

Operations, Management and Maintenance Issues Paper

1. PURPOSE

The purpose of this paper is to examine operations, management and maintenance (O&M) issues and requirements associated with intelligent transportation systems, namely freeway management and traffic signal control systems. A brief section on transit system management is included, however not much ITS-specific information for transit O&M was available. This paper addresses and discusses preventative and response maintenance programs, schedules for performing such maintenance programs, operational staffing requirements, funding alternatives, and alternative implementation approaches to carrying out the suggested maintenance activities. A section summarizing O&M recommendations is also included. Operational requirements, including system management functions, are examined and used to develop a matrix of conceptual staffing guidelines to assist in planning ITS operations.

2. BACKGROUND

There are many issues that agencies need to consider in developing an O&M plan. For example, consider the following issues and points that can impact O&M practices:

- Technology – The elements of flip disk VMS need to be lubricated to prevent the disks from sticking. It is not uncommon for some disks to go unused for six to nine months, and when put to use they can stick. Of course, some vendors have eliminated this problem altogether by designing their systems to flip the disks once a week.
- Policy – Constant usage of light emitting diode VMS tends to reduce the service life of the sign whereas agencies that display no message during non-eventful periods should get a longer life expectancy for light emitting diode VMS.
- Implementation Approach – Should agencies provide O&M support using in-house staff or should they outsource the work? The Maryland State Highway Administration will begin outsourcing all VMS maintenance in 1999, even though outsourcing the work costs 2.5 times greater than using in-house staff.
- Program Content – O&M costs are greatly impacted by the type of maintenance an agency elects to conduct. While most agencies typically provide response maintenance to repair identified problems, there are still many agencies that do not provide preventative maintenance on a regular set schedule.

It is important to realize that there exists no one O&M model that fits all agencies. A 1997 National Cooperative Highway Research Program (NCHRP) study that addressed O&M issues received organizational charts from 42 agencies outlining each agency structure. No two were alike. Such is the world of O&M.

The content of this O&M Issues Paper is based in part upon the review of professional publications that address O&M issues such as the aforementioned 1997 NCHRP report and information obtained from Florida ITS Strategic Plan survey. In addition, discussions were held with representatives of the Maryland State Highway Administration (MD SHA) and the Virginia Department of Transportation's Northern Virginia District (VDOT NOVA) to obtain real-world insights into agency maintenance practices. Some early information was also available from the following publications that are under development:

- *Transportation Management Center Functions*; NCHRP Project 20-5, TRB, Final Draft, June 1998 (final publication scheduled for January 1999)
- *A Proposed Recommended Practice for Operations & Management of Intelligent Transportation Systems*, ITE, Final Draft, August, 1998 (final publication scheduled for March, 1999)
- *Traffic Signal Installation and Maintenance Manual*, ITE, Final Draft, December 1998 (this is an update to the 1988 Manual and is scheduled for final publication in early 1999)

The issues related to transportation system management and operations policy and the resulting requirements for staff and other resources have been the subject of much study and debate within agencies across the country and within FHWA and FTA. These issues transcend the ITS world and really get at the heart of how pro-active we need to be about real-time management of the transportation system. Other issue papers for this Strategic Plan project, as well as the Vision, Guiding Principles, and ITS Business Plan, will help FDOT establish these policies.

This O&M Issues Paper includes a brief section on transit management systems. Much of the information presented has been taken from a recent draft of NCHRP Project 20-5, *Transportation Management Center Functions* and from discussions with representatives from a few agencies that use bus tracking systems and computer-aided dispatching systems. The prevalent attitude towards ITS O&M in most transit agencies is that a "if it's not broke, don't fix it."

3. MAINTENANCE REQUIREMENTS

Scope of System Maintenance

ITS requires an appropriate level of maintenance. Good maintenance will assure reliability and proper operation will protect the investment and enable adjustment to changing conditions. The maintenance of ITS is important in that malfunction can critically affect the ability of the system to perform its intended functions. Failure to function as intended could negatively impact traffic safety, public acceptance and transportation network capacity. Failure of the system also has the potential to cause measurable economic loss and increase congestion, fuel consumption, pollutants, and traffic accidents.

ITS O&M considerations should be evaluated before implementing a technology. For example, conducting a life-cycle cost analysis to compare using higher priced components in order to reduce regular maintenance costs. O&M of ITS technologies and systems extends beyond simply keeping the equipment working. Reacting to emergency failure conditions, maintaining accurate maintenance logs, and conducting preventative maintenance programs all require highly skilled staff that is motivated and fully trained. A maintenance program can also be used to track failures and decrease the time needed to fix the failures.

Response Maintenance

Most, if not all, public agencies provide maintenance in response to alarms or identified problems. Response maintenance is defined as the repair of failed equipment and its restoration to safe, normal operation. It requires action based on the priority of the subsystem that has failed and takes precedence over preventative maintenance activities for the duration of the emergency.

Response maintenance is a critical element of a comprehensive ITS maintenance plan. The importance stems from agencies' responsibility to keep traffic systems operating safely at all times. The safety of the traveling public and minimizing the agencies exposure to liability represent the two strongest reasons for establishing a sound approach to response maintenance. Typically, response maintenance requires that a qualified technician be on-call to receive notice of any and all problems that arise with field equipment.

Although outside factors may cause some problems and delays, the desired response times are usually based on agency priorities. As shown in Table 1, the Ministry of Transportation of Ontario has developed a formal plan that documents response maintenance priorities, yet it is rare that agencies have such a formal plan. Many agencies send technicians in the field on an as-needed basis or every morning to respond to identified problems or failures that occurred overnight or during the previous day. A 1997 NCHRP study found that out of 76 traffic engineering agencies surveyed, only about 45% responded to traffic signal system problems on an "as needed basis", and that only 15% responded during all hours of the day. However, when responding, the vast majority of the surveyed agencies were able to do so within two hours.

TABLE 1: RESPONSE MAINTENANCE PRIORITIES

Priority	Time to Respond	Problem	Time to Repair
High	4 hours	Critical	Before next rush hour
		Non-critical	Before 5 working days
Medium	8 hours	Critical	Before 2 working days
		Non-critical	Before 10 working days
Low	Next working day	Critical	Before 5 working days
		Non-critical	Before 20 working days

Response maintenance may involve both field and shop maintenance procedures to fully repair a failed component. Frequently, spares are kept in a ready state in the shop so that they can be used to switch-out the failed device in the field. This provides a means to effect a full and rapid repair in the field and permit the failed device to be completely repaired in the shop where comprehensive diagnostic tools are available and weather elements can be avoided. Spare components suitable to the maintenance demand should be kept on hand for repairs to equipment.

Again, the Ministry of Transportation of Ontario offers some general guidelines for stocking spare ITS parts, including:

- Electronic spare components should be kept in sufficient quantities to repair board failures. It is also advisable to keep some full spare printed circuit boards.
- Spare components are not interchangeable with those of different generations of equipment. It is advisable to note the differences and stock each component.
- Normally, a percentage of components relating to the total existing pieces of equipment in the field are required. A variable message sign is used to demonstrate the wide range of percentages -- 0.1% LED pixels, 2% controllers, 8% fans, 10% surge protectors, and 100% filters.
- Where failures of certain components become common, it is advisable to stock more than the recommended percentage.
- Large expensive items such as VMS signcases complete with the internal equipment would be desirable to stock for the eventuality of a catastrophe, but such are obviously too expensive to carry on the books. It is therefore not recommended to stock such "big ticket" items.

The Institute of Transportation Engineer's Traffic Signal Installation and Maintenance Manual and Operations and maintenance of Electronic traffic Control Systems Manual provide similar general guidelines for establishing an equipment inventory for spare traffic signal parts.

Most operating agencies in Florida provide high priority response maintenance for items such as traffic signals. This maintenance is provided by various means, including in-house staff and contract maintenance.

Preventative Maintenance

While most, if not all, public agencies provide response maintenance, few provide preventative maintenance on a regular, routine scheduled basis. Preventative maintenance, or routine maintenance as it is sometimes referred to, is defined as a set of checks and procedures to be performed at regularly scheduled intervals for the upkeep of equipment. It includes checking, testing, inspection, record keeping, cleaning, and replacement based on the function and rated service life of the device and its components. Preventative maintenance is intended to ensure reliable mechanical and electrical functioning and operation of equipment, thereby reducing equipment failures, response maintenance, road user costs, and liability exposure. The emphasis in preventative maintenance is checking for proper operation and taking proactive steps to repair or replace defective equipment, thus ensuring that problems are not left until failure occurs.

Lack of staffing and funds is often cited as primary reasons why preventative maintenance is not carried out. Furthermore, most ITS field devices are comprised of solid-state components that have become much more reliable in quality in over the past five years. As such, most agencies simply replace these components when they fail.

On the other hand, the MD SHA routinely conducts visual inspections and cleans equipment components when maintenance staff conducts response maintenance. Staff can perform some limited preventative maintenance functions in the field, and it is cost effective to do so, particularly when a lane or shoulder closure has been implemented to perform the response maintenance. In essence this "double up" approach represents a large component of their preventative maintenance

program. MD SHA does, however, conduct preventative maintenance on an annual basis for CCTV cameras, roadway weather information systems (roadway sensors require cleaning prior to the winter) and frequency deviation checks on highway advisory radio stations as mandated by the Federal Communications Commission. Such preventative maintenance functions are carried out on a regular basis to ensure proper operations of equipment.

The Florida ITS Strategic Plan survey indicated that a few states upgrade ITS equipment as part of routine maintenance, in part to address the continual rapid changes in advanced technologies. The majority of agencies responding to the survey, however indicated that they did not routinely upgrade their deployed ITS equipment.

Maintenance Cycles

Freeway Management Systems

Freeway management systems have been planned, designed, and deployed throughout Florida to manage the roadway network in a proactive manner. These systems typically consist of various subsystems, i.e., detectors that monitor roadway conditions, CCTV cameras that verify roadway conditions, variable message signs that provide en-route traveler information to motorists, and ramp metering systems that increase capacity at major interstate ramp junctures. Operations and control of these various devices typically occurs from a traffic control center.

The ability to obtain and communicate real-time information about roadway conditions is essential to the successful operation of freeway management systems, and the traveling public's trust in using the relayed information. As such, a proactive maintenance program is essential to the continued successful operation of freeway management systems.

By and large, most agencies surveyed have no formal response or preventative maintenance plan and schedule in place to support their freeway management systems. Most agencies replace parts that have failed or malfunctioned rather than conduct preventative maintenance functions. As previously noted, this is due in part to a lack of funding and a lack of adequate staffing, but also to the wide use of advanced solid-state electronics that are contained in controllers and other ITS field devices that allow them to operate for extended periods of time. Furthermore, most agency staff realize that the device has malfunctioned when they find out that data is no longer being provided from the detector, that they cannot pan the CCTV camera, etc. Beyond visual inspection and some minor testing to verify the proper operation of the equipment, there is very little preventative maintenance that can be performed on equipment that operates using solid-state electronics. As such, the "if its not broke, don't fix it" philosophy is fairly prevalent among public agencies operating ITS systems.

Such issues only serve to further the point that agencies should consider the development of maintenance programs that are tailored to their own specific systems and needs. As an example, the Ministry of Transportation of Ontario has developed "Maintenance Quality Standards Guidelines for Freeway Management Systems" for their own systems. Those standards for selected freeway management subsystems are summarized in Table 2. In general, specific maintenance requirements unique to an individual piece of equipment as provided in the manufacturer's maintenance manual should be followed. Where no manufacturer maintenance recommendations exist, agencies should consider developing their own standards.

The freeway management systems in Orlando (I-4 SMIS) and Daytona Beach (DASH) have the longest history of system maintenance. These systems have been under contract maintenance

since construction. The contract calls for on-going preventative maintenance and work-order issued response maintenance.

TABLE 2: SUMMARY OF MINISTRY OF TRANSPORTATION OF ONTARIO O&M GUIDELINES

Subsystem	Minor Maintenance	Major Maintenance	Major Rehabilitation	Life Expectancy
Field Systems				
Cabinets	--	26 weeks	10 years	20 years
Power Supply	26 weeks	5 years	10 years	20 years
Grounding	1 year	5 years	10 years	25 years
Vehicle Detection Systems				
Loop Detectors and Cables	26 weeks	1 year	5 years	10 years
Controllers	--	26 weeks	2 years	7 years
CCTV Camera Systems				
Poles	26 weeks	5 years	15 years	50 years
Silicon Intensified Target (SIT) Cameras	--	26 weeks	1.5 years	6 years
Charged Coupled Device (CCD) Cameras	--	26 weeks	2 years	10 years
Pan Tilt Zoom (PTZ) Units	26 weeks	1 year	3 years	10 years
Receivers	--	26 weeks	3 years	10 years
Monitors	26 weeks	5 years	--	5 years

Table 2: Summary of Ministry of Transportation of Ontario O&M Guidelines (Cont.)

Subsystem	Minor Maintenance	Major Maintenance	Major Rehabilitation	Life Expectancy
Variable Message Sign Systems				
Signcase	--	26 weeks	1.5 years	10 years
Protective Devices	26 weeks	1 year	2 years	10 years
Pixels, Modules, and Drivers	--	26 weeks	3 years	6 years
Controllers	--	26 weeks	3 years	6 years
Ramp Metering Systems				
Signal Wiring	13 weeks	5 Years	-	15 years
Signal Heads and Hardware	13 weeks	1 year	1 Year	10 years
Poles and Footings	1 year	5 years	10 Years	25 years
Loops and Cables	13 weeks	26 weeks	5 years	10 years
Sensor Units	--	13 weeks	--	7 years
Controllers	--	13 weeks	2 years	7 years

The Ministry defines the activities associated with minor and major maintenance activities and major rehabilitation as follows:

- Minor Maintenance - Minor maintenance is that which can be carried out without large scale testing or the use of heavy equipment. It includes visual inspection and checking of many items, elementary testing, cleaning, lubricating and minor repairs that can be carried out with hand tools or portable instruments.
- Major Maintenance - As well as all items normally done under minor maintenance, major maintenance also includes extensive testing and overhauling, and replacement of components that require a scheduled power outage, use of bucket trucks and other heavy equipment.

- Major Rehabilitation – Major rehabilitation, or complete replacement, is contemplated for devices that experience frequent malfunction or failures.

A Maintenance and Management Plan completed in 1997 for MD SHA’s CHART program offered suggested preventative maintenance tasks and schedule intervals. By and large, preventative maintenance was recommended on a semi-annual basis. It is also worth noting that the plan was developed in part to provide a basis to obtain cost proposals for contract maintenance purposes.

Traffic Signal Control Systems

Traffic signal systems that can react to changing traffic conditions are an important component in improving transportation system efficiency. To be effective, advanced traffic signal control systems require an accurate current picture of the traffic flow and status of the roadway network. This information typically consists of real-time inputs from traffic detectors, and status and incident reports from police and public call-in programs. Advanced traffic signal systems automate the use of real-time traffic flow information to change the signal timing to efficiently accommodate traffic demands on all streets.

Similar to freeway management systems, the ability to obtain and use real-time information about roadway conditions is essential to the successful operation of traffic signal systems. As such, a proactive maintenance program is essential to their continued successful operation. Yet, a 1990 FHWA study found only two out of 24 agencies perform preventative maintenance. Similar to freeway management systems, solid-state electronics devices are prevalent in today’s traffic signal systems. Furthermore, the "if its not broke, don't fix it" philosophy is also prevalent. None the less, preventative maintenance needs to be conducted for traffic signal systems and their equipment because of the safety and liability issues associated with a signalized intersection. To that end, the Institute of Transportation Engineers "Traffic Signal Installation and Maintenance Manual" sets forth suggested maintenance intervals for traffic signals. They are summarized in Table 3.

A 1997 NCHRP survey (Program Synthesis No. 245) of 76 agencies found the leading preventative maintenance activities to be relamping, inspection and replacement of controllers and cabinets, testing conflict monitors, cleaning signal heads and lenses, and checking and replacing loop detectors. All other types of preventive maintenance activities were conducted by less than 10% of the 76 agencies. The same NCHRP survey also found that 50% of the agencies conducted preventative maintenance on an annual basis, and 15% of the agencies conducted it on a semi-annual basis.

All 76 agencies surveyed as part of the NCHRP effort have a response maintenance program in place for their traffic signal systems. On average, these programs account for approximately 50% of their overall maintenance program. Similarly, preventative maintenance accounts for roughly 33% of the overall maintenance program.

TABLE 3: ITS TRAFFIC SIGNAL MAINTENANCE GUIDELINES

SUBSYSTEM	MINOR MAINTENANCE	MAJOR MAINTENANCE
-----------	-------------------	-------------------

CABINETS	26 WEEKS	2 - 5 YEARS
SIGNAL HEADS	26 WEEKS	2 - 5 YEARS
SPAN WIRE AND POLES	1 YEAR	N/A
DETECTORS	13 WEEKS	N/A
CONTROLLER	1 YEAR	N/A
INTERCONNECT EQUIPMENT	1 YEAR	N/A

TRANSIT SYSTEMS

Transit systems, by their very nature, are much more concerned about the O&M of their various assets and systems. Because of this, O&M procedures are very advanced for scheduling routes, dispatchers and operators as well as for the maintenance of buses and train cars. Transit experience with ITS technology, however, has been very limited. Some transit agencies have deployed signal preemption equipment, however the bulk of this technology is similar to (and part of) traffic signal control systems. Large scale deployment of ITS technology such as automatic vehicle location (AVL) first started in Seattle and Denver in the early 1990s. Experience with required maintenance cycles for transit specific ITS technology has not been established. The field hardware, on-board electronic systems and central computer systems are similar to those used in traffic signal and freeway systems, therefore it is reasonable to assume that the maintenance cycle requirements for advanced public transit systems (APTS) would be no worse or no better.

COMMUNICATIONS SYSTEMS

Communications provides for the transmission of all information -- data, voice, and video --between the various elements within the ITS infrastructure. The communications network of most ITS projects can contain some of the most complex and advanced technology deployed in the system, including transmitters, receivers, power supplies, video multiplexers and demultiplexers, redundant circuits, and other advance devices. An adequately maintained communications network ensuring a continuous link that is transparent to an ITS system is essential.

Again, the aforementioned Ministry of Transportation of Ontario maintenance guidelines includes suggested maintenance intervals for fiber optic cable communications. These are noted in Table 4. Maintenance guidelines should also be established for other communications technologies prevalent in ITS systems. Potential maintenance intervals, based upon engineering judgement, have been noted in Table 4.

TABLE 4: COMMUNICATIONS MAINTENANCE GUIDELINES

TECHNOLOGY	MINOR MAINTENANCE	MAJOR MAINTENANCE	MAJOR REHABILITATION	LIFE EXPECTANCY
FIBER OPTIC CABLE PLANT	1 YEAR	5 YEARS	25 YEARS	25 YEARS
FIBER OPTIC PLANT VIDEO AND DATA EQUIPMENT	--	26 WEEKS	3 YEARS	10 YEARS
TWISTED PAIR CABLE	2 YEARS	8 YEARS	30 YEARS	40 YEARS
COAXIAL CABLE	1 YEAR	6 YEARS	20 YEARS	30 YEARS
SPREAD SPECTRUM	26 WEEKS	4 YEARS	10 YEARS	20 YEARS

The fiber optic cable itself requires little to no maintenance and does not “wear out.” Technicians do, however, need to be familiar with special handling and transporting requirements as well as with performing fiber optic splices. All underground cable is susceptible damage from construction, however repairs to fiber optic cable can be extremely expensive. The maintaining agency should have an active program of utility location associated with construction activity. Twisted pair and coaxial cable are reliable and proven technologies and were used extensively in older systems. A properly designed and installed system consisting of either technology results in reasonable low maintenance requirements in terms of average time between failures, average time of repair, and the necessary levels of required skill and equipment. Beyond maintaining the hardware associated with spread spectrum radio communications, agencies need to be concerned with providing (and maintaining) a clear line-of-sight to ensure proper operations. This requirement will vary depending on the frequency-range used. Even vegetation can significantly degrade the signal and require the installation of additional transceivers at close spacing.

Leased line communications is prevalent in a number of freeway management systems around the country. The maintenance of the circuits used when leasing lines is typically provided by the utility company that owns the lines. Response times and time-to-repair are critical elements in such leasing arrangements and should be clearly defined in order to assure system up-time and availability.

The inability of telecommunication utilities to provide the desired level of response maintenance has been a big factor in the move to agency owned communications plants. In Florida, this has recently been the case for most telecommunications installations for both traffic signal control systems and other ITS projects.

Software

Agencies frequently overlook software when assessing total system maintenance requirements. Software commonly experiences isolated failures and/or recurring bugs. Computer programs can also be highly complex, making it impossible to test and debug every possible logical path. As such, warranties and maintenance functions take on added importance. Steps that can be taken to mitigate common software problems include:

- Monitor environmental conditions. The operations center may have recorders that keep track of temperature and voltages. This could prove useful in determining whether hardware or software caused a problem.
- All system components should be sufficiently documented by the agency to support on-going and future maintenance activities. Documentation will also facilitate software expansion and/or upgrades in a logical manner.
- Establish coding standards for software enhancements and the generation of new programs. Coding standards will greatly simplify efforts that support debugging, modification, and the addition of enhancements, as they will ensure that the same style and format of programming is used among all system programmers.
- All system software elements should be backed-up on a regular basis. A system in Los Angeles County has experienced numerous hard drive failures in the past 13 years. The utilization of system back-ups has minimized the impact of this recurring problem.

The Florida ITS Strategic Plan survey results indicated that there is no consensus among the respondents on how to maintain software. Many approaches are used including maintenance contracts, in-house staff, using maintenance as a line item in the software contract, and suing O&M funding sources.

4. OPERATIONS REQUIREMENTS

O&M staffing is important to ITS in order to achieve the full potential of the system. In essence, a good system plus good people equal good operations. To attain full system potential, agencies should consider the operations staff as much a part of the system as the hardware and software itself. They should also consider using a Memorandum of Understanding to document inter-agency O&M issues and agreements. This is commonly done by many agencies and has proved to be a successful tool in facilitating O&M functions.

The results of the Florida ITS Strategic Plan survey indicated that a majority of the respondents use their own staff to carry out O&M activities. Even so, only three agencies have reported a specific person or division that is responsible for O&M activities. With a lack of available and qualified staff, several agencies are now using private contractors for O&M activities.

OPERATIONS REQUIREMENTS BY SYSTEM TYPE

FREEWAY MANAGEMENT SYSTEMS

While no published standards that set forth the minimum (or even suggested) number of personnel and their responsibilities are available, there have been a number of professional papers and articles published on the topic. Furthermore, professional organizations such as the Institute of Transportation Engineers have convened workshops and issued "White Papers" that typically include some recommendations on the topic, even if they are high level in nature. ITE's "Operation and Maintenance of Electronic Traffic Control Systems" report, published in 1995, offers some detailed insight regarding this issue, as well as ITE's forthcoming "Recommended Practices for Operations and Management of Intelligent Transportation Systems" report.

Most agencies around the country break out O&M staffing for freeway management systems into two categories -- field personnel and traffic control center personnel. In general terms, these positions and their responsibilities include:

Field Personnel

- Field Technician - Responsible for maintaining ITS field devices and identifying failures of surveillance and control devices. He/she should also be capable of assisting an electronics technician in troubleshooting and testing incoming equipment.
- Electronics Technician - Responsible for diagnostic maintenance to a predetermined level. They should be capable of diagnosing a failure and initiating corrective action as well as performing or monitoring preventative maintenance on ITS field devices.
- Field Administrator - In addition to being capable of performing Field and Electronics technician duties, the Field Administrator would be responsible for scheduling and monitoring work performance of the group, equipment inventory and replenishment, cost estimates, and the annual budget.

What staff size and composition are required to maintain ITS field equipment? There appears to be no "rule of thumb" that agencies can rely upon to develop a sound estimate. In practice, the MD SHA employs eight technicians to conduct both response and limited preventative maintenance for 35 permanent and close to 100 portable signs. MD SHA has another 11 technicians that are responsible for both response and limited preventative maintenance for 250 field devices including CCTV cameras, roadway weather information systems, detectors, and travelers advisory radio units. For VDOT's Northern Virginia ATMS, the District employs seven technicians and one engineer on a full time basis to conduct response maintenance for over 1500 devices, including CCTV cameras, VMS, and detectors. The District seldom conducts preventative maintenance.

Technology can, and does for some agencies, impact the size of the required maintenance staff. For example, over time some agencies have secured the ownership of portable variable message signs at the completion of construction projects. As all projects tend to have different specifications, geographic, and contractual constraints and opportunities, agencies end up with a wide variety of different technologies that comprise their portable variable message sign fleet, thus complicating maintenance activities. Developing an agency-wide specification can mitigate this type of problem for all equipment; however, many agencies still find themselves in a position where they own, and thus need to use and maintain, a wide variety of technologies and ITS equipment.

Traffic Control Center Personnel

- Control Center Technician - Responsible for identifying hardware failures and making the necessary repair or replace decisions. He or she will need training in the maintenance of

analog and digital electronic equipment, and will need to be experienced in troubleshooting and testing procedures.

- Communications Technician - Responsible for maintaining all communications within the operations center.
- System Administrator - Responsible for user access management, communications configuration, configuration management, upgrades to the system and off-the-shelf-software, testing, installation, user trouble reports, and supports remote users.
- System Operator - Responsible for operating the system, notifying emergency response agencies, system maintenance staff, and other outside agencies and organizations.
- Database Manager - Responsible for database management system operations, adjusting the configuration as required, installing upgrades, and overseeing administrative tasks.
- Configuration Manager - Responsible for documenting, tracking, testing, and maintaining software versions during the active development of software upgrades or installations.

System requirements can only be met by a staff of highly trained individuals who have specific knowledge and experience to maintain and tune these systems for optimum performance. The result of this is that there should be an increase in effort required for system administration. Most agencies that operate and maintain freeway management systems have a minimal staff that can perform the functions of the Control Center Technician and a System Administrator as noted above. On the other hand, the number of system operators is dependent on the size of the system, the complexity of the system, roles and responsibilities of the system operator, and the hours of operation.

For example, the Maryland State Highway Administration operates their CHART program, a statewide freeway oriented ITS program, from a statewide operations center and two satellite traffic operations centers. While the working pace during non-peak periods can be slow, SHA has implemented a policy that mandates no fewer than two system operators shall be on duty during any time at each center. Assuming two system operators a shift and three eight hour shifts a day, nine (9) system operators are theoretically required to operate a traffic control center 24 hours a day, 365 days a year, not six. As such, this approach helps to maintain a core staff of sufficient size to cover all required seats on all shifts

The Montgomery County Department of Transportation and Public Works (Maryland) uses two system operators during the peak travel periods, yet reduces the number to one during non-peak periods. The reduction occurs, in part, because their system is a local arterial oriented system that is deployed primarily in one section of the County where fluctuations in traffic flow and travel between the peak and non-peak travel periods is substantial. Other agencies report using similar staffing levels. The Colorado DOT uses three system operators over the course of 12 hours for a typical weekday, while Washington DOT reports using two system operators over the course of 12 hours for a typical weekday.

Part-time support for database administration and configuration management is typically required to support ongoing O&M of the applications system. The database administrator will monitor and control the database. The configuration management position is required to manage system upgrades, control versions of both the applications and commercial-off-the-shelf (COTS) software, and to ensure that appropriate processes and procedures are followed and documentation maintained when upgrades or modifications are made to the system.

Detailed information on ITS operational staffing has been difficult to document. The most recent FHWA Traffic Control Systems Handbook provides some information. The survey conducted under Task 1 of this study provided more general information, but did not generate a significant amount of detail. District 2 of FDOT conducted their own research and survey of several ATMS installations around the country. Table 5 summarizes O&M staffing arrangements for selected freeway traffic management systems throughout the country as identified in these sources.

TABLE 5: FREEWAY MANAGEMENT SYSTEMS O&M STAFFING SUMMARY

SYSTEM (SOURCE)	POP.	MILES	RAMP METERS	CCTV	VMS	HOV	OP. STAFF	MAIN. STAFF
SEATTLE (1)	516,000	87	31	118	30	YES	12	4
MINN. / ST. PAUL (1)	641,000	97	316	108	34	YES	14	7
DETROIT (1)	1,028,000	32	49	11	14	NO	9	4
CHICAGO (1)	2,783,000	130	95	0	23	YES	15	5
LONG ISLAND (1)	3,300,000	136	75	44	101	YES	28	8
ATLANTA (2)	2,000,000	75	5	59	45	YES	8	72 (incl. service patrols)
MD -CHART (2)	9,000,000	645	NO	21	35	YES	3	23
HOUSTON TRANSTAR	4,000,000	160	NO	N/A	N/A	YES	7	84 (incl. service patrols)
SANANTONIO TRANSGUIDE (2)	1,200,000	53	NO	89	100	YES	7	24 (incl. ATIS)
PHOENIX TRAILMASTER		N/A	39	29	23	NO	N/A	

Sources:

- (1) Traffic Control Systems Handbook, FHWA
- (2) FDOT District 2 Survey / Research

TRAFFIC SIGNAL CONTROL SYSTEMS

In order to keep traffic signal systems operational and up to date, it is essential to perform preventative maintenance. In addition, many timing schedules and algorithms age with time, so it is necessary to update parameters in order to adjust to current condition.

Many agencies develop a preventative maintenance plan that allows for personnel to determine if all equipment is properly operating. This plan may include staffing requirements for maintenance and operations. What staff size and composition is required to operate a traffic signal system? A general rule of thumb that appears to be popular in the profession is to assume one traffic signal technician for every 40-50 traffic signals and one traffic signal engineer for every 100 traffic signals. Recent studies have confirmed that these rules-of-thumb can be considered accurate.

- A recent survey of 23 cities, similar in size to Hampton, Virginia (pop. 141,000), was conducted for the City of Hampton as part of their traffic signal system upgrade project. The survey found

an average of one traffic engineer per 76 traffic signals and one traffic signal technician per 47.1 traffic signals.

- An NCHRP survey found that a single maintenance person could maintain 38-43 traffic signals.
- The City of Menlo Park, California recommends one traffic signal technician for every 50 traffic signals and one traffic signal engineer for every 100 traffic signals to ensure adequate O&M of their traffic signal system.

TRANSIT SYSTEMS

As mentioned earlier, with regard to maintenance cycles, there is not much experience with ITS technology for transit (APTS). Data from a recent survey of traffic management centers (TMC) provides some basis for determining operations and management requirements. This survey, conducted for the NCHRP Project 20-5, polled TMCs of various type (highway surveillance, traffic signal control, bridge/tunnel, and transit). Transit TMCs reported the second highest frequency, at 75% of respondents, for 24 hour / 7 day a week operation (bridge and tunnel TMCs were first with 83%). For agencies that provided at least limited coverage of their TMC at all times, transit centers had the highest average (16 hours per day). Transit operations require a lot of interaction between drivers and dispatchers, so this finding is not surprising. The primary goal of ITS applications for transit is to allow transit agencies to provide more services without having to add operations personnel. Thus, the addition of ITS to the existing transit management should not significantly increase operational staffing requirements.

There is little information on the maintenance requirements for APTS technology, especially field and mobile hardware. The NCHRP Project 20-5 survey reported a wide range of O&M costs for all types of TMCs, including transit TMCs. Both the range and average values for total O&M costs for transit TMCs was very close to that reported by highway and signal system TMCs (average O&M costs were \$1.3 million to \$1.9 million per year per TMC) Interestingly, the maintenance component of these average costs was also very close among all TMC types (average maintenance costs, for TMC equipment only, was \$300,000 to \$450,000 per year per TMC).

COMMUNICATIONS SYSTEMS

Communications maintenance is typically outsourced, as most agencies do not possess the required expertise in-house to oversee the maintenance. Requirements of communications technicians tend to include an in-depth knowledge of operations of fiber optic cable, radio, microwave, voice, spread-spectrum, and landline technologies.

5. FUNDING ALTERNATIVES

The annual costs for O&M activities associated with freeway and traffic signal control systems are a "large ticket item". Participants in a National Conference of Operating and Maintaining Traffic Control Systems held in October 1994 noted that estimates for the annual cost of operating freeway systems with ATMS elements were as high as \$2.4 million. There was a wide variation in the reported data and was attributed to the agency's lack of experience in operating and maintaining freeway management systems.

More current data also supports the notion that O&M activities are a “large ticket item”. Washington DOT spends \$1,900,000 annually to operate and maintain 800 traffic signals and 120 miles of freeway management system(s). Individually, both components can be expensive. VDOT spends over \$1.0 million annually to provide response maintenance for their freeway management system in northern Virginia. MD SHA budgets close to \$3,500,000 annually to operate their CHART program – a 375-mile freeway management system and \$900,000 for response and limited preventative maintenance activities. A recent study completed for MD SHA found that implementing a preventative maintenance program for their field devices on a semi-annual basis could add an additional \$3.0 - \$3.4 million, and if outsourced, could add \$3.8 million. While O&M costs are frequently considered “after the fact”, it is not surprising that the majority of the Florida ITS Strategic Plan survey respondents rated inadequate funding as the biggest challenge facing ITS in their jurisdiction.

Participants in the aforementioned October 1994 conference also noted that insufficient funds were being devoted to operating and maintaining traffic signals systems. A survey of 117 traffic-engineering agencies found that approximately \$1,900 per signal was spent on O&M functions. However, the survey also found that the agencies felt they needed approximately \$2,400 per traffic signal.

Funding issues related to the establishment of an adequate, dependable, and long-term O&M funding source for ITS continues to be a major challenge facing local and regional agencies today. These projects are essential in order to maximize the use of roadway capacities, yet available funds for O&M are limited. The question is how to provide the additional funds required for operation and maintenance after the initial project capital expenditures have been exhausted and the system is operational.

In recent years, public agency funding sources have been squeezed to the point where they have very little supplemental funding available for the O&M costs associated with the deployment of ITS. A recent survey by the Transportation Research Board concluded that local taxes used for maintenance are trending downward in most local jurisdictions. The increasing burden of borrowing costs and the inability to raise taxes or revenues limits the availability of general funds, even though there is no restriction on their use for maintenance costs. Increasing costs of maintaining roadways and bridges is also crowding out other uses of state and local gas tax funds. Therefore, O&M funding issues, when considering ITS, will continue to be a major factor affecting an agency's decision to deploy ITS.

The recently approved Transportation Equity Act for the 21st Century (TEA-21) retains O&M funding eligibility originally set forth in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and amended in the National Highway System Act of 1995 as follows:

- The Surface Transportation Program (STP) program can be used to fund the "capital and operational costs for traffic management and control". The STP program clearly states that freeway surveillance systems, traffic signal systems, and operations centers are eligible for funding. Eligible operating costs include operational and maintenance system staffing, and the tools required to make a system respond to traffic control strategies effectively. No time limit is set for the use of operational support funding. STP funds are also renewable on a yearly basis, which provides for flexibility in requesting funds for operational activities.
- The National Highway System (NHS) program can be used to fund ongoing operating costs for traffic monitoring, management and control facilities. The term "operating costs for traffic monitoring, management, and control" includes labor costs, administrative costs, costs of

utilities and rent, and other costs associated with the continuous operation of ITS. Similar to STP funds, no time limit is set for the use of operational support funding.

- The Congestion Mitigation and Air Quality (CMAQ) fund can be used to fund both capital and operational costs, only if an air quality benefit can be determined. CMAQ funding for operations is, however, limited to a three-year time frame. After this, the improvement is considered part of the “base” transportation network.

The Federal government continues to recognize the need to provide O&M funding for ITS investments and is continuing to commit to making Federal funds available. They alone, however, are not likely to offset the full amount of funds required to implement a comprehensive O&M plan. Table 6 summarizes the opportunity to use Federal funds to support ITS O&M activities. As the State Gasoline Tax is also a source of available funding, it has been included in the table for reference.

TABLE 6: SUMMARY OF POTENTIAL O&M FUNDING SOURCES

TYPE OF FUND	OPERATIONS	MAINTENANCE
SURFACE TRANSPORTATION PROGRAM (STP)	OP	OP
NATIONAL HIGHWAY SYSTEM (NHS)	OP	OP
CONGESTION MANAGEMENT AND AIR QUALITY (CMAQ)	LNO	LNO
STATE GASOLINE TAX	SIG	SIG
INTERSTATE MAINTENANCE (IM) FUNDS	LNO	OP

OP = SOME OPPORTUNITY TO USE THE FUNDS
 LNO = LITTLE OR NO OPPORTUNITY TO USE THE FUNDS
 SIG = SIGNIFICANT OPPORTUNITY TO USE THE FUNDS

The Florida ITS Strategic Plan survey results indicate that none of the 11 agencies surveyed are currently making use of federal funds. Six agencies report using state maintenance funds, two agencies use local funds, and two agencies use public/private partnership funds.

The Florida Division office of FHWA is in the process of establishing a policy on operations and maintenance. This policy will reflect current FHWA requirements and clarify activities that are eligible for Federal-aid Funding. This proposed policy should be considered for incorporation into the Statewide ITS Strategic Plan. The proposed FHWA policy on O&M is as follows:

"Operations, system maintenance and other management costs, which provide for the continuous operation of the traffic control facility (i.e., system) are eligible for Federal funding. These activities, which are designed to ensure peak performance of the traffic control system, shall be fully described in an operations and maintenance plan as required by 23 CFR 655.

Preventative maintenance, which ensures the continuous and efficient operations of the system, should be the foundation upon which the maintenance plan is established. Responsive maintenance should be limited to activities that extend the

useful life of the system and are economically justified. Maintenance activities, which result from deferred maintenance of the system or neglect, are not eligible for Federal funds."

6. IMPLEMENTATION APPROACH

There are three approaches that can be followed to provide O&M support for ITS systems -- in-house, outsourcing, and facilities management. Each has their own distinct benefits and risks associated with them. Florida DOT should identify and select a course of action best suited to its needs.

IN-HOUSE SUPPORT

From an operations perspective, using all agency staff is ideal because managers and team leaders have a single personnel management system to deal with and team cohesiveness is easier to establish and maintain. But given today's trends of downsizing and doing more with less, many agencies around the country have a difficult time in finding, training, and keeping the required talented staff to operate and maintain their ITS.

One approach to building an in-house O&M staff is to use the resources of other maintenance, construction inspection, safety or other engineering staff who's work is seasonally oriented, or requires "fair weather" to complete. Talented, capable staff may be available within an organization if a flexible certification, training, and refresher program is provided and maintained. This approach also enhances the organization as well as the individual. Table 7 illustrates some of the benefits from in-house support.

TABLE 7: IN-HOUSE SUPPORT BENEFITS AND RISKS

IN-HOUSE BENEFITS	RISKS
<ul style="list-style-type: none"> · ESTABLISH A HIGH-TECH CAREER TRACK WITHIN THE STATE GOVERNMENT. · SHARE STAFF WITH OTHER DEPARTMENTS WITH SIMILAR NEEDS. · SENSE OF "OWNERSHIP" AND UNDERSTANDING OF THE SYSTEM. 	<ul style="list-style-type: none"> · RECRUITING, RETENTION, AND STAFFING TECHNOLOGY POSITIONS IS DIFFICULT IN THIS REGION, WITH PRIVATE FIRMS OFFERING HIGH SALARIES TO PERSONNEL WITH SIMILAR QUALIFICATIONS · TRADITIONALLY DIFFICULT TO CONTROL COSTS AND MAINTAIN QUALITY STANDARDS, FOR THE REASONS CITED ABOVE · COMPETING PRIORITIES WITHIN THE STATE GOVERNMENT MAKE IT DIFFICULT OVER THE LONG TERM TO MAINTAIN THE COMMITMENT

A problem with utilizing in-house support is the maintaining of skills necessary to support the fast changing technologies. Where required, in-house support can be supplemented by utilizing outsourcing.

OUTSOURCING

It is becoming increasingly difficult for public agencies to fill highly technical positions that usually require special classifications and high pay scale. Personnel departments within the public sector tend to resist creating special classifications and typically follow a policy of setting pay scales by the number of persons supervised even though positions requiring highly specialized skills often do not supervise many people, if any at all.

Staffing from within an agency has many advantages; however, in an era of downsizing government, State and local agencies are for the most part facing diminishing budgets year after year. This leads to pressures to cut staffs and freeze existing vacancies even in those cases where outside non-general fund budget sources are available. Unfilled vacancies in an ITS supporting role will usually result in significantly reduced system effectiveness.

Outsourcing can often by-pass these problems. Staffing through outsourcing does not result in a "higher body count". The budgetary item for outsourcing is often treated by the agency administration like a line item for the electricity to run the TMC and field equipment, with none of the negative perceptions involved in the financing of new staff positions. It is also easier for a private firm to fill vacancies with appropriately skilled personnel as well as fire poorly performing employees.

While outsourcing offers solutions to the types of staffing problems noted above, it is not without its own set of problems. These include the necessity of continuing tight administration of performance under the contract, potential higher turnover rates in contractor personnel than in-house staff, scarcity of private sector personnel with adequate traffic experience, and friction with in-house staff.

Outsourcing is characterized by careful development of a detailed, clearly defined set of contractor requirements, including task descriptions, schedules, performance standards, and payment terms. The INFORM system on Long Island use separate outsourcing contracts to computer hardware, loop detector assemblies, VMS, and communications. In addition, outsourcing normally:

- Obligates the contractor to commit to a certain number of hours for a lump sum fee, or for an unlimited number of hours for a set rate per hour
- Specifies exactly what tasks the contractor will perform and what tasks the Owner will perform
- Requires little or no contractor investment
- Specifies performance standards and accomplishment criteria for detailed tasks

Outsourcing has been a mainstay in the service industry for decades, and, therefore, many contract models are available for public agencies to utilize. Table 8 illustrates some benefits resulting from outsourcing O&M responsibilities.

TABLE 8: OUTSOURCING BENEFITS AND RISKS

OUTSOURCING BENEFITS	RISKS
----------------------	-------

<ul style="list-style-type: none"> · CLEAR SEPARATION BETWEEN AGENCY AND CONTRACTOR RESPONSIBILITIES · AGENCY CAN DECIDE WHAT TASKS IT WISHES FOR THE CONTRACTOR TO PERFORM, AND WHICH IT WISHES TO PERFORM WITH ITS OWN FORCES 	<ul style="list-style-type: none"> · LITTLE FLEXIBILITY TO GET SERVICES OUTSIDE THE SPECIFIC SCOPE WITHOUT EXTENSIVE ADMINISTRATION AND ADDITIONAL COST · LITTLE INCENTIVE FOR THE CONTRACTOR TO EXCEED PERFORMANCE STANDARDS OR ACCOMPLISHMENT CRITERIA
---	--

FACILITIES MANAGEMENT

The third option is for agencies to engage a facilities management contractor in a public-private venture for the purposes of providing ITS O&M. While facilities management shares some characteristics with contracting out, it also provides a level of flexibility and incentives for both parties that a service contract does not.

Facilities management, or facilities outsourcing, involves use of private-sector staff to perform traditional government services, working on a broad mission basis, and targeting the standard of mission accomplishment. Although facilities management is a new concept in traffic management, it is a tried and true method for providing service in other high-technology environments, including computer facilities, law enforcement dispatching systems and telecommunications systems.

Facilities management is different than outsourcing, where the private contractor is required to follow the explicit directions of the government manager. With outsourcing, there is little incentive for the private contractor to control costs, because it is paid by the person-hour employed. Under facilities management, the private-sector firm and the public agency have congruent goals and the same incentive to succeed. Because it is paid for mission fulfillment, the private-sector contractor has the incentive to seek efficiencies and cost-effective techniques for achieving the contract objectives. Table 9 summarizes potential benefits and risks associated with facilities management.

TABLE 9: FACILITIES MANAGEMENT BENEFITS AND RISKS

FACILITIES MANAGEMENT BENEFITS	RISKS
<ul style="list-style-type: none"> · KEEP UP WITH TECHNICAL REALITIES · KEEP UP WITH BUSINESS REALITIES · PROVIDES COMMON GOALS AND THE SAME INCENTIVE TO SUCCEED FOR ALL PARTIES INVOLVED 	<ul style="list-style-type: none"> · ALL PUBLIC/PRIVATE VENTURES ARE RISKS IF INCENTIVES ARE NOT CAREFULLY CRAFTED. · CONTROL AND LIABILITY CONCERNS.

7. RECOMMENDATIONS

MAINTENANCE REQUIREMENTS

- Agencies should document all ITS operations and maintenance costs, by component, and develop a process to reliably estimate the cost of providing response maintenance for use and support in obtaining adequate funds to carry out maintenance responsibilities. VDOT's NOVA District has been tracking in-house maintenance costs for over five years, and their management has found the process helpful in budgeting and requesting funds. Documenting in-house costs will also allow agencies to estimate outsourcing costs if they elect to outsource maintenance activities.
- Whether maintenance is provided by in-house or outsourced resources, agencies should develop a preventative maintenance plan. A good preventative maintenance plan will clearly note all required materials, equipment, and procedures, thus allowing in-house staff to expedite and achieve a higher level of consistency and quality in conducting preventative maintenance activities. A good preventative maintenance plan will also allow agencies seeking to outsource to properly budget, advertise and receive quality proposals from interested parties. Either way, preventative maintenance, if carried out properly, will reduce response maintenance activities.
- An adequate spare parts inventory should be developed and maintained to support proper and professional in-house response maintenance activities.
- In recognition of safety requirements, liability, acceptance levels of service, and the degree to which various types of malfunctions can be tolerated, priorities need to be developed for the maintenance of specific ITS equipment. Overall, scheduled preventative maintenance is an important element of a comprehensive ITS maintenance program. However, it is also realistic to expect that response maintenance will also create a significant demand on maintenance resources.
- Provide the necessary maintenance support of field equipment linked to traffic control centers. The prompt repair of field communications and other equipment linked to the traffic control center is essential to the effective real-time functioning of ITS system.
- Maintain complete as-built and as-modified drawings and specifications of all system equipment. Doing so will assist in maintenance operations.
- System maintenance should be given a high priority to minimize liability risk. As such, public agencies need to commit adequate funding and staffing resources for effective software maintenance. Staffing levels should be maintained for overseeing those areas that can be maintained in-house and funding should be provided for those areas that require outsourcing.
- Agency maintenance staff should be as familiar as possible with the operation and interaction of the software because with highly complex software, best results are obtained when in-house and outsourcing staff can work closely together.
- Obtain an annual maintenance contract on all computers and other hardware that is not easily supported by agency maintenance staff.
- Obtain an annual maintenance contract on all computer software.

- Maintain detailed inventory of all system components.

OPERATIONS REQUIREMENTS

- Staffing levels should support the needs and intent of the system. Adequate staff considers all shifts without jeopardizing the individual staff member's mental and physical well being and their ability to perform the task at hand. A signal systems oriented traffic control center that is highly automated and typically addresses routine day-to-day functions could operate with a reduced staff. On the other hand, a traffic operations center with a need for interagency communications, information and data sharing on a 24-hour basis will be required to maintain a significantly greater number of staff.
- Appropriate staff qualifications and classifications should be developed. The staffing level and corresponding qualifications should be developed to support the operations plan.
- Provide an operations manual for system operator reference. A typical manual should cover three basic areas -- general information, policies and procedures on internal O&M, and policies and procedures involving traffic management.
- Agencies should develop a staffing plan that provides for sufficient, qualified, and experienced staff for both operating and maintaining systems. Furthermore, agencies should provide back-up capabilities to allow operations to continue when staffing shortages or peaks in workload occur. Cross training within an agency is one way to provide this capability.
- Agencies should develop and maintain an on-going training program to provide a well-trained and cross-trained staff for both operating and maintaining systems. For each position, the training program should identify skill levels, responsibility levels, and training needs. Elements of the training program should include exposure to other traffic, transit and related operational systems, debriefings of actual events, and funding requirements for each element of the system.
- O&M personnel should be included in all phases of the project to ensure that their perspective is included in all phases of the system life cycle. This approach will also help train these staff in all aspects of the system they will be operating and maintaining.
- For freeway management systems, consider staffing with no less than two system operators per shift. Obviously, this issue depends upon the composition, intent, and functionality of the traffic operations center. The need for a break, personal security, lavatory relief, meals, and continuity of operations requires more than one system operator, particularly during major incident and events.

A recommended set of staffing guidelines for a typical freeway operations center in a Florida urban area is shown in Table 10. These are guidelines only and will depend greatly on the type of program and concept of operations at each center. Other factors that will impact the staffing requirements of a particular traffic management center include deployment phasing and geographic area of coverage.

Position Descriptions

The Institute of Transportation Engineers classifies personnel required for maintenance and operation of traffic signal and control equipment into five categories that have been established based on responsibilities, knowledge, and skills. These positions include:

- Traffic Signal Mechanic - Responsible for diagnostic maintenance up to the device exchange level in the field, including complete responsibility for the operation of controllers. He or she is capable of diagnosing a failure and initiating corrective action and of performing preventative maintenance on the signal heads and suspension gear.
- Supervising Traffic Signal Mechanic - In addition to the responsibilities described for the signal mechanic, a Supervising Traffic Signal Mechanic is also responsible for scheduling and recording work performed by the other signal mechanics in the group, and for preparing quantity and cost estimates for the annual budget.
- Traffic Signal Technician - Responsible for maintaining solid state equipment in the field as well as identifying failures at an intersection. He or she will also be able to assist the signal engineer in troubleshooting, testing incoming equipment, and setting controller timing as specified by the traffic engineer.
- Traffic Signal Engineer - One who has extensive training and troubleshooting skills in electronics and software, as well as a thorough knowledge of the theory of operations of the equipment. The Traffic Signal Engineer is responsible for the diagnostics and repair of all solid state controllers to the chip level. He or she occasionally makes field trips to aid the Traffic Signal Technician in returning the equipment for normal operation, and, if unable to identify the problem, requests factory assistance.
- Traffic Engineer - Responsible for traffic signal design, design modifications, signal timing plans, and administration of signal installation and maintenance.

There are equivalent positions for freeway/expressway operations, incident response and traveler information systems. These ITS operational functions are not as clearly defined as those for traffic signal control systems. Some of the functional level descriptions for ITS operations and maintenance include:

- Program Development - engineers and planners to develop and maintain the ITS concept of operations that the systems are required to support. These staff develop the necessary inter-agency agreements and provide liaison between agencies. They also monitor system performance and modify operational strategies as needed to maximize user services. Program development staff will identify needs for new ITS services and/or technologies for inclusion in the work program.
- Communications Support - engineers and technicians to operate and maintain fiber optic, twisted pair, coaxial, and / or wireless communications systems
- Information Service Provider (ISP) Facilitator - staff to register and administer private sector participation in traveler information services.

- ISP Technical Support - engineers and technicians to provide the information services and connections to registered ISPs, including video and data feeds
- Website Development / Support - programmers and graphic artists to provide Website administration, development and technical support
- Outreach - public information specialists to promote and market the ITS and traveler information services that have been developed. This staff also provides outreach and support for ITS related public/private partnerships.
- Administration - this is similar to the day-to-day office operation, human resource, and accounting functions within the Department, however additional administrative support is needed for the new ITS program and its staff - both at the District level and at Central Office.

These ITS specific functions have been taken from requirements listed in the NCHRP 20-5 Transportation Management Center Functions report. Specific ITS staff functional descriptions were taken from a staffing proposal from Smart Trek, the Seattle Metropolitan Model Deployment Initiative (MMDI) project, that outlines the O&M requirements for that system once it is completed sometime in 1999. Smart Trek is primarily a real-time traveler information system with a cable television station, HAR, Website and various pager delivery mechanisms to deliver traffic and transit information. Deployment of the Smart Trek is expected to cost about \$10 million and includes the software and database development, system integration, and some initial operations. Annual operation and maintenance of Smart Trek, including only those systems used to collect and deliver the information (not subsystems, such as the freeway management systems) is projected to cost over \$1.1 million per year nearly 7 full-time equivalent (FTE) staff.

FDOT Staffing Recommendations

The following tables present recommended staffing guidelines for the operation of ITS in Florida. Because there are a wide variety of ITS user services that could be offered in a "typical" TMC, several tables are presented. Recommended staffing tables are shown for the ITS Market Packages of Freeway Operations, Incident Management, and Regional Multimodal Traveler Information.

An underlying assumption in each of these tables is that these staffing requirements are for the stand-alone needs of each particular ITS Market Package / User Service. That is, these are all new positions needed to operate (and in the case of TOC computer equipment, maintain) each representative ITS operation. In most cases, these operations will be integrated and combined at one or more levels within each District. There are opportunities for combining and sharing positions for operations that are integrated, especially those that are co-located in the same building, such as within a TOC. For example, a freeway operations center is often used to enhance the effectiveness of freeway service patrols. In this example, the positions of Program Manager and Administrative Support could be combined into one position, but the positions required for tow-truck drivers could not be combined with any existing positions in the TOC.. These guidelines are presented as separate tables for example only. Each District will have the flexibility to combine positions and provide the appropriate level of service.

Table 10 presents the recommended staffing for a TMC in a "typical" urban area in Florida. A "Level of Service" categorization is used to define the different staffing needs of different levels of operation. The assumptions used to develop this table are shown below.

TABLE 10. FREEWAY / EXPRESSWAY OPERATIONS CENTER
 FDOT DISTRICT STAFFING GUIDELINES - FOR A TYPICAL URBAN AREA
 (Final Version - 6/6/99)

LEVEL OF SERVICE	PROGRAM / CENTER MANAGER	SHIFT MANAGER / SUPERVISOR	SYSTEM OPERATOR	COMPUTER / NETWORK SUPPORT	PUBLIC SAFETY LIAISON	ADMIN. SUPPORT	TOTAL
LOS 1: AD HOC, AS-NEEDED RESPONSE	1 (F-1)	-	-	-	-	-	1.0
LOS 2: PEAK PERIOD COVERAGE	1 (F-1)	1 (F-1)	1 (F-1)	0.5 (C)	1 (F-1)	-	4.5
LOS 3: FULL WEEKDAY 12+ HOURS	1 (F-1)	1.5 (F-1)	2 (F-1)	1 (C)	1.5 (F-1.5)	1 (C)	8.0
LOS 4: EXTENDED DAY 16+ HOURS	1 (F-1)	3 (F-2)	5 (F-2)	1.5 (C)	2 (F-2)	1.5 (C)	15.0
LOS 5: FULL 24 HR / 7 DAY COVERAGE	1 (F-1)	5 (F-2)	9 (F-3)	2 (C)	5 (F-5)	2 (C)	24.0

Notes::

(C) - These positions could be either Contractor or FDOT provided employees.

(F-#) - These positions must be FDOT or other government employees (# = how many out of the total).

Staffing Guideline Assumptions:

1. All staffing shown in terms of full-time equivalents (FTE) at 1854 staff-hours per year.
2. "Typical urban area" refers to one of Florida's major cities. Tampa, St. Petersburg, Miami, Ft. Lauderdale and Palm Beach would all be considered separate urban areas for this assumption. Moderate complexity (roadway coverage and number of incidents). It is assumed that the system would be capable of being handled by one to two system operators and one (1) dispatcher during peak periods.
3. Does not include field equipment maintenance personnel.
4. Public safety dispatcher may be provided by law-enforcement agency (i.e., FHP). Does not include service patrol personnel or dispatchers.
5. Does not include District or Central Office Traffic Operations or Systems Planning personnel (see Table 10).
6. Does not include multimodal or transit operations personnel
7. Personnel shown above are total FTEs, contract operations could be provided by consultant services. In order of priority, the following positions could be provided by consultants: Computer/Network Support, System Operator, Admin Support, Dispatcher, Supervisor. It is recommended that the Ops Center Manager always be FDOT personnel.

Table 11 presents the recommended staffing for a Incident Management operation. Ideally, this operation would be coordinated through a TMC like the one described above, but this is not necessary. The Incident Management operation would include functions such as service patrols and incident coordinators. The same "Level of Service" concept used for the TMC

operation is used for this Market Package. The assumptions used in this table are shown below.

TABLE 11. SERVICE PATROL / INCIDENT MANAGEMENT OPERATION
 FDOT DISTRICT STAFFING GUIDELINES FOR TYPICAL URBAN AREA
 (Final Version - 6/6/99)

LEVEL OF SERVICE	PROGRAM MANAGER	PROJECT MANAGER / SUPERVISOR	SERVICE PATROL DISPATCHER	FIELD PERSONNEL / DRIVERS	PUBLIC SAFETY LIAISON	ADMIN. SUPPORT	TOTAL
LOS 1: AD HOC, AS-NEEDED RESPONSE	1 (F-1)	-	-	-	-	-	1.0
LOS 2: PEAK PERIOD COVERAGE	1 (F-1)	1 (C)	1 (C)	5 (C)	1 (F-1)	1 (C)	10.0
LOS 3: FULL WEEKDAY 12+ HOURS	1 (F-1)	1.5 (C)	2 (C)	8 (C)	2 (F-2)	1 (C)	15.5
LOS 4: EXTENDED DAY 16+ HOURS A DAY	1 (F-1)	3 (C)	5 (C)	10 (C)	3 (F-3)	1.5 (C)	23.5
LOS 5 : FULL 24 HR / 7 DAY COVERAGE	1 (F-1)	5 (C)	9 (C)	15 (C)	5 (F-5)	2 (C)	37.0

Notes:

Field Personnel / Drivers based on 30 centerline miles of freeway in a “typical” Florida urban area.

(C) - These positions could be either Contractor or FDOT provided employees.

(F-#) - These positions must be FDOT or other government employees (# = how many out of the total).

Staffing Guideline Assumptions:

1. All staffing shown in terms of full-time equivalents (FTE) at 1854 staff-hours per year.
2. “Typical urban area” refers to one of Florida’s major cities. Tampa, St. Petersburg, Miami, Ft. Lauderdale and Palm Beach would all be considered separate urban areas for this assumption. Assumes moderate complexity (roadway coverage and number of incidents). Mileage of coverage for this staffing level is typically no more than 30 linear miles of freeway.
3. Maintenance of Service Patrol trucks is NOT included.
4. Public safety liaison may be provided by law-enforcement agency (i.e., FHP). However, the role of this position is Incident Clearance (not law enforcement).
5. Does not include District or Central Office Traffic Operations or Systems Planning personnel (see Table 10).
6. Personnel shown above are total FTEs, contract operations could be provided by consultant services. In order of priority, the following positions could be provided by consultants: Service Patrol Driver, Admin Support, Dispatcher, Supervisor. It is recommended that the Program Manager always be FDOT personnel.

Table 12 presents the recommended staffing for a Regional Multimodal Traveler Information System. As a Market Package, this operation is dependant on the information gathering functions of the Freeway Operations package and (ideally) on similar functions in Traffic Control systems. The same “Level of Service” concept used for the TMC operation is used for this Market Package. The staffing recommendations in this table are based, in part on the

proposed staffing for Smart Trek, the Seattle area traveler information system. Other assumptions used in this table are shown below.

TABLE 12. REGIONAL MULTIMODAL TRAVELER INFORMATION SYSTEM
 FDOT DISTRICT STAFFING GUIDELINES - FOR TYPICAL URBAN AREA
 (Final Version - 6/6/99)

LEVEL OF SERVICE	PROGRAM MANAGER	PROJECT MANAGER	HELP DESK STAFF	ISP / USER LIAISON	COMPUTER / NETWORK SUPPORT	ADMIN. SUPPORT	TOTAL
LOS 1: AD HOC, AS-NEEDED RESPONSE	1 (F-1)	-	-	1 (C)	0.5 (C)	-	2.5
LOS 2: PEAK PERIOD COVERAGE	1 (F-1)	1 (F-1)	0.5 (C)	1 (C)	1 (C)	0.5 (C)	5.0
LOS 3: FULL WEEKDAY 12+ HOURS	1 (F-1)	1 (F-1)	1 (C)	1 (C)	2 (C)	0.5 (C)	6.5
LOS 4: EXTENDED DAY 16+ HOURS A DAY	1 (F-1)	1 (F-1)	1 (C)	1.5 (C)	2 (C)	1 (C)	7.5
LOS 5: FULL 24 HR / 7 DAY COVERAGE	1 (F-1)	1 (F-1)	2 (C)	2 (C)	2 (C)	1.5 (C)	9.5

Notes:

(C) - These positions could be either Contractor or FDOT provided employees.

(F-#) - These positions must be FDOT or other government employees (# = how many out of the total).

Staffing Guideline Assumptions:

1. All staffing shown in terms of full-time equivalents (FTE) at 1854 staff-hours per year.
2. "Typical urban area" refers to one of Florida's major cities. Tampa, St. Petersburg, Miami, Ft. Lauderdale and Palm Beach would all be considered separate urban areas for this assumption. Assumes moderate complexity (roadway coverage and number of incidents). Mileage of coverage for this staffing level is typically no more than 30 linear miles of freeway.
3. Information gathering is not included (see Table 11).
4. Does not include District or Central Office personnel (see Table 10).
5. Personnel shown above are total FTEs, contract operations could be provided by consultant services. Because of the public/private nature of this market package, all functions could be provided by consultant / private sector personnel.

Finally, it is important to provide the administrative support for Florida's ITS program. This is needed at both the District and Central Office levels. It is assumed that much of the existing FDOT organizational structure and responsibility will remain, with the possibility of additional divisions or offices at both the Central Office and the District levels. The details of this organization is the subject of other issue papers and the Business Plan., however some general recommendations can be made for administrative and technical support for the ITS program with the Central Office of FDOT. Based on our research, there were not a lot of organizational models from other states from which to build on. Some states have a centralized structure with a single office responsible for all ITS planning and development. Some has divided the organizational responsibilities along functional lines. Washington State DOT is proposing to use

this format with managers for each of the major ITS “Bundles” such as ATMS, ATIS, APTS, ARTS, and CVO. As we have reported from the Strategic Plan survey, California’s CALTRANS is most similar to Florida in that it is a very decentralized agency. California also has multiple urbanized areas, much like Florida. The central office of CALTRANS provides support to the district through an Advanced Transportation Systems Center. FDOT currently provides a similar organizational approach through the Central Office of Traffic Operations and the Transportation Research Laboratory (TRL), although on a much smaller scale. As the ITS program grows within each of the FDOT districts, the support for that program (in Traffic Operations, Public Transportation and Planning) should grow as well. A recommended staffing level for the Central Office ITS program support is shown in Table 14. A commensurate level of staffing will also be needed in each District with an active ITS program.

TABLE 14. GENERAL ITS PROGRAM SUPPORT
 FDOT CENTRAL OFFICE STAFFING GUIDELINES
 (Final Version - 6/6/99)

PROGRAM SUPPORT ROLE	PROGRAM MANAGER	PROJECT MANAGER	ITS ENGINEER	ITS PLANNER	ADMIN. SUPPORT	TOTALS
STATEWIDE ARCHITECTURE DEVELOPMENT	0.5	1	1	1	1	4.5
FREEWAY / EXPRESSWAY OPERATIONS	0.5	1	1	0.5	1	4.0
TRAVELER INFORMATION SYSTEMS	0.5	0.5	1	0.5	0.5	3.0
RURAL / INTER-URBAN PROGRAMS		0.5	0.5	0.5	0.5	2.0
TRANSIT MANAGEMENT	0.5	1	1	1	0.5	4.0
RESEARCH & DEVELOPMENT	0.5	1	1	-	0.5	3.0
ITS COMMUNICATIONS	-	0.5	0.5	0.5	-	1.5

Staffing Guideline Assumptions:

1. All staffing shown in terms of full-time equivalents (FTE) at 1854 staff-hours per year.
2. The positions shown are all new staff, in addition to existing staff. Organizational hierarchy is not shown. New staff positions recommended for both Traffic Operations and Systems Planning.
3. Personnel shown above are total FTEs, contract operations could be provided by consultant services (GEC type contract). Program Manager positions should be staffed by only FDOT personnel.
4. The Department of Management Services (DMS) will manage the Florida Fiber Net system. The staff shown here are to provide ITS specific support for District and Central Office use of this network.

Combined ITS Operations Center

Table 15. presents the recommended staffing for a combined ITS operations center. In this scenario, the functions of a freeway operations center are combined with that of a freeway service patrol and a traveler information system for a “typical” urban area in Florida. The same “Level of Service” categorization is used to define the different staffing needs of different levels of operation. This combined center will allow the sharing of responsibilities among several

positions, thereby reducing the total staffing required. The following position descriptions highlight the differences and similarities between several of the overlapping positions.

- **Program Manager / Ops Center Manager.** These refer to the overall manager of the program or operations center. As a senior level manager, this position can most easily assume the additional responsibilities of a combined center.
- **Shift Manager / Supervisor / Project Manager.** As a middle level manager, this position is responsible for shift operations and projects. Therefore, some sharing of responsibilities is possible.
- **System Operator / Dispatcher / Liaison.** These positions were used in different contexts with the individual ITS functions previous tables. In this table, these positions are assumed to be less specialized and can perform multiple functions, but are listed separately for clarity. The system operator is responsible for confirming incidents, initiating response and disseminating traveler information. The dispatcher is primarily responsible for dispatching and communicating with the service patrol drivers, but can also assist in incident response by communicating with public safety providers. The liaison position can be a “catch-all”, providing general interface with local agencies and the public, including (in the case of the ATIS function) help desk functions for the information service providers (ISPs).
- **Computer / Network Support.** These positions are similar in all of the individual function scenarios, therefore some responsibility sharing is possible in a combined center.
- **Administrative Support.** This position is very easily shared in combined operations center. This position can also pick up some of the Liaison responsibilities.

The other assumptions used to develop these recommendations are shown following the table.

TABLE 15 COMBINED ITS OPERATIONS CENTER
 FDOT DISTRICT STAFFING GUIDELINES - FOR A TYPICAL URBAN AREA
 (Final Version - 6/6/99)

LEVEL OF SERVICE	PROGRAM/ CENTER MANAGER	SHIFT MANAGER / SUPERVISOR	SYSTEM OPERATOR	DIS- PATCHER	FIELD PERSONNEL / DRIVERS	PUBLIC SAFETY OPS CENTER LIAISON	COMPUTER / NETWORK SUPPORT	ADMIN. SUPPORT	TOTAL
LOS 1: AD HOC, AS- NEEDED RESPONSE	1 (F-1)	-	0.5	-	-	1 (F-1)	0.5 (C)	-	32.0
LOS 2: PEAK PERIOD COVERAGE	1 (F-1)	1 (F-1)	1 (F-1)	1 (C)	5 (C)	1 (F-1)	1 (C)	1 (C)	12.0
LOS 3: FULL WEEKDAY 12+ HOURS	1 (F-1)	2 (F-1)	2 (F-1)	2 (C)	8 (C)	2 (F-2)	2 (C)	1 (C)	20.0
LOS 4: EXTENDED DAY 16+ HOURS A DAY	1 (F-1)	3 (F-2)	5 (F-2)	3 (C)	10 (C)	3 (F-3)	3 (C)	2 (C)	30.0
LOS 5: FULL 24 HR / 7 DAY COVERAGE	1 (F-1)	5 (F-3)	9 (F-3)	5 (C)	15 (C)	5 (F-5)	4 (C)	2 (C)	46.0

Notes:

Field Personnel / Drivers based on 30 centerline miles of freeway in a “typical” Florida urban area.

(C) - These positions could be either Contractor or FDOT provided employees.

(F-#) - These positions must be FDOT or other government employees (# = how many out of the total).

Staffing Guideline Assumptions:

1. All staffing shown in terms of full-time equivalents (FTE) at 1854 staff-hours per year. All positions, except Program Manager, could be provide through contract or consultant operations.
2. "Typical urban area" refers to one of Florida's major cities. Tampa, St. Petersburg, Miami, Ft. Lauderdale and Palm Beach would all be considered separate urban areas for this assumption. Moderate complexity (roadway coverage and number of incidents). It is assumed that the system would be capable of being handled by one to two system operators and one (1) dispatcher during peak periods.
3. Freeway service patrol requirements are dependant on length of coverage and desired response time. Table assumes approximately 30 miles of freeway and maximum 15 minute response time.
4. Does not include field equipment maintenance personnel.
5. Ops Center Liaison may be provided by law-enforcement agency (i.e., FHP).
6. Does not include District or Central Office Traffic Operations or Systems Planning personnel (see Table 14).
7. Does not include multimodal or transit operations personnel.

Funding Alternatives

- Agencies should estimate and fund recurring costs such as response and preventative maintenance activities, staffing, spare parts inventory, and in-house equipment needed to operate and maintain systems. In areas of rapid technology change that are subject to significant pricing variations, like communications and computer systems, special attention should be directed to updating the strategy.
- Funding estimates for all systems should include the cost of anticipated system and component replacements that deliver the same functionality as the deployed system. Driving forces in anticipating these "in-kind" replacements include the service life of the components, technology obsolescence, cost and availability of spares, and access to qualified O&M staffing resources.
- System O&M costs should be estimated in a manner that allows agencies to take full opportunity in securing Federal STP, NHS, IM and CMAQ funds.
- Innovative funding sources should be explored within statutory constraints to supplement available federal and state funds. These potential funding sources could include public / private partnerships, resource sharing with public agencies both within and external to the organizational context of the O & M agency or agencies, and revenue opportunities.
- System expansion costs should be developed and included in the strategic management plan.
- Agencies should consider the training requirements for all personnel when preparing plans and budgets.

IMPLEMENTATION ALTERNATIVES

- A sound estimate that addresses the agency's strengths and weaknesses should be developed prior to the agency determining the appropriate O&M implementation course. Liabilities and risks should also be considered in selecting the best implementation course.
- Outsourcing should be considered as an appropriate method to obtain the necessary staff to provide support for O&M issues and to supplement agency staff. Software and hardware maintenance, relamping of traffic signals and VMS, communications maintenance, and system administration lend themselves to outsourcing.