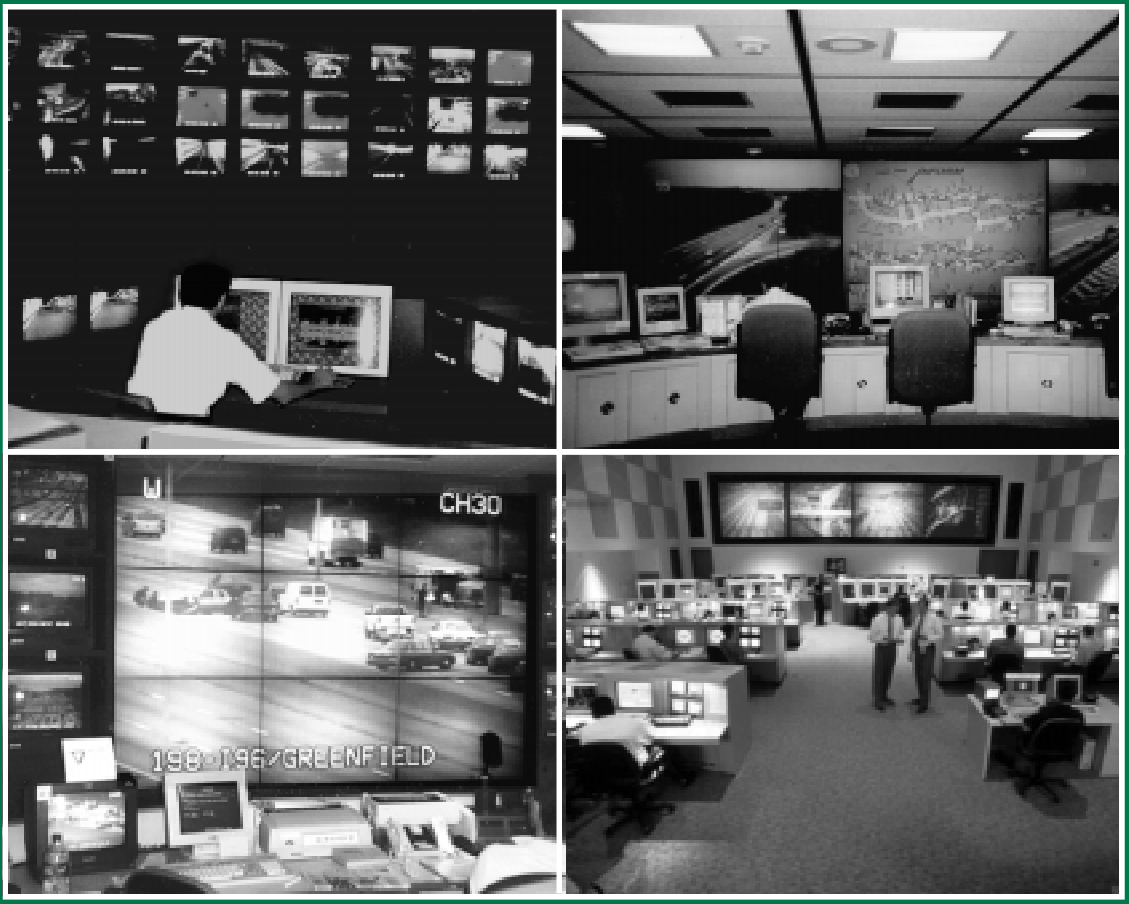
Metropolitan Transportation Management Center Concepts of Operation

A Cross-Cutting Study



Improving Transportation Network Efficiency

October 1999

Foreword

Dear Reader,

We have scanned the country and brought together the collective wisdom and expertise of transportation professionals implementing Intelligent Transportation Systems (ITS) projects across the United States. This information will prove helpful as you set out to plan, design, and deploy ITS in your communities.

This document is one in a series of products designed to help you provide ITS solutions that meet your local and regional transportation needs. We have developed a variety of formats to communicate with people at various levels within your organization and among your community stakeholders:

- **Benefits Brochures** let experienced community leaders explain in their own words how specific ITS technologies have benefited their areas;

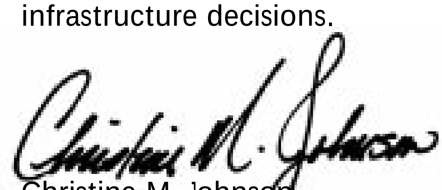
- **Cross-Cutting Studies** examine various ITS approaches that can be taken to meet your community's goals;

- **Case Studies** provide in-depth coverage of specific approaches taken in real-life communities across the United States; and

- **Implementation Guides** serve as "how to" manuals to assist your project staff in the technical details of implementing ITS.

ITS has matured to the point that you don't have to go it alone. We have gained experience and are committed to providing our state and local partners with the knowledge they need to lead their communities into the next century.

The inside back cover contains details on the documents in this series, as well as sources to obtain additional information. We hope you find these documents useful tools for making important transportation infrastructure decisions.



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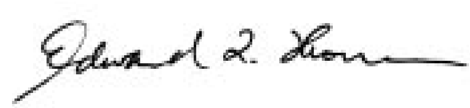

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Background

The implementor and operator of a regional transportation management center (TMC) face a challenging task. Operators of TMCs—the primary point of coordination for managing transportation resources—typically control millions of dollars of intelligent transportation system (ITS) equipment implemented regionwide. Yet relatively sparse material has been published regarding TMC implementation and operation. Thus, to support the TMC's implementation and operation, the implementor and operator have had to depend on personal experience, the knowledge and expertise of other individuals within their agency, a personal network within the transportation trade, and the firm or firms hired to assist the agency implementing the TMC.

If the implementing agency has little or no experience using technology-intensive systems to manage transportation, the concept of how the TMC's systems are to be used may not be well formed, and it will be difficult to communicate this vision clearly to the design team and to the implementor. The unfortunate result may be a system that the operations staff members find difficult to manage and that is both less effective and shorter lived than is desired.

Developing and documenting a concept of operations forces the implementing agency to explicitly address and understand operational issues, such as staffing, education, and training; information and control sharing; and the decision-making hierarchy. It also assists in more clearly defining the system configuration and information content, user interface, and other system parameters for the system designer and developer.

This document provides information on operations at various TMCs within the United States and Canada. While a primary focus of each of these centers is freeway management, several are also responsible for traffic signal system operation and various aspects of transit system management. The majority of the study addresses the centers' freeway management activity. The study team, in its in-depth review of these centers, began with a review of existing published TMC operations material and a current listing of major U.S. freeway management centers. The following eight centers were chosen for detailed investigation and documentation, representing a broad range in their systems' size, age, purpose, and technical approach:

- Detroit, Michigan, Intelligent Transportation Systems Center
- Milwaukee, Wisconsin, MONITOR
- Long Island, New York, INFORM
- Boston, Massachusetts, Integrated Project Control System
- Houston, Texas, TranStar
- Phoenix, Arizona, TrailMaster
- Atlanta, Georgia, NaviGAtor
- Toronto, Ontario, COMPASS.

Background

Based on the operations concept defined in the article, "The ITS Operations Concept: A Missing Link in System Definition," in the Winter 1997/Spring 1998 edition of *ITS Quarterly*, a three-page survey was prepared as a data gathering tool. The study team visited each of the eight TMCs for 1 to 2 days, interviewed TMC personnel at all levels of operations and maintenance responsibility, and observed system operation for several hours, typically including a complete multihour peak period.

The situation and mission of each TMC vary, so different lessons and experiences—documented in this study—were gained from each TMC visited. The study team gathered "best practices" and "lessons learned" in the operation of those TMCs. The team also identified major issues that were challenging most existing centers, such as staffing and the relationship between operations and maintenance functions. The team asked study participants to provide their perspectives on future directions for TMCs and TMC support systems. Interviews at each of the TMCs typically resulted in 10 to 15 pages of typed notes.

The data the study team gathered throughout its efforts are consolidated in this document. As such, this document provides potential TMC implementors and existing TMCs that desire to improve their own operations with real-world examples of how their peers are addressing daily operational issues.

Location of TMCs included in this study

The study team discovered that a majority of TMCs lacked a documented concept of operations. A thorough understanding of the operations approach is essential when acquiring systems and developing procedures. A concept of operations can be a valuable tool in achieving and sharing this understanding.

Some of the lessons learned and described in this document (e.g., underestimation of operator workload, transition from video monitor walls) are indicative of human factors issues which are concerned with the design of TMC system elements. Additional good human factors practices related to equipment, operator tasks, and procedures are documented in the report, *Comparable Systems Analysis: Design and Operation of Advanced Control Centers* (August 1995). Also, *Preliminary Human Factors Guidelines for Traffic Management Centers* will provide guidance on human factors design issues for TMCs (September 1999).

Background

Basic Outline of a TMC Concept of Operation

The data the study team gathered have been condensed into sections on Best Practices, Lessons Learned, Issues, and Future Directions. The Best Practices and Lessons Learned sections follow the basic outline for a TMC concept of operations as shown below. Lessons Learned were gathered on a nonattribution basis, and staff at each TMC were willing to contribute generously of their hard-earned experiences.

Throughout the remainder of this document each TMC will be referred to by the name of the city in which it is located, although several of the TMCs manage either regional or statewide road networks.

The basic outline of a TMC concept of operations used for this study is as follows:

- Background
  - The need, purpose, and concept for the system
  - The mission, vision, goals, and objectives that relate to the services the system delivers
- System design and implementation
  - General system design parameters
  - Devices in the system and their interoperation
  - Method of system implementation
  - System testing
  - Operations readiness testing
  - System training and documentation
- System operation
  - Workload and performance
  - Coordination
  - Conflict resolution
  - Nonstandard operations
  - Fault detection and correction
- System maintenance
  - Configuration management
  - Logistics
  - Maintenance
  - Operations simulation.

Background

This outlined concept of operations provides more background information, particularly in the area of procurement, than would be the case with a concept of operations for a new system or for a more scientific application—such as a National Aeronautics and Space Administration [NASA] control center—because this information was considered useful to agencies implementing TMCs. Some subsection topics, such as systems testing, are applicable multiple times during the life cycle of a TMC, both at its beginning and any time it undergoes a significant change or upgrade. Other subsections, such as nonstandard operations, reflect multiple conditions (e.g., special events and emergency operations) combined into a single section.

TMC Summary Descriptions

Boston Central Artery/Tunnel Integrated Project Control System

The **Integrated Project Control System** is an integrated traffic management and tunnel systems control application for Boston's 7.5 mile Central Artery/Tunnel system. It is one of the most complex and reliable systems of its type, featuring an extremely high density of field equipment, and double or triple redundancy in many elements. The objective of this system is to monitor security, traffic, and systems (fire, water level, air quality) status, and to respond to incidents, nonstandard needs, or failures rapidly and effectively. The traffic management components also support management of traffic through the heart of Boston and to and from Logan Airport, and thus they are also involved in supporting both daily travel and any special events that occur on Boston's roadways. The Integrated Project Control System applies vehicle detectors, overheight detectors, closed-circuit television, lane control signals, and variable message signs communicating over a fiber optic network. The system is being implemented by the Massachusetts Highway Department, and is operated by the Massachusetts Turnpike Authority.

Toronto, Ontario COMPASS Downsview TMC

The **COMPASS Downsview TMC**, built and operated by the Ministry of Transport, Ontario, balances traffic between express and collector lanes on Highway 401, and provides incident detection and incident management. COMPASS uses vehicle detectors, closed-circuit television, and variable message signs communicating over a fiber optic network. A 1994 evaluation showed that the COMPASS system has resulted in a reduction in average duration of incidents from 86 minutes to 30 minutes, that the system prevents about 200 accidents per year, and that average speed has increased 7 to 19 percent. Two smaller COMPASS TMCs in the Toronto area monitor adjacent roadways.

Long Island, New York INFORM

The **INFORM** system on Long Island uses vehicle detectors, closed-circuit television, traffic signals, ramp metering, and variable message signs communicating over a coaxial network to identify traffic congestion and incidents or situations likely to cause congestion, and to provide information to motorists and incident management resources to minimize the duration and impact of such situations. The system monitors and manages traffic on Long Island's three major east-west limited access routes, with work under way to instrument north-south arterial connector routes as well. The INFORM TMC also hosts the regional motorist assistance patrol. INFORM was implemented by the New York State Department of Transportation, and is operated under contract. Results of INFORM studies show that freeway speeds increased 13 percent despite an increase of 5 percent vehicle miles traveled for the afternoon peak. The number of locations with speeds of less than 30 mph decreased by 50 percent for the morning peak. A study of INFORM ramp metering found a 15 percent accident reduction and a 9 percent increase in speed.

TMC Summary Descriptions

Detroit, Michigan Intelligent Transportation System Center

The **Michigan Intelligent Transportation System Center** contains both an original system dating from 1981 covering 32.5 miles, and an expansion of the system to cover a total of 180 centerline miles of freeway that is still under way. The former system includes ramp meters, detectors, and closed-circuit television with communications via coaxial cable. The latter system includes the same components and highway advisory radio, communicating via microwave and spread spectrum radio to an OC-48 fiber optic network. The focus of the TMC is to make the traveler’s trip less stressful by providing better information so the traveler can avoid congestion or other driving problems. The system is being implemented by the Michigan DOT, and is in the process of privatizing operation. The TMC is jointly staffed with Michigan State Patrol. A study of ramp meters in Detroit measured a 50 percent accident reduction, an 8 percent increase in speed and a 12.5 percent increase in demand. The current expansion of the freeway management system is expected to reduce delays from incidents by about 40 percent. This would lead to an annual reduction of 41.3 million gallons of fuel used, a reduction of 122,000 tons of carbon monoxide, 1,400 tons of hydrocarbon and 1,200 tons of nitrogen oxides.

Milwaukee, Wisconsin MONITOR

MONITOR is the Wisconsin DOT’s freeway traffic management system for metro Milwaukee. MONITOR was implemented to address congestion problems on and incident vulnerability of the region’s incomplete freeway system. MONITOR uses vehicle detectors, closed-circuit television, traffic responsive ramp metering with high occupancy vehicle (HOV) priority, freeway and arterial variable message signs, and highway advisory radio. A full-time liaison from the county Sheriff’s department in the TMC provides coordination with law enforcement. The TMC is also the focus for regional distribution of road closure information. Wisconsin DOT has reported a 14.8 percent reduction in crashes and travel time reductions of 9, 12, and 16 percent on three separate roadway segments as a result of MONITOR’s systems. AM peak period average speed has increased 3 percent while volume has increased 22 percent. Net savings of 1,454 driver hours per peak hour have been calculated as a result of ramp metering alone.

TMC Summary Descriptions

Atlanta, Georgia NaviGAtor

Atlanta's **NaviGAtor** was originally conceived to address transportation needs for incident management, congestion management, and motorist assistance during the 1996 Olympic Games in Atlanta. It accomplishes these goals by providing to motorists accurate and timely information for navigating the roads of Georgia. NaviGAtor's mission has been expanded to serve as part of the Georgia DOT's statewide freeway incident management program. It uses vehicle detectors, closed-circuit television, variable message signs, and ramp meters communicating over a fiber optic and microwave network. The NaviGAtor TMC also hosts the area motorist assistance patrol program and the state's commercial vehicle operations enforcement program. The delay between the report of a crash and dispatch of emergency services has been cut in half, and accidents are cleared from the roadway 38 percent faster.

Phoenix, Arizona TrailMaster

The **TrailMaster TMC** in Phoenix is the hub of the Arizona Department of Transportation's statewide freeway incident management program. The objectives of TrailMaster are to support optimum utilization of the freeway system, provide a safe and efficient environment for users, and ensure efficient utilization of ADOT resources. The system uses vehicle detectors, closed-circuit television, and variable message signs communicating to the control center over a fiber optic network. Traveler information is provided via multiple methods, including on-site broadcaster, Web site, video feeds to other media, and the AZTech metropolitan model deployment initiative kiosks, onboard navigation, computerized telephone, and bulletin board systems. The TMC also hosts the state's highway closure reporting system. In a study of a typical incident, Arizona DOT found that the rapid incident detection and response from TrailMaster resulted in diversion of 21 percent of the vehicles traveling on the affected roadway, resulting in a savings of 1,452 vehicle hours for this incident.

Houston, Texas TranStar

Houston TranStar is a multiagency transportation management center providing traffic management, traveler information, and emergency management for the greater Houston area, including limited assets in Galveston. Agencies involved include the Texas DOT, the City of Houston, Harris County, and Houston Metro. Houston and Harris County Offices of Emergency Management are also present. The goals of Houston TranStar are to manage emergency response, promote emergency management awareness and public safety, promote the benefits of Houston TranStar, increase efficiency, improve productivity, and enhance mobility, congestion management, and safety. TranStar resources include variable message signs, highway advisory radio, loop detectors, closed-circuit television, lane control signals, ramp meters, a motorist assistance patrol, and an AVI-based congestion detection system extending beyond the conventionally detectorized area. An extensive (3,000 intersection) traffic signal system upgrade/replacement is also under way. A conservative estimate of average freeway incident time savings as a result of the TranStar system is 5 minutes, but analysis has shown that a savings of 30 minutes is possible for major freeway incidents. Total annual delay savings is estimated at 573,095 vehicle-hours, resulting in about $8.4 million in savings per year.

Planning

None of the eight TMCs visited had developed a concept of operations before the TMC was implemented, although most had conducted planning before implementing their systems. Interviewees from TMCs that conducted thorough planning confirmed that the sense of direction gained by documenting the TMC's understood mission, vision, goals, and objectives made center operations much easier. Houston, having recently undergone its first leadership transition, was actively revisiting its strategy to focus its efforts and redefine priorities and methods. Toronto was also revisiting its defined and documented system objectives given current changes in agency and program direction.

Phoenix's strategic view was long term, including all 17 phases of ITS deployment in the metro Phoenix region, and its transition to a statewide center. Much of the early planning in Phoenix, as at several other TMCs, had been established in its feasibility study and functional design documents.

Planning provided a strong sense of direction for all TMCs, but was more effective when backed up by ongoing performance analysis and process improvement. Both Toronto and Atlanta performed benefits analysis studies. In addition, Atlanta had a vigorous program of monitoring and evaluating responsiveness to traveler calls. Several of the eight TMCs evaluated their performance after large or unusual incidents, seeking ways to improve. Most of the newer systems provided fully automated logging of data, status, and actions, making such analysis possible. Phoenix performs ongoing analysis of advanced traffic management system collected data, examines operations performance, and identifies areas for improving the region's overall traffic conditions.

System Design and Implementation

General

Most TMCs have found that, once they are operational, public and agency expectations for their assistance build rapidly. One effect of this demand is that most TMCs implement computer systems that have significant redundancy so that they remain operational even if the primary computer fails. Boston, whose computer provides life-critical (pumping, ventilation, fire control) as well as traffic management functions, has implemented a triple-redundant computer system. Although this level of redundancy is unnecessary at most TMCs, other TMCs such as Houston and Atlanta have seen value in implementing computer systems with increased reliability. Two approaches followed have included "high-availability" processing with a hot backup system, where loss of a single processor does not disable the entire system, and distributed processing where functions from a malfunctioning processor can be redistributed to other processors within the system.

As discussed earlier, the primary purpose of developing a concept of operations is so that the system will match the users' operational needs. An additional tool used in Houston to ensure this match was to create a simulator during system development. As Houston's system was developed, the simulator allowed Houston's operations personnel to verify that the system's "look and feel" matched their concept of how transportation would be managed at their TMC. Houston's developer was able to test concepts within the system design at a relatively low cost—before significant investment was made in fully coding system functions and building an elaborate user interface. Phoenix required its system developer to provide the computer-aided software engineering tools that had been used in developing its system and to support long-term system documentation and improvement.

A complementary development technique is to create a database of traffic data for testing new or revised system functions or releases, as Houston, Milwaukee, and Phoenix did.

Training and Documentation

When TMC operations staff members are hired, bringing them up to speed and keeping them informed of proper procedures is critical for ensuring successful operations. Several of the TMCs had developed and refined their operations procedures. The study team reviewed those from Boston, Toronto, and Atlanta in detail as examples. Innovative training and documentation procedures observed include Boston's plans for online procedures, Toronto's "functionally" oriented help function, and Atlanta's use of hypertext in help and training materials.

Boston—due to the constantly changing condition of its road network because of the construction of the Central Artery/ Tunnel—has a program of continually updating its procedures. Toronto has reorganized its operations department to include an individual assigned to maintain and update its procedures, and Atlanta has created a training and documentation staff within its operations department. Atlanta has also created a position in its ITS organization for document control.

Sample Control Center Documentation

Toronto	Atlanta
Standard Operating Procedures	Standard Operating Procedures
Patrol List	Incident Management Handbook
Tech and Electrical Binder	MOVER Manual
Nuclear Emergency/ Provincial Emergency Manual	Equipment Manual
Schematic Drawings	Location Guide
Emergency Telephone Numbers	ATMS User Guide
Construction Contract Listings	Signals Listing
Driver and Vehicle System Binder	TMC Equipment Guide
Service Crew Binder	Operations Supervisor Guide
Burlington Emergency Contacts	Information Directory (Points of Contact)
QEW Schematic Drawings	

Because of the frequent change of its procedures, Boston has implemented desktop rehearsal and new and altered procedure simulations to ensure operational readiness. Atlanta periodically assigns its operators to accompany the services they support and interact with, such as the motorist assistance patrol.

Atlanta's training program offers examples of several valuable practices. Atlanta has established a training unit in its planning department, which prepares operations procedures. New operators begin with a 2-week formal training program on the operator console and software and progress to 3 to 4 days each of training on various duties, procedures, and response plans. New hires are provided tours of the project area to gain familiarity with the road network and device locations. They also ride with the motorist assistance patrol during their new hire training.

Milwaukee recognized the need for a different orientation in the training of its law enforcement partner and has developed a customized training manual for its use. Milwaukee has provided a system workstation at the law enforcement dispatch site and has received positive feedback from the law enforcement dispatchers regarding this access.

Incident/Congestion Detection Methods

Boston	Toronto	Long Island	Detroit	Milwaukee	Atlanta	Phoenix	Houston
Loops	Loops	Loops	Loops	Loops	Loops	Loops	Loops
CCTV	CCTV	CCTV	CCTV	Radar	Radar	PAD	CCTV
MAP	Police	MAP	Police	CCTV	VIDS	CCTV	Police
Scanner	Motorist Calls		MAP	Police	CCTV	MAP	Buses
					MAP	Police	MAP
					*DOT Calls		Probes
					Other Agencies		
					Police		

CCTV—Closed-Circuit Television
MAP—Motorist Assistance Patrol
PAD—Passive Acoustic Detector
VIDS—Video Imaging Detectioon System

Successful Practices

System Operations

General

The study team noted many excellent practices in the regular operation of TMCs. Both Detroit and Milwaukee were able to streamline their incident detection by leveraging the information from cellular 911 calls received by law enforcement agencies that were located in their control rooms. To monitor roadways under construction and gain an effective picture of the subsequent traffic disruption, Milwaukee used relocatable detection equipment. Houston exploited its existing toll tag population, using vehicles as probes and extending its detection network far beyond the instrumented area.

Several TMCs have begun implementing travel time or congestion-level messages as defaults on their variable message signs during peak periods. Toronto, whose initial goal was flow balancing, pioneered the use of congestion-level messages. Atlanta and Milwaukee now display travel times or time ranges on their variable message signs. Although there are multiple methods for travel time calculation and varying opinions on their accuracy, no TMC that posts travel times had received negative feedback regarding the posted times or criticism for investing in expensive but unused assets.

As with the volumes of valuable traffic data that TMC systems generate, TMCs are also realizing the value of videotaping traffic patterns for traffic studies.

Phoenix and Toronto have supplemented the typical traffic information available to their TMC operators with information from their road weather information systems (RWIS) devices. Typically, this information is available via a separate terminal, but it can be very useful in developing the optimal traveler information strategy.

The study team noted several innovative shift change procedures, such as Milwaukee's "shift transfer function" within its advanced traffic management system, which transfers full history and control of all open incidents assigned to a departing operator to his or her replacement for the next shift. Most TMCs organized their operations shifts to overlap 15 to 30 minutes, with possibly greater overlap for shift leads and supervisors. In Boston, "pass down," "shift change," and "close out" logs provided incoming TMC operators with a clear picture of what activity had occurred, what was under way, and what had changed in the system. To support operations both during and across shifts, several TMC systems had operator "reminder" functions, ensuring that variable message sign messages did not remain in place longer than was needed.

Staffing

One of the most difficult components of TMC operations and maintenance is staffing. Detroit, having lost approval for its full-time operations positions, has revised its operations to run with temporary personnel. Detroit operations are being privatized. Supplementing its two full-time operators, Milwaukee employs college students in operations. Milwaukee is also contracting for maintenance support. Long Island has a history of successful operations contracting and is considering how this support can be extended to an integrated operations and maintenance contract.

TMC Staffing

	Boston	Toronto	Long Island	Detroit	Milwaukee	Atlanta	Phoenix	Houston
Centerline Miles	7.5	60	165	180	63	220	254	122
Number of Operator Positions	10	9	5	6	3	12	6	18
Number of Prime Shift Operators	3+	3+	5	4	2+	5	2	12
Total Operations Staff	10	12	12	9	5	18	8	19
Number of Operation Staff Levels	3	3	2	2	1	1	2	1
Operations Staff Source	MassPike as Contractor	Agency Staff (FT and PT)	Contractor Personnel	Temporary Part-time	Staff, Students	Staff, Students	Agency Staff	Agency Staff
Number of Shifts	3	3	3	2	2	3	3	3
Backup Operations Staff Resources	Supervision, Off-shift, Overtime	Supervision, Off-shift	Contractor Responsibility	Supervision, Off-shift	Supervision, Professional Staff, Off-shift, Students	Supervision, Professional Staff, Off-shift, Students	Supervision, Off-shift	Varies by Agency

Hiring Sources for TMC Operations Personnel

Community Colleges
Postings within Agency
Agency Surplus Personnel

Common Backgrounds for TMC Operations Personnel

Traffic Equipment Maintenance
Air Traffic Controllers
Radio Operators
Clerical/Administrative Personnel
Students
Dispatchers

The Massachusetts Highway Department has contracted Boston's operations and maintenance to another agency, the Massachusetts Turnpike Authority. Toronto has contracted for overall preventive maintenance and total maintenance of its variable message signs and its fiber optic communications network. Atlanta has contracted for its variable message signs preventive maintenance program.

Hiring and retaining operations and maintenance personnel is yet another challenge. Long Island, leveraging its location near three major airports, has had success hiring former air traffic controllers as its operators. In Toronto, several radio operators, either from within the agency or from outside, have served as operations staff. Toronto has also had great success hiring graduates from a local 2-year academic institution that features traffic courses. Both Toronto and Atlanta have developed meaningful operator career paths. For example, two Toronto operators have progressed into operations management. Atlanta bases operator pay increases on measured workload and performance.

TMC Participants

	Boston	Toronto	Long Island	Detroit	Milwaukee	Atlanta	Phoenix	Houston
Functions in Control Room	Traffic Operations, Tunnel Control	Traffic Operations, Vehicle Information	Traffic Operations, MAP, Traveler Information	Traffic Operations, MAP	Traffic Operations	Traffic Operations, MAP, Traveler Information, Broadcast	Traffic Operations, Incident Teams, Broadcast	Traffic Operations, Transit Dispatch, Law Enforcement, MAP, Broadcast
Other Functions in TMC	Various (Major Office Building)	Planning, Design, Training, Maintenance, Various (Agency Office Building)	N/A (State Office Building)	Design	Planning, Design, Inspection, Outreach	Planning, Design, Training, Senior Management, HOV & CVO Enforcement, Outreach	Design, Analysis	Projects, Design, Special Events, Emergency Operations, Outreach
Agencies in TMC	MHD, MassPike	MTO	NYSDOT, Contractor	MDOT, Mich. State Patrol	WisDOT	GDOT (Multiple Functions)	ADOT, Arizona State Patrol	TxDOT, Metro Transit, City, County
Approx. TMC Area	5000 sq. ft.	2500 sq. ft.	3000 sq. ft.	14,000 sq. ft.	6500 sq. ft.	73500 sq. ft.	18000 sq. ft.	54000 sq. ft.
Control Room Size	2400 sq. ft.	1800 sq. ft.	625 sq. ft.	3,600 sq. ft.	600 sq. ft.	1300 sq. ft.	2400 sq. ft.	3600 sq. ft.
Number of Operator Positions	10	9	5	6	3	12	6	18

SCADA—System Control and Data Acquisition
CVO—Commercial Vehicle Operations
HOV—High Occupancy Vehicle
MAP—Motorist Assistance Patrol
MHD—Massachusetts Highway Department
MTO—Ministry of Transportation of Ontario

Coordination—Interagency Interaction

Interaction with partner agencies in the incident management process is one of the most important and complex components of TMC operations. The study team observed a wide range of techniques used for this interaction. Both Detroit and Milwaukee had law enforcement officers onsite at their TMCs, with Detroit cohabiting the control room with Michigan State Police dispatchers, and Milwaukee having a dedicated, captain-level liaison on site from the Milwaukee County Sheriff's department. When the captain was attending other duties, a Sheriff's department radio, tuned to the appropriate traffic frequency, remained in operation in Milwaukee's control room. Houston hosts officers from both Houston Metro and Harris County in its control room, and Atlanta has a full-time control room console position for a Georgia Department of Transportation (GDOT) commercial vehicle operation (CVO) and high occupancy vehicle (HOV) enforcement officer. Atlanta noted that it regularly received calls from area law enforcement agencies requesting that it dispatch motorist assistance patrol vehicles to existing incident sites. Extending this relationship to the incident scene, Houston is investigating the feasibility of mobile command centers for incidents and special events, drawing on both military experience and more recent activity in work zone traffic management. Phoenix's ALERT incident site traffic management teams are an important component in scene management.

Because of the numerous agencies involved in transportation in their areas of coverage, Arizona (statewide), Long Island, and Atlanta (also statewide) face the greatest challenges when coordinating with multiple law enforcement units. This coordination is typically conducted via telephone, with either dedicated or "speed-dial" lines to the dispatch functions at the relevant agencies. Long Island also coordinates its efforts with a multitude of agencies because of the significant number of townships on the island.

Houston, given its complex multiagency, multifunction role, recognized the value of having a resource to facilitate its multifaceted activities. The Houston facilitator allows each agency to focus on its skills, resources, and primary purpose in any situation, resulting in faster consensus.

Several of the TMCs the study team visited were focal points for collecting and disseminating information regarding construction-related road closures. Milwaukee has the enviable position of having preapproval authority over all closures on its road network and for being the final authority on initiation of any road or lane closure. The Arizona Highway Closure Reporting System (HCRS) has been so successful that adjacent states have approached the Arizona Department of Transportation (ADOT) about expanding the system for multistate, regional application. Toronto has developed a low-workload system for capturing information about lane closures and faxing that information, regularly updated, to relevant agencies and other interested parties. Atlanta's system—featuring both the central GDOT TMC and traffic control centers (TCC) at the city, counties, and outlying areas in which traffic management is being implemented—shares all such information over the distributed network, allowing partner agencies full access to the closure information in the system.

Interagency coordination is also critical for special event planning. Detroit has implemented procedures to coordinate with its large downtown parking facilities when major events, such as the Society of Automotive Engineers (SAE) annual meeting, which draws 50,000 to 75,000 people to the downtown Cobo Hall occur. Houston monitors parking availability during similar large events. Houston has on-site Houston Metro officers who perform detailed special event planning, and who participate in event execution and coordination. Houston Metro estimated that the Houston TMC manages one special event per week, including some that involve the planned presence of livestock on the roads, and others that may last for several days. Atlanta, supplementing the information it receives from its existing agency relationships, monitors numerous commercial Web sites to ensure it is aware of upcoming activities in the metropolitan area that could affect traffic flow.

Emergency operations are a form of special event that stresses TMC resources. Recently created TMCs had uninterruptible power supplies and diesel generators to ensure their system operations during crises, and several had incorporated shower and locker facilities for personnel assigned to long-term duties. Atlanta had incorporated overnight facilities for personnel in these situations. Houston's emergency operations center is located within the TMC. Houston officials were enthusiastic about the effectiveness of collocating the emergency

TMC Support Facilities

	Boston	Toronto	Long Island	Detroit	Milwaukee	Atlanta	Phoenix	Houston
Uninterruptible Power Supply	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Diesel Generator	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Lockers/Showers	Yes	Yes	No	No	Proposed	Yes	Yes	Yes
Overnight Facilities	No	No	No	No	No	Yes	No	No
Garage	Yes	No	Yes	No	No	Yes	No	No
Dock	No	Yes	Yes	No	No	Yes	No	Yes
Lab/Testbed	Yes	Nearby	No	Nearby	Proposed	Nearby	Yes	Yes
Maintenance Shop	Yes	Nearby	No	Nearby	Nearby	Yes	Yes	Nearby
Fitness Center	No	Yes	No	No	No	No	No	No

operations center and TMC, citing outstanding cooperation and coordination during emergency operations. Toronto has prepared an area adjoining its TMC control room for emergency operations, and Atlanta's TMC is located adjacent to the Georgia emergency operations center.

Toronto noted the importance of reaching consensus with other regional agencies regarding which variable message signs messaging protocols to follow. With highly interdependent freeway, tollroad, and surface street networks, inconsistent message meanings and message-posting procedures among the three organizations involved could create considerable traveler confusion in an already traffic-challenged environment.

University relationships have benefited almost every TMC. Houston has extensively used the Texas Transportation Institute to fulfill research, design, development, operations, and maintenance roles. Milwaukee draws on its two local universities for operations personnel and for students to work on special projects such as improving documentation. Atlanta has used student support to develop its advanced Help function. Phoenix has benefited from using students to conduct both research and Web development.

Coordination with wrecker services is a regular activity for many TMCs. In many cases, wrecker services are contracted for specified areas, and standard practices are established for interaction. The Houston area is supported by an alliance of wrecker companies, working from a common dispatch center. The alliance is presently discussing relocating its dispatch function to a location within the TMC to further improve coordination.

Coordination—Intra-agency Interaction

Although intra-agency interaction is intuitively easier than interagency interaction, it can often be equally complex. Intra-agency coordination typically involves interaction among planning, design, construction, and inspection operations, and maintenance functions within the Department of Transportation (DOT). Effective intra-agency coordination can significantly improve the efficiency of the TMC and help support the DOT in its overall mission.

Similarly, understanding of the TMC's activity and experiences and access to the information it collects can be invaluable to the planning department in assessing future transportation needs and priorities, to the engineering department in designing similar systems for other parts of the state, to administrative departments in determining needs for institutional (procurement, contracting, human resource) reform, and to the maintenance department in planning its staffing and logistics programs.

Milwaukee and Atlanta have taken a direct approach to their TMC intra-agency coordination. Both collocate their planning, design, inspection, and operations under a single TMC organizational unit. For most TMCs, maintenance is located in a separate facility in the metropolitan area and typically reports to the DOT district office, rather than to the ITS unit. On Long Island and in Milwaukee, the operations and maintenance departments are actively involved in system implementation and acceptance. In Houston, extensive daily interaction occurs—by phone, radio, and e-mail—between operations and maintenance regarding equipment status. Phoenix maintains contact with ADOT maintenance statewide through its radio system (in the control room) and via pagers. Also in Phoenix, operations, maintenance, and systems supervisors maintain a joint list of desired system improvements. In Milwaukee, both operations and management personnel can access the advanced traffic management system remotely via a dial-up connection.

Maintenance Staffing

	Boston	Toronto	Long Island	Detroit	Milwaukee	Atlanta	Phoenix	Houston
Number of Maintenance Staff	N/A	3+	N/A	3	3	*	3+	3+
Organization Responsible for Maintenance	Installation Contractor	Agency, Contractors	Maintenance Contractor	Agency District Office	Agency District Office, Communication Contractor, Maintenance Contractors	Agency, System Manager, PM Contractor	Agency District Office TMC Systems Team	Agency District Office
Special Maintenance Elements	None	None	None	None	Information Technology Specialist	Information Technology Team	Systems Team	None
Number of Centerline Miles	7.5	60	165	180	63	220	254	122
Types of Field Equipment	SCADA, VMS, Loops, CCTV, Gates, Overheight, FO Network, AM/FM Rebroadcast	VMS, Loops, CCTV, FO Network, Ramp Meters, RWIS	VMS, Loops, CCTV, Coax Network, Ramp Meters, Traffic Signals	VMS, Loops, CCTV, Coax & FO & Microwave Network, HAR, Ramp Meters	VMS, Loops, Microwave Detectors, AVC, CCTV, Ramp & Freeway Meters, HAR, RWIS	VMS, Loops, Radar, VIDS, CCTV, FO Network, Ramp Meters	VMS, Loops, PAD, CCTV, FO Network, RWIS	VMS, LCS, Loops, CCTV, Gates, FO Network, Ramp Meters

* TMC maintenance is not clearly separable from other maintenance functions.

AVC—Automated Vehicle Classification
CCTV—Closed Circuit Television
FO—Field Office
HAR—Highway Advisory Radio
LCS—Lane Control Signal
PAD—Passive Acoustic Detector
PM—Preventative Maintenence
RWIS—Road Weather Information System
SCADA—System Control and Data Acquisition
VMS—Variable Message Sign
VIDS—Video Imaging Detection System

Transit integration with TMC operation varies widely, driven by both ability and need. Many transit agencies' fleets operate almost totally on signalized roadways, which were not the focus of the eight TMCs studied for this report. In such situations, the need and financial justification for extensive integration is not great, although travelers may be interested in seeing both traffic and transit information while making their mode choice. In situations where the transit fleet depends upon the roads managed by the TMC, such as for express and circulator routes, the value and extent of integration can be significant. Similarly, in situations where the TMC's detection and surveillance networks are limited, information from AVL and operators on buses serving as traffic probes can significantly expand the traffic network information available to the TMC.

Centralized integration typically features transit personnel in the TMC control room. In such cases, often other transit functions, such as bus dispatch, are also migrated to the TMC. Decentralized integration is also possible, through extensive electronic sharing of voice, data, video, and control capability over communications lines between the TMC and transit control centers.

Coordination—Media Interface

Positive TMC interaction with the media can greatly benefit the TMC's mission. Although TMCs are not necessarily designed for such a public relations role, they often become the focus of outreach to the public, to the media, and to the professional transportation community. Although the study team did not focus on this area, several findings of interest were discovered.

Milwaukee, Houston, and Atlanta have outreach staff on site, facilitating their relationship with the media and expanding their ability to broaden understanding of their advanced traffic management system and purpose by the traveling public and key decision makers. Atlanta has initiated direct public outreach efforts through billboards and bus advertisements and regularly leverages the extremely positive image of its motorist assistance patrol program to build support for the state's ITS activities. Atlanta also features preinstalled media hookups and a dedicated media broadcast area. The Phoenix control room hosts a local broadcaster during peak periods, as does Long Island when the broadcaster is available. Toronto, pressed to reduce its operational costs, requires media to pay a subscription fee to access its video feeds, for which media equipment has been placed on site. In both Atlanta and Milwaukee, the media were required to pay for the acquisition and installation of the equipment the media needed to access their computer and video feeds.

Media Interface Examples

	Toronto	Long Island	Detroit	Milwaukee	Atlanta	Phoenix	Houston
Number of Outreach Personnel in TMC	0	0	0	1+	2	0	1
Media Accommodations in TMC	None	None	Being Privatized	None	Broadcast Booth	Broadcast Position	Broadcast Booth/office
Media Agencies On site	None	Metro	Being Privatized	Metro in Building	Radio	Metro	Metro (Designated ISP)
Information Sharing Methods	Faxes to Media Video Feed Subscriptions	Phone to Media Media Visits 1-800 Roadwork Telephone Info & Video to Cable Weather & Traffic Channel Road Closure Faxes Travel Delay & Accident Info Faxes	Incident Report Faxes Road Closure Faxes	Video Feeds Data Stream Road Closure Faxes Data Feed to GCM CTIC	Website Calls to/from Media Calls to TV Stations Press Releases	Website Video Feeds Traveler Telephone Kiosks Onboard Navigation Bulletin Board System	Website

CTIC—Corridorwide Traveler Information Center
ISP—Information Service Provider
GCM—Gary, Chicago, Milwaukee

Successful Practices

System Maintenance

Configuration management is a process of documenting and keeping current key information (manufacturer, model, serial number, software version, date installed, etc.) for all hardware and software. Specific settings for devices and changes to the installation such as software upgrades or modifications are also recorded.

Configuration management of systems was a challenge for almost every TMC. Few TMCs had prepared a configuration management database or had implemented such systems at the TMC's inception, but each cited the need for a configuration management database when operations and maintenance began. Atlanta recently staffed two full-time positions for configuration management and has a 100 percent configuration review of its software under way. Toronto also created and maintains a configuration management database, and Boston has integrated its baseline configuration management database with an automated maintenance management tool. Phoenix—in an innovative way to address the challenge of its changing configurations—recently renewed the multiyear purchase agreement with its preferred variable message signs vendor, providing Phoenix total control over the proliferation of brands and models of variable message signs installed in its system.

Most TMC systems automatically detected and reported some device and communication failures, although communication limitations that decreased the polling rate to field equipment could limit the effectiveness. Typically, device failures were displayed by changes in color of the relevant icons on the system map. Atlanta had implemented a system of alarms based on device failure, but found that alarm overload was a major operator workload challenge. Atlanta also found that camera failures could be identified by its Web-based image capture program. Long Island's system provided a menu function that allowed for a full listing of equipment status.

Preventive maintenance was an equally active area for TMCs, both for those newly created and for those experiencing the challenges of maintaining legacy equipment. Phoenix and Boston have both implemented impressive preventative maintenance programs, while Atlanta has contracted for preventative maintenance of its variable message signs. Phoenix has developed special repair techniques to economically manage ongoing maintenance problems such as damage from gun shot. Phoenix has performed a logistics analysis to determine appropriate spares levels and how spares should be divided between piece parts and complete units. Phoenix has also recently completed a study of the 15-year expected cost of maintenance, providing a basis for planning, budgeting, and staffing. Phoenix is planning a similar analysis on distribution of spares statewide as it becomes responsible for additional field equipment at significant distances from Phoenix. To avoid problems with repairing their legacy equipment, both Toronto and Milwaukee implemented planned system upgrades, while Michigan and Long Island were examining methods to continue support for their legacy equipment.

The TMCs the study team investigated were all forthcoming about the challenges they had faced during the planning, implementation, and operations and maintenance of their systems. To most freely express this valuable information, lessons learned are not attributed to specific TMCs or agencies, and neither firms nor products are named.

Lessons Learned

Background

Planning

TMCs noted several important lessons learned for planning, including—

- Early and strong Metropolitan Planning Organization (MPO) support for the TMC concept in the region helped provide a good foundation for advancing a TMC system and traffic management concepts for many years. Gaining such support also helped define, for those responsible for examining the long-term transportation situation, the regional needs the TMC would meet.
- The TMCs stated that the implementing agency must predetermine (in a feasibility study or conceptual design study) the purpose of the TMC and then ensure that the Advanced Traffic Management System would support that purpose effectively. A system design that did not address and support the specific, known transportation needs of the region (and did not support the involved agencies' long-term transportation strategy) could result in negative public and political reaction and many challenging years of ITS program management.

System Design and Implementation

General System Design Parameters—Control Center Design

Regarding design factors that influence long-term control center operations and maintenance, various lessons emerged, including—

- Most control center locations provided easy access to the interstate network for which they were responsible, but two centers were located where downtown street networks hindered quick access to the highway network. These centers noted the value of easy, convenient access for both passenger vehicles and for larger, more unwieldy maintenance and construction vehicles that close proximity to a highway would provide.
- A common theme TMCs expressed was the need for adequate room, including the value of having a facility that could be expanded as space needs increased. Most TMCs soon discovered that when their site was operational, an ongoing stream of agencies and functions found it beneficial to locate within their TMC.
- In multiagency circumstances, one TMC noted the importance of each agency having some "home turf" in the TMC, in which it could comfortably address sensitive internal issues, away from other TMC residents.
- There was general agreement that providing dedicated space to media within the center (typically in or adjoining the control room) supported an effective (and less disruptive) media relationship, and built positively on the TMC's outreach program.
- Levels of security varied widely—from one control center that had adopted a policy of complete and free accessibility (except for the control room) to another where "swipe cards" were needed for every room, stairwell, and elevator.
- Security needs appeared to be driven by the TMC's location (i.e., neighborhood) and by the services provided in the TMC.
- The presence of law enforcement officers in the TMC provided a boost to the security level at those centers with such arrangements.
- A common challenge in control rooms was managing the level of noise, particularly when radios and scanners were being used, including locations where the control center received incoming calls such as cellular 911 or "*DOT." Generally, control centers found that some operators preferred headsets, while others preferred handsets to communicate with outside organizations.
- "Communication by overhearing" also worked effectively at some centers. Only in the largest (or most noisy) control centers were intercoms between console positions needed.

- Those TMCs that hosted both traffic management and emergency management capabilities noted that the TMC needed to be properly configured and outfitted for that mission. Appropriate requirements typically included adequate sizing of backup power units, communications connections, and accommodations for personnel working around the clock.
- Especially for those TMCs where multiple elements of the ITS program (planning, design, construction/inspection, operations, maintenance) were colocated, there was significant value gained by designing laboratory and testing facilities into the TMC. Such facilities supported evaluation of new equipment, testing and calibration of new and repaired units, and debugging of interfaces between the equipment and computer and communications systems.

General System Design Parameters—System Design

The TMCs surveyed in this study offered several lessons learned in the design of traffic management systems, including—

- Most TMCs stated they were developing methods for managing workstation "image overload," a condition where the amount of detail on the workstation reached an unproductive level. It was stated that the occurrence of such situations were likely to increase as TMCs became responsible for increasingly large geographic areas. Conveniently controlling the view (most often through a map) of the program area would be essential to effective operation.
- Unstable video cameras created distracting "shaking" images that were insufficient to support incident investigation. Latency in camera actuation was similarly distracting to operators and also negatively affected operational efficiency.
- Widely spaced detector stations were significantly less effective for incident detection.
- The inability to view variable message signs (to verify message status) from cameras was an impediment to both operations and maintenance.
- Both effective video camera placement to provide useful coverage of the road network and adequate magnification were required to gain a sufficient return on the video system investment.
- An adequate networkwide communication capacity was necessary to maintain regular contact with field devices.
- Placing cameras on both arterials and freeways was valuable, even if the agency was responsible only for managing traffic on freeways.
- There was a loss of effectiveness noted from the incomplete integration of management of freeways and surface streets, and from the management of an incomplete highway network.
- Video images displayed on video monitors, rather than shown on a computer screen, was preferred. Using two computer monitors for each computer workstation rather than one per operator was also favored.
- Large systems in particular were transitioning from video monitor walls with dozens of images to fewer, larger projection units that offered only needed video and computer images in varying sizes.

Method of System Implementation—Procurement

Effective management is key to acquiring the right facility, systems, and services at a reasonable price. The TMCs visited shared various experiences in ITS procurement, including—

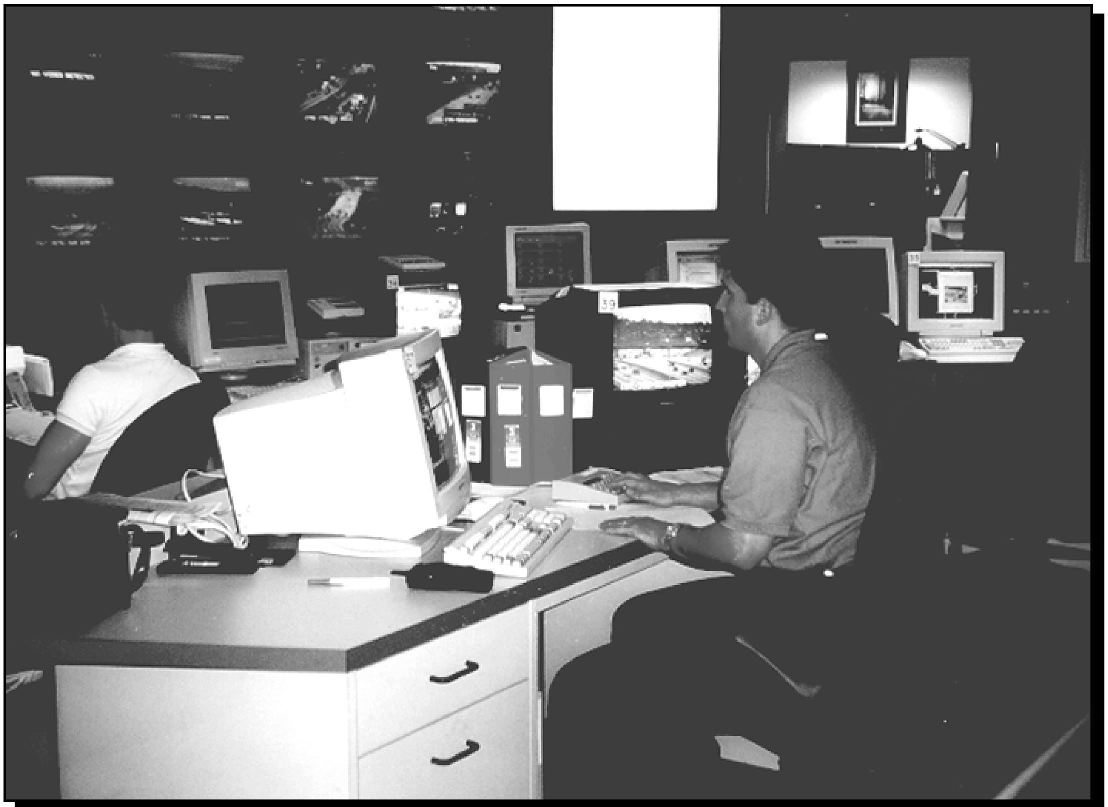
- An important lesson learned in TMC procurement was that TMCs were unique facilities, and that architects and engineers who were unfamiliar with the particular aspects of TMCs, with how they were used, and with the devices and systems they contained would often make design errors, resulting in either operational difficulties or requiring expensive rework after the TMC was completed.
- Several TMCs reported negative experiences when software was developed at a remote off-site location rather than local to the TMC, but at least one TMC attributed its significant expense and difficulties to its local developer's lack of software development experience when the TMC required that its software be developed locally.
- One TMC described how important it was to have an independent "second technical opinion," allowing the TMC to avoid total dependence on the primary design or development consultant's opinion. Another TMC seconded that point, and added it had had significant success hiring specialist consultants for particularly complex areas such as fiber optic network design and geographic information systems. A third TMC added that it had found significant utility in hiring an independent inspection consultant who had previous ITS implementation experience.
- Two TMCs warned against accepting software that was less than satisfactory from the developer, thus losing leverage over the developer in resolving problems that would eventually plague operations and maintenance.
- Although customized commercial off-the-shelf software was viewed by some TMCs as a panacea, one TMC warned against assuming that accepting such a solution was faster, more reliable, or less costly than a more purpose-build system.
- Regarding contracting, one TMC warned that TMCs—if they fully understood what was needed—should buy their own hardware directly rather than through contractors or consultants to reduce cost, simplify warranty and maintenance management, and ease the process of replacing obsolete equipment.

- One TMC, whose system had been built within significant time constraints by several contractors, noted the complexity of wide-scale integration of installations by multiple low-bid contractors. Another TMC commented that integration must be planned for—in budgets and in the implementation schedule—and that appropriate expertise (procured in an appropriate manner) must be retained if integration was to be successful.
- Yet another TMC discussed both the perils of having a general, non-ITS, contractor as the prime contractor in a systems contract and the inevitability of cost growth in a fixed-price, low-bid environment.
- TMCs essentially recognized the need for operations and maintenance to be involved in the request for proposal (RFP) development and design process.
- One TMC, involved in contracting for operations and maintenance, detailed how important it was to carefully and completely specify which services would be provided by the privatizer when privatization was being considered.
- One TMC shared its difficult experience in procuring key products and services as items “subsidiary to the bid.” Placing no price or value on such items made it both difficult to ensure satisfaction and to change if the need should arise. Similar difficulties were experienced by one TMC that used very few bid items to procure its entire system.
- Mixing generic, performance, and detailed specifications in a single TMC acquisition led to difficulty in obtaining the desired flexibility while controlling the risk distribution within the project.

Training and Documentation

For operations, effective training and documentation ranked immediately behind hiring and staffing as critical priorities in ensuring effective operations. Some lessons noted included—

- Operations documentation that was not user-friendly hindered both the training of personnel and opportunities to ensure consistent, complete, quality operator performance.
- One TMC described its success in employing college students—under the guidance of an experienced senior operator—to develop additional procedural and system service material.
- Several TMCs mentioned the importance of specifying training for both systems and field equipment in the respective procurement documents.
- One TMC noted how important it was to specify the correct timing of training in field equipment procurement documents because training conducted too early or too late was of little value. The same TMC emphasized the importance of personnel receiving workable training materials with their initial training, so that personnel arriving later could come up to speed efficiently.
- One TMC noted that having an affordable tool that maintained thorough systems documentation as the advanced traffic management system software was modified was valuable. TMCs should also be aware of the ongoing need to update their design documents to reflect their systems' "as-installed" configuration. This need is supported by the TMCs receiving documentation electronically and in print from their software providers. A document development tool is equally valuable for supporting advanced traffic management system maintenance and improving TMC procedures as it is for basic systems documentation.
- Two sites mentioned the value of an effective online Help function, for both experienced and new operators.
- One site mentioned the importance of obtaining training in the operations and maintenance of special equipment within the TMC, such as the uninterruptible power supply (UPS), video switches, and the projection units.



System Operations

Workload and Performance—Staffing

The most difficult recurring challenges TMCs noted were related to operations and maintenance staffing.

- One TMC cited the importance of creating meaningful career paths within ITS for its operators, while another noted that agency policies, including unclear job descriptions, low pay rates, and stringent hiring qualifications, created major difficulties in hiring qualified operations personnel.
- One TMC's management believed it was critical to have correct and adequate staff immediately, rather than waiting for the advanced traffic management system to be completed and accepted.
- The same center that had had excellent results in hiring operators from a local community college's traffic program added that retired engineers made poor operators.

Workload and Performance—Workload

Two sites addressed operator workload issues.

- One TMC stated that it was easy to underestimate the operator workload from multiple tasks, particularly when such tasks were outside the traditional traffic management role.
- The other site discussed the significant workload that could result from manual logging, which it was addressing by investigating voice logging and use of automated recording of incident video.

Operations also provided several important lessons learned regarding its role within the traffic management process, including—

- TMCs that had begun interim, partial (or "beneficial use") operations before conducting final system testing and acceptance discovered such operations were frustrating. In addition, their contractors were concerned about the inefficient environment that such a practice created for testing and integration.
- TMCs cautioned against accepting software (either commercial off-the-shelf or software developed for another TMC) that had been inadequately customized to meet the individual TMC's unique operational needs.
- TMCs noted the operation of separate, unintegrated systems, i.e., legacy and new, was frustrating and inefficient.
- TMCs noted they received negative public reaction in response to an extended nonoperational period of variable message signs, primarily due to a misperception that the variable message signs were installed but not working.
- Many TMCs noted the value and importance of motorist assistance patrols to the overall incident and congestion management process.
- Several TMCs noted they received periodic calls from police officers at the scene of incidents requesting information about traffic conditions extending beyond their view of the incident scene. This information—which TMCs could often easily determine from the closed-circuit television cameras covering areas surrounding the incident—often helped the officer understand the extent of the queue behind the incident and the officer's alternatives for rerouting traffic at the head of the queue.

- Several TMCs noted the value—both in analyzing TMC performance and in identifying opportunities to improve traffic conditions—of having easy access to the traffic and activity information that the advanced traffic management system logged automatically. One TMC added that advanced traffic management system data should be retained for extended periods. That site had archived detailed traffic data on compact disks (CD)—one per month—since it opened, and another had had instances where 5 years of data were analyzed (to answer traffic flow questions that arose).
- Most TMCs did not plan how they would operate under emergency conditions or how they would manage the road network in emergencies. One site that had experienced an unusual weather emergency in the past year strongly urged that all TMCs plan for emergencies, and that those plans be revisited regularly. It was observed that TMCs where emergency conditions were more common might have multiple emergency scenarios (e.g., hurricane, refinery fire, flooding).
- Although tours were an important component of outreach to many audiences, several TMCs commented on the significant disruption from such visits. Often tours began before system acceptance and created disruption of not only agency activity but of the work being performed by the system integrator and testing teams.

Workload and Performance—Computer Systems

Issues TMCs noted regarding computer systems operations included—

- Requiring operators to enter address-based incident locations into the system was inefficient.
- Representing long-term construction lane closures as incidents within the system was inefficient. It was suggested that closures should be shown differently, perhaps as a separate icon color on the system map.
- Although the computer systems captured a great deal of information, that information was useful only if it was readily accessible, using retrieval and reporting tools that were convenient and easy to use.

Both operations and maintenance personnel recognized the significant value of effective automated detection and reporting of faults in field equipment by the central computer system.

Lessons Learned

Coordination

The study team identified several lessons learned for organizing effective TMC operations and maintenance, including—

- The most common problem TMCs cited was a lack of close coordination between operations and maintenance if the two were located in organizationally separate parts of an agency.
- At a fundamental level, agencies should carefully consider where the TMC belonged organizationally within the agency to work effectively, especially if the TMC was delivering statewide services. Decisions on where to place the TMC—as each department within the agency or district statewide would have differing overall goals and objectives, varying access to key resources, and distinct support from or access to key decision makers—could greatly influence the TMC's progress.

TMCs expressed the following differing opinions regarding the importance of a separate Information Technology team supporting their operations.

- One TMC cited a gulf between its information technology team and TMC operations, even though both belonged to the overall TMC organization.
- In another case, the TMC information technology team was hailed as the source of salvation in reducing system problems to a workable level and in gaining from systems consultants the functions that TMC operations desired, delivered in ways that TMC operations could easily use.

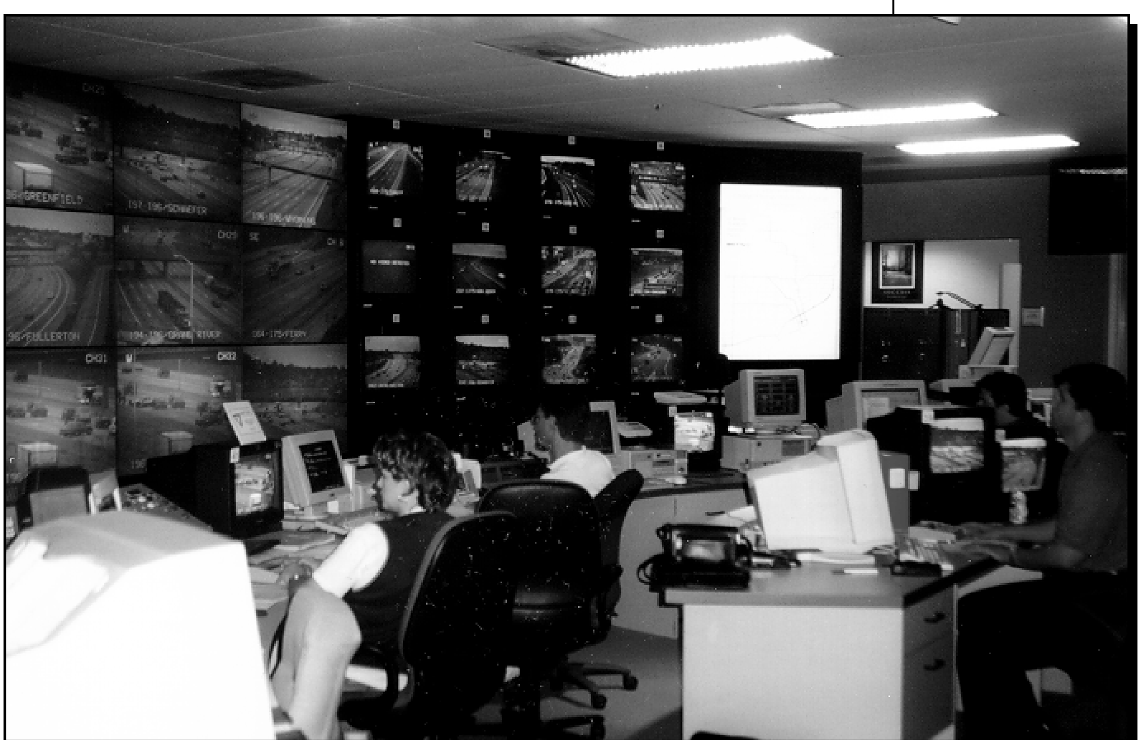
Lessons Learned

System Maintenance

Both TMC operations and maintenance offered lessons learned for maintaining ITS, including—

- A significant difference between services covered by "warranty" and "maintenance" existed, and TMCs should be quite clear which was desired before contracting for either. For example, warranties typically did not include repairs of damage from weather, vandalism, improper operation, or vehicle impact. The amount and type of preventive maintenance performed under a warranty was typically at the discretion of the warrantor. The type of service (return for repair vs. repair/replace in place) also varied depending on the specifics of the warranty contract.
- Many TMCs encountered significant difficulty in their attempts to obtain parts for legacy systems. Planned upgrade programs and development of workaround solutions could lead to significant savings and improve system reliability.
- Integrating the maintenance tracking system with the advanced traffic management system usually increased the efficiency of the interaction between operations and maintenance personnel in the identification and resolution of device failures, and in bringing devices back into use after repairs had been completed.
- Operations staff members frequently determined the status of field devices by referring to their workstations. In doing so, the best possible traffic management solution, given the available and operational field devices, was applied for each traffic situation.
- Both operations and maintenance experienced difficulty when using leading edge technology that was more difficult to update because it required specialized skills and was less stable and proven in traffic management applications.

- Several TMCs used or contracted their maintenance support. As with other types of contracting support, the TMCs had several lessons learned, including—
  - TMCs expressed the need to have contract support personnel located on site to gain the desired value from their efforts
  - Maintenance contracting by low bid with no prequalification was particularly perilous, because much was left to chance in acquiring an effective contractor. TMCs also noted how important it was to carefully specify all skills required because general contractor categories (such as electrical contractors) might not offer a full set of the needed skills (such as communications technology). One TMC was also specifying the types of equipment required for maintenance, having experienced situations where its contractor did not have appropriate bucket trucks to safely reach the installed equipment.
  - One site mentioned that it had to oversee the traffic control and safety practices of maintenance contractors to ensure that appropriate regulations and practices were followed.
  - One TMC received superior results in separating its maintenance contracts based on the type of device being maintained, with one contractor supporting variable message signs maintenance and the other supporting other devices.



Issues

A core set of issues challenged each TMC visited for the study. Each TMC was addressing its core issues, with different TMCs often applying different solutions. Because the common issues concern concepts that are critical to the future of all TMCs, they are highlighted as follows:

Issue 1: Ensuring an adequate staffing level and budget for TMC operations and maintenance.

Even for TMCs where adequate funding was provided, often agencies had adopted policies limiting the number of full-time agency personnel. Although many TMC functions could be performed by temporary or contractor personnel, most TMCs cited the need for a core set of agency personnel to lead, perform, or oversee the TMC's primary functions. Lack of adequate agency staff, in the appropriate classifications, and with the right skills, caused ongoing stress in achieving the TMC's goals and objectives. That issue was even more severe when the TMC was being pressured to reduce its cost and staffing, often while duties were being expanded, and when additional centerline miles of road network coverage by the advanced traffic management system were being implemented.

Issue 2: Losing qualified TMC maintenance personnel to the private sector.

This issue combines multiple challenges—noncompetitive pay rates, career progression, and limited training and skill opportunities. The maintenance skills a TMC requires of its personnel, particularly for computer systems and communications, are in high demand by the private sector (and in one case noted, by other local agencies). Effective TMC maintenance, including its field equipment, is critical for ensuring the TMC's ability to perform its duties and functions.

Issue 3: Addressing technological evolution and obsolescence.

The use of technology by the typical TMC requires skills from a significantly different paradigm than those required for implementing roadways. The usable lifetime of TMC technologies and their need for active maintenance differs greatly from traditional road infrastructure. For example, an agency would be considered foolish if it began replacing road surface a year or two after paving it, yet not replacing computer hardware frequently might condemn the TMC to extremely limited functionality, rapidly escalating cost, and increased difficulty in obtaining support and replacement parts.

Issue 4: Estimating the time it takes for a TMC to become operationally stable.

In many cases, it appeared that unrealistic expectations were set for the time frame necessary to proceed from TMC system design through implementation to stable operation. Most TMCs have since learned that their computer systems (even if designed, developed, and integrated by experienced integrators) will require continual fixes throughout the first few years after acceptance.

Issue 5: Mitigating false alarm rates.

Regardless of substantial progress in improving incident detection algorithms, most TMCs depended on other methods to detect incidents. Although the direct access of some TMCs to cellular 911 and incident reporting calls (i.e., DOT) mitigated the false alarm problems, not all TMCs had such access.

Future Directions

Based on discussions with TMC leaders during the study, several future directions for TMCs appeared to emerge as follows:

Direction 1: Fully integrated workstations.

Consistent with human factors research in similar areas, most TMCs wanted to monitor or control all their devices and information from a single workstation. Older, less integrated systems (such as those requiring multiple computers or control panels to fully investigate or respond to an incident) were commonly recognized as less productive and as requiring more maintenance.

Direction 2: On-site integration of agencies.

Opinion regarding the need for the physical presence of multiple agencies in a single TMC or whether multiple agencies interacting via a "virtual TMC" could achieve equivalent results varied significantly. However, the overall opinion appeared to be that when agencies worked together in the same physical facility, more was achieved.

Direction 3: Integration of freeway and arterial control.

During the survey, existing TMCs were increasingly recognizing that the full benefits of transportation management were achieved only when control of freeways and surface streets was performed in an integrated manner. Although integration typically required coordination across agency lines, performing integrated total network management was viewed as desirable by almost all TMCs. Based on existing experience, that integration would likely include placement of closed-circuit television and variable message signs on arterials and control of ramp metering and signal timing.

Direction 4: Integration of traffic management and transit.

TMCs, having made great strides in developing cooperative relationships between traffic management and law enforcement, noted the next major area offering great benefit would be a similar integration of traffic management with transit. Houston noted that, although no formal procedures existed for interaction between traffic operations and transit, much traffic information was passed back and forth between the TMC-based dispatchers and buses. Houston stated it would be investigating the possibility of information transfer between its computer-aided dispatch system and its advanced traffic management system.

Direction 5: Preventive and reactive traffic management.

Many TMCs reacted effectively to incidents or congestion that already existed. However, an increasing number of TMCs planned to provide information to motorists that would allow motorists to avoid anticipated problems and would help the TMCs balance the flow among the various available road network components. This goal would achieve even greater success if pursued in combination with Direction 4 by accomplishing mode shifts when known travel route and mode combinations were expected to be highly congested.

Direction 6: Increased operator support from the workstation.

Future workstations will be expected to provide increasingly integrated sources of support for existing TMC functions. TMC operators and leaders will also be expected to use single workstations that provide support for various other operator functions, such as report generation or assisting in equipment maintenance. The increased integration of operations and maintenance functions within a single workstation is a highly desired goal, even as the level of automation support to maintenance increases rapidly.

Direction 7: Contract or privatized operations and maintenance.

The desire for downsizing government is forcing TMCs to do more with less. TMCs, based on federal experience with successful service contracting (including many years of contracting for consulting services), are increasingly likely to hire contractors to provide most TMC operations and maintenance activity.

Conclusion

A TMC is a highly visible element of a transportation management strategy, and it is critical in generating successful results from the investment in public infrastructure. In this study, the Concept of Operations has been used as a tool to investigate the differences in approach between TMCs in the United States and Canada, and to gather and organize best practices, lessons learned, common issues, and future directions. The purpose of gathering and disseminating this information is to provide existing TMCs with ideas for improvement of their own operations and to provide agencies implementing new TMCs with input to their implementation process.

A comparison of the methods used in the eight TMCs that were examined shows that there are multiple effective approaches in the operation and management of the TMC and the resources under its control. This diversity of approach allows each TMC to address the specific transportation needs of its geographic area, applying the policies, procedures, and resources that are made available by its participating agencies. Although various challenges facing many of the TMCs are yet to be resolved, both policy and technology evolution will continue to offer opportunities for improvement of the TMC and its Intelligent Transportation Systems program.

A valuable reference in planning and executing operation and management of Intelligent Transportation Systems assets is the Institute of Transportation Engineers Recommended Practices for Operation and Management of Intelligent Transportation Systems which were completed in mid-1998. These practices were developed during a 3-year period by panels of Intelligent Transportation Systems practitioners. Although they have significantly broader applicability than only TMCs, the recommended practices were compared to the findings of this document to ensure that all relevant topics had been addressed.

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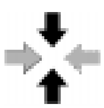

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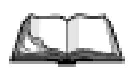

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"An agency that develops a concept of operations will find it much easier to clearly understand its operational issues. Staffing, education and training, information and control sharing, and the decision-making processes are important aspects that need to be addressed in TMC planning, implementation, and operation and management. Clearly identifying the agencies' needs and preferences in these areas before specifying a system will help build a well-defined system configuration, an effective user interface, and specific system parameters for the system designer and developer."

—Joe Stapleton, Assistant State Traffic Operations Engineer, Georgia Department of Transportation

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