: 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.

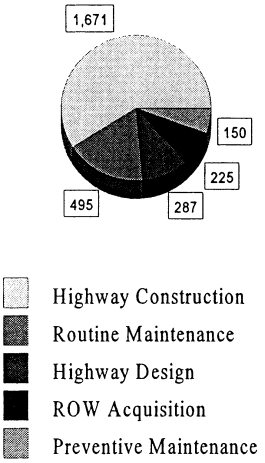

FIGURE 1 ITS/ATMS O&M funding sources in Texas: TxDOT appropriations, FY 1997 highway-related funding ($ millions) (*5*).

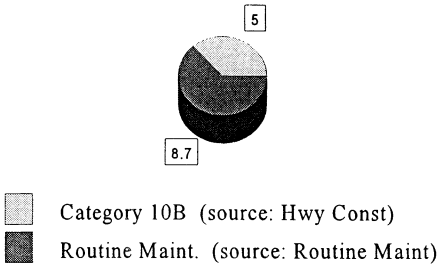

FIGURE 2 ITS/ATMS O&M funding sources in Texas: TxDOT O&M funding, FY 1997 for ITS/ATMS ($ millions) (*5*).

personnel. Nearly all of the metropolitan district operations engineers interviewed have some traffic management personnel budgeted in district programs other than maintenance, such as design or construction programs. Budgeting for administrative and public affairs personnel is extraordinarily difficult under this scenario. Furthermore, the traditional job classifications and salary levels of O&M personnel are not always consistent with the skills required for new technologies, which create difficulties in attracting and retaining competent employees.

While this diffusion of staff resources to various accounts mitigates the immediate need to fund O&M for traffic management, it makes it almost 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 intentionally separates traffic management into a separate function code. Otherwise, the true O&M costs of the system under the department's standard accounting configuration are not readily available without extensive staff time to compile the data.

Policies and Procedures Affecting O&M

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 limited revenues, the department is struggling to find the best approaches to performing services within a changing organizational culture. The issues examined in this section include limitations to adding staff, requirements for minimum contracting levels, recovery of third-party damage claims, and procurement of commodities needed to sustain system operation and maintenance.

Findings

Staffing and Contracting Mandates Legislative mandates, such as the full-time equivalent (FTE) employee cap and minimum contracting requirements (Article VII, Chapter 1063, appropriations legislation for TxDOT, 74th Legislature), limit a local district's ability to provide new services in-house. Contracting certain ITS operations and maintenance functions might be the most efficient approach for some activities. For others, it may be the most costly approach in the long term, resulting in a loss of in-house expertise as well as accountability problems with multiple vendors performing interrelated functions. Although agencies that outsource are more likely to perform operational activities in-house and contract out maintenance tasks, there are examples of successful privatization of operational activities (3,4). Concerns about performance and liability can be minimized with a well-structured contract and thorough oversight.

Recovery of Third-Party Damage Claims Because of 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 districts in procuring the hardware, spare parts, software, and equipment needed to sustain their operations is 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 using the process to its full potential, including the negotiation aspects and catalog updating features.

Public and Private Partnerships and O&M

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 signal maintenance effort, there is an obvious savings to involved agencies, 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 funding pie is increased.

However, barriers to interagency coordination are created by (*a*) the traditional organizational culture that defines boundaries between jurisdictions and other transportation modes, and between the agency and the private sector; (*b*) the lack of communications standards for data transmission; and (*c*) the multitude of unique operating circumstances between local districts 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 local district level than of 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 sheer number of overlapping jurisdictions.

The TxDOT *ITS Deployment Strategy* (*5*) 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.

Information sharing across traditional boundaries creates a whole set of problems 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/National Electrical Manufacturers Association committee.

Interoperability and interchangeability among traffic control and ITS devices will provide many O&M benefits, including (*6*):

- *Improved interjurisdictional coordination and integration*. Equipment that is compatible across agency boundaries will provide operations.
- *Enhanced opportunities to share communications costs with other agencies*. Standards will allow multiple agencies to share communication systems.
- *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.

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 O&M activities.

One issue discussed in other areas of the country and considered a means of recouping O&M costs is the concept of 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, 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 could be considered as providing reproduced data and charged according to the actual cost to provide the information.

System Design and Replacement Implications Related to O&M Costs

Issues

Although this paper does not specifically address system design, no discussion of operations and maintenance funding would be complete without mentioning the effect of system design 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 enough planning for capital costs in the budgeting process. 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 than by 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 (*7*).

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 (*6*). 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 inventories of spare parts. The NTCIP initiative described previously will provide a communications standard that facilitates interchangeability among traffic control and ITS device and results in O&M benefits.

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 primarily is being absorbed through state-funded Traffic Management System Rehabilitation (Category 10B) and routine maintenance budgets. However, additional funding needs to be devoted to these accounts 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. On the basis of interviews with other states, there is no process under way to address systematically and intentionally the issue of reinvestment in existing ITS/ATMS systems.

RECOMMENDATIONS

1. *Estimate ITS/ATMS operation and maintenance costs using the cost estimate tables developed in this paper*. The tables are based on actual and documented costs and are flexible enough to apply to different system configurations. They can also be used as a means for allocating maintenance and operations funding at the state level.

2. *Track O&M costs over the long term to maintain the validity and usefulness of the O&M cost estimate tables.* This includes an annual reconciliation of projected and actual costs, updates to the O&M cost estimate tables as necessary, and an assessment of personnel allocation to traffic management system O&M.

3. *Examine the source and level of funding of ITS/ATMS operations and maintenance to ensure that a balance of funding is achieved between all maintenance and operation activities*. This can be accomplished by (*a*) identifying and documenting the benefits of ITS O&M to provide decision makers with objective criteria for balancing funding demands; (*b*) considering a departmental policy that acknowledges increased funding requirements for maintenance and operation of all transportation system expansions; and (*c*) 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 made to refrain from building new infrastructure if it cannot be adequately operated or maintained.

4. *Improve budgeting and tracking of O&M expenses by developing a separate budget account for traffic management systems*. This is a critical step toward reconciling projected and annual O&M costs, documenting the benefits of ITS operations, and effectively managing overall infrastructure maintenance needs. Consideration should be made toward recognizing the operational component of transportation systems by including the word "operation" in addition to maintenance in the name of the appropriations strategy from which the funding comes.

5. *Modify departmental processes and approaches in order to stretch current funding*. Examples of specific TxDOT 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 by providing district-level incentives, and building on the success of the catalog procurement process for information resources.

6. *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.

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

8. *Emphasize lifetime O&M costs in the system design process*. All opportunities for reducing O&M costs should be considered 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.

9. *Improve planning efforts for system reinvestment*. Funding should be increased in existing budget categories that are used to upgrade and rehabilitate current systems.

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