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Intelligent Transportation Systems (ITS)
Operational Support Contracts
Implementation Plan

FINAL REPORT
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Submitted by

Raman K. Patel, Ph.D., P.E.
Principal Investigator
Transportation Research Center
Civil Engineering Department
Polytechnic University

In cooperation with

University Transportation Research Center, Region 2
City College of New York

New Jersey Department of Transportation
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16. Abstract The New Jersey Department of Transportation (NJDOT) is currently facing a significant challenge in keeping Intelligent Transportation Systems (ITS) at a high level of availability at the Transportation Operation Center North (TOC North) and Transportation Operation Center South (TOC South). As more and more components are added to the ITS infrastructure, system administration, system management and system operational support become very critical for TOCs. This project was initiated to review current issues facing NJDOT and investigate practices of the other states' TOCs, and report on the findings that may be helpful to the NJDOT in devising its operational support contracts for TOC North and TOC South. This report outlines the issues faced by the NJDOT in operating and maintaining ITS, and recommends an implementation plan for the maintenance and support requirements. The report makes recommendations on policy, staffing and operational support needs based on the survey results and visits of other states' TOCs, and literature review and examination of the current practices of TOCs in the country. The report provides Job specifications for the recommended positions. The NJDOT will consider these recommendations in developing next steps for the TOC operational support for TOC North and TOC South.					
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TABLE OF CONTENTS

	<u>Page</u>
SUMMARY.....	1
INTRODUCTION.....	4
Importance of Intelligent Transportation Systems (ITS) in New Jersey.....	4
The Typical New Jersey Department of Transportation (NJDOT)	
ITS System.....	5
Project Objectives.....	6
Project Methodology.....	8
Report Organization.....	8
ITS MAINTENANCE AND SUPPORT ISSUES FACING NJDOT.....	10
Introduction.....	10
NJDOT Transportation Operations Centers (TOCs).....	10
NJDOT ITS Maintenance Objective.....	12
NJDOT ITS Maintenance Practice.....	13
Addressing the Gap: Desired Information by the NJDOT.....	14
NJDOT ITS Operational Support Issues.....	16
ITS MAINTENANCE AND SUPPORT PRACTICES OF	
OTHER STATES' TOCs.....	22
Typical Functions Performed by TOC.....	22
Critical Maintenance Issues Expressed by Other States' TOCs.....	23
Elements of Maintenance Practices of Other States' TOCs.....	24
Maintenance Approach: No One Model Fits All Needs.....	25
Operation and Maintenance Practices of Other States' TOCs.....	26
Fiber Optic Cable Maintenance.....	29
ITS OPERATIONAL SUPPORT CONTRACTS IMPLEMENTATION PLAN.....	31
What is an Implementation Plan?.....	31
Why Does NJDOT Need an Implementation Plan?.....	31
Criteria for Development of an Implementation Plan.....	32
Implementation Plan Elements.....	33
CONCLUSIONS.....	72
RECOMMENDATIONS.....	73
Policy Recommendations.....	73
Staffing Recommendations.....	75
Operational Support Recommendations.....	76
APPENDIX.....	83
Job Specifications for Recommended Titles.....	83
Preventative Maintenance Procedures Checklists.....	99
Maintenance Activities.....	103
List of TOC Benefits and Costs.....	105
Operating Cost Eligibility Under Federal-Aid Highway Program.....	106
Other States' TOCs Contact Information.....	112
REFERENCES	113

LIST OF FIGURES

	<u>Page</u>
Figure 1.	TOC North ITS Elements.....11
Figure 2.	TOC South ITS Elements.....12
Figure 3.	Typical Functions Performed by TOC.....22
Figure 4.	Typical Concept of Operations Diagram of a TOC.....34
Figure 5.	NJDOT Statewide Traffic Operations (October 2004).....35
Figure 6.	Annual Maintenance Costs by Type of Device.....50

LIST OF TABLES

Table 1.	Summary of Recommendations.....	3
Table 2.	NJDOT Central ITS System Maintenance Elements.....	13
Table 3.	NJDOT Field ITS System Maintenance Elements.....	14
Table 4.	Central and Field System Maintenance by Other States' TOCs.....	28
Table 5.	System Software Maintenance by Other States' TOCs.....	28
Table 6.	Fiber Optic Cable Maintenance by Other States' TOCs.....	30
Table 7.	Concept of Operations Elements.....	37
Table 8.	Cost of Preventative Maintenance per ITS Device.....	41
Table 9.	Preferred Frequency of Preventative Maintenance of ITS Elements.....	43
Table 10.	Operation and Maintenance Support Elements.....	48
Table 11.	Sample Annual Maintenance Costs.....	49
Table 12.	Annual Maintenance Costs of the NJDOT ITS (Partial).....	49
Table 13.	Staffing, Training and Documentation Elements.....	52
Table 14.	Sample Estimate for Staffing Needs.....	70
Table 15.	Policy Recommendations.....	74
Table 16.	Staffing Recommendations.....	75
Table 17.	Operational Support Recommendations.....	77
Table 18.	Other State TOCs Contact Information.....	112

LIST OF ABBREVIATIONS AND SYMBOLS

AASHTO	American Association of State Highway and Transportation Officials
ATMS	Advanced Transportation Management System
ATIS	Advanced Traveler Information System
CCTV	Closed Circuit Television
CM	Configuration Management
DMS	Dynamic Message Sign
ESP	Emergency Service Patrol
ESS	Environmental Sensors Station

FHWA	Federal Highway Administration
FMS	Freeway Management System
FTA	Federal Transit Administration
HAR	Highway Advisory Radio
IMRT	Incident Management Response Team
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
IMRT	Incident Management Response Team
ITS	Intelligent Transportation Systems
LCR	L (Inductance) C (Capacitance) and R (Resistance)
MAGIC	Metropolitan Area Guidance Information and Control
MIST	Management Information Systems for Transportation (by PB Farradyne)
MTBF	Mean Time before Failure
MTTR	Mean Time to Repair
NEMA	National Electrical Manufacturers Association
NJDOT	New Jersey Department of Transportation
NTCIP	National Transportation Communications for ITS Protocol
OEM	Original Equipment Manufacturer
OTDR	Optical Time Domain Refelctometer
RPSIP	Research Project Selection and Implementation Panel
RTMS	Remote Traffic Microwave Sensor
RWIS	Road Weather Information System
SHA	(Maryland) State Highway Administration
TMS	Traffic Management System
TMC	Traffic Management Center
TOC	Transportation Operations Center
TRANSCOM	Transportation Operations Coordinating Committee
TRB	Transportation Research Board
VMS	Variable Message Sign

SUMMARY

The purpose of this project is to develop an Intelligent Transportation Systems (ITS) operational support and contract implementation plan for the NJDOT TOCs. The project was initiated to review the current operations and maintenance practices of the NJDOT and further investigate the best practices of other states' TOCs to develop recommendations for the Research Project Selection and Implementation Panel (RPSIP). The recommendations stated in this report define requirements and approach to provide for ITS TOC technical personnel, either through staffing guidance and/or contracts, so that the ITS will operate at peak efficiency.

This project began with a simple hypothesis: a better maintenance plan for ITS systems and devices, and reduced downtime in TOCs for network, hardware, and software made possible by better system administration will allow the NJDOT to achieve peak efficiency at both TOCs.

The project took the approach that there are significant number of successful TOCs in other states that have faced similar challenges and devised plan that improve their operational efficiency. Towards that end, the first step was taken to investigate the operational support issues facing the NJDOT TOCs, followed by the examination of the practices of other states' TOCs. An extensive literature review was conducted and the information collected (through surveys and site visits) was synthesized on current practices of other states' TOCs. This information became the basis for further analysis and synthesis done by this project.

Based on this synthesis, 22 specific recommendations in three categories: Policy, Staffing, and Operational Support, and are made to the NJDOT and are briefly summarized in Table 1, page 3, with the implementation timeframe. The detailed discussions on these recommendations are provided on pages 72 through 81.

The project concluded that by providing TOC managers with operational support in three critical areas — system administration, network management, and ITS inventory, parts and equipment management, will improve the system's technical performance and overall operational efficiency. For each TOC, a team of three additional positions a (system administrator, a network system technician, and a Purchasing assistant) is recommended.

The project investigation has also found that the successful practices of other states's TOCs in initiating preventive maintenance program for ITS devices have contributed to peak operational efficiency, and the NJDOT should seriously consider building on successful TOC examples. System component level performance checks and on the spot repairs will avoid system breakdowns and reduce system downtime, and raise the will allow TOCs desired system availability level of 99.67% and higher.

It is anticipated that the RPSIP will consider these recommendations as part of the NJDOT's next steps towards facilitating ITS operations in the State. These anticipated next steps may result in additional support positions at both TOCs and operational support contracts for ITS maintenance in the State.

Table 1. Summary of Recommendations.

#	Policy Recommendations	Time Frame
1	Develop a NJDOT TOC Concept Of Operations Plan	Short Term *
2	Develop NJDOT TOC Operations Manual	Short Term
3	Develop or Integrate a Statewide Policy on Fiber Optics/Wireless Technologies	Long Term *
Staffing Recommendations		
1	Hire Two New <i>System Administrators (One for each TOC)</i>	Short Term
2	Hire Two New <i>ITS Purchasing Assistants (One for each TOC)</i>	Short Term
3	Hire Two New <i>Network Systems Technicians (One for Each TOC)</i>	Short Term
Operational Support Recommendations		
1	Strengthen In-house Operational Support by implementing a statewide <i>ITS Maintenance Management System (MMS)</i>	Short Term
2	Continue with current In-house fiber optic cable maintenance, but add two <i>Network Systems Technicians</i>	Short Term
3	Strengthen Statewide ITS Support Contract by modifying and renaming the current Statewide ITS maintenance contract to include preventive maintenance of ITS devices	Short Term
4	Modify TOC North central system operational support management with three new positions: <i>Network System Technician, System Administrator and a Purchasing Assistant</i>	Short Term
5	Modify TOC South central system operational support management with three new positions: <i>Network System Technician, System Administrator, and a Purchasing Assistant</i>	Short Term
6	Institute Spare Parts and Equipment Management	Short Term
7	Develop and Implement a Policy on ITS standardization	Medium Term *
8	Purchase Special Vehicles for In-house Maintenance to include a High-Reach (80 feet) Bucket Truck and a “Network Support” Van for each TOC	Short Term
9	Procurement of Test Equipment	Short Term
10	Evaluate ITS Maintenance Programs	Short Term
11	Institute Configuration Management	Short Term
12	Institute Logging and Event Tracking System	Medium Term
13	Incorporate National ITS Architecture User Service-Maintenance and Construction Operations (MCO)	Medium Term
14	Institute Semi-annual Training Sessions for TOC Staff	Short Term
15	Convene an Annual TOC Workshop with Peers	Short Term
16	Continue with Further Research on TOC and Traffic Management Issues	Medium Term

* The project defines timeframes as: Short Term- 1 to 2 years, Medium Term- 2 to 5 years, Long Term-over 5 years.

INTRODUCTION

Importance of Intelligent Transportation Systems (ITS) in New Jersey

As part of fulfilling its mission “to provide reliable, environmentally and socially responsible transportation and motor vehicle networks and services to support and improve the safety and mobility of people and goods in New Jersey”, the New Jersey Department of Transportation (NJDOT) is increasingly relying on the ITS. In recent years, ITS elements have supported Homeland security and AMBER alert initiatives that go beyond its original design to preserve and protect vital transportation infrastructure links in the region.

New Jersey, the most densely populated state in the Nation, needs a fully operable ITS because it is a vital tool in the effective management of traffic. Delays cost each motorist 60 hours per year and have a cumulative yearly economic loss to New Jersey of \$7.3 billion in time, fuel, and additional vehicle operating costs. Each year, there are over 700 roadway fatalities, 100,000 injuries, and 330,000 accidents in New Jersey. ⁽¹⁾ New Jersey’s highly developed industrial base and geographic location in the economically dense Northeast corridor makes the management of its transportation assets (highways/bridges/tunnels, transit, rails, ports, aviation, ferries) a high priority.

ITS, when used effectively with operational strategies, helps to reduce congestion, enables motorists to be aware of highway traffic conditions and alternative routes and modes, provides for the efficient movement of freight and goods, and most importantly, makes the highway system safer to travel. According to the FHWA, freeway management systems in metropolitan areas have helped reduce accidents by 15 percent and increase capacity by 17 percent to 25 percent while incident management programs such as New Jersey’s Incident Management Response Team (IMRT) can

reduce incident related congestion by up to 50 percent. ⁽¹⁾ The NJDOT began installing ITS in 1992 .Through the use of these systems; the average incident duration has been reduced to less than two hours from two and one-quarter hours, resulting in billions of dollars in savings to the citizens. ITS infrastructure, an essential part of the State's highway system, has contributed significantly to reducing incident detection time and the dissemination of real-time information to the motoring public. ⁽¹⁾

The Typical NJDOT ITS System

ITS uses advanced communications, computer, and information technologies to improve safety and efficiency of the transportation system. These systems are designed to support the NJDOT's mission, goals, and objectives in coordinating and providing transportation services across modes in the region.

Generally, a TOC houses a central computer-base system with application software (for traffic and travel information management), communications modems and servers, video wall, and workstations for operators interface. The field hardware consists of cameras, electronic display signs, detectors, traffic controllers, and highway advisory radios to inform motorists on traffic conditions. Other ITS elements such as environmental sensor stations for weather information are added as systems are expanded.

A typical communication system uses fiber optic cables or telephone lines or wireless mediums that will allow high-speed data communication between the central system and the field elements installed over a wide area. TOCs are designed to oversee daily functions and coordinate with other entities from one central location.

The Office of the Director of Traffic Operations conducts daily traffic operations through two TOCs: Traffic Operation Center North located at Elmwood Park covers the

northern half of New Jersey area including major corridor leading to and from New York City, and Traffic Operation Center South located at Cherry Hill covers the southern part of the State and maintains coordination with the Delaware Valley Regional Planning Commission (DVRPC), and the Pennsylvania DOT.

The typical ITS in New Jersey consists of a portable and fixed variable message signs (VMSs), closed circuit television (CCTV) cameras, fiber optic interconnect cable, radar detectors, transmitters (E-ZPass readers), traffic signal hardware and software, central and field communication and control equipment, central computers and servers, central applications software, road weather information system (RWIS), highway advisory radio (HAR) system, etc. These systems are designed to provide the functionality needed to support the goals and objectives for public safety (e.g., managing evacuation and route guidance during emergencies such as an approaching hurricane, terrorist attacks, etc.), support statewide Incident Management Response Team (IMRT), dissemination of real-time travel information to the public, and a regional information exchange (e.g. TRANSCOM). The NJDOT also has access to regional ITS systems managed by TRANSCOM and I-95 Corridor Coalition.

Project Objectives

The NJDOT staff has identified key technical issues facing traffic operations that are affecting the efficiency of the ITS operations. This situation has developed due to the increasing burden of the expanded functionality of a complex ITS. The resources to support and maintain a high level of ITS operation efficiency are inadequate. The NJDOT defines the successful operation of the ITS as at least 99 percent operational ⁽²⁾ throughout the year (the study has, however, recommended an approach that results in 99.67% availability). Only adequately administered, managed and maintained ITS will achieve peak efficiency of operation. As more and more systems and devices come online, the role of system administration, system management, and system operational support becomes much more critical. ⁽²⁾

To have a better understanding of the issues facing the NJDOT TOCs and to develop an implementation plan to support ITS, (particularly in operation and maintenance support), the NJDOT has initiated a Technology Transfer effort to review the current operation and maintenance practices of the NJDOT and investigate the best practices of the other states' TOCs to develop a set of next-step recommendations for the Research Project Selection and Implementation Panel (RPSIP). ⁽²⁾

Based on the results from the initial literature survey and the discussions with the operation staff, RPSIP directed the research team to investigate issues and make recommendations with the following objectives in mind:

- Develop operational and maintenance support requirements to provide for ITS TOC technical personnel either through staffing guidance and/or contracts so that the ITS will operate at peak efficiency. The systems include all ITS network systems hardware and software. Included in the ITS' components that should be investigated for operational support methods are traffic signal systems hardware (including loop detectors) and software components.
- Develop ITS system administration (statewide) support requirements to reduce network, hardware and software downtime in the TOCs by focusing on system administration.
- Prepare TOC job specifications with a focus on repair, maintenance and operational support contracts, including the enhancement of the NJDOT supplied job specification for Systems Administrator: ITS Systems Administration (statewide).
- Provide guidance on a suitable method for maintaining fiber optic communication interconnect cables.

Project Methodology

A preliminary scan of the literature on current maintenance practices was initiated to gather pertinent information for the presentation to the RPSIP. Based on the assessment, the RPSIP renewed the research focus on the ITS operational support contracts. This was followed by a series of related tasks designed to gather information from the NJDOT TOCs and also from other state TOCs. A detailed literature review was conducted to identify current guidelines, manuals, recommended practices, lessons learned, handbooks and other published materials encompassing ITS system administration, management, and operations. The NJDOT TOC operations staff provided information on the important issues facing their operations, and on existing system administration, system management and system operational policies, procedures, specifications, system inventory, warranties, manufacturers, etc. This was followed by a detailed survey and visits to other state TOCs to obtain information on TOC operations, staffing and maintenance practices. The information gathered was organized under three areas: Organization and Operation, Maintenance and Support, and Documentation and Training. This formed the basis for the report.

Based on the findings of the previous work, the RPSIP guided the research team to focus on developing an “Implementation Plan” for ITS operation and maintenance support contracts. The task included preparing job specification enhancement for Systems Administrator: ITS Systems Administration (statewide). This report addresses these needs.

Report Organization

The report starts with the **Introduction** of the ITS role in the NJDOT and states the objectives and methodology of the study. The second section, **ITS Maintenance and Support Issues Facing the NJDOT** lists issues facing the NJDOT TOCs. The section on **ITS Maintenance and Support Practices of Other States’ TOC** presents key

points of the current maintenance practices and approaches by other successful TOCs in the country. The information obtained from these TOCs and literature review provided basic input to the NJDOT. **ITS Operational Support Contracts Implementation Plan** section discusses a set of elements which forms the basis for developing recommendations for the NJDOT. The **Conclusion** sections states major conclusions of the project.

The **Recommendations** section contains a total of 22 recommendations in three categories: Policy, staffing, and operational support.

The Appendix provides additional TOC related information, including job specifications for new titles recommended by the project. A detailed checklist on preventative maintenance and Federal guidelines for operational support are also included for ready use by the NJDOT.

ITS MAINTENANCE AND SUPPORT ISSUES FACING THE NEW JERSEY DOT

Introduction

The focus of this project is on repair, maintenance and operational support requirements for the NJDOT Intelligent Transportation Systems (ITS). The purpose is to assess current operation support requirements and to establish a mechanism for the ITS operation support that will be adequately administered, managed, and maintained in order to operate at peak efficiency in inadequate areas. The advent of the large-scale deployment of ITS functions and complex systems installed in the State infrastructure has created a critical need for the NJDOT (a traditional highway organization) to develop a formal support mechanism to ensure ITS components are functioning as intended.

The project reviewed the current practices and ITS operational support issues facing the NJDOT TOCs. The study also conducted extensive investigation of the ITS operations conducted by other state TOCs. Based on the information collected from various sources, a set of recommendations were developed in consultation with the RPSIP. This section presents operational support issues facing the NJDOT. (A later section covers a set of recommendations that follows up on the issues discussed.)

NJDOT Transportation Operation Centers (TOCs)

The NJDOT currently has two regional TOCs: TOC North and TOC South. TOC North operates from Elmwood Park and serves the eleven counties located in the northern part of the State. Located in Cherry Hill, TOC South covers the ten southern counties. Separate state toll authorities operate the New Jersey Turnpike, The Garden State Parkway and the Atlantic City Expressway from their own operation centers located in the central and southern part of the State. Both TOCs cover the weekday's peak-periods and weekends, special events, and seasonal coverage, on as needed basis. It

The NJDOT plans to interconnect with fiber cable the TOCs North and TOC South, Trenton Headquarters Control Center (TECC), the Dispatch Unit, and the New Jersey State Police (NJSP), to complete the missing segments of fiber optic backbone. ⁽¹⁾

The following four components make up the ITS operations management at both TOCs:

- Traffic Operation Center (TOC) Management
- ITS Maintenance Management
- Incident Management Response Team (IMRT)
- Emergency Service Patrol (ESP)

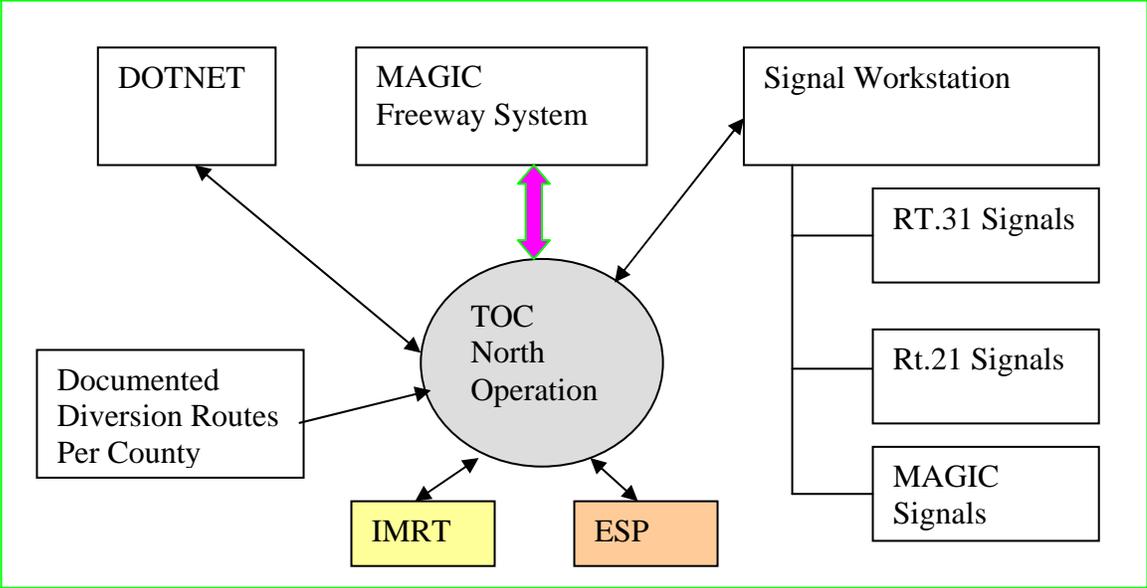


Figure 1. TOC North ITS Elements.

The Figure 1 shows the ITS elements of the freeway management system installed at the TOC North and Figure 2 shows ITS traffic management elements at the TOC South. Currently these centers are not interconnected for real-time information exchange. However, as stated earlier the NJDOT intends to complete the fiber optic interconnect to tie these centers in near future, including and other transportation centers in the state.

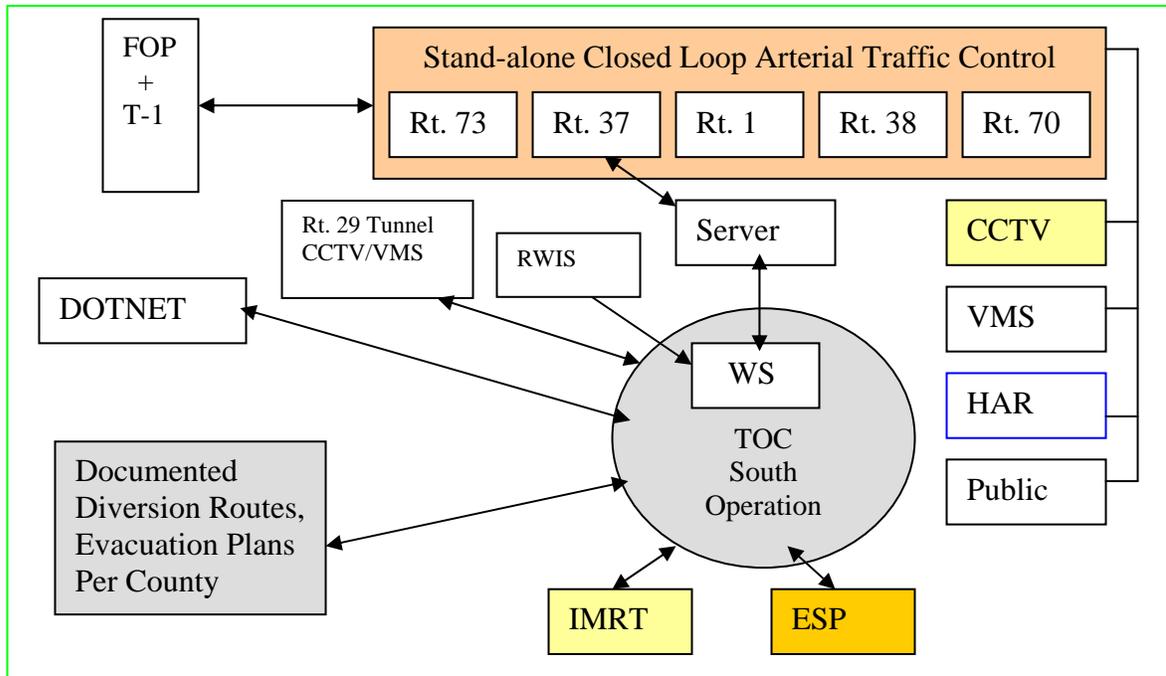


Figure 2. TOC South ITS Elements.

NJDOT ITS Maintenance Objective

The stated objective of the NJDOT ITS Strategic Deployment Plan is to establish a system to provide network and systems support for both preventive and emergency maintenance: ⁽²⁾

- Train the NJDOT staff to handle routine maintenance and equipment repairs and be able to triage system emergencies.
- Initiate emergency repairs immediately to ensure systems are running efficiently at all times.
- Administer contracts as necessary to handle complicated and/or other repairs that cannot be handled by the NJDOT staff.

- Implement Configuration Management to keep track of current equipment, software versions, etc., its location, maintain awareness of latest software versions available for upgrading and plans for future upgrades.

NJDOT ITS Maintenance Practice

The current NJDOT maintenance practice is to perform ITS support and maintenance in a hybrid manner, which includes deploying in-house TOC communication systems technician and electrical technician, and hiring an outside highway maintenance contractor to perform a variety of services, including some ITS devices, but not all.

Table 2. NJDOT Central ITS System Maintenance Elements.

#	Elements	Maintenance by In-house unit	Maintenance by Contract
1	Central Computer Hardware	X	
2	Central Computer Software	X	X
3	Workstations	X	
4	Communications Servers	X	X
5	Communications Modems/MUX	X	
6	CCTV/Video wall	X	
7	Configuration Management		X
8	Warranty	X	X
9	Web pages	X	
10	HAR recording studio	X	

The central computer system hardware and software elements shown in the Table 2 are currently supported the on-call technical experts (consultants). The Electrical Maintenance Unit of the NJDOT also maintains the traffic signal controllers, power system, cables, pull boxes, etc., using in-house staff. The small-scale fiber optics communications cable repairs are typically performed by in-house forces while a statewide outside contract takes care of repairs that involve excavation, cable pulling and other major repairs. The statewide ITS maintenance contract also takes care of

routine maintenance, such as the cleaning and inspecting of field components. In-house staff handles repairs for the field devices such as CCTV cameras, VMS, etc.

Table 3. NJDOT Field ITS System Maintenance Elements.

#	Elements	Quantity	Maintenance by In-house unit	Maintenance by Contract
1	Traffic Controllers Arterials		X	
2	CCTV Cameras	125	X	X
3	VMS Signs	75	X	
4	Fiber Optic Cable	300 mi	X	X
5	Telephone lines		X	X
6	Co-axial cables		X	
7	HAR	12	X	
8	Communication Cabinets		X	
9	Electric Power for cabinets		X	
10	Environmental Sensor Stations ESS	5	X	
11	Loop Detectors	2400		X

Table 3 provides a breakdown of field devices maintenance. The maintenance for the ITS components shown in the Table 1 and Table 2 indicate that the current emphasis is placed on the in-house handling for the hardware maintenance with limited number of ITS devices are included in the statewide contract., The software and communications maintenance is left to the outside consultants. The NJDOT annual statewide contract for maintenance of ITS facilities handles a limited number of ITS devices and other traffic equipment. ⁽³⁾

Desired Information by the NJDOT

The NJDOT defines the successful operation of ITS systems as at least 99 percent operational through the year. ⁽²⁾ To receive benefits from the large-scale ITS investments in the State, the NJDOT should ensure that the ITS operate at peak efficiency and that network, hardware and software down-time is minimized. Dedicated

maintenance of ITS devices and systems installed across the State will ensure full benefits. This will require (at both TOCs):

- Increasing the operational support necessary for the TOC technical personnel, either through adding staff or by working with outside contractors or a combination of both.
- Using the system administration resources to reduce network, hardware, and software down-time, and for configuration management.
- Implementing a maintenance plan for the fiber optics communication system throughout the state for ITS integration and wide-area coverage. (As of 2002, the NJDOT had about 300 miles of fiber optic cable installed in the State). ⁽¹⁾

This project reviewed the concept of operations and ITS functions and services performed by the TOC North and TOC South. These centers support the NJDOT mission and traffic management functions as follows:

- The TOC North supports a large-scale freeway management system (FMS) that includes a range of ITS devices such as CCTV, VMS, HAR, travel information, and incident management support. A MIST central management system performs a broad range of ITS functions.
- The TOC South includes a significant number of legacy-based closed loop arterial traffic management systems (TMS), in addition to the freeways located in the southern part of the State. These traffic control systems are different from each other in terms of software and hardware implementations and are not integrated. The ITS operations, however, are carried out on several servers equipped with proprietary interfaces at the TOC South. As a result, operators are presented with a significant challenge in keeping these stand-alone systems and field devices functioning at peak efficiency.

NJDOT ITS Operational Support Issues

- **Lack of Spare Parts Availability:** A lack of spare parts inventories and difficulties in procuring critical spare parts in a timely manner are two key concerns expressed by the TOCs. It has been suggested that the creation of new position of a purchasing assistant for active procurement of spare parts will help the operations at both centers. If implemented, this step will allow TOCs to cut down response time on field maintenance significantly, as procurement delays will be reduced.

The research team found that the practices of other state TOCs varies and most large TOCs do carry critical parts in their inventory, or they force contractors to carry such items on hand.

- **Lack of ITS System Integration:** Freeway and traffic control systems are not integrated. The Metropolitan Area Guidance Information and Control (MAGIC) is a centralized freeway management system that covers I-80 and the vicinity and two separate traffic signal control systems are operating independent of each other and are currently not integrated at the TOC North. At the TOC South, legacy-based closed loop traffic control systems are also not integrated. Lack of integration of these IITS components prevents efficient TOC operations and has adverse impact on the maintenance of various components.

State TOCs are moving towards replacing first generation proprietary systems with integrated systems that are open-system based. Maryland's Coordinated Highways Action Response Team (CHART), New York City's Vehicular Traffic Control System (VTCS), and Automated Traffic Surveillance and Control (ATSAC) of the City of Los Angeles have made successful transitions to a second generation of integrated systems. Such open-system based centralized facilities are easier to operate and maintain.

- **Lack of System Administrators:** System administration does not exist at either TOC location and should be instituted at both TOCs as soon as possible. As ITS systems are expanded and system complexity rises, a full time system administrator at TOCs is needed to support operations. Most centers have a full-time staff available, when needed, from agency support groups. The NJDOT should seriously consider this concept. This project recommends a dedicated position of System Administrator at both TOCs.
- **Communications Protocols:** At present, variable message signs (VMS) from three different vendors, DAKTRONICS, Infocite and Vultron, are deployed using three different proprietary protocols. This makes it difficult to coordinate and creates problems training the operators. Most state TOCs have already in operation or are in the process of purchasing VMS signs with National Transportation Communications for ITS Protocol (NTCIP) protocol, which is used by multiple vendors' products. The NJDOT should consider replacing non NTCIP-based signs with NTCIP-based signs and incorporate NTCIP in new procurements in the future.
- **Communications Link between TOC North and TOC South:** This does not yet exist and the lack of a link hinders statewide coordination in real-time by limiting control and the ability to share field device functions and travel information. High bandwidth communications can greatly facilitate the sharing of video and data in real-time between the two TOCs. It will also allow both TOCs to operate their workstations remotely in a situation where a statewide emergency unfolds and a wider impact is anticipated or disaster recovery is needed.

The NJDOT ITS strategic plan also calls for interconnectivity between the two TOCs and other centers in the State. The NJDOT's IT division also has an interest in statewide connectivity to tie all DOT facilities together for interoperability purposes.

- **Fiber Optic Cable Connectivity:** Fiber optic connectivity is one of the most discussed issues by all state TOCs that the team visited, primarily because it offers unlimited bandwidth for video and data needs. Most states have statewide coverage and work is still going on in some cases to extend it into rural areas. The NJDOT ITS strategic plan calls for interconnectivity between the two TOCs and other centers in the State. ⁽¹⁾ The NJDOT has already installed 300 miles of fiber and intends to close thirteen identified gaps by spending \$40 million for various on going construction projects. ⁽¹⁾ The NJDOT's IT department has expressed an interest in a statewide connectivity to tie all DOT facilities together to achieve interoperability.
- **Fiber Optic Cable Maintenance:** The NJDOT has a statewide contract for repairing large breaks in fiber cables. The response time of outside contractors is a major problem facing fiber cable maintenance. Another problem with outside contractors is the lack of expertise and this requires close monitoring of their performance using quality control techniques. As a result, both TOCs have expressed preference to maintaining the fiber cable links internally if proper resources are made available. Resources needed for fiber cable maintenance includes trained crew, spare cables, splicing equipment and diagnostics scopes, fusion process materials and equipment, and continuous training. A dedicated fiber optic *maintenance van* can support handling of maintenance parts and transport activities for the crew. (The NJDOT has two splice trailers for splicing operations).
- **Traffic Signal Control System Software:** Different signal systems acquired from different vendors and proprietary protocols make it very difficult to maintain. Different systems evolved over times and working independent of each other pose operational difficulties. Lack of integration among various systems is a major issues facing ITS. TOC South has a several systems installed as separate applications on the same workstation. The TOC South has a separate software

maintenance contract for Route 1 system elements such as CCTV, HAR, and VMS.

- Similar Needs at Both Centers: During the various meetings, it became apparent that the main concerns of both TOCs lie in the area of maintenance needs. Both TOCs work in a similar manner, their procedures are similar, and ITS maintenance issues tend to be the same.
- The NJDOT Single Statewide Maintenance Contract: Both TOCs currently use a single ITS maintenance contract for the following:
 - Maintenance on conduits and fiber optic cables
 - CCTV maintenance is done once or twice a year, including the checking of bolts, cleaning the lenses, and trimming the branches.

At the time of interviews, TOC South was administering this contract in rotation with the TOC North. A new replacement contract has been prepared by the TOC North for use in 2004. Two important criteria were considered in the performance evaluation of the contractor: time of repair (easier to assess) and quality of repair (more difficult to assess).

- Job Vacancies: There are 2-3 positions vacant and they should be filled as workloads at both centers demand additional help. This will also favorably impact ITS operational efficiency, a key goal of the NJDOT.
- Lack of an Experienced Operator: TOC South has expressed a need for one additional operator to meet current workloads. Lack of proper level of experienced operators available at the TOC has direct impact on the emergency and incident management. For example, the regional coordination and information dissemination process both will suffer due to lack of operators during major emergency.

- Maintenance Funding: The funding for maintenance mainly comes from Federal funding. Maintenance is considered an operational support item and funding is provided for equipment and spare parts for the TOCs.

- Specific Concerns of TOC North:
 - Integration of system components in the TOC is needed.
 - Fiber optic link to the TOC South is warranted.
 - Disaster recovery station needs to be implemented.
 - MAGIC to Signal Integrations is pending.
 - Technical support is needed to assist in the migration to NTCIP for VMS.
 - Existing job vacancies need to be filled.

- Specific Concerns of TOC South:
 - Funding Maintenance and Need for an Inventory Clerk: The operational support funding is fully provided by Federal funding sources for TOC maintenance and spare parts. However, both TOCs have a strong need for an inventory–procurement position to manage the inventory of spare parts for maintenance activities.
 - Fiber Optic Connectivity Not Complete: Fiber cable installation in the State is not complete and breaks in the fiber cables do occur. The statewide contract covers lateral repairs of the fiber cable. The TOCs prefers to maintain the 300 miles of cable plant in-house, if the resources are made available, largely due to the slow response time of the outside contractors. Fiber optic cable is a major problem that needs to be addressed by the NJDOT. Another serious problem with the outside contractors is the lack of expertise and this requires close monitoring of their performance using quality control techniques.
 - Multiple Traffic Signal Software Systems Present Problems: There are several traffic signal software systems running at the same time mainly resulting from the low bid method of procurements. The TOC South has

installed a single workstation interface to access all of the individual systems. All NJDOT ITS systems are not fully integrated. Providing operational support for software integration and maintenance has become a priority that needs to be addressed.

- Disaster Recovery Center: At present, there is no provision for a disaster recovery center for TOC operations. A disaster operation center facility is should be away from the current locations and should have ITS operational capabilities, in the event the services are lost at the TOCs. After the experiences of the local and regional TOCs's role in managing the 9/11 emergency events in the New York and Washington areas, state and local agencies are considering a disaster recovery facility. In such consideration by the NJDOT, the NJDOT's IT division or NJ State Police facilities offer a good option to locate TOC operation.

ITS MAINTENANCE AND SUPPORT PRACTICES OF OTHER STATES' TOCs

Typical Functions Performed By TOCs

TOCs have become a focal point for traffic operations and coordinating transportation services. In recent years, monitoring, surveillance and command and control functions are closely integrated for operational efficiency. In general, TOC functions occur in three key areas: central system operations, field system operations and communication links for data transmission. Each of these areas requires dedicated operational support to ensure full functionality and availability of systems to manage traffic operations.

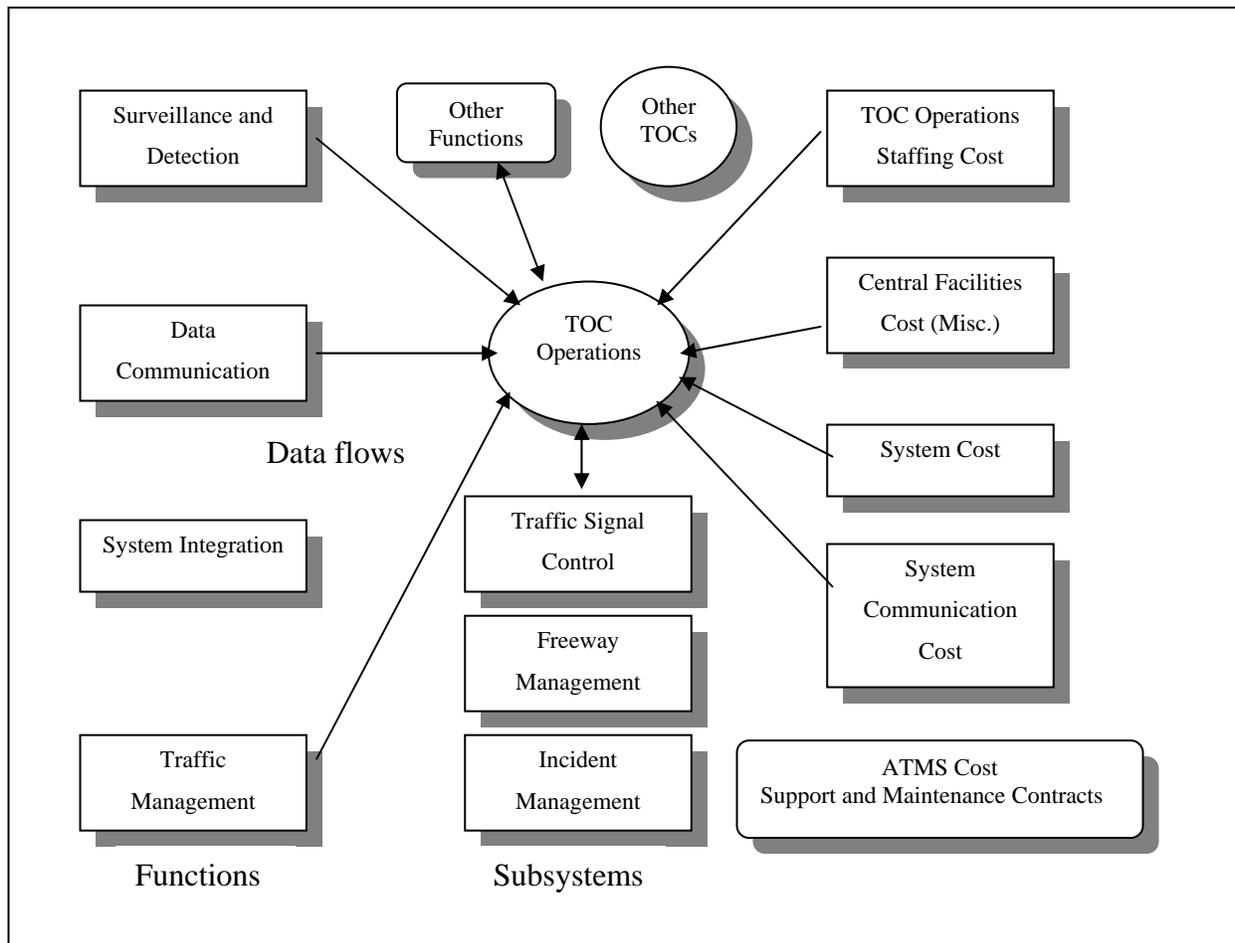


Figure 3. Typical Functions Performed by Other States' TOCs.

Figure 3 shows typical TOC functions performed by most state TOCs studied by the research team. ^(4, 7)

Most State TOCs are located in urban areas to cover a region or a district and include highway operation management functions. Local TOCs typically take care of surface streets management functions, including traffic management. Statewide centers such Maryland's CHART provide coordination services with various TOCs on a statewide basis or for multiple states as TRANSCOM does in New York/New Jersey/Connecticut areas. New York State has organized their TOC on a region-basis, such as Region-11 for New York City area and Region-10 for the Long Island area.

TOCs systems typically operate in real-time. A TOC's ability to synthesize and communicate information on a real-time basis makes the role of TOCs unique. It is clear that without a TOC, response to an incident would be severely delayed due to the time needed to acquire, interpretation, and dissemination of the information to the various personnel. However, with the deployment of advanced ITS field and central hardware equipment, skilled TOC personnel are able to centrally acquire this information, synthesize and transmit it back to the end-users. Coordination of these activities by a TOC for quicker response to incidents reduces the impact of recurrent and non-recurrent traffic congestion. The NJDOT is among the states and local agencies who have invested significant efforts to manage incidents on their highways and streets.

Critical Maintenance Issues Expressed by Other States' TOCs

Based on the literature review and the information reports obtained from the other states, the following critical issues facing ITS maintenance are stated:

- Inadequate staffing levels and/or conflicting priorities
- Ambiguous responsibilities

- Inadequate training and necessary skills
- Poor logging and tracking systems, inventory of equipment, model numbers and serial numbers of parts.
- Non-standardized devices, resulting into incompatible parts, sizes, connectors etc. (Non-standardized devices are not plug-replaceable and cannot be interchanged.)

Operation staff at TOCs are supportive of the need for a comprehensive ITS maintenance plan that would serve as a foundation for addressing all issues and develop a process for maintaining new technology once it is implemented, raise awareness of staffing, training, maintenance, and standardization needs, and clearly define organizational responsibilities.⁽⁶⁾ These issues are also identified by the NJDOT TOCs personnel in some form and will need additional considerations as more and more ITS devices are added in New Jersey.

Elements of Maintenance Practices of Other States' TOCs

Based on the information gathered from the previously reported survey of other states' TOCs questionnaire results⁽⁵⁾ (15 responded, out of 25 TOCs contacted, 13 TOCs were visited, for detailed refer to Reference 5, Table 1, and page 3) and the follow up discussions with the other state TOCs, ITS operations and maintenance practice elements can be stated as:

- Central Systems (computers, video walls, web-sites, etc.).
- Field equipment and devices (CCTV cameras, VMS signs, HAR, etc.).
- Communications mediums and hardware (fiber optic cable, wireless, etc.).
- System Administration (software).
- Staff Training (operator workstation skills, database, log-ins, etc.).

A lack of equipment and dedicated operational support were the two most often stated reasons why TOCs suffer from operational efficiency. Many TOCs are also expanding geographical coverage of ITS devices and additional functionalities, thus requiring more operator interface and training in complex systems operation. This project has recommended that the NJDOT carefully consider the above elements to strengthen current operations and maintenance practices.

Maintenance Approach: No One Model Fits All Needs

Progress towards maintenance support is slow and needs further improvements. TOCs acknowledge that lack of dedicated funding and staffing to operate and maintain ITS systems for peak efficiency is the single most important issue bothering them. Some suggested that they follow reactive maintenance, “putting out fires” rather than proactive or preventive maintenance. During bad times, agencies often reduce operating budgets, which in turn affects the ITS maintenance. Under such circumstances no one approach to maintenance can be depended upon.

For example, critical emergency repairs are rapidly done by in-house employees to eliminate safety hazards, liability, and to alleviate congestion in the region. A combination of in-house staff and outside contracts for providing maintenance support is a preferred compromise that was expressed by some as a good tradeoff between the various approaches (no one approach delivers needed services in a desired service timeframe).^(5, 6)

Clearly, when response time is critical (e.g., loss of an entire interconnect cable from a TOC to a hub in the field), agency forces can be mobilized quickly, as compared to an outside contractor. On the other hand, large number of ITS devices spread over a region can be maintained by contractors in a cost-effective manner.

For example, Los Angeles' and New York City's centers routinely deploy agency staff to make critical emergency repairs (field forces are redirected instantly to a problem site), while outside contractors are used for making a maintenance call on field equipment within two hours. Many agencies use in-house staff to make small fiber optic cable repairs (Los Angeles and NJDOT), while large-size and prolonged work is performed by specialize fiber optics contractors. These contractors are required to have trained personnel and a high-reaching bucket truck. ⁽⁵⁾

While in some mature centers in the country have achieved ITS operational stability, most centers are still in flux due to inadequate funding for staffing and maintenance. (During our study, several policy makers had suggested that a lack of dedicated Federal funding for maintenance have contributed to this problem.) Complicating the maintenance practices at most TOCs is the downsizing and early retirement incentives offered resulting in lost services of their most experienced operators, operation and maintenance staff.

Operation and Maintenance Practices of Other States' TOCs

The other states' TOC survey conducted by this project revealed the following four methods used in developing TOC operations and maintenance support ⁽⁵⁾:

- Using TOC staff (includes agency staff, other divisions).
- Establishing a system manager or a system integrator or a system operator.
- Contracting with an outside general or electrical contractor who provides preventive, emergency or response maintenance.
- Combining the above three methods, partly by in-house staff, partly by outside contractor. (This may result in several small contracts).

The current practices of the other states' TOCs are presented in Tables 4-6 below ⁽⁵⁾:

- Table 4 shows central and field hardware maintenance preferences of the TOCs.
- Table 5 shows the TOC software maintenance preferences (includes configuration management, system administration, version control logging, server management, operating systems, applications programming interfaces, HELP DESK, software upgrading, vendor selection, problem identifications, and system documentation).
- Table 6 shows the fiber optic cable maintenance practices of the other states' TOCs.

Table 4. Central and Field System Maintenance by Other States' TOCs.

#	TOC	Maintenance by In-house	Maintenance by Others	Maintenance by Contract
1	Anaheim, CA TMC	X		X
2	Los Angeles, CA DOT?	X		X
3	CALTRANS D-11	X	X	X
4	CALTRAN D-12	X		
5	Dallas, TX DOT DALTrans	X		
6	Hampton Roads, VA STC, VDOT	X		X
7	Houston, TX TranStar		X	X
8	Maryland Statewide CHART	X		
9	Detroit, MI ITS Center	X	X	X
10	Minneapolis, MN DOT	X		X
11	Nova STC, VDOT	X		
12	NYC DOT			X
13	NYS DOT Region 1		X	X
14	Santa Anna, CA			X
15	Seattle, WS DOT			X
16	TRANSCOM			X
17	Utah DOT	X		X

Table 5. System Software Maintenance by Other States' TOCs.

#	TOC	Maintenance by In-house	Maintenance by Others	Maintenance by Contract
1	Anaheim, CA TMC			X
2	Los Angeles, CA DOT	X		X
3	CALTRANS D-11	X		
4	CALTRAN D-12			X
5	Dallas, TX DOT DAITrans	X		
6	Hampton Roads, VA STC, VDOT	X		X
7	Houston, TX TranStar			X
8	Maryland Statewide CHART	X		
9	Detroit, MI ITS Center	X		X
10	Minneapolis, MN DOT	X		X
11	Nova STC, VDOT			X
12	NYC DOT	X		X
13	NYS DOT Region 1	X		
14	Santa Anna, CA			X
15	Seattle, WS DOT	X		
16	TRANSCOM			X
17	Utah DOT	X		

A recent TOC trend has emerged in the area of system operations. A full-time system software engineer is now a requirement at most TOCs. For example, the City of Los Angeles has an in-house software team to take care of the City's traffic signals, and receives support from three IT department staff members for software maintenance. The entire staff reports to the TOC manager. As more ITS devices and software complexities are being added to ITS in New Jersey, the issue of system administration to take care of the software management become a critical one and needs to be addressed. This project recommends a dedicated position of system administrator at TOC to support such growing needs.

Fiber Optic Cable Maintenance

A typical a fiber optic cable maintenance includes the interconnect cable, conduit and installation, splicing, power, cabinets, and the ability to call maintenance in a specified time (usually 2 hours).

Most TOCs indicated that the fiber installation training and proper test equipment are necessary to ensure proper installation. Several TOCs stated that while it is feasible to do large-scale in-house fiber maintenance, the lack of experienced and trained personnel prevented them from committing to in-house maintenance on a long-term basis.

Generally, smaller repairs are performed by in-house support staff, while bigger jobs (particularly installing and repairing a longer stretch of cable) are outsourced to a qualified contractor. Table 6 reflects the current trend and a practice of fiber optic cable maintenance by the TOCs.

Table 6. Fiber Optic Cable Maintenance by Other States' TOCs.

#	TOC Location	Maintenance by In-house	Maintenance by Others	Maintenance by Contract
1	Anaheim, CA TMC	X		X
2	Los Angeles, CA DOT	X		X
3	CALTRANS D-11 Location	X	X	
4	CALTRAN D-12 Location		n/a	
5	Dallas, TX DOT, DalTrans	X		
6	Hampton Roads, VA STC, VDOT	X		X
7	Houston, TXTranStar		X	X
8	Maryland Statewide CHART		n/a	
9	Detroit, MI ITS Center	X		
10	Minneapolis, MN DOT	X		
11	Nova STC, VDOT Location		n/a	
12	NYC DOT			X
13	NYS DOT Region 1 Location		n/a	
14	Santa Anna, CA			X
15	Seattle, WS DOT		n/a	
16	TRANSCOM Location		None	X
17	Utah DOT Location	X		X
18	Colorado TMC	X		X

ITS OPERATIONAL SUPPORT CONTRACTS IMPLEMENTATION PLAN

What is an ITS Implementation Plan?

For the purpose of this study, an ITS implantation plan is defined as a document that outlines a series of system operations and maintenance (operational support) actions required for peak operational efficiency of the ITS system (as intended by the design) and the reduction of equipment down-time.

The implementation plan addresses questions such as: *What should I do to operate and maintain my ITS systems? How should I do it? What resources do I need? What options or steps should I take?* The implementation plan is based on a master plan or ITS strategic plan which typically contains the agency's vision, theory of ITS deployments, and the ITS operation strategy (9-5 or 24/7 or other time periods) from a TOC. The implementation plan clarifies key operational issues and presents a requirements analysis and a timeframe in which they should be resolved. The TOC in turn receives operational and maintenance support as specified in the implementation plan. The agency uses the implementation plan as a guide to allocate and plan resources including staffing, funding, and other resources from their agency or outside sources.

Why Does NJDOT Need an Implementation Plan?

The NJDOT, like many other states' DOTs, is faced with the growth in transportation demands and congestion on highways. States can no longer afford both, from a fiscal and environmental standpoint, to widen or add new highway capacity to ease congestion problems. To help mitigate these issues, the NJDOT is depending on modern ITS systems and operational strategies to manage transportation capacity and demand. This approach to capacity management requires a stable operation and

maintenance support program to achieve peak efficiency of the ITS systems. A well thought out Implementation Plan fulfills that need.

This section provides background on the key elements of the “*ITS Operational Support Implementation Plan*”. A separate section covers the specific recommendations for the Research Project Selection and Implementation Panel (RPSIP) for further considerations.

Criteria for Development of an Implementation Plan

In developing recommendations, the study considered the following questions posed by the NJDOT:

- How does one maintain (support) the Intelligent Transportation Systems?
- What operational support contracts are needed?
- What functions should be done by consultants, by subcontractors, by vendors, by manufacturers, etc.? What are the issues for in-house versus outside maintenance? How are other states' TOCs handling these issues?
- What contract terms, conditions, etc. should apply for ITS system repair and maintenance functions that are performed by contractors? ⁽²⁾

At present, the NJDOT has instituted several steps to address ITS operational support needs in the annual statewide service contract. However, maintenance support plans need further review due to the impact of the expanding role of ITS operation and concerns for the improvements in operational efficiency. The NJDOT desires that the ITS operational support contracts address the following requirements:

- Provide for ITS TOCs more technical personnel either through increased staffing and/or the addition of contractors so that the ITS systems will operate at peak efficiency.

- To reduce network, hardware and software down-time in the TOCs by focusing on system administration. ⁽²⁾

This study has reviewed the current TOC practices in the country and the findings are incorporated in the proposed implementation plan for the NJDOT.

Implementation Plan Elements

The elements of the implementation plan are organized around the following areas:

- Concept of Operations
- System Operations and Maintenance (Operational) Support
- TOC Staffing and ITS Training
- Contracting Types (Methods)

These elements are outlined below in detail.

Concept of Operations

A TOC is a highly visible element in a transportation strategy, and is generating successful results from the investment in this public infrastructure. Most TOCs in the country have found that, once they are operational, public and agency expectations for their functional performance build rapidly. More and more services are demanded and geographical expansion of ITS in the region places an additional burden on TOCs. Coordination functions The FHWA Final Rule /FTA Final Policy (Rule 940) ⁽⁷⁾ also require use of regional ITS architecture and standards for all federally funded ITS projects in 2005. In addition, the *Systems Engineering Process (SEP)* ⁽⁶⁾ is also recommended as a preferred method for developing ITS projects. *Systems Engineering* is a structured technique for thinking about system development and

begins with the concept of operations. A concept of operations summarizes what the system is supposed to accomplish and under what conditions it will be done. ⁽⁸⁾ From this first step, all other steps take shape: the set of functional requirements, system design, implementation, integration, operation and maintenance support needs. ^(4, 6, 7)

A comprehensive concept of the operations plan articulates the agency’s vision, goals, and objectives, identify high-level roles and responsibilities, and the practices and procedures to be followed by the TOC in daily operation. It also covers how the TOC coordinates and communicates with other entities in the region for best results. This guiding document allows the agency to proceed further in developing ITS projects and allocating funding. Some of the ITS initiatives typically addressed in a statewide ITS plan include, ITS architecture, TOC operation, incident management, highway service patrol, traffic control systems, freeway systems, and travel information. The NJDOT TOCs are currently engaged in these functions.

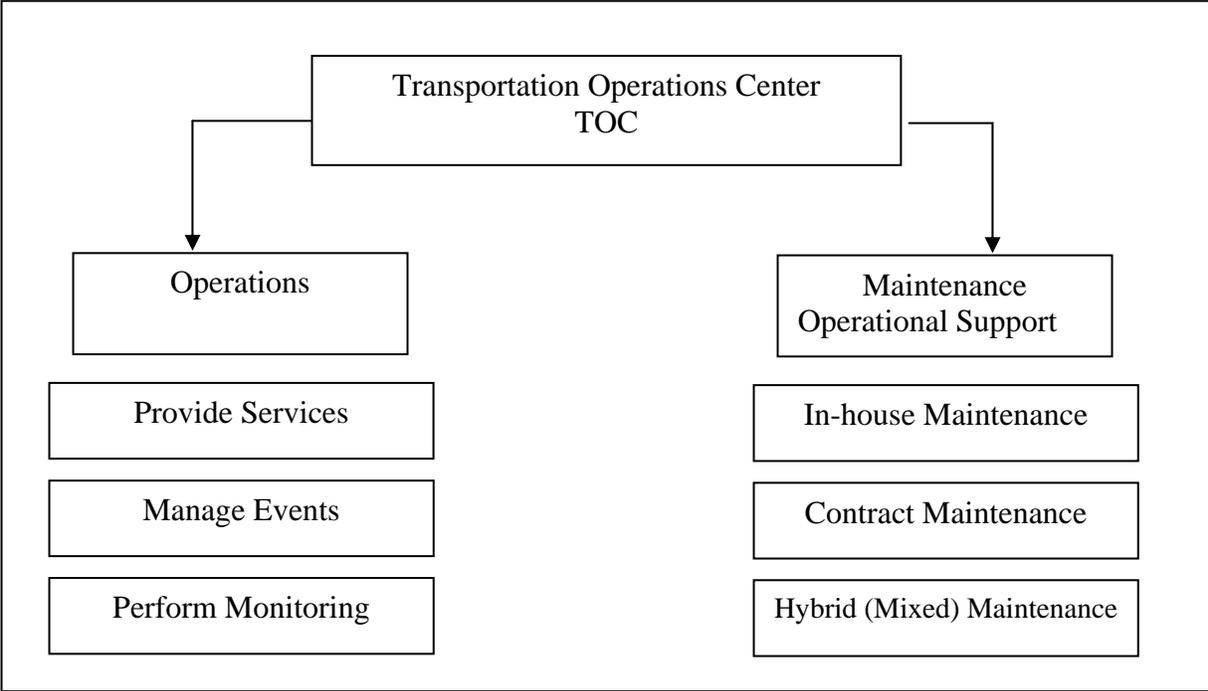


Figure 4. Typical Concept of Operations Diagram of a TOC.

The day to day activities of the TOC functions are typically divided into two tracks: operations and maintenance as shown in the Figure 4. ⁽⁴⁾

A typical TOC staffing and support organization can also be a complex reporting scheme within a DOT, and varies from state to state. In some cases ITS research and development unit, and traffic engineering and ITS design units are managed by a single division, including Toc operations.

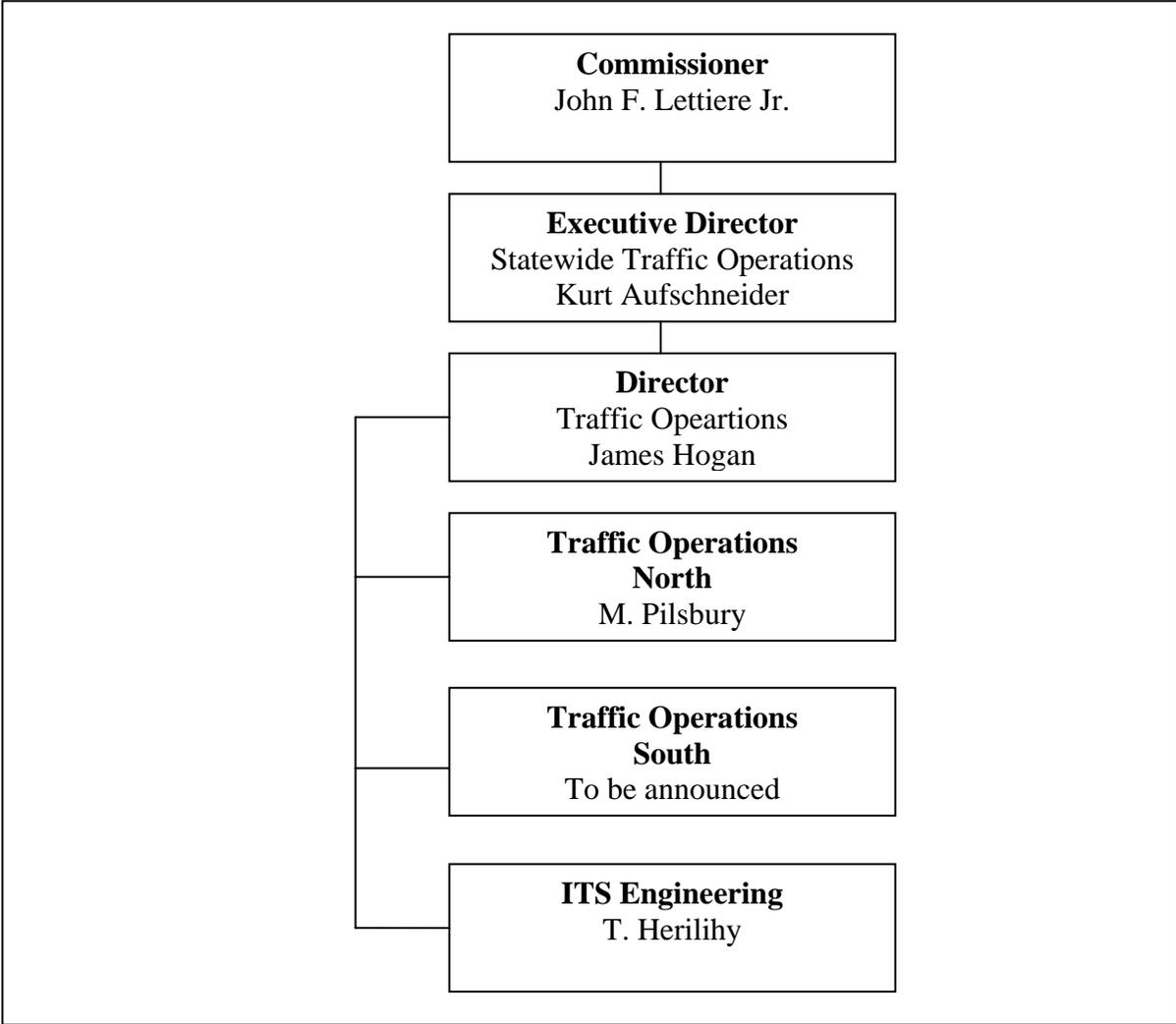


Figure 5. NJDOT Statewide Traffic Operations (October 2004).

As shown in Figure 5, the NJDOT has a Statewide Division of Traffic Operations, which includes the Bureau of Intelligent Transportation systems (ITS) to provide technical

support fro ITS initiatives in planning and scope development. It includes traffic signal systems, incident management systems and traffic management systems, and TOC operations.

The NJDOT ITS Strategic Plan ⁽¹⁾ outlines the NJDOT ITS Program and how NJDOT intends to deploy the technology. It addresses the following ITS operational elements:

- ITS objectives.
- Communications system.
- ITS standards.
- ITS maintenance.
- Incident management.
- Route 29 Tunnel operations.
- Emergency service patrol.
- New Jersey reconstruction projects' elements:
 - Improve internet service.
 - Capital program priorities.
 - Operational priorities - complete fiber optic backbone, co-locate communications dispatch unit with State Police, and establish central call taking center.
 - New ITS deployments.
 - Staffing and vehicles.

Most of these objectives and programs are implemented in varying degrees by the NJDOT to provide ITS functions in the State. The TOCs are providing daily support and traffic management services to the agency. ⁽¹⁾ These functions and services are typically included in the concept of an operations plan, migration strategy, and operations manual, as shown in Table 7.

One of the key operational documents that the TOCs need is an updated version of the *TOC Operations Manual*. The operations manual typically covers daily TOC operations and maintenance procedures, coordination and communications requirements, and contacts within the agency and outside of the agency. This is the main document that operators and traffic engineers refer to during the course of daily TOC operations. The Institute of Transportation Engineers (ITE) has developed an annotated outline of a TOC operations manual developed based on the national consensus serves as a checklist for the current recommended practice requirements.

This project strongly recommends that the NJDOT incorporate pertinent elements and consult other reference materials ^(5, 9, and 10) for the development of the NJDOT TOC Operation Manual.

Table 7. Concept of Operations Elements.

#	Elements/Issues to be Addressed	How/Where is it Addressed?
1	Concept of Operation (Policy)	NJDOT ITS Strategic Plan, May 2003
2	Migration Strategy (A path to near-term and long-term implementation)	ITS deployments, TOC operations, ESP, 24/7 IMRT are implemented
3	TOC Operation Manual (Procedures)	Under preparation by a joint effort between NJDOT staff and consultant, NJDOT should consult Reference8.
4	Basic Operations/Maintenance Needs	Baseline requirements are currently implemented in a maintenance contract supported by federal funding.

System Operations and Maintenance (Operational) Support

Maintenance or operational support involves all processes that keep the system performing satisfactorily, including upgrades of equipment and software from earlier versions to enhance the system's performance as its volume grows. It is also important that TOC staff keeps monitoring the ITS system's performance against its original performance requirements. This is particularly important as demand on the system increases. In this section, the study outlines the issues that typically impact the NJDOT TOC operation and maintenance of ITS central and field devices, and communications. Specific staffing issues are discussed separately.

What is Operations?

Key components of a modern TOC include the staffing, operator interface-workstations, documentation, standard operating procedures (SOP), configuration management (CM), internal and external coordination, keeping records, dealing with public calls and inquiries from others, and hours of TOC operation. Traffic management, incident management and emergency management are key services that are supported by operations. Modern TOC ITS operations are not necessarily conducted from one location and not all TOCs operate on 24/7 basis.

In short, a TOC operation is carried out by control and command functions of an ITS system, by providing information to the agency and public, and by coordinating with other affected parties in the region. All of these functions and performances of a TOC are heavily dependent on the operational support provided to it by the agency and outside resources.

Thus, the provision for the operational support is an important requirement for a TOC's success, without which full benefits of ITS deployments will not be realized. This fact has been recognized by the NJDOT and the study's sponsor, the FHWA.

What is Maintenance (Operational) Support?

Maintenance support or operational support is essential to keeping an ITS system running in the manner in which it was designed. A lack of maintenance leads to all sorts of problems; eventually resulting in partial or complete failure of the system (a failure can be defined as the inability of a system or system component to perform a required function within specified limits) and its withdrawal from the agency's toolbox for alleviating congestion. Investments made in the ITS system installation, public acceptance of ITS services, and the level of continuing services suffer greatly if proper upkeep of ITS devices is not practiced.

According to the *Transportation Systems Management & Operations: Operating Cost Eligibility Under the Federal-Aid Highway Program*⁽¹¹⁾ (see also Appendix, page 108 of this report), virtually any ITS system activity can draw support from the Federal funding, except for routine maintenance (such as painting a traffic signal cabinet or exterior of the TOC building) that are not critical to the successful operation of the system. There are successful case studies in which local and state agencies are drawing operational support from federal sources. The New York City Traffic Management Center located in Queens, and New York State Region-10 TOC on Long Island have successfully tapped federal funding for TOC operational support, including staffing, equipment, central systems support, TOC facility support, and field devices maintenance.⁽¹²⁾ A recommended practice for funding advanced traffic management systems (ATMS) in Texas and New York has been widely adopted.⁽¹³⁾

This project considers all ITS maintenance items as ***operational support***, including staffing, spare parts, and contract management (issues faced by the NJDOT TOCs) and strongly recommends that the NJDOT consider operational support model adopted by other local and state agencies.

Maintenance needs for ITS devices are diverse. Because the range of potential maintenance actions is so broad, a wide variety of expertise and skills are required. In recent years, many agencies have begun to develop a “maintenance concept” to ensure proper functioning of ITS systems. A good maintenance plan, for example, will describe the maintenance needs, how it is performed, and how it can be implemented and budgeted. ⁽⁶⁾

Most maintenance activities performed by the NJDOT (regardless of how they are performed) can be grouped into these categories: preventive, corrective or responsive, and emergency maintenance. The definitions are stated below. ⁽⁴⁾

Preventive Maintenance

Preventive maintenance consists of scheduled operations or actions performed to keep the systems and components operating. Preventive maintenance includes mundane operations such as cleaning CCTV camera lenses and housing faces, group replacements of traffic signals lamps, and VMS sign face cleaning. For example, Georgia DOT hired a contractor to perform preventive maintenance every six months for VMS that includes changing bulbs and optical filters and reporting likely problem areas. This trend is consistent with the Georgia DOT’s objective of keeping the public informed through variable message signs (VMS) signs, which are fully functional and available to TOC when needed.

In most cases, preventive maintenance is performed by an outside contractor on an annual basis or a shorter frequency from 13 weeks to 26 weeks depending upon the criticality of the equipment to daily operation. Materials for the preventive maintenance may be supplied by the contractor or by the sponsoring agency, in which case the provisions are made for the contractor to pick up the parts from the maintenance yard storage facility of the agency. (The current NJDOT maintenance contract directs the contractor to pick up and return unused materials to Cherry Hill or Elmwood Park TOC facilities). ⁽³⁾

Preventive maintenance is acknowledged as critical to successful ITS, due to a shortage of resources, preventive maintenance tasks are often performed concurrently with repair maintenance tasks. ^(4, 14)

Cost of Preventive Maintenance per ITS Device

Frequency, severity, complexity of equipment, travel time, and the maintenance of traffic impact the cost of preventive maintenance varies from state to state. Typically, a maintenance supervisor sets priorities for repairs based on the device's relative necessity to daily operation and the history of previous failures. Most preventive maintenance is performed while the technicians are already at the location for other reasons. ITS preventive maintenance costs per device (originally reported in 1999 dollars are adjusted here in 2004 dollars) are based on data from the Virginia Department of Transportation and is stated in Table 8. ⁽¹⁴⁾

Table 8. Cost of Preventive Maintenance per ITS Device.

#	Device	Costs per device
1	Traffic signals	\$3,511
2	CCTV	\$1,514
3	VMS	\$2,057
4	Portable VMS	\$3,652
5	Detector station	\$1,650
6	HAR	\$900
7	Weather station	\$198

The above cost compares with Arizona DOT per-device cost: VMS \$2,000, CCTV \$2,000, ramp meter \$3,500, vehicle detector \$500 and RWIS \$4,500. ⁽¹⁵⁾

Table 9 shows a frequency of preventive maintenance performed by the Washington State DOT on various ITS elements. The current annual maintenance costs of the Washington State's 100 miles of fiber optic cable-based Surveillance, Control and Driver Information System is \$1,380,000, which includes parts, labor, and equipment. Annual operations costs are \$2,626,584, which includes power, phone, maintenance, personnel, and vehicles. These costs are for a system with a capital cost of \$66,000,000, which includes field devices, central software (\$5.6M), fiber optics cable (100 miles at \$35M), computer hardware, and communications. ⁽¹⁶⁾

Table 9. Preferred Frequency of Preventive Maintenance of ITS Elements.

#	Device	Frequency
1	Cabinets and Components	Annually
2	Communication Housings 26 weeks	26 weeks
3	Grounding	Annually
4	Poles/Mountings	26 weeks
5	Coaxial cables and connectors, amplifiers, power supplies, pilot generators	26 weeks
6	Video monitors	13 weeks
7	Data modems	13 weeks
8	CCTV Subsystem: Cameras, housing, PTZ, Receivers, Junction box	26 weeks
9	170 Traffic controllers, loop detectors, load switches, signal heads	13 weeks
10	Variable Message Signs, sign housing, modems, controllers, pixels, modules, drivers	26 weeks
11	Highway Advisory Radio, Signs-beacons, Transmitters, Receivers, Encoder/decoder	13 weeks
	HAR Antenna and Mount, Relay panel	26 weeks

Note: The above frequency will be needed for a matured or fully developed ITS program. However, for a newly initiated ITS program, a ramp-up in activities will be needed for transitioning from non-existent preventative program to a strong proactive preventive maintenance program. This project recommends that NJDOT consider this issue further.

Corrective (Responsive) Maintenance

Corrective or responsive maintenance refers to operations that are initiated by a fault or trouble report and responded to within set time with a priority. The report can come from a person (citizens, field highway TOC staff, police patrol, etc.) or generated by the system software installed in the TOC (based on the device's remote diagnostic capability, software triggers an alarm). In recent years, citizens' cellular calls have also reported devices malfunctioning to a central number such as 311 in the New York City. (NJDOT is considering a central call receiving center).⁽¹⁾ Most faults fall into the responsive maintenance category. Most of these calls are responded to within a few hours (real-time safety functions such as traffic signal repairs are responded to within two hours). There are some exceptions such as a cable break, which may take over 12 hours. If spare parts are not available, repairs may take days to complete and may even create safety hazards and can result in liability and/or damages.

Responsive maintenance has five distinct steps to be completed within a set time:

- Receive notification
- Secure the site
- Diagnose the problem
- Perform repairs
- Log the activity

Responsive maintenance often requires a two-step process; field maintenance procedures to restore operations, shop procedures for repair, and tests for malfunctioning equipment. Technicians on-site often swap the parts and restore service to hasten the repairs. This appears to be a common practice in the ITS area as most equipment repairs are often done by either original equipment manufacturer (OEM), which is located somewhere else, or by a contractor who is often required to provide repairs within a geographic area. Both conditions affect repair time.^(6, 14)

ITS devices are often complex, are difficult to repair on the spot, may require qualified personnel to make repairs and calibrate the equipment to function as originally intended. These are the resources found in a repair shop. A significant ITS maintenance concern that is reported in the literature is a lack of trained personnel available from both in-house and outside contractors, which results in a poor state of ITS devices in the field. These concerns should be addressed by in-house and/or contract responsive maintenance.

ITS devices are deployed over a wide area in the State. To support these devices, the NJDOT TOCs have traditionally relied on a statewide annual maintenance contract. In order to improve the response time and the operational efficiency, the study has developed a new approach as part of the recommendations covered later in this report for the NJDOT consideration beginning year in the 2005 service contract.

Emergency Management

Emergency management is similar to responsive maintenance in that it is initiated by a fault or trouble report. However, in this case, the fault is more serious and requires immediate action for repair. Events such as knockdowns, spills, exposed power supplies, live wires, a pole lying on the pavement, are some of the examples that trigger emergency response. Highway agencies generally respond effectively to such emergencies and use both in-house resources and contractor services to speed up the response and removal of hazards. Such situations are widely reported in the media as they affect the mobility and the safety of travelers. The media frequently issues reports to motorists on emergency repairs to stay away from these areas. The TOCs provide updated information on such repairs to the media.

Components of an ITS Maintenance Plan

Proper functioning of ITS devices deployed over a wide geographic area requires a close watch by the TOC operations and the maintenance staff. In practice, however, maintenance is typically done through various units of the agency. It is therefore important to develop a plan that not only addresses TOC operations, but also outlines the other units in the agency that are either performing maintenance or managing outside contractors to carry out maintenance. For example, traffic controllers are considered electrical equipment and are routinely maintained by the electrical unit of the NJDOT, but the more complex, programmable electronic field master is the responsibility of the TOC technical staff. Such practices are common throughout the country. ⁽⁶⁾

An agency trying to develop a good maintenance plan should consider the following core elements: ⁽⁶⁾

ITS Elements Covered Under Maintenance

The ITS maintenance plan should specifically identify the ITS elements and devices with number of units to be serviced. These components are typically classified according to the functions they provide as shown below:

Central Systems Hardware/Software

- Central computer hardware (servers, work stations, firmware).
- Central Computer Operating System Software (Windows XP).
- Central Computer Application software (e.g. MIST, Closed-loop).
- Video wall monitors for CCTV displays.
- HAR Recoding Studio/Booth.
- Central Communications (modems, servers, cable terminators, protocols).
- Media connections for live access by TV and radio stations.

- TOC Websites to provide real-time travel information, video images, and construction details to guide travelers in the areas.
- Incident Management System (e.g. NJDOT IMRT).
- TOC Facility Management (power, battery backup, and air conditioning).

Field ITS Elements

- Closed Circuit Television (CCTV) Cameras.
- Variable Message Signs (VMS).
- Traffic Controllers (freeway ramp and streets intersections)
- Vehicle Detectors (inductive loops, RTMS microwave radar, video).
- Highway advisory Radios (HAR).

Communications

- Fiber optic cable interconnects.
- Coaxial-cables and telephone lines.
- Field pull-boxes and electrical power.
- Spread-spectrum links.
- T-1 circuits.

The maintenance plan for the equipment discussed above should include an automatic reporting of device failures either by an alarm or through a logged online report. During off-hours, maintenance personnel may periodically monitor equipment malfunctions or TOC equipment operations. In some cases, the system hardware and software provides self-monitoring capability and automatically notifies an on-call operator or supervisor when an unexpected event arises. Another option for a TOC is to transfer late night and weekend operations to a regional 24/7 TOC. ⁽¹²⁾ Table 10 shows the operations and maintenance support elements necessary for the successful operation of the ITS systems.

Table 10. Operation and Maintenance Support Elements.

#	Elements/Issues to be Addressed	How/Where is it Addressed? Page # in this Report
1	What is Operational/Maintenance Support?	Defined in this report on page 6
2*	In-house Maintenance - TOC staff	Defined in this report on page
3	In-house Maintenance Electrical Div.	Defined by statewide contract, Ref. 3
4*	Contract Maintenance	NJDOT statewide contract
5*	On-Call Technical Support Contract	NJDOT consultant services
6	Hybrid Maintenance	NJDOT/Contracts
7*	Preventive Maintenance	Contract maintenance in this report
8	Response Maintenance	Contract maintenance in this report
9	Emergency Maintenance	In-house maintenance in this report
10*	Central System Hardware Maintenance	Contract maintenance in this report
11*	Central System Software Maintenance	Contract maintenance in this report
12*	Video-wall Monitors	Contract maintenance in this report
13	Special Equipment Maintenance	In-house support
14	TOC Website for Travel Information	In-house support
15*	Central Communications Maintenance	Contract maintenance in this report
16*	Fiber Optic Cable Maintenance	In-house/statewide contract
17	Communications Alternatives	Information gathering
18*	ITS Field Elements Maintenance: VMS HAR, Cameras, ESS, Traffic controllers	CCTV by contract; rest by in-house staff
19*	Spare Parts Procurement/Warranty Management	New position recommended
20*	ITS Devices Standardization Policy	This study recommends a policy
21*	High-reach Bucket Truck for In-house Operational Support	This study recommends purchasing one high-reach Bucket Truck
22	99.67% ITS System Availability – should be considered. How well is TOC performing?	Requires redundant power supplies, network, spare-parts, disaster recovery, system administrator, etc.

(* These elements are addressed by the recommendations made in this report)

Sample Maintenance Cost Data per Device

The literature review of ITS systems installed in throughout the country indicates that the annual maintenance costs vary from state to state and depend on equipment, labor, travel time, spare parts, and plant size. However, there is no one suitable computational method or empirical formula available that can be used to make judgments on how much it will cost to maintain an ITS device. Table 11 provides sample costs data for four successful ITS systems operating in the various parts of the country. Both the number of miles under ITS operation, and the scope or size of devices indicates the range of ITS functions and statewide nature of expansion. ⁽⁶⁾

Table 11 Sample Annual Maintenance Costs.

#	Location ITS System,	Annual Maintenance Costs, \$	# of Miles	# of Devices	Cost per Device
1	ODOT, ARTIMIS	1,000,000	88	1,200	\$833
2	VDOT, Nova	2,800,000	150	2,743	\$1,020
3	Orlando	150,000 (preventive)	39	223	\$672
4	Caltrans	2,640,000	N/A	2212	\$1,193

The NJDOT is currently in the process of adding more ITS devices geographically under its reconstruction projects. The current annual maintenance costs for the field devices are shown in Table 12. ⁽³⁾ (Computation for cost per device is not available at this time).

Table 12. Annual Maintenance Costs of the NJDOT ITS (Partial). ⁽³⁾

#	Location ITS System,	Annual Maintenance Costs, \$	# of Miles	# of Devices	Cost per Device
1	NJDOT-Statewide	620,541	88	N/A	N/A

Note: This cost includes fiber optic cable, rental truck, traffic control, and other traditional maintenance on traffic hardware. Cost does not include system software, central hardware and central equipment maintenance costs as well as personnel costs.

Annual Maintenance Costs by Device Type

ITS device type has several characteristics: complexity of operation, range of functions, its relative importance in operation, need for maintenance or swapping with a new unit, and level of maintenance costs. For example, a loop detector will cost much less than a weather station. As ITS systems and functions are expanded, TOC operational support cost also rise. For example, different closed loop traffic control systems, computer operating systems, and VMS from multiple vendors will drive the cost of maintenance up according to the above factors. At present, there is no single method or a database that can be accessed to compute average cost per device. Figure 6 shows average costs derived from reports compiled in literature.⁽⁶⁾ The maintenance cost associated with a VMS varies significantly based on technology and roadside location. Estimated maintenance cost reported in the literature range from \$2000 to 3200 per sign (1999 dollars).^(6, 14)

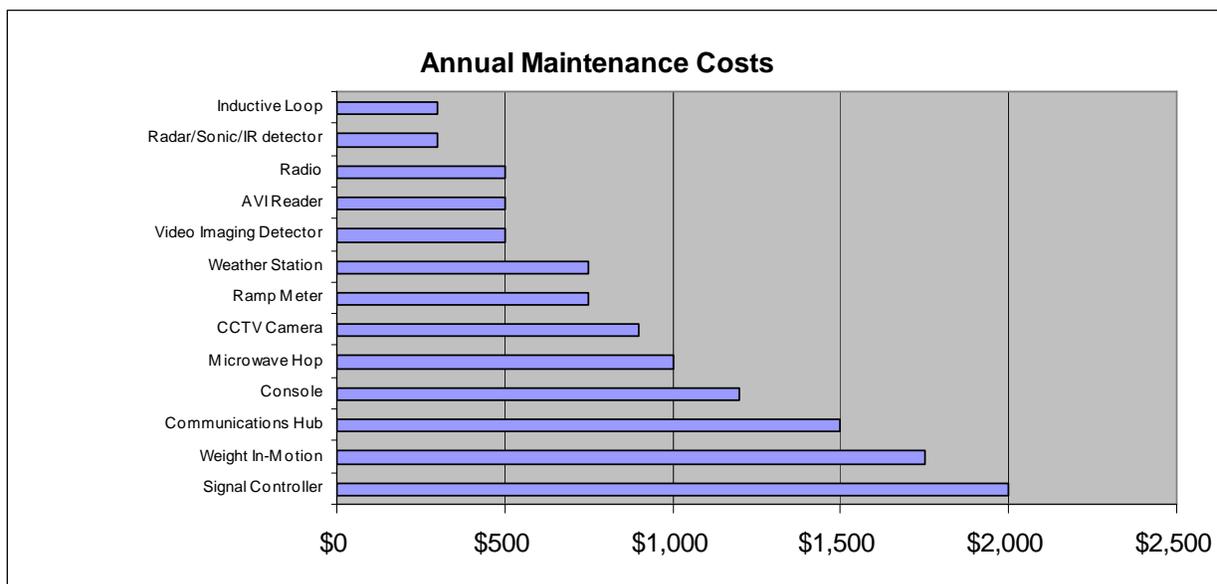


Figure 6. Annual Maintenance Costs by Type of Device.⁽⁶⁾

TOC Staffing and ITS Training

The following factors affect the level of TOC staffing requirements:

- 24/7 operation.
- Regional operation.
- Size and complexity of the ITS system.
- Co-location with State Police, EMS, and Media.
- Support from other agency personnel: IT department, electrical unit, ITS design.
- Operation support contracts.
- Maintenance support contracts.
- TOC staff training availability.
- Agency versus Outsourcing.
- TOC budget.

There are several vacancies at both TOCs, which should be filled in order to continue supporting current workloads. This project only considered new positions necessary to improve the daily operations at both TOCs. The current trend in the country is to operate TOCs on a 24/7 basis and it is likely that the NJDOT may follow the trend (The NJDOT TOC South is operating on a 24/7 basis at this time) and consolidate other transportation functions to increase benefit from ITS investments. Concerned with the transportation security and protection of critical infrastructure under Homeland Security initiatives, many states DOTs are turning to TOC operations for monitoring and surveillance and vehicle tracking activities. Increased coordination requirements during emergencies among region's agencies are also placing emphasis on TOC operation schedules.

The following types of personnel are typically deployed at a TOC to operate ITS systems: ⁽¹³⁾

- TOC manager/director.
- Supervisors (for operations, engineering, maintenance, etc.).

- Workstation operators and analysts.
- Transportation and electrical engineers.
- Electronic/maintenance technicians.
- Communications specialists/operators.
- System administrators (for computer hardware/software).
- System engineers.
- Software developers/programmers.
- Inspectors (for field equipment).
- HAR broadcasters.
- Radio dispatchers.
- Administrative staff.
- Public relations and media relations personnel.
- Trainees/interns.

Table 13. Staffing, Training and Documentation Issues.

#	Elements/Issues	Recommendation
1	Purchasing Assistant Title (New)	Create one new position
2	System Administrator Title (New)	Create two new positions
3	Configuration Management	Develop a plan and implement in 2005
4	Logging and Documentation Library	Develop a plan and implement in 2005
5	Measures of Performance	Develop a plan and implement in 2006
6	Training for TOC/Maintenance Staff	Develop a training schedule for 2005: <ul style="list-style-type: none"> ○ Operator standard operation procedures training ○ System engineers training ○ ITS deployment training ○ Maintenance practices
7	Annual TOC User Workshop with Peers	A peer to peer TOC workshop to learn from each other on annual basis
8	Future TOC Research	As a follow up to this project, develop an ITS implantation strategy for NJDOT

Table 13 contains a list of staffing, training, and documentation issues that should be addressed by the NJDOT. In planning for a good operational and maintenance support program, the NJDOT will rely on the following:

- Steady allocations of funding for the support program should be identified (including federal sources). The ballpark estimates of 4-5 percent of the capital ITS costs are reported in the literature for the annual maintenance support. However, variations in size of ITS functionality, local weather, geography, and staffing factors should be considered on a case-by-case basis in resources allocations. ^(4, 15)
- Extended warranties for specialized equipment.
- Spare parts inventory and procurement process with a dedicated purchasing assistant (ITS system availability depends on ready availability of key parts).
- Each device should maintain a list of recommended spare parts by vendor.
- An organized training program for technicians, system engineers, and TOC operators.
- Develop configuration management tool and implement it.
- Seek additional support from the system consultants who are already on the current ITS jobs. Learn from their experiences and steps.

Regardless of the contracting method used, (by in-house staff or by a contractor) sufficient quantities of key parts should be available for maintenance. Some agencies routinely keep on-hand 5-10 percent of the original quantity as spare parts. ⁽¹⁷⁾ Such an approach will result in time-saving and reduces the downtime of expensive ITS devices. Vendor-specific equipment (one of a kind) also increases delays and specialized parts have to be ordered in advance. It is not known how many spare parts are on-hand at NJDOT for ITS devices. This project recommends the creation of a new position (Purchasing Assistant) to manage parts, warranties, and equipment purchases for ITS operation at each TOC. The concept is to have a dedicated staff to handle largely in-house maintenance and also coordinate materials handling with the

outside contractors. This situation is better understood as more and more ITS activities are carried out in the State.

Anecdotal evidence has suggested that the ability to get spare parts quickly is one of the most common reasons to rely on contract maintenance, reflecting on the governmental procedures that might tend to delay the reestablishment of ITS operations. The issue is even more serious when sole source is involved.

Configuration Management

ITS system operations are becoming complex and constantly undergoing expansion, revisions, replacements, and modifications. Under such conditions, system engineers face significant challenges in keeping accurate documentation that is consistent with the physical design that are also available, if needed, for disaster recovery.

Configuration Management (CM) describes a series of processes and procedures developed in the information technology community to establish and maintain system integrity. For example, replacing a failed ITS device with an updated model should be documented and approved through a CM process. Georgia DOT has two staff positions to handle CM for its large statewide ITS operations and software. ^(18, 19)

There are two fundamental purposes of CM – to establish system integrity and to maintain system integrity. A system with integrity is one in which:

- All components are well defined and documented
- A working baseline is always available to implement and provide transportation management services
- Integration with other regional systems can be readily accomplished
- A high degree of traceability exists, allowing one to easily identify how system functions are provided

CM provides a holistic approach for effectively controlling system change and creates a baseline. It helps to verify that changes to subsystems are considered in terms of the entire system, minimizing adverse effects. Changes to the system are proposed, evaluated, and implemented using a standardized, systematic approach that ensures consistency. All proposed changes are evaluated in terms of their anticipated impact on the entire system. CM also verifies that changes are carried out as prescribed and that documentation of items and systems reflects their true configuration. A complete CM Program includes provisions for the storing, tracking, and updating of all system information on a component subsystem, with a system basis. ^(18, 19)

Contracting Types (Methods)

Although many public organizations often begin with a self-help in-house maintenance activity, alternatives to in-house maintenance are considered as more and more complex devices and systems are brought online and integrated into a larger central system.

The range of factors that influence the selection of an appropriate method of maintenance includes:

- The size of the ITS deployments.
- TOC (local or statewide).
- System Complexity.
- Geographic coverage.
- Operation Schedule: 24/7 operation.
- Funding availability.
- Knowledge, Skill and Abilities (KSAs) of staff, a training factor.
- Technology base and expertise of staff, training and staffing factor.
- Organizational difficulties and delays in contracting and procuring services from qualified contactors and consultants.
- Ability to store parts and vehicles/equipment.

Key Maintenance Issues

The following key maintenance issues facing other state TOCs were reported during the course of this study:

- TOCs' experiences have shown that the DOTs usually **lack the necessary and required technical skills and expertise** to maintain complex and heavily computer-based ITS systems. ITS require expertise in areas such as communications, computer and information technology, and applications. The information technology division (IT) has a computer knowledge base and systems skill set, but they are not exposed to the NJDOT ITS applications may have different mission and priority. This issue of drawing support from IT divisions is not recommended by this project as it is clear that ITS require its own resources and priority in daily operations. Most state TOC, for this reason, has adopted a dedicated staff for TOC operations support.
- TOC ITS **software maintenance** requires the unique software skills of a developer or an experienced integrator. Washington State's TOC and Los Angeles DOT each have their own software staffs who work with outside software experts. Software maintenance includes operating systems (Windows, UNIX, Linux, etc.), Commercial Off-the-Shelf (COTS) packages (Word, EXCEL, DBMS, etc.), and Applications Software (MIST, 170, etc.). Several TOCs, Detroit, Michigan, INFORM, Long Island, New York State Region-11, Connecticut, hire outside system operators (often a third party) who are responsible for day-to-day TOC operations and software maintenance.

The NJDOT has not evaluated the need for an outside contractor to operate the system, but it does have a series of contracts to support systems software.

However, it does not have an in-house software staff presently assigned to perform software maintenance in the TOCs. To smooth the operation at both TOCs, this study recommends instituting a configuration management protocol and hiring two systems administrators, one for each TOC operations support. This project has developed a job specification for the position of system administrator in appendix.

- DOTs are always lacking sufficient **staff and the funding** needed for the TOCs. Early retirement or head-count reductions (resulting in vacancies, the NJDOT's TOCs are no exception) and frequent budget shortages result in a poorly managed in-house maintenance program. Many agencies prefer to initiate contract maintenance for complex items, while undertaking small emergency repairs in-house.
- DOTs have continuing problems in **recruiting and retaining personnel** who possess the skills necessary to operate and maintain the sophisticated hardware associated with computer-based traffic systems. Proper maintenance of these systems can require salary schedules higher than the typical maintenance or electrician rates, which DOTs are unable to pay. Accordingly, some agencies have determined that the best alternative is to use outside contractors. These contractors can also be hired to supplement regular staff and to stock specialized spare parts during emergencies.
- TOCs often **lack test equipment and maintenance vehicles** needed for performing diagnostics, testing, and repairs. For example, agencies often use contractors with a high reach bucket truck to do repairs on CCTV cameras, and for large fiber optic cable repairs.
- **Fiber optic communication system maintenance** is a necessity and a critical link to proper functioning of all ITS field devices as it carries data, voice, video to

TOCs and to control devices. This project has found that some local and state DOTs have some form of preventive maintenance and small repair program for the fiber cable (which requires special equipment and trained technicians to perform splicing), they largely outsource large-scale work to experienced outside contractors. (Los angeles DOT, NYCDOT and NJDOT are among the agencies that typically rely on outside contractor for fiber maintenance support).

Contracting Options Available to DOT

In the event that a DOT determines that some component of their TOC maintenance is better suited for contracting, there are a variety of procurement options to choose from. However, some of these options are constrained by local procurement rules. ⁽⁶⁾

- **Engineer/Contractor:** An engineer develops the plans and detailed specifications for ITS elements. Contractors are selected by low-bid only. For ITS field elements, this option allows the hiring of a general or electrical contractor who is usually familiar with local areas and organization set up. However, electronics-based systems should not be included in the general contract. The NJDOT should ensure that sufficient contractual terms and management resources are used to adequately monitor and enforce the process. (The NJDOT currently uses this method for ITS field devices).
- **System Manager/Integrator:** Plans, specifications, and system software are developed by an engineer. Selection of the equipment and installation contractor is by low-bid. The engineer provides system integration and can take on the maintenance of software and the control centers. (A system integrator is often allowed to procure hardware and services, usually by low-bid, on behalf of the agency.)
- **Best-Value Contracting:** Used where the contractor is to provide some technical designs or configurations. The selection of a contractor is based on a combined technical score and price.

- **Design-Build (DB):** Performance specifications are open for bid by teams of engineers and contractors. Selection is usually based on combined technical and price factors.
- **Design-Build-Operate-Maintain (DBOM):** The same as Design-Build, but with a requirement that the contractor operates and maintains the system for a period of time.
- **Franchise or Lease:** Also known as Design-Build-Own-Transfer. The contractor provides initial financing, engineering, and construction in exchange for a lease payment over a period of time. Eventually the equipment and activities are transferred to the agency.

Key Factors Affecting Maintenance Decisions

There are six primary factors that influence the decision on the maintenance approach:

(7)

1. In-house capability is generally required for mission-critical business, such as safety and security.
2. Contractors would be required if significant technical ability is not available within DOT.
3. Known training deficiency at the agency.
4. Outside contractors support may not be available in rural areas, and DOT may have to institute in-house program for outline areas.
5. Contractors are appropriate for non-standardized equipment.
6. Level of staffing available for maintenance.

In-house Maintenance versus Contract Maintenance

This project has found that throughout the country TOC maintenance is performed under the following options:

- Using in-house staff
- Contract maintenance
- A hybrid of part in-house and part contract maintenance

The current approach at the NJDOT is to rely on the hybrid method. The NJDOT also uses resources from within the agency to maintain its traffic signals, field masters, other traffic devices.

This study has found that a large-scale TOC operation such as NYCDOT, LADOT, and Detroit TOC retain many support functions within TOC for a quicker response, mandatory emergency response and for better coordination among internal divisions. A broader literature review (not part of the survey or visits to sites) also indicated that the practices are mixed: for example, Ohio DOT has a turnkey (outside contractor) approach to maintenance that includes all system maintenance, while NYSDOT in Albany handles all system maintenance internally. The following summarizes the pros and cons of both in-house and contract maintenance. ⁽⁶⁾

- **In-house maintenance:** Using in-house maintenance makes TOC staff more self-reliant and removes the dependencies on contractor businesses often found to be unstable or inconvenient to reach. It provides a career path for employees, control is retained in-house, and it creates a sense of ownership in ITS for the state. The DOT or public agency often owns the transportation and communication infrastructure and will have a somewhat easier task in coordinating with other agencies, such as police and other contractors. This

study has found that DOT employees often express job satisfaction in dealing with emerging and new technologies and the challenges they present.

ITS field devices are composed of many different technologies and are tedious to fix, which makes their maintenance more suitable for outside contractors that can be more responsive. As new devices are added or a new technology is implemented the TOC staff needs training and agency training programs may not be able to meet the current needs. Training is often the first items that get cut in a budget crunch.

In the communications area, in-house staff resources often have to work without modern diagnostic and testing equipment, and test equipment can be expensive and rarely budgeted. The use of in-house teams will avoid invoicing and administrative processing, along with the possibility of reducing legal problems that may arise with the use of an outside contractor.

- **Contract maintenance:** A contractor has access to people who are knowledgeable, skilled, and experienced to perform desired functions without constraints. Contractor's personnel are better equipped and ready to work after-hours and responsive to completing a job. They are also better trained and specialized in handling special equipment, techniques and diagnostics. Many contractors, who are general or electrical contractors, now have the acquired basic skills in working with. Contracting method is better suited for ITS devices installed over a large area. For example, maintenance of a fiber cable plant that provides coverage over a long distance is better suited for outside contractor. Other examples include maintenance of VMS spread out over a very large area.

If contracting option is chosen by an agency to maintain complex ITS devices, there will be only minimum need to train agency staff on a continuous basis and keeping large inventory of spare parts.

There are several apparent disadvantages that must be considered in considering outside contractor:

- Agencies' often detect higher costs of hiring an outside contractor. However, a TOC should perform a cost analysis to compare all costs on both sides, including fringe and overhead (public agencies also have overheads and fringe costs for government services, but often not considered in cost analysis).
- Contractors tend to do their own thing and sometime deviate from agency norms and DOTs may lose some control on their activities or repair completion.
- Contractors often demand a public storage space and are reluctant to purchase large quantity of spares parts and instead demand that the agency purchase parts and supply to the contractor.
- Public agency is required to accept low bidder as a hired contractor who may not be familiar with the region and may not be as efficient as others.
- It has been observed by many TOC managers that outside contractors tend to assume higher risks in supporting the central systems and communications medium, and try to cover their risks by adding undue costs.
- TOC managers fear the legal liability for the agency arising from the neglect, accidents and late responses on part of the contractor.
- Agency incurs administration costs for coordination and contract management, supervision, payments processing, and payment disputes with outside contractors.

If an agency decides to contract for maintenance, it should make sure that the terms and conditions amply reflect control and risk analysis. Well defined and verifiable performance measures should be developed and inserted in the contract prior to an award.

Example: Colorado Transportation Management Center (CTMC) ⁽²⁰⁾

The Colorado Transportation Management Center maintenance division is responsible for deployment, maintenance, and development of Intelligent Transportation System field devices. The current staff includes one electronic engineer working as crew supervisor, one electronic specialist I, one electronic specialist II and one electronic specialist intern. Additional support is provided by two contract maintenance staff members.

The primary function of the Colorado Transportation Management Center (CTMC) maintenance crew is the upkeep of ITS field equipment that is controlled by the Colorado Traffic Management Center. This equipment includes variable message signs, highway advisory radio transmitters, CCTV cameras and video switchers, roadside emergency call boxes, wireless communication devices, highway traffic sensors, and fiber optic cable equipment. Additional equipment is continually being added to their inventory as the ITS infrastructure grows. Although the majority of ITS devices are located north and west of Denver, equipment locations maintained by the CTMC range from Vail on I-70 to as far south as Pueblo, Wolf Creek Pass in the southwest, and north to the Wyoming border. The number of devices maintained by the CTMC is now in excess of 100.

The CTMC maintenance department is charged with deployment of field devices. Everything from installation of highway advisory radio equipment to closed circuit television cameras are handled by the CTMC crew. The CTMC has a fleet of 10 portable variable message signs (VMS boards) at its disposal. Used for road information and in support of law enforcement check points, these signs are deployed by the maintenance crew within a 100 mile radius of Denver. The CTMC maintenance fleet also includes a bucket truck with an 80 ft. reach and a dedicated “network support” vehicle used to diagnose problems with the Department of Transportation’s (CDOT)

fiber optic network. CDOT follows many other states DOTs in this approach to fiber maintenance. (This is similar to the current NJDOT issues).

The CTMC maintenance department designs and fabricates new electronic systems that are used to assist the motoring public. These systems frequently make use of both fiber optic and wireless communication devices. For example, they are currently working on the development of remote controlled “trailblazer” signs that make use of wireless technology. These signs are used to direct traffic flow when detours are required because of various road conditions on our highways. ⁽²⁰⁾

CDOT also issues task orders to outside subcontractors to supplement their own efforts for preventive, as well as, reactionary (responsive) maintenance for ITS equipment and subsystems. The maintenance task orders have been a positive and successful experience for both CDOT and the system integrator. A complete inventory of all ITS devices deployed on all Colorado highways has been completed, and the ITS maintenance unit focuses on keeping an accurate database of repairs and replacement data in order to determine mean time between failures (MTBF). This information will allow CDOT to formulate a preventive maintenance schedule based on level of service.

Fiber Optic Cable Maintenance

The literature review and findings from the site visits to TOCs suggest that many TOCs prefer hybrid maintenance (partly in-house maintenance and partly by contract maintenance). This approach mainly affects fiber optic cable maintenance.

There are variations to this scenario as in the case of the Ohio DOT’s turnkey system maintenance contract and Albany’s (New York) system maintenance using solely in-house staff. ⁽⁶⁾ The New York City DOT provides in-house maintenance for complex ITS communications cable and video system maintenance for the borough of Manhattan ATMS, while three electrical contractors maintain the traffic controllers. The

City's TOC central system equipment is supported by a series of technical equipment contracts. This approach has kept the ITS system's effectiveness at near perfect levels of readiness and at peak operational efficiency.

The City of Los Angeles has a crew of six technicians and four supervising electricians assigned to maintenance service for CCTV and small fiber optic jobs, while an outside contractor is responsible for providing communications network maintenance (presumably faster than the City's response). Across the country, opinions vary on the use of in-house maintenance for fiber optic cables. Some TOCs feel that although it is feasible to do in-house fiber maintenance, lack of experienced personnel and training needs on specialized equipment prevented them from doing so. In recent years, the fiber optic cable installation and splicing techniques have matured and training and other resources are widely available from outside service providers (vendors) and contractors at competitive prices.

Equipment for ITS Operational Support

The literature review suggests that state TOCs are very uncomfortable with going into in-house maintenance program without having the right equipment and trained technicians to diagnose and repair communications problems, and repair malfunctioned equipment.

For example, it is virtually impossible to troubleshoot a fiber optic communications system without specialized (and often expensive) equipment, such as an optical time-domain reflectometer (OTDR). An OTDR injects a short, intense laser pulse into the optical fiber and measures the backscatter and reflection of light as a function of time. The reflected light characteristics are analyzed to determine the location of any fiber optic breaks or splice losses. (OTDR prices range from a little over US\$5000 for a basic/low-end unit to more than US\$20 000 for a high-performance unit, depending on specifications).

Sample maintenance contracts from Michigan DOT, LADOT, NYCDOT, and Washington State DOT are very specific in the types of equipment that the contractor should have in order to complete their work. Examples of the types of specialty equipment needed by maintenance contractors for a freeway management system include the following: ⁽⁶⁾

- Bucket Truck for repairing cameras, overhead VMS, pole-mounted detectors and communication equipment.
- Timed Domain Reflectometer (for either optical or copper conductor, as necessary) for testing attenuation in communications cable. Light-source and power meter, also for testing fiber optic cable.
- Multi-meters for various electrical tests of power supplies, grounding etc.
- Protocol analyzers and “exercisers” for testing the communications protocols and standards (i.e., RS-232, RS-422, and NTCIP, or proprietary protocols).
- Ethernet “sniffers” for bandwidth analysis, network configuration and troubleshooting.
- Utility location detectors for finding the markers associated with buried utilities and other infrastructure.
- Video signal analyzers for testing and tuning video signal parameters.

Estimating Number of Technicians Required to Support ITS Devices

There is no empirical formula available to estimate staffing needs. There are three basic approaches that can be taken to arrive at the staffing needs for ITS maintenance.

1. ***Annual Hours Available Calculations:*** Basic calculations based on per year hours available, travel time, and estimated repair times per device. This simple process allows for multitasking the agency’s needs for general staffing titles. ⁽¹¹⁾

2. **Predictive Method:** Compile agency time series data on mean time to repair (MTTR) and mean time before failure (MTBF) for each device and compute probability tables and time required for service. ⁽⁶⁾
3. **ODOT Multi-regions Model:** Use Oregon DOT model to compute Device-by-Device resources estimates based on inventory, components, annual number of visits and hours per visits per staffing class and travel time. Staffing needs are than computed for each staffing class. However, this is very cumbersome process and applies to multi-regions analysis. ⁽¹¹⁾

Calculations for Annual Hours Available

The calculation for maintenance staffing levels are based on the field experiences, information gathered in the literature review ⁽⁶⁾, and interviews of TOC staff ⁽⁵⁾ (Alternatively, a more scientific approach can be used if agency specific device data are compiled to calculate Mean Time To Repair (MTTR) and Mean Time Before Failure (MTBF):

Estimated Annual Work Hours per Person

- The available work hours per year: 52 weeks x 8 hours = 2080 hours per year.
- Vacation: 3 week x 40 hrs = 120 hrs.
- Sick leave: 2 weeks x40 hrs= 80 hrs.
- Annual Training: 1 week x 40 hrs= 40 hrs.
- Legal holidays: 13 days x 8 hrs= 104 hrs.
- Break: 1 hr x 217 days = 217 hrs.
- Net production time: 2080 -120-80-40-104-217 = 1519 hrs (190 days) per year.
- Technician travel time, round trip, 2 hrs per day (suggested by NJDOT), 1 hr for set up and maintenance of traffic details totals 3 hrs per day are used up without doing any repair activity: 190 days x 3 hrs = 570 hrs for response time.
- Time available to complete actual repair: 1519 production hrs – 570 response time = 949 hrs per year per technician.

Assuming a trained technician can repair a VMS and other associated work on location in some cases for 4 hrs, CCTV in 4 hrs, 4 hrs for traffic controller, and an average repair time can be set around 4 hrs per device, including logging, event reporting, etc. This means that one technician can ideally repair, $949/4 = 237$ devices per year. In practical terms discounted by 30 percent, only 166 devices can be serviced, if one assumes that time saving (days when the technician is at the TOC) will be used by the TOC to support other central functions. (This number is not computed scientifically, however, it is anecdotally supported by knowledgeable individuals in the field.).

Sample Staffing Estimates of Field ITS Maintenance

The types and number of devices that are included is site specific but using the following parameters a staffing estimate can be made. ⁽⁶⁾ Table 14 presents a sample estimate for staffing needs for ITS elements.

- **Field Device:** ITS equipment and components out in the field
- **Device Count:** Total count of devices
- **Preventive Maintenance Schedule:** Total vendor-recommended periodic maintenance trips during the service period (typically at 6 or 12-month intervals)
- **Labor Hours per Person:** Labor effort needed to perform the recommended maintenance procedures.
- **Number of Persons per Crew:** Assess adequacy of the number of personnel and crews to perform the preventive maintenance procedures safely and efficiently.
- **Travel Time One-Way:** Average distance to be traveled one-way to the maintenance location.
- **Labor Hours + Travel Time (Round-Trip)** is the total time in hours for the crew size and travel times.
- **Total Hours for Labor/Travel and Devices** is the total time needed to perform the preventive maintenance for each ITS field device type.

- **Average Number of Responsive Maintenance Visits per Year:** This average comes from other ITS Agency's maintenance reports and vendor information given for their devices.

Table 14. Sample Estimate for Staffing Needs. ⁽⁶⁾

Preventive Maintenance (Hours)							
Field Device	Schedule Months	Device Count	Labor Hours per Person	Crew Size	Travel Time	Labor Hours + Travel Time	Total Labor Hours
Variable Message Sign,	6	25	2.0	3	3.0	15.0	750
Highway Advisory Radio	12	5	2.0	2	2.0	10.0	50
Weather/Pavement Sensor	12	10	2.0	2	3.0	10.0	100
Camera- CCTV	6	40	2.0	3	2.0	12.0	480
Non-intrusive Count Stations Video/ Radar	12	60	2.0	2	2.0	8.0	480
Permanent Count Stations –Connected to controller	12	1	1.0	2	2.0	6.0	6
Permanent Count Stations- not Connected	12	20	1.0	2	2.0	6.0	120
Video Detection at Signals	12	20	2.0	2	2.0	8.0	160
Total Hours = 2146							

Responsive Maintenance (Hours)				
Field Device and Preventive Maintenance Schedule (Crew size =2)	Labor Hours per Person	Labor Hours + Travel Time	Average Number of Visits per Year (1/3 of devices)	Total Labor Hours
Variable Message Sign	4.0	14.0	8.3	116
Highway Advisory Radio	2.0	8.0	1.7	13
Weather/Pavement Sensor	2.0	10.0	3.3	33
Camera- CCTV	2.0	8.0	13.2	106
Non-intrusive Count Stations Video/ Radar,	2.0	8.0	19.8	158
Permanent Count Stations – Connected to controller	2.0	8.0	0.3	3
Permanent Count Stations- not Connected	2.0	8.0	6.6	53
Video Detection at Signals	2.0	8.0	6.6	53
Total Hours =534				

ITS Devices Suitable for Contract Maintenance

The literature review suggests that many states have opted for outside contract maintenance for the following devices. The reasons often mentioned are longer travel distances, wide geographic areas, non-real-time or non-critical functions, and limitations on in-house staff and specialized personnel.

- CCTV.
- VMS (DMS).
- HAR/Callboxes.
- Ramp Meters.
- Microwave Detectors.
- Loop Detectors.
- Traffic signals.
- ETTM.
- RWIS (ESS- Environmental Sensor Stations).
- E-ZPass roadside readers.

CONCLUSIONS

The project began with a quick scan of the literature on TOC operations and maintenance support. Based on the initial findings, the RPSIP directed the project to move forward with operational support contract requirements. Working closely with the project management team and the TOC managers (research customers), the project focused on the issues faced by the NJDOT and investigated practices of the other states' TOC, collecting significant information during the course of the study. Based on the information gathered from other states' TOCs and findings from the literature review, and TOC practices in the country, a total of 22 recommendations are developed to achieve peak efficiency of the ITS systems in the State. Tables 15-17 contain 22 recommendations for the NJDOT consideration.

The major conclusion of this project is that the ITS deployment in the State is still evolving and by providing additional operational support at this juncture in the life-cycle process will significantly improve operational efficiency and return on ITS investment. Equipped with proper skills and support mechanism the technical response teams will be in a much better position to ensure proper functioning of ITS systems and field devices, and management of ITS contracts. Such actions will generate a wider ITS knowledge-base and allow NJDOT to develop integrated statewide ITS applications. Such capability will also enhance regional coordination and information exchange. This conclusion is based on the successes of the other states' TOCs operational capabilities (Maryland State Highway Administration, for example) for statewide ITS deployments.

The project concludes that the NJDOT should seek higher level of Federal funding for operational support needs and develop a long-term secured source to improve system management at both TOCs. The operational support, additional positions and improved maintenance practice (including preventive maintenance) together will result in an efficient management of a spare parts inventory, better integrated software systems and efficient network management that can support interconnected TOCs and statewide ITS operations. The climate to implement these steps is ripe at the NJDOT.

RECOMMENDATIONS

Based on the extensive work done by this project, the following tables present 16 recommendations in three separate categories:

- Table 15: Policy Recommendations.
- Table 16: Staffing Recommendations.
- Table 17: Operational Support Recommendations.

Each recommendation has a suggested time frame for implementation by the NJDOT and provides an impact statement and areas of influence. These recommendations address the resources needed to achieve peak operational efficiency and a reduction in equipment down-time. The issues facing the NJDOT TOCs were also carefully studied and addressed by the recommendations. The literature review, surveys sent to other states' TOCs, actual visits, and the information reports obtained from these sources formed the basis for the implementation plan and specific recommendations. The guidance provided by the RPSIP and TOC staff provided additional focus on the key issues facing New Jersey.

Policy Recommendations

The recommendations shown in Table 15 present an opportunity for the NJDOT to develop a unified approach to creating and enforcing a statewide ITS deployment policy. If implemented in the short term (1-2 years) while ITS deployments are still evolving in the State and the region, the project team feels that the substantial benefits will result from the enhanced regional interoperability, uniformity in implementation and efficiency improvements. These recommendations will also enhance coordination with other transportation agencies within the State, including toll authorities. The study suggests that the overall policy objectives of delivering transportation services that

meet safety, security, and mobility needs should be tied to the ITS deployments and TOC's operational efficiency performance criteria.

Table 15. Policy Recommendations.

Time Frame*	Policy Recommendations	Areas of Impact
Short Term	1. Develop a NJDOT TOC Concept Of Operations Plan , which includes ITS Strategic Plan elements and migration strategy in alignment with funding priorities.	ITS Policy, deployments, and creates a path to next steps. A unified ITS direction for New Jersey.
Short Term	2. Develop NJDOT TOC Operations Manual based on the recommended practices by ITE's current standard as per Reference 9.	Lessons Learned from other states' TOCs and the effectiveness of current procedures will help NJDOT to refine its own TOC operations.
Long Term	3. Develop and Integrate into a Statewide Policy on Fiber Optics/Wireless Technologies for ITS deployments.	Will result into a statewide integrated communication network for ITS.

* The project defines timeframes as: Short Term- 1 to 2 years, Medium Term- 2 to 5 years, Long Term-over 5 years.

There is a need for an *Operational Manual* specific to each TOC, but with uniform procedures, for day-to-day TOC operations. This manual should be based on the current state of the art practices of other states' TOCs and lessons learned from their operational experiences. This project strongly recommends that this step be taken as soon as possible.

As stated in Table 15, a statewide policy for fiber optic and wireless technologies is needed for the NJDOT to address two critical aspects of ITS network integration: It will provide necessary bandwidth and full connectivity (without gaps in cable links or the geographic region) necessary to support ITS devices, and allow different communications technologies to work together without interference from each other. Several state DOTs (CDOT)⁽²⁰⁾ has a policy on a wireless communications shared

resource agreement with a local provider) have formed public/private partnership arrangements to meet such ITS needs and the project recommends that NJDOT explore that possibility further with assistance from the local FHWA resources. The City of New York has issued an Request for Proposals (RFP) ⁽²¹⁾ from private ventures to implement a citywide wireless network using city-owned operating band frequency of 4.9 GH for fire and police departments, traffic signals control system, public safety and emergency management applications. If successful, such arrangements with private sector will allow ready access to latest technologies to public agencies.

Staffing Recommendations

Table 16. Staffing Recommendations.

Time Frame	Staffing Recommendations	Areas of Impact
Short Term	1. Hire a <i>System Administrator</i> for each TOCs system support and administration.	TOC operational efficiency, ITS systems.
Short Term	2. Hire <i>ITS Purchasing Assistants</i> to support system parts and equipment purchases, and management of warranties at each TOC.	Will improve system operation due to better handling of spare parts.
Short Term	3. Hire <i>Network Systems Technicians</i> to support In-house maintenance of the expanding fiber optic communications, and system networks at each TOC. Example of job specifications is provided for recommended positions.	Will improve communications and help lower system down-time, an objective of this study.

* The project defines timeframes as: Short Term- 1 to 2 years, Medium Term- 2 to 5 years, Long Term-over 5 years.

The staffing recommendations stated in Table 16, if implemented, will close the current gaps in ITS operational support by adding qualified staff. Operational efficiency will be greatly enhanced with a focus on network administration, system performance, spare parts and equipment availability, and reduction in down-time. These positions are commonly provided to the TOCs and overall ITS operations are better coordinated with

support from system staff and technicians who ensure network performance. With these staffing recommendations, the NJDOT will also create an in-house knowledge-base that covers a range of ITS devices and functions comparable with the achievements of many TOCs in the country.

This project strongly recommends an inventory of ITS components and a spare parts management system under a dedicated Purchasing Assistant to facilitate materials handling. ITS, by definition, is made whole by the sum of its parts, and procuring parts, repairs, management of warranties, etc. is a necessity that can not be mixed with other activities or generalized and allowed to deteriorate.

Operational Support Recommendations

The recommendations presented in Table 17 are based on the severity of the current issues faced by the NJDOT TOCs. Each recommendation supports the stated objectives of the NJDOT to keep the ITS systems functioning at peak efficiency. These recommendations are derived from an assessment of the current ITS maintenance and support practices of the TOCs located in other states and interviews with various TOC managers across the country. A detailed technical memorandum submitted to the NJDOT previously contained key findings from these efforts.

Many TOCs in the country have now entered into their second-generation life cycle and have successfully implemented day-to-day TOC operations in their jurisdictions. The literature review indicates that the TOCs from California, Minnesota, Florida, Washington, New York, and Maryland as well as cities like Los Angeles and New York City have successfully built second-generation systems with a good level of operational support. Many are now receiving federal funding for operational support, which ensures operational stability and efficiency. New York City DOT Traffic management Center receives over \$19 million annually for operational support from the federal

funding, which covers costs for its signal maintenance, staffing and equipment support.
 (11) This project strongly recommends that the NJDOT expand the current approach to provide operational support using federal funds. It is anticipated that the NJDOT will also continue its current practice of providing operational support through federal funding sources.

Table 17. Operational Support Recommendations.

Time Frame	Operational Support Recommendations	Areas of Impact
Short Term	Strengthen In-house Operational Support 1. Research and implement a statewide ITS Maintenance Management System (MMS) for logging and tracking ITS maintenance activities. This step is necessary for both In-house and contract maintenance based on the current and future ITS inventory.	Will result in better control and operational efficiency, and standard practice for the NJDOT. Database Standardization.
Short Term	2. Continue with current in-house fiber optic cable maintenance, but add Network Systems Technician positions to manage TOC network systems needs, statewide interoperability, and communications knowledge-base to TOCs.	Specialized work will ensure communications availability to ITS systems, keeping downtime to minimum. Recent gains in wireless technology will have a major impact.
Short Term	3. Strengthen Statewide ITS Support Contract Modify and rename the current Statewide ITS maintenance contract to include preventive maintenance of ITS devices such as CCTV, VMS, ESS, HAR, and detector stations, and a preventive checklist and performance measures.	System operations will improve because ITS devices will be checked more frequently under a preventive maintenance program.

* The project defines timeframes as: Short Term- 1 to 2 years, Medium Term- 2 to 5 years, Long Term-over 5 years.

Table 17. Operational Support Recommendations (Cont.).

Time Frame	Operational Support Recommendations	Areas of Impact
Short Term	<p>Central System Operational Support</p> <p>4. Modify TOC North central system operational support management under a <i>Network System Technician</i>, and software support and configuration management under a <i>System Administrator</i>. Consider extending the equipment warranties under the <i>Purchasing Assistant</i> position.</p> <p>These steps will ensure that the ITS systems, communications, and spare parts management across all platforms will work as intended.</p> <p>A valuable service focus will result in a long-term knowledge-base at TOCs from which better operations will emerge.</p> <p>TOC North has unique opportunities to integrate FMS functions as initial steps are already in place by MIST platform. The MIST system is based on the system administration concept.</p> <p>These positions work as a cluster and form a core group to support day-to-day TOC operations. This will reduce dependency on outside experts and reduce down-time.</p> <p>5. Modify TOC South Central System Same recommendations as above also apply here. Additionally, the issue of integration is more of a problem in TOC South and should be addressed now as the costs of integration are rising.</p> <p>System administration concept will enhance integration of closed loop systems installed at TOC South.</p>	<p>Peak operation efficiency</p> <p>Reduced downtime</p> <p>Create Knowledge, Skills and abilities (KSAs)</p> <p>Knowledge-base Integrated services</p> <p>Fosters interoperability</p> <p>Software compatibility Easier to upgrade</p> <p>Bandwidth management</p> <p>Better quality of Video images in the TOCs</p> <p>Statewide ITS logging/tracking system will emerge in NJDOT.</p> <p>In addition to the above, a better monitoring and operation control of ITS systems at TOC South will result in supporting traffic signals control and freeway systems elements.</p>

Table 17. Operational Support Recommendations (Cont.).

Time Frame	Operational Support Recommendations	Areas of Impact
Short Term	<p>6. Institute Spare Parts and Equipment Management</p> <p>Develop an inventory spare Parts Management system at both TOCs under a <i>Purchasing Assistant</i> position to secure critical spare parts for in-house maintenance and warrantee care. ITS systems will suffer increased down-time and deficiencies in operation functions.</p> <p>ITS technologies are complex, and swapping a new part for a defective one can be a quick and simple, yet a solution that will keep ITS benefits flowing. TOCs across the country are reporting 10-15 percent spare parts on hand.</p>	<p>Reduce operations costs</p> <p>Better assets management and ITS database will contribute to system efficiency.</p> <p>Inability to replace a defective part-however small- can affect the system reliability and availability.</p>
Medium Time	<p>7. Develop and Implement a Policy on ITS devices standardization</p> <p>Develop and Implement a Policy on ITS devices standardization to make parts interoperable and interchangeable.</p> <p>This will ensure that ITS devices, systems, communications, and spare parts will work as intended in an interoperable manner. This also allows TOCs to replace parts without fear of different vendors' products. System operators will also be better prepared to deal with operation details.</p> <p>Standardization would have the added benefit of reducing the amount of spare parts needed to be kept on-hand to respond to repairs. For example, NTCIP family of standards on VMS, ESS, Traffic controllers, etc. will produce an integrated and interoperable system.</p>	<p>Peak-operation efficiency</p> <p>Fosters interoperability Software compatibility Easier to upgrade</p> <p>Better real-time control on different devices from different vendors.</p> <p>NJDOT should consider this a requirement for all ITS devices.</p> <p>Standardization will contribute to system efficiency and maintenance activities.</p>

Table 17. Operational Support Recommendations (Cont.).

Time Frame	Operational Support Recommendations	Areas of Impact
Short Term	<p>8. Purchase Special Vehicles for In-house Maintenance Purchase a high-reach (80 feet) Bucket Truck and a “network support” Van to enhance current diagnostics and maintenance operations. These vehicles will support emergency repairs and will be critical during major disasters.</p> <p>Successful TOCs, including NYCDOT, Colorado TMC, LADOT all report highly productive use of Bucket Trucks and Network Vans to repair CCTV, VMS, Cable plants, overhead microwave detectors.</p>	<p>Reduced down time, and costs. This investment will add significant capabilities to meet statewide emergencies.</p> <p>A dedicated vehicle can be quickly deployed to facilitate installation of temporary devices during evacuation.</p>
Short Term	<p>9. Procurement of Test Equipment Digital devices used in ITS applications are signal and bandwidth based, which requires the measuring of signal strengths. Fiber optic cable splicing and fusion techniques require calibration, testing and validation. Protocol analyzers are widely used tools.</p> <p>State TOCs, such as those operated by Florida DOT, Virginia DOT, and Michigan DOT are very specific in the types of equipment that the contractor should have in order to complete their work. This applies equally to in-house plans.</p>	<p>Proper tools and equipment make field repairs faster, easier diagnostics, reducing down-time.</p> <p>Digital data, video and voice signals will be transmitted as intended on modern ITS systems.</p>
Short Term	<p>10. Evaluate ITS Maintenance Programs Regularly evaluate the maintenance program using a series of performance measures, including repair response time and device down-times. Provide feedback to ITS planning and design units to improve future designs to meet maintenance needs.</p> <p>System availability, system reliability, MTTR, MTBF, number of failed devices are key parameters that can be used as performance measures. With an expanding ITS, operational complexity will increase.</p>	<p>Provides an answer to, How well we are doing? TOC?</p> <p>Design ITS with operations and maintenance in mind.</p> <p>NJDOT’s objective is to achieve 99.67% availability for ITS operation.</p>

Table 17. Operational Support Recommendations (Cont.).

Time Frame	Operational Support Recommendations	Areas of Impact
Short Term	<p>11. Institute a Configuration Management (CM) CM will make it easier to upgrade, manage software issues, add ITS devices, expand system functions, integration and provide for COTS applications</p>	<p>System integrity Baseline Easier evaluation of new products Subsystems</p>
Medium Term	<p>12. Institute a Logging and Event Tracking System Using a tag or bar code and a hand-held scanner in conjunction with a maintenance management system (MMS) will automate inventory and event tracking, thus reducing or even eliminating much of the paper tracking.</p>	<p>Inventory Paperless Long-term records Sorting capability by device type, frequency, etc.</p>
Medium Term	<p>13. Incorporate National ITS Architecture User Service-Maintenance and Construction Operations (MCO), V5.0. This user service ensures functions to support monitoring, operating, and maintaining, and improving and managing the physical condition of roadways, infrastructure, fleet management, and tracking vehicles. Market package, a specific collection of interfaces and equipment needed to achieve specific user service- is implemented as needed.</p>	<p>If implemented, the NJDOT will meet with Architecture, and Will allow better weather tracking, Winter maintenance, and Work zone management</p>
Short Term	<p>14. Institute Semi-annual Training Sessions for TOC Staff The availability of skilled and trained staff is critical to getting the most out of TOC operations. On-site training sessions should be designed to help create a knowledge-base on current technologies, standard operating procedures, lessons learned, and case studies, emerging ITS standards, architecture, system engineering topics, and incident management. These topics are timely and are part of ITS deployments. .</p>	<p>Incident management System operators, Traffic engineers, Software specialists, Communications specialist, Maintenance staff, TOC managers and supervisors</p>

Table 17. Operational Support Recommendations (Cont.).

Time Frame	Operational Support Recommendations	Areas of Impact
Short Term	<p>15. Convene an Annual TOC Workshop with Peers</p> <p>TOC operations practices are constantly evolving as better integration techniques are used and technologies are refined. Meeting with other peers in the region will create a better technology transfer among concerned professionals and invited experts on subjects. A day-long agenda will produce a focused set of answers on current issues faced by the NJDOT.</p> <p>Professional organizations: Allow out of state travel by TOC staff to attend technical conferences organized by the professional organizations such as AASHTO, ITE, TRB and ITS America to learn from others on ways and means to improve TOC operation and traffic management. Encourage staff to write papers and make presentations.</p>	<p>TOC operations Communications Microwave technology Vehicle tracking Maintenance experiences Vendors' products and demos</p> <p>Knowledge of staff Keep up to date on communications technologies, operating systems, GPS/GIS, AVL, algorithms, signal hardware, VMS and other ITS devices.</p>
Medium Term	<p>16. Continue with Further Research on TOC and Traffic Management Issues</p> <p>Continuity in current research on ITS and TOC operation, system maintenance, recommended practices, and latest operation manuals will allow NJDOT to link policies and programs to ITS deployments and enhance statewide interoperability goals.</p> <p>Suggested topics: Role of TOC in protecting critical infrastructure in the State, updated operations manual, latest adaptive signal controls, wireless communications, traffic detection/counts using video images, and ITS standards. Test-bed for evolving technologies.</p>	<p>Incident management algorithms</p> <p>Adaptive signal timing control techniques</p> <p>Traffic counts using TOC Video images New materials and technology Productivity Current issues Up to date staff skills Future investments Sensor technology</p>

APPENDIX

JOB SPECIFICATIONS FOR RECOMMENDED TITLES

State of New Jersey
Department of Personnel
Job Specification

NETWORK ADMINISTRATOR

DEFINITION

Under direction performs professional work, which includes Intelligent Transportation Systems (ITS) systems/devices, development, implementation, and maintenance of multi-network, multi-user Local Area Networks (LAN), Metropolitan Area Networks (MAN), and/or Wide Area Networks (WAN); maintains centralized, decentralized, and remote network services; maintains network security and data integrity; provides consultations and recommendations to infrastructure managers as required to troubleshoot and resolve network problems, monitor overall performance, and conduct upgrades as required; does other related duties.

ESSENTIAL FUNCTION STATEMENTS

Essential Functions:

1. Supervises the development, implementation, and maintenance of multi-network, multi-user ITS/Transportation environment;
2. Maintains availability of centralized, decentralized, and remote network services including but not limited to file service, printing, local electronic mail, Internet electronic mail, office applications, remote access, Internet web connectivity, and mainframe gateway;
3. Schedules and dispatches resources to track/troubleshoot/correct network related to issues either logged through the help desk and/or recorded through the monitoring of the network;
4. Plans and installs software upgrades for network services, gateways, and associated telecommunication devices;
5. Maintains accurate and up-to-date documentation for network hardware/software;
6. Plans, configures, and troubleshoots networked devices including but not limited to printers, personal computers, facsimiles, modems, plotters, and scanners;

7. Plans, configures, and troubleshoot network client software installations and updates;
8. Provides guidance to infrastructure managers/technicians to troubleshoot and resolve network problems, monitor overall performance, and conduct upgrades as needed;
9. Administers user access to network resources and adds/modifies/deletes user accounts for file/print and dial-in servers;
10. Administers electronic mail gateways, both internal and Internet;
11. Diagnoses and repair or coordinates repair of network hardware;
12. Monitors disk capacity and takes appropriate action to ensure adequate disk space is available to networked users, software applications, and attached devices;
13. Checks and response appropriately to errors logged by the server and/or network devices;
14. Maintains accurate and up-to-date documentation (manual or through an online log file) of all errors of high severity and action taken to correct the error;
15. Develops, tests, implements, and periodically updates a disaster recovery plan for the enterprise;
16. Ensure that daily or weekly and incremental or full backups are performed and verified, and rotates media offsite;
17. Ensure that clients are able to restore files from backup and/or archive;
18. Provides technical support to end-users;
19. Maintains knowledge of network-related emerging technologies and evaluates vendor products for potential use within the agency;
20. Coordinates with OTIS and other government agencies to ensure optimal use of the network topology, WAN, and wiring infrastructure;
21. Leads the capacity planning process to ensure timely and cost effective advancement of the network;
22. Prepares an annual budget for the development, implementation, installation, and termination of network servers and related hardware/software/telecommunications

components; and

23. Be required to learn to utilize various types of electronic and/or manual recording and information systems used by the agency, office, or related units.

QUALIFICATIONS

Knowledge of:

Knowledge of industry standard Network Operation Systems (NOS);

Knowledge of server hardware and associated software;

Knowledge of telecommunication components used to interconnect servers to communication devices and ultimately clients (PCs);

Knowledge of countermeasures for dealing with network security and virus protection; and

Knowledge of techniques to determine system capacity and cost effectiveness of system utilization

Ability to:

Ability to troubleshoot and repair problems inherent to computer networks;

Ability to establish goals and set priorities;

Ability to schedule and organize work activities and identify/resolve problems which arise;

Ability to interact with orders and come to consensus on various issues;

Ability to prepare clear, sound, accurate, and informative reports containing findings, conclusions, and recommendations;

Ability to work independently or in a team environment;

Ability to utilize various types of electronic and/or manual recording and information systems used by the agency, office or related units; and

Ability to read, write, speak, understand, and communicate in English sufficiently to perform duties of this position

Experience and Training Requirements:

Experience:

Three (3) years of experience in the development, implementation, and maintenance of multi-network, multi-user Local Area Networks (LAN), Metropolitan Area Networks (MAN), and/or Wide Area Networks (WAN) environments. Familiarity with ITS devices such as CCTV, VMS, ESS are essential.

Training:

Graduation from an accredited college or university with a Bachelor's degree which must include a minimum of eighteen (18) semester hour credits in mathematics and/or computer science.

Note:

- (1) Applicants who do not possess the Bachelor's degree but possess the 18 semester hour credits may substitute additional experience as indicated below on a year-for-year basis with thirty (30) semester hour credits being equal to one (1) year of experience.
- (2) Evidence of formal training in Computer Science/Information Technology received at an accredited institution may be submitted with your application for evaluation by the Department of Personnel for possible credit. These training courses will be examined to see how they compare, both in hours/content, to college courses to which they equate, sixteen (16) training hours being equal to one (1) college credit,. In house training courses will not be accepted as meeting these criteria; thus, they will not be evaluated. The Department of Personnel's decision in this matter is final and not subject to appeal.

License or Certificate

Appointees will be required to possess a driver's license valid in New Jersey only if the operation of a vehicle, rather than employee mobility, is necessary to perform essential duties of the position.

**State of New Jersey
Department of Personnel
Job Specification**

NETWORK SYSTEMS TECHNICIAN

DEFINITION

Under general supervision, in an ITS, Transportation, and Communications environment, direct hands on support is provided to a work shift of the TOC in resolving network problems from verbal or written problem reports; consults with TOC, network management and systems programming staff for problem diagnosis, assistance, and resolution; monitors and allocates space or direct access storage devices; uses productivity aids in implementing and maintaining software, applications, and systems libraries; or in client/server environment, provides hardware/software support to end users; installs hardware and software on servers and or workstations; does other related duties.

DISTINGUISHING CHARACTERISTICS

Positions at this level are distinguished from other classes within the series by the level of responsibility assumed and the complexity of duties assigned. Employees perform the most difficult and responsible types of duties. Employees at this level are required to be fully trained in all procedures related to assigned area of responsibility. Employees are fully aware of the operating procedures and policies of the work unit.

ESSENTIAL FUNCTION STATEMENTS

Essential Functions:

1. Assisting in the resolution of TOC problem reports in a timely and accurate service to all approved; consults with the network management and staff for assistance in resolution of more difficult problems;
2. Assisting other ITS personnel and user personnel in the use of ITS devices, utilizing programs and testing debugging programs;
3. Answering inquires from system users; explaining systems functions and provide technical assistance in the use and application of system features;
4. Providing support in the ITS subsystems, fiber and wireless communications;
5. Installing, configuring and setting up printers and work stations; installing software

programs;

6. Responding to requests for assistance; identifying and correcting hardware, software, and printer problems;
7. Troubleshooting application errors;
8. Identifying and resolving network problems;
9. Reviewing operational assistance by moving batch and online programs and job control language to production libraries, creating generation data group entries, and assisting in the review of application dumps;
10. Preparing clear, accurate, and concise technical reports;
11. Maintaining records and files; and
12. Being required to learn to utilize various types of electronic and/or manual recording and information systems used by the agency, office, or related units.

Marginal Functions:

1. Dealing with vendors on equipment specifications, delivery and maintenance problems; conferring with vendors on hardware technical issues;
2. Recommending computer hardware to management; maintaining inventory of PC's and related peripherals; and maintaining system hardware manuals and reference material;
3. Performing "back up" system administration duties including user account maintenance in the absence of the System Administrator;
4. Responding to network emergencies during evenings and weekends; and
5. Performing related duties and responsibilities as required.

Note: The above functions of work for this title are for illustrative purposes only. A particular position using this title may not perform all duties listed in this job specification. Conversely, all duties performed on the job may not be listed.

QUALIFICATIONS

Knowledge of:

- Knowledge of ITS applications and computer networks, servers, and Personal Computers and their hardware components;
- Knowledge of the facilities generally provided by operating systems software associated with multi-programmed and multi-process oriented computer systems;
- Knowledge of special vendor or client/server productivity aid packages;
- Knowledge of job control language statements and utility programs for use by data processing production operations;
- Knowledge of data communications network equipment and software;
- Knowledge of principles and practices of electronic theory, use and operation of various scopes, meters, and counters with understanding of component-level operation;
- Knowledge of pertinent federal, state and local codes, laws, and regulations regarding electronics
- Knowledge of basic mathematical principles;
- Knowledge of tools, equipment and methods used in installing, maintaining and repairing electronics solid state equipment;
- Knowledge of principles and practices of the use of diagnostic and utility software to find problems and repair system equipment and hardware;
- Knowledge of writing requirements and basic operation of personal computers, mainframe terminals, printers and other peripheral devices;
- Knowledge of basic principles of data communications facilities, standards, and implementation;
- Knowledge of troubleshooting techniques for PC hardware problems;
- Knowledge of preventive maintenance techniques and procedures; and
- Knowledge of occupational hazards and standard safety practices

Ability to:

- Ability to analyze production problems and recommend necessary changes;
- Ability to use interactive programming and system diagnosis tools;
- Ability to use various Data Center or Network Center productivity aids;
- Ability to use various programming languages and software packages;
- Ability to prepare clear, accurate, and concise technical reports;
- Ability to maintain records and files;
- Ability to utilize various types of electronic and/or manual recording and information systems used by the agency, office, or related units;
- Ability to troubleshoot, repair or modify electronic computer and networking equipment;
- Ability to read, interpret and apply information from technical publications, manuals and other documents;
- Ability to establish and maintain effective working relationships with those contacted in the course of work;
- Ability to communicate clearly and concisely, both orally and in writing;
- Ability to troubleshoot PC hardware and networking problems and affect a solution;
- Ability to operate a personal computer, including a variety of software programs;
- Ability to operate advanced electronic test equipment;
- Ability to troubleshoot and repair data communication equipment and cable;
- Ability to maintain physical condition appropriate to the performance of assigned duties and responsibilities, which may include the following;
 - Sitting for long periods of time; and
 - Operating assigned equipment.
- Ability to maintain effective audio-visual perception needed for;
 - Making observations;
 - Communicating with others;
 - Reading and writing; and

- Operating assigned equipment.
- Ability to read, write, speak, understand, and communicate in English sufficiently to perform the duties of this position;

Note:

- (1) American Sign Language or Braille may also be considered as acceptable forms of communication.
- (2) Persons with mental or physical disabilities are eligible as long as they can perform essential functions of this job after reasonable accommodation is made to their known limitations.
- (3) If the accommodation cannot be made because it would cause the employer undue hardship, such persons may not be eligible.

Experience and Training Requirements:

Experience:

Four (4) years of experience in ITS and/or computer systems analysis and programming design, or the analysis of work methods and processes, or the operation of multi-program or client/server computer systems, or working in the support areas of computer scheduling, Input/Output control and magnetic data control in the data processing field or help desk, one (1) year of which shall have been in the technical support area solving user problems in a help desk.

Training:

At minimum, graduation from an accredited college or university with A Bachelor's degree in Computer Science or Electrical Engineering.

License or Certificate

Appointees will be required to possess a driver's license valid in New Jersey only if the operation of a vehicle, rather than employee mobility, is necessary to perform essential duties of the position.

WORKING CONDITIONS

Environmental Conditions:

Office and shop environment; travel from site to site; exposure to electrical energy, high voltage, computer screens, heat, cold, noise, dust, fumes and inclement weather conditions.

**State of New Jersey
Department of Personnel
Job Specification**

PURCHASING ASSISTANT

DEFINITION

Under direction from TOC manager, compiles information to prepare purchase orders for procurement of Intelligent Transportation systems (ITS) devices such as CCTV, VMS, ESS, fiber optic cables etc., materials, supplies, equipment, or service, reviews and edits purchase of orders for proper description, number identification, and completion, records the requisition and receipt of goods and services, and makes arrangements for purchase of equipment, materials, and supplies used by various departments; does related work as required.

Manage warranties and inventory systems for ITS plant, data inputting, and report preparation.

ESSENTIAL FUNCTION STATEMENTS

Essential Functions:

1. Maintaining numerical and alphabetical coding of purchased material and material in stock;
2. Reviewing, editing, and recording purchase orders for proper description, number identification, and ensure correctness before giving to buyer;
3. Receiving and recording invoices from vendors, checking to see that goods have been delivered and then forwards to accounts/payable section;
4. Keeping records of dispositions of purchase orders and invoices received;
5. Comparing, correcting, and updating nomenclatures and specifications on purchase orders;
6. Checking unit price on purchase order for conformity to established market prices;
7. Contacting vendors to expedite deliveries;
8. Contacting different divisions and projects to verify deliveries;
9. Consolidating procurement of materials and supplies for various departments and projects;

10. Ensuring that correct supplies are shipped by vendor;
11. Making arrangements with vendors to correct situations involving incorrect shipments;
12. Recording letters of acknowledgement from vendors;
13. Reviewing requisitions for materials not normally kept in inventory for proper distribution code identification and ensuring correctness;
14. Receiving, tabulating, and recording requests submitted by using agencies required in various purchasing operations for the purchase of equipment, materials, and supplies;
15. Performing the clerical work involved in the preparation of contracts following the awarding of bids;
16. Following the awarding of contracts, entering contract unit prices into a contract price book;
17. Being required to learn to utilize various types of electronic and/or manual recording and computerized information systems used by the agency, office, or related units;
18. Preparing proposals for solicitation of bids, in the tabulation of bids, and in processing orders for purchase of commodities;
19. Submitting samples of orders and delivered commodities to the laboratory, and assists in inspection and testing required determining conformity with established specifications;
20. Discussing specification details with appropriate personnel and where necessary visits factories, mills, warehouses, and other sources of supply for further marketing information by observing or inspecting the manufacturing or processing of commodities;
21. Making studies and analyses of procurement operations and submits statistical reports containing findings, conclusions, and recommendations;
22. Preparing routines reports and correspondence; and Maintaining records files of various supply programs; and
23. Being required to learn to utilize various types of electronic and/or manual recording and information systems used by the agency, office, or related units.

QUALIFICATIONS

Knowledge of:

Knowledge of the proper methods and procedures involved in the purchase of equipment, materials, and/or supplies; computer systems and inventory.

Knowledge of methods and procedures involved in purchase of equipment, materials, and supplies; and

Knowledge of problems likely to be encountered in field and office purchasing work.

Ability to:

Ability to comprehend and analyze the individual supply problems and particular needs of the various departments;

Ability to deal effectively with salesmen and vendors;

Ability to prepare reports;

Ability to establish and maintain essential records and files;

Ability to learn to utilize various types of electronic and/or manual recording and information systems used by the agency, office, or related units;

Ability to read, write, speak, understand, or communicate in English sufficiently to perform the duties of this position;

Ability to organize assigned field, office, and other purchasing work, and develop effective work methods in accord with prescribed procedures;

Ability to comprehend and analyze individual routine and seasonal supply problems and requirements;

Ability to comprehend, analyze, interpret relevant purchase regulations, and apply these to specific purchase situations;

Ability to work harmoniously with associates, superior officers, department officers, vendors, salespersons, and with others interested in or concerned with purchase matters;

Ability to assist with field and office work involved in receiving, tabulating, and recording requisitions in one or more fields received from different agencies, in the preparation of proposals to be sent to vendors, in checking of bids, and in submission of samples of ordered and delivered commodities;

Ability to interview salespersons and vendors, department and agency heads, and others;

Ability to make field visits required to expedite delivery of purchases;

Ability to draft correspondence;

Ability to prepare factual reports;

Ability to maintain records and files; and

Ability to utilize various types of electronic and/or manual recording and information systems used by the agency, office, or related units.

Experience and Training Requirements:

Experience:

One (1) year of experience in the preparation and processing of requisitions and/or the purchase of equipment, materials, and/or supplies.

Training:

Graduation from an accredited college or university with a Bachelor's degree

Note: Applicants who do not possess the required education may substitute additional experience as indicated on a year-for-year basis with thirty (30) semester hour credits being equal to one (1) year of experience.

License or Certificate

Appointees will be required to possess a driver's license valid in New Jersey only if the operation of a vehicle, rather than employee mobility, is necessary to perform essential duties of the position.

State of New Jersey
Department of Personnel
Job Specification

SYSTEM ADMINISTRATOR

DEFINITION

Under general supervision of TOC Manager, in a ITS/Transportation environment, installs, revises and maintains software of a ITS computer systems; resolves computer system software problems; and manages computer equipment maintenance and undertakes configuration management tasks.

ESSENTIAL FUNCTION STATEMENTS

Essential Functions:

1. Installs and maintains computers, operating system software, and applications programming, and provide user support, security, and data integrity.
2. Creates and updates databases and database software;
3. Creates and updates data communication networks for mainframe terminals and printers;
4. Creates programs and procedures to improve or supplement system and application software;
5. Troubleshoots and resolves operating system, database and data communication problems; recommend new equipment as appropriate;
6. Assists programming staff in resolving application software problems, and web design issues.
7. Coordinates system and application software for maximum efficiency; work with staff in evaluating system; recommend changes or upgrades;
8. Evaluates and installs software packages supplied by vendors; confer with vendors on software and hardware technical issues;
9. Develops procedures to minimize system downtime; provides technical support for maintaining the system; and
10. Conducts studies of new system and application software to determine impact on operating system; recommends modifications as appropriate.

Marginal Functions:

6. Maintains system software manuals and reference material;
7. Maintains data security and user passwords;
8. Provides technical support to programming staff, PC users and other system users;
9. Performs related duties and responsibilities as required.

QUALIFICATIONS

Knowledge of:

Knowledge of principles of data processing administration;

Knowledge of data communication networks, standards and protocols, and their software and hardware components, and ITS devices;

Knowledge of principles and techniques of computer programming in system and application software; and Knowledge of statistical methods and procedures

Ability to:

Ability to install, update and maintain system software on a mainframe computer;

Ability to analyze and correct complex system and application problems and errors;

Ability to analyze and develop complex system and application software;

Ability to provide assistance and technical support to others in use of the system and the creation and use of computer software;

Ability to troubleshoot, repair or modify electronic control equipment;

Ability to read, interpret and apply technical publications, manuals and other documents;

Ability to understand and follow oral and written instructions;

Ability to establish and maintain effective working relationships with those contacted in the course of work;

Ability to communicate clearly and concisely, both orally and in writing;

Ability to maintain mental capacity which allows for effective interaction and communication with others;

Ability to maintain physical condition appropriate to the performance of assigned duties.

Experience and Training Requirements:

At least 2 years of practical experience on systems and/or ITS systems. Any combination of experience and training that would likely provide the required knowledge and abilities is qualifying. A typical way to obtain the know / edge and abilities would be:

Experience:

Two years of increasingly responsible systems programming experience.

Training:

Equivalent to an Associate's degree from an accredited college or university with major course work in computer science or a related field

WORKING CONDITIONS

Environmental Conditions:

Office environment; exposure to computer screens; electrical energy

Physical Conditions:

Essential and marginal functions may require maintaining physical condition necessary for light lifting; bending, stooping, kneeling, crawling; sitting for prolonged periods of time.

PREVENTIVE MAINTENANCE PROCEDURES/CHECKLISTS

The lists below include examples of preventive maintenance procedures for a variety of common device types. Maintenance staffs need to develop their own set of procedures based on the devices they have and the information from the manufacturer and owners manual. Keeping documentation of the procedures and when they are performed will put the Agency in a better position in the case of disputes concerning warranties and in providing the MTBF data discussed earlier. ⁽⁶⁾

Closed-Circuit Television Camera Preventive Maintenance

Camera Preventive Maintenance at Pole Level — Every Six Months

- Check camera housing pressure (typically 5psi +/- 1psi). Pressurize with dry nitrogen if not within
- Limits and document readings on sheet provided
- Visually inspect camera housing
- Clean glass with suitable glass cleaning agent
- Inspect pan and tilt mechanism and adjust limit switches where applicable
- Inspect housing mounting for corrosion.
- Remove any bird nests around the camera housing.
- Check and inspect the integrity of all cable harness and connectors. Replace defective items where applicable
- Check integrity of surge protector - replace where applicable
- Check wiper blades and wiper assembly unit - replace defective units
- Replace filter in camera housing
- Check operation of thermostat inside camera housing
- Check for corrosion of connections terminals inside housing

Camera Preventive Maintenance at Cabinet Level — Every Three Months

- Check integrity of all cables and connectors
- Check raw video from the camera with a waveform monitor (raw video shall measure 1.00Vp/p).
- Adjust per specifications in specialty camera manual
- Check all local functions (Pan, Tilt, Zoom in, Zoom out, Focus Far, Focus near)
- Check integrity of surge protectors
- Check and ensure that all relays are firmly seated on the control board
- Check operation of auto-iris and adjust for correct operation per operational and maintenance manual
- Check circuit box at the base of the camera pole to ensure that the terminal strips are corrosion free
- Check proper function of the thermostat
- Check fan and replace where applicable
- Clean and vacuum inside of cabinet
- Inspect and change the filter where applicable
- Check the light bulb and replace where applicable.
- Check incoming power for proper voltage and correct if not within tolerances
- Check cabinet door for proper closure

Camera Preventive Maintenance at Control Center — Weekly

- Using the waveform monitor, perform the following measurements and ensure that the results recorded are within manufacturers specifications. Document the results.
- Check raw video
- Measure peak white
- Measure color burst
- Measures synch pulse.
- Check integrity of all connectors
- Check all of the camera video at night focusing.

Variable Message Signs (VMS) Preventive Maintenance — Annually at the Sign
(As applicable to both fixed and portable VMS signs)

Every Three Months at the Cabinet

- Photo Cell - clean photo cell aperture.
- Ventilation - clean filters.
- Lexan cleaning - clean front surface with approved detergent.
- Cabinet Filter - clean or change filters.
- Fans - check fan condition and thermostat settings.
- Vacuum cabinet and clean.
- Test - Row and Column Check.
- Test - All "ON" and ALL "OFF".
- Test - check alpha numeric characters.

Back up Battery Assemblies — Annually

- String voltage - measure /record.
- Individual Voltages - measure /record.
- Pilot unit Voltage - measure /record.
- Ambient temperature - measure /record.
- Unit interconnection - inspect, clean.
- The unit must be cleaned quarterly to remove dust from covers.
- If signs of corrosion, clean with a solution of baking soda and water or isopropyl alcohol.
- If corrosion reoccurs, report to the Department.

Air Conditioning Unit Preventive Maintenance — Every Three Months

- Air Filter - remove and clean or replace.
- Blower unit - check for bearing noise.
- Compressor - check functions - reset thermal overload.

- Refrigerant loss - check refrigerant level and pressure, check for cracks & leaks in the pipe lines.

Loops and Piezo Detectors Preventive Maintenance

Loop Preventive Maintenance — Annually

At the Cabinet Level

- Disconnect loop.
- With LCR meter, provides measurements of L-inductance, C-capacitance, and R-resistance.
- With LCR meter measure and record resistance (R= ohms).
- With a MEGGER meter, A test instrument for measuring the insulation resistance of conductors and other electrical equipment; specifically, a mega-ohm (million ohms) meter; this is a registered trademark of the James Biddle Co., measure and record the insulation resistance (100 meg >).
- If readings are outside specification, disconnect lead-in at the splice box and check all three parameters at that level.
- From the readings determine whether loop or the lead-in needs repair.

Piezoelectric Detector Preventive Maintenance — Every Three Months

- Check cracks in the asphalt at the shoulder.
- Check cracks in the sensor at the shoulder.
- Check cracks in the sensor at the wheel tracks.
- Check cracks at the sensor /asphalt interface.
- Using LCR meter measure capacitance (C= μ F).
- Using LCR meter measure resistance (R = ohms)
- Use manufactures recommended procedure for checking detectors.

MAINTENANCE ACTIVITIES

Maintenance activities constitute one of the main activities in a TOC: ⁽⁷⁾

1. **Dispatch function** is the dispatch of personnel for both emergency and preventive maintenance.
2. **Distribution of maintenance responsibilities** among TMC personnel as well as among involved agencies and subcontractors hired to perform certain maintenance activities.
3. **Preparations** to ensure the timely and efficient coordination between maintenance and operations staff to avoid possible problems. In terms of maintenance activities this translates into providing the following information to the operations personnel:
 - Beginning of a shift – type, impact of the maintenance along with the actions required.
 - Beginning and termination times of each task and the time the equipment can be made fully operational again.
 - Need for additional support and the termination time of this support activity (i.e. traffic control).
 - Preparation of the activity log at shift completion to document the accomplishments during the period plans for additional activities, verification of the changes in the status of devices.

The same report identifies computer related maintenance as a major maintenance activity in addition to the more traditional field equipment related maintenance. This activity includes: ⁽⁷⁾

- Software Maintenance
 1. Debugging of operational code.
 2. Small system improvements.
 3. Implementation of new user needs and desires.

4. System modification to improve performance.
 5. User interface modifications.
 6. Addition of new algorithms.
- Computer and Software Maintenance:
 7. Replacement of obsolete computers.
 8. Replacement of parts and peripherals.
 9. Addition of new computers.

Finally, it is very important to monitor maintenance activities to improve the efficiency of the future operations and address some of the current problems as well as future decision making in terms of equipment and system selection. This effort includes:

Record keeping: Records regarding the maintenance activities and the reliability of the equipment are needed for both preventive maintenance and future planning of resources.

Analysis of maintenance data: This data is very important for future decision making in terms of system expansion and obtaining proper financial resources for the performance of necessary performance functions. The data include:

- a. Device maintenance data including mean time between failures and repairs.
- b. Device performance data including reliability and extent and type of repairs performed.
- c. Resources needed for maintenance including manpower, consumables, tools, test equipment, and support equipment.

LIST OF TOC BENEFITS AND COSTS ⁽⁶⁾

Benefits: Generally, TOC operations have demonstrated benefits in the following areas:

1. Transportation safety.
2. Productivity.
3. Efficiency.
4. Environmental impact.

Costs: There are essentially two categories of costs when considering the development of a TOC; central system costs and annual operation and maintenance costs. Generally, central system costs consist of:

2. Physical TOC costs.
3. Equipment costs.
4. Design costs.
5. Software and integration costs.

Operation costs may encompass items such as:

1. Personnel wages.
2. Computer usage.
3. Vehicle costs.
4. Electrical and communication infrastructure requirements.

Maintenance costs may consist of the maintenance of these items as well as the salaries of any dedicated maintenance personnel for field equipment or central hardware.

OPERATING COST ELIGIBILITY UNDER FEDERAL-AID HIGHWAY PROGRAM

Transportation Systems Management & Operations: Operating Cost Eligibility Under the Federal-Aid Highway Program (Based on <http://ops.fhwa.dot.gov/travel/Ops-guide.htm>)

Note: References cited in this appendix only refers to the following 23 USC (They don't apply to the main Final Report references):

1. 23 USC 101(a) (17).
2. 23 USC 101(a) (18).
3. 23 USC 103(b) (6) (H) and 23 USC 133(b) (6).
4. 23 USC 103(b) (6) (O) and 23 USC 133(b) (13).
5. 23 USC 149(b) (4).
6. 23 USC 149(b) (5).
7. 23 USC 116(d).

Federal-aid Eligibility Policy Guide

The operating costs for traffic monitoring, management, and control systems, such as integrated traffic control systems, incident management programs, and traffic control centers, are eligible for Federal reimbursement from National Highway System and Surface Transportation Program funding. For projects located in air quality non-attainment and maintenance areas, and in accordance with the eligibility requirements of 23 USC 149(b), Congestion Mitigation and Air Quality Improvement Program funds may be used for operating costs for a 3-year period, so long as those systems measurably demonstrate reductions in traffic delays. Operating costs include labor costs, administrative costs, costs of utilities and rent, and other costs, including system maintenance costs, associated with the continuous operation of the system.

Introduction

The movement of people, goods, and vehicles on the nation's surface transportation system is now critically dependent on how effectively that system is managed and operated. Adding to the roadway system is necessary in some key locations and corridors to serve the demands for this movement, and in some cases, provide for economic development in the area. However, the construction of new lanes will never

alleviate the need for effective management and operations of the system - on existing as well as new segments. Well planned, cost-effective transportation operations and management actions can improve mobility, safety, and productivity of the system for transportation users in urban and rural areas.

Background - Legislative

The Transportation Equity Act for the 21st Century (TEA-21), signed into law on June 9, 1998, reinforces the Federal commitment to manage and operate the nation's transportation system. Under TEA-21, the Federal-aid Highway Program continues eligibility of operating costs for traffic monitoring, management, and control. The legislation defines operating costs as including labor costs, administrative costs, costs of utilities and rent, and other costs associated with the continuous management and operation of traffic systems, such as integrated traffic control systems, incident management programs, and traffic control centers.⁽¹⁾ An "operational improvement" continues to mean a capital improvement for installation of traffic surveillance and control equipment; computerized signal systems; motorist information systems; integrated traffic control systems; incident management programs; transportation demand management facilities; strategies, and programs; and such other capital improvements to public roads as the Secretary may designate, by regulation.⁽²⁾ By definition, an operational improvement still does not include restoration or rehabilitating improvements; construction of additional lanes, interchanges, and grade separations; and construction of a new facility on a new location.

For both National Highway System (NHS) and Surface Transportation Program (STP), TEA-21 continues the eligibility of capital and operating costs for traffic monitoring, management, and control facilities and programs.⁽³⁾ Also, TEA-21 clarifies the eligibility of NHS and STP funds for Intelligent Transportation Systems (ITS) capital improvements to specifically allow funds to be spent for infrastructure-based ITS capital improvements.⁽⁴⁾

For the Congestion Mitigation and Air Quality Improvement Program, TEA-21 continues to include the establishment or operation of a traffic monitoring, management, and control facility or program as potentially eligible projects.⁽⁵⁾ TEA-21 also explicitly adds, as an eligible condition for funding, programs or projects that improve traffic flow, including projects to improve signalization, construct high occupancy vehicle lanes, improve intersections, and implement ITS strategies.⁽⁶⁾

Interpretation / Rationale

Examples of typical eligible operating cost and expenses for traffic monitoring, management, and control include those costs mentioned in the legislative definition for operating costs.¹ In order to assure continuous operation, costs associated with maintaining these systems are necessary operating expenses so that traffic monitoring, management, and control facilities or programs provide their intended functions. Examples of these maintenance costs include system maintenance activities to assure peak performance (preventive computer maintenance) and replacement of defective or damaged computer components and other traffic management system hardware (including street-side hardware). Specific eligibility determinations related to traffic control operational costs and maintenance expenses are the discretion of the FHWA Division Office in a particular state.

This interpretation is consistent with the FHWA Strategic Plan, specifically related to the Mobility Goal and the Strategic Objective to "Improve the operation of the highway systems and intermodal linkages to increase transportation access for all people and commodities." In light of TEA-21, which reaffirms and increases the Federal commitment to manage and operate the nation's surface transportation system, this interpretation is also consistent with the intent of Congress.

It is appropriate for FHWA to adopt policies that encourage efficient management and operation of surface transportation. With a greater shift toward applying technology to addressing transportation needs, a broader life-cycle view of transportation operations is warranted that includes all activities related to sustaining system performance.

Examples

Some of the types of Federal-aid projects that may be funded include the installation and integration of the Intelligent Transportation Systems Infrastructure such as:

- Planning for regional Management and Operations programs.
- Traffic Signal Control Systems.
- Freeway Management Systems.
- Incident Management Systems.
- Multimodal Traveler Information Systems.
- Transit Management Systems.
- Electronic Toll Collection Systems.
- Electronic Fare Payment Systems.
- Railroad Grade Crossing Systems.
- Emergency Services.
- Implementation of the National ITS Architecture for metropolitan and rural areas
- Development of regional ITS Architecture.

Some examples of typical Federal-aid capital improvement projects that may include eligible operating costs include:

- System Integration.
- Telecommunications.
- Reconstruction of Buildings or Structures that house system components.
- Control / Management Center (Construction) and System Hardware and Software for the projects.
- Infrastructure-based Intelligent Transportation System capital improvements to link systems to improve transportation and public safety services.
- Dynamic / Variable message signs.
- Traffic Signals.

Some examples of typical eligible operating cost and expenses for traffic monitoring, management, and control include:

- Labor Costs.
- Administrative costs.
- Costs of Utilities and Rent.
- Other costs associated with the continuous operation of the above-mentioned facilities and systems.
- System Maintenance (activities to assure peak performance).
- Replacement of defective or damaged computer components and other traffic management system hardware (including street-side hardware).
- Computer hardware and software upgrades to remedy Year 2000 (Y2K) problems.

Questions and Answers

Q. What would not be considered eligible as an operating cost?

A. The discretion and flexibility afforded FHWA Division Offices in determining the eligibility of specific activities under this guidance, the allowances for preventive maintenance in Title 23⁽⁷⁾, and other Federal-aid policies can allow for virtually any activity to be eligible. However, routine maintenance items those are not critical to the successful operation of the system, such as the painting of traffic signal controller cabinets or the maintenance of the exterior of transportation management center buildings would normally fall outside of eligible operating costs.

Q. What are some typical activities associated with transportation management center computers whose costs could be eligible under Federal-aid?

A. Besides the costs associated with designing and procuring the computer system, other eligible activities could include regular checking of the computer components to make sure they are fully functional. Any corrective measures or upgrades (software or hardware) that are necessary would be eligible activities.

Q: Can "spare parts" be eligible for federal-aid?

A: System-critical parts (i.e., ones that are essential for the successful operation of the system) that are susceptible to failure, regardless of reason - acts of God, crashes,

electronic "infant mortality" - have been determined by some FHWA Division Offices as eligible for federal-aid reimbursement.

Q: What documentation do states or local governments need to submit (or present upon request) for approval or authorization of operating costs?

A: The amount and specific nature of documentation are left to the judgment of the FHWA Division Office, but the documentation should be sufficient to determine that the proposed expenditures would be eligible for Federal-aid reimbursement.

Q: Besides TEA-21 and Title 23, what overall rules govern the eligible operating costs and procurement method?

A: The Office of Management and Budget (OMB) Circular A-87, Cost Principles for State and Local Governments (available at <http://www.whitehouse.gov/OMB/circulars/a087/a087-all.html>) establishes principles for determining the allowable costs incurred by State, local, and federally-recognized Indian tribal governments under grants, cost reimbursement contracts, and other agreements with the Federal Government. Part 18 of Title 49 of the Code of Federal Regulations (49 CFR Part 18, available at <http://www.access.gpo.gov/nara/cfr/index.html>) also includes information related to the administration of grants and cooperative agreements with State and local governments.

Q. Where can I find out more about the Congestion Mitigation and Air Quality Improvement (CMAQ) Program?

A. The latest guidance on the CMAQ Program was issued April 28, 1999, and is available from FHWA Division and FTA Regional offices. The guidance, along with other CMAQ Program information, is available on the internet at <http://www.fhwa.dot.gov/environment/cmaq.htm>

1. 23 USC 101(a) (17)
2. 23 USC 101(a) (18)
3. 23 USC 103(b) (6) (H) and 23 USC 133(b) (6)
4. 23 USC 103(b) (6) (O) and 23 USC 133(b) (13)
5. 23 USC 149(b) (4)
6. 23 USC 149(b) (5)
7. 23 USC 116(d).

Table 18. Other States' TOCs Contact Information.

#	TOC/TMC Visited	Location Contact
1	Hampton Roads, VA	Dwayne K. Cook, Maintenance Engineer 757-424-9908
2	Northern Virginia, VA	Jimmy Chu, Manager, 703-383-2621 Marlowwe K. Dixon, Elect. Tech. Supervisor
3	Maryland, Statewide Center, MD	Craig A. Fetzer, Chief of Communications 410-747-8590
4	City of Los Angeles, CA	Dennis E. Mitchell, TMC Mgr., 213-485-8523 Steve Rostam, 213-473-3955
5	City of Santa Anna, CA	T.C. Sutaria, City Traffic Engineer 714-647-5604
6	City of Anaheim, CA	John Thai, Principal Traffic Engineer 714-765-5202
7	CALTRAN-12 Orange Ct. CA	Mahesh Bhatt, Chief TMC & Field Operation 949-936-3413, Paul King, Maintenance , 949- 936-3410
8	Michigan-Detroit-MI	Jams P. Schultz, Manger, 313-256-9800x301 Thomas D. Mullin, 313-256-9800
9	Minneapolis/St. Paul, MN	Nick Thompson, Operation manager, TMC 612-648-1736, Teresa Hyde, TMC Supervisor, Ray A. Starr, Elect. Eng. 651-284-3434
10	Utah DOT, UT	Joseph C. McBride, TOC Asset Mgr., Denny Simmons Supervisor, 801-887-3716
11	Washington State DOT, WA	Michael L. Forbis, system Administrator 206-440-4463
12	Arizona AzTech, AZ	Manny Anga, 800-379-3701 ADOT TOC
13	NYC DOT, NY	Edward Chen, 718-786-20008 Mohamad Talas, 718-433-3339,3390 TOC

REFERENCES

1. New Jersey Department of Transportation, *Intelligent Transportation Systems, Strategic Deployment Plan*, Division of Traffic Operations, May 2003.
2. New Jersey Department of Transportation, *Scope and Request for Proposal, Project 2000-12, Intelligent Transportation System (ITS) Operational Support Contracts*, April 2000.
3. New Jersey Department of Transportation, *Maintenance of ITS Facilities, Contract Statewide 2004*, Federal Project # Q24000S853, January 2004.
4. Kraft, Walter H., D. Eng. Sc., P.E. "NCHRP" in Synthesis 270: Transportation Management Center Functions. Washington, D.C. Transportation Research Board, National Research Council, National Academy Press, Washington, DC, 1998.
5. New Jersey Department of Transportation, *Summary of other State TOC Survey, Technical Memorandum for Task-3*, March 2003.
6. Federal Highway Administration, *Guidelines for Transportation Management Systems Maintenance Concepts and Plans*, PB Farradyne, December 2002.
7. FHWA Final Rule and FTA Final Policy on ITS Architecture and Standards (Rule 940), January 2001, http://www.ops.fhwa.dot.gov/its_arch_imp/policy.htm.
8. Federal Highway Administration, *TMC Concept of Operations Implementation Guide*. Washington, D.C.: FHWA/USDOT, Washington, DC, December 1999.
9. TMC Pooled Fund Study (PFS) web site (<http://tmcpfs.ops.fhwa.dot.gov>).
10. Institute of Transportation Engineers, ITS Council – Management and Operations Committee, *An Annotated Outline for a Traffic Management Center Operations Manual*, ITE, Washington, DC 2001.
11. Federal Highway Administration, *Transportation Systems Management & Operations: Operating Cost Eligibility Under the Federal-Aid Highway Program*, November 2004, (Based on <http://ops.fhwa.dot.gov/travel/Ops-guide.htm>).
12. Raman K. Patel, *Operations and Maintenance Funding, Resources and support for Traffic Management Centers*, Institute of Transportation Engineers Conference on O &M, Minneapolis, MN, and September 14-15, 1996.

13. Raman K. Patel, and Ginger Daniels, *Funding for Operation and Maintenance of Advanced Traffic Management Systems*, Institute of Transportation Engineers (ITE) Annual Meeting, Boston, MA, August 3-6, 1997.
14. Kraft, Walter H, and James M. Giblin, *Traffic Control System Operations, Installation, Management, and Maintenance*, Institute of Transportation Engineers, Washington, DC, 2000.
15. Western Transportation Institute, Montana State University, *ITS Maintenance Workshop Notes*, August 2003.
16. Washington State Department of Transportation, *Surveillance, Control and Driver information System*, Seattle, Washington, 2003.
17. Western Transportation Institute, Montana State University, *Intelligent Transportation Systems Maintenance Plan*, Volume-one, Volume 2, Oregon State Department of Transportation, December 1999.
18. "Configuration Management for Transportation Management Systems", 2003 TMC Pooled Fund Study website <http://tmcpfs.ops.fhwa.dot.gov>.
19. Federal Highway Administration, *Freeway Operations and Management Handbook, Final Report*, FHWA/USDOT, Washington, DC September 2003.
20. Colorado Department of Transportation, CTMC, ITS Maintenance, <http://www.cotrip.org/its>
21. City of New York, Department of Information Technology and Telecommunications, Request for Proposal (RFP), Citywide Mobile Wireless Network, PIN 85804CSP0009, March 2004. [http:// www.doitt.nyc.gov](http://www.doitt.nyc.gov).