270

National Cooperative Highway Research Program

NCHRP Synthesis 270

Transportation Management Center Functions

A Synthesis of Highway Practice

Transportation Research Board
National Research Council

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Synthesis of Highway Practice 270

Transportation Management Center Functions

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

Transportation management centers (TMCs), or traffic management centers, have become a vital part of the transportation fabric in many urban areas. This synthesis presents information on the current operational and technical practices used by highway, transit, and multimodal TMCs in several urbanized areas. It will be of interest to transportation system administrators, traffic engineers, maintenance engineers, and other officials in state departments of transportation, as well as those responsible for local transportation management and control. In addition, this synthesis will be useful to state and local law enforcement and emergency response personnel. It also provides information to developers and suppliers of hardware and software for traffic control technology and communications systems.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

This report of the Transportation Research Board describes the various types of TMCs, their functions, and details of design, operations, and staffing. It describes the practice of agencies in the United States and Canada, based on survey responses from 147 TMCs. These agencies are responsible for highways, surface streets, bridges and tunnels, transit, including bus and rail, and several integrated TMCs that include more than one mode. Design criteria describe in detail the physical facility design of TMCs, as well as the software configurations and the interrelationships among TMCs of various types. The required staffing and the personnel roles are highlighted. To the extent that data are available, ranges of costs and benefits for TMCs are included in the report.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the research in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

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TRANSPORTATION MANAGEMENT CENTER FUNCTIONS

SUMMARY

Regional transportation management is undergoing a technological metamorphosis. As new technologies and communications systems are introduced and installed, there is an increased need for operating agencies to reassess the facilities and methods used to manage these systems and the base transportation networks they serve. It is widely recognized that multiagency and multimodal transportation management centers (TMCs) or integrated networks of smaller management centers are required to efficiently manage regional transportation networks. Perhaps the most important aspects of the TMC are the incident management and enhanced customer service capabilities, whether controlled by a single agency or multiple agencies. Additionally, existing TMCs serve important roles in providing specialized management functions ranging from bus dispatch operations to signal control systems. Existing TMC system designs are in the process of being modified to include the requirements and protocols of evolving intelligent transportation system (ITS) architectures.

This synthesis of current practice examines the functions, characteristics, design criteria, and benefits of TMCs. In addition to a comprehensive literature review, a TMC functions survey was sent to a total of 190 agencies, authorities, and organizations: 52 state and Canadian provincial departments of transportation, 80 municipal and eight county transportation agencies, and 50 transportation authorities and commissions. State, Canadian provincial, municipal, or county agencies with multiple TMCs were requested to send a copy of the survey to a representative from each of their TMCs. Responses were received from 126 agencies for an overall response rate of 66 percent.

The synthesis analyzes seven types of TMCs: highway, surface street, bridge/tunnel, transit (bus), transit (light rail/subway), rail (commuter and intercity), and integrated. Integrated TMCs are defined as two or more types of TMCs and their corresponding functions that are located within the same facility. The primary categories of TMC characteristics include function, facility configuration, transportation system coverage, and institutional coordination and arrangements.

The TMC, in a simplistic sense, provides an informational flow process. Three basic functions define this flow for every TMC: information gathering, synthesis, and dissemination. The functions performed most frequently by all types of TMCs are emergency coordination, special event management, incident management, interagency information sharing, and surveillance.

The configuration of the TMC facility is properly designed through the identification and incorporation of operational and physical requirements for each operation. A relationship exists between the facility configuration and the function performed that is forged through the recognition and fulfillment of the spatial, equipment, and staffing requirements. A typical spatial layout of a TMC includes space for the control room, an equipment room, conference media rooms and visitor facilities, and office and personal facilities. Equipment requirements include computer servers and workstations, network connections, communications, printer display components, and software capabilities. The responsible agency generally provides dedicated personnel to staff the TMC. Depending on the functions performed and philosophy of the TMC, the staffing structure includes all employees,

from managers to student assistants, needed to support the functions of the TMC, including full-time, part-time, and temporary employees. Other staffing concerns involve training and coordination with emergency personnel. Common task requirements for all TMCs, regardless of their individual goals and objectives, are documentation, equipment tracking and performance, and reporting of progress.

The transportation system coverage defines the type of TMC and, to a larger extent, the functions performed. Typical transportation system coverage parameters include lane or centerline miles of roadway by type for highway and bridge/tunnel TMCs; number of intersections for surface street TMCs; bus route miles and track miles for transit TMCs.

Among the most important characteristics involving the organization of a TMC are those related to institutional coordination. Resolution of intrajurisdictional (where the TMC reports within the agency's hierarchy) and interjurisdictional (how the TMC is related to regional agencies' TMCs and the regional responsibilities) coordination issues leads to less confusion and more visibility among the agency's high-level decisionmakers.

According to leading freeway, incident management, and TMC experts, a variety of design criteria have been identified as vital components to address prior to, during, and after deployment. The design criteria evaluated in the synthesis include justification and feasibility, communication, staffing and hours of operation, operations and maintenance, costs, public relations and media involvement, information dissemination and sharing issues, resource sharing, liability and litigation, procurement procedures, and software issues.

Responsible agencies can anticipate numerous benefits from the operational and technological capabilities provided by the TMC. Some of the expected, or goal-oriented, benefits and the criteria used to evaluate them are common across all types of TMCs, while other benefits and evaluation criteria are TMC-specific. The expected benefits can be categorized into system related and institutional related benefits for each type of TMC. To capably measure the effectiveness of its TMC, agencies use an appropriate evaluation method. Expected benefits become realized when the evaluation criteria thresholds are met.

In the near future, it is likely that there will be greater use of regional TMCs. Newer and more regional TMCs will emphasize multijurisdictional and multimodal operations. This integrated approach is expected to result in further linking of TMCs in urban areas into more complex, hierarchical, and hybrid TMC communication architectures. The Model Deployment Initiative (MDI), established in 1996 by the United States Department of Transportation (USDOT), calls for the implementation of intelligent transportation infrastructure through the creation of innovative public-private partnerships in four urban areas throughout the country. The MDI uses advanced communication technologies and region-wide advanced traveler information system and advanced traffic management system capabilities to integrate a variety of its components, with the TMC as the focal point, in providing a seamless flow of multimodal travel information.

CHAPTER ONE

INTRODUCTION

BACKGROUND

A substantial increase in roadway congestion has occurred in past decades, creating challenges that are compounded by overburdened transit systems and limited land resources. Although government spending for transportation has increased, other societal demands have also increased. As a result, there is an increased competition for limited government dollars. While not a panacea for solving traffic congestion problems, the transportation management center (TMC) concept has become one of the major themes in the operations of streets, freeways, toll roads, railroads, and transit facilities. For many levels of government, TMCs act as a focal point in the deployment of the Intelligent Transportation System (ITS).

Agencies refer to their TMCs using a variety of terms depending on function. Frequently used variations in TMC nomenclature include: the transportation operations center (TOC), transportation information center (TIC), operations center (OC), and traffic management center (TMC). A TMC may be defined as a central facility that controls, monitors, and manages the surface street, highway, transit and bridge/tunnel control systems within its coverage area. To accomplish these tasks, the transportation management center aims to manage the operation of the transportation system by communicating travel condition information, making necessary modifications to traffic and transit control systems, and directing response activities.

Figure 1 shows a model for a simple TMC system. As shown, the information and data on the condition of the transportation system are collected by the TMC through various forms of communication, synthesized and analyzed within the TMC, and disseminated through various communication media. Although not shown in the model, the outgoing information may be disseminated to a variety of termini, including traffic or transit control systems, the commuting public, and involved organizations. A TMC may consist of a number of functions, and these will be noted later in the synthesis, however, one of the most important aspects of the TMC is its contribution to traffic and transit management, incident management, and emergency management.

Transportation management centers are generally concentrated in urbanized areas where there are traffic congestion problems and extensive transit services. Generally, a typical TMC consists of a central operations room, computer and communications circuit room or channel facility, maintenance room, and hardware components such as television screens, map displays, and computer workstations. What makes the deployment of the TMC concept unique is its ability to synthesize and communicate information on a real-time basis, which can result in the effective management of transportation facilities. Most of the information collected by the TMC ordinarily comes in the form of a variety of congestion or incident indicators and is updated on a real-time basis. Hence, without a TMC, response to an incident or information on the deterioration of traffic conditions would be severely delayed due to the time needed to acquire, understand, and disseminate the information. However, with the deployment of advanced field and central hardware equipment, skilled TMC personnel are able to synthesize and transmit information to end users. The TMC coordinates these activities for a quicker response to incidents and helps mitigate recurring peak travel conditions. Although this basic purpose is common to every TMC, the centers vary in nature and size. The three primary characteristics of a typical TMC are:

- Its role in the regional transportation management system and corresponding functions,
- The nature and extent of coverage, and
- The mode(s) of transportation under its control.

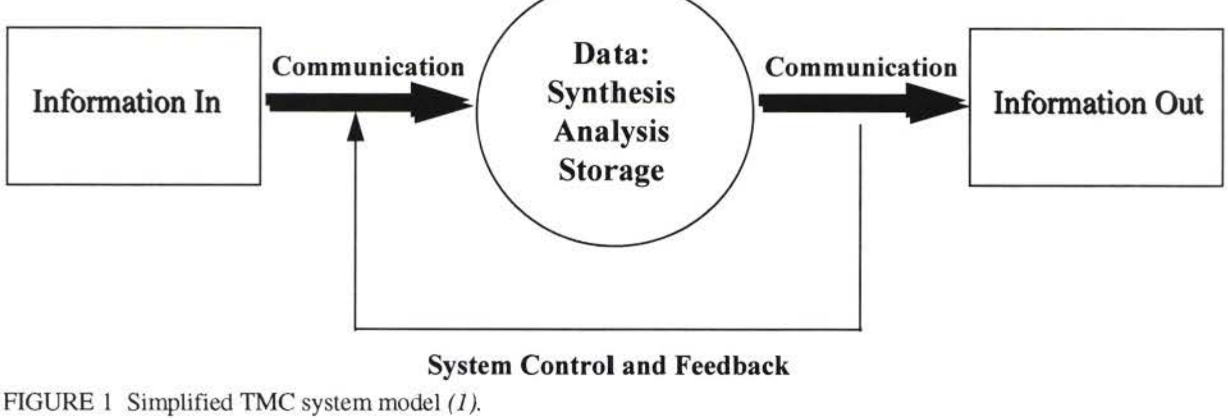

FIGURE 1 Simplified TMC system model *(1)*.

These primary characteristics are discussed in greater detail in chapter 2. The purpose of this synthesis is to examine the state of the practice in functions, characteristics, design criteria, and benefits of TMCs. This document contains information of value to agencies planning to develop new traffic management programs and to administrators with substantial traffic management programs and/or existing TMCs. Three efforts were undertaken to achieve the purpose of this synthesis:

- A search of literature related to transportation management centers was performed and a study of the pertinent resources was conducted.
- A questionnaire focusing on TMC characteristics, design criteria, and benefits was developed and mailed to selected state/provincial, municipal, and county agencies as well as transportation commissions, authorities, and agencies in the United States and Canada. The list of survey recipients was developed from a wide spectrum of agencies whose TMC characteristics vary according to function, geographic area, and mode type.
- A telephone survey focusing on TMC characteristics, functions, design criteria, and benefits was developed and used to profile a few selected highway and transit agencies.

The survey questionnaire was sent to one representative from each of the 50 state and two Canadian provincial departments of transportation, 80 municipal and eight county transportation agencies, and 50 transportation authorities and commissions for the purposes of gathering survey responses. Of the 190 surveys mailed to the transportation agencies, responses from 126 agencies were received, for an overall response rate of 66 percent. Agencies were asked to provide information on the functions for each of the TMCs in their jurisdiction. Additionally, the agencies were asked to provide copies of any supporting data, brochures, manuals, reports, photographs, TMC floor plans or organizational staffing charts. A breakdown of response percentages by type of agency is presented in Table 1.

TABLE 1

BREAKDOWN OF RESPONDENTS AND RESPONSE RATE BY AGENCY TYPE

Agency Type	Number of Respondents	Total Surveyed (%)
State and Canadian province	45	86.5
Municipal and County	50	56.8
Other	31	62.0
Total	126	66.3

A follow-up telephone survey of a number of candidate state/provincial, municipal, and county agencies, and other transportation authorities was an additional aspect of the information gathering effort. Various aspects of the characteristics, functions, design criteria, and benefits of the TMCs of candidate agencies were profiled. Each type of TMC was represented in the follow-up survey. This synthesis presents the results of the literature review and the two surveys by discussing, in chapter 1, the background of TMCs, a historical perspective, types, and system concept. Current practice with respect to TMC characteristics related to their function, physical configuration, transportation system, and institutional arrangements and coordination are described in chapter 2. Information on current practice related to design criteria is presented in chapter 3. Chapter 4 discusses the expected benefits of TMCs, and evaluation criteria for assessing them. Conclusions drawn from the study are presented in chapter 5.

Appendix A is the "TMC Functions" survey instrument and the questionnaire used for the follow-up telephone survey of selected agencies. Survey respondents are listed in Appendix B, which provides the tabular summation of the survey results, including how many agencies responded, the types of agencies, and the types of TMCs. Appendix C contains two TMC surveys conducted by the *Urban Transportation Monitor*, one published in 1995 and one in 1998. These two surveys differ both in terms of the respondents and of the questions asked. For example, respondents to the 1998 survey were asked what they would recommend other agencies consider when planning a new TMC. A dominant theme of the responses was that communication, both with other agencies and within the TMC is important, as are flexibility of both space design and operating capability. Appendix D contains a progress report for the INFORM system in Long Island, New York.

HISTORICAL PERSPECTIVE

Mankind has used some form of information, operation, or management center for managing and facilitating transportation movement throughout the ages. Information has always been a common factor in the evolution of transportation centers from earliest recorded history to the present. Hundreds of years ago, captains of ships used for exploration and in battle gathered information on other lands, foes, and the seas. The information was brought home upon completion of the quest and passed on to fellow seamen at their home port or to someone who was a gatherer of such information. At that time, the information was passed either through word of mouth or written manuscripts and charts. In the early times of rail freight, rail companies collected and used information they believed critical to the timely and safe delivery of cargo. It was important to the freight companies that their vehicles be tracked and be able to communicate with a central monitoring location. In their vision, use of a transportation center served to communicate information with the vehicle operator and track the locations of the freight vehicles so that expected arrival times could be estimated and delivery performance levels could be met. In both eras, a central location for information was needed so that it was possible to know when vehicles passed certain locations along their trip. As was evident in these earlier times, both the communication and use of information were static functions and the benefit of the information was useful only for future trips, rather than for the present one. Technology has allowed information gathering, usage, and communication to become dynamic. Dynamic travel information is useful in that it can allow both present and future users to manipulate, control, and modify their travel characteristics. In transportation, dynamic information functions have taken on real-time aspects, which permit data to be analyzed and communicated as they are collected.

As railroad and surface street signal systems moved toward the use of improved communications and computers, it became easier to control individual signals and network them into larger and more complex systems. Early transportation management center facilities served small networks of signalized surface streets, bridge and tunnel facilities, and short highway corridors. Their functions were to manage traffic signal systems with master controllers or a central computer that could communicate with the field-located master controller for signalized intersections. A number of agencies have had TMCs in place for many years. The TMC in the Chicago area for the Illinois Department of Transportation has been in existence since 1961 and has been performing real-time functions for many years. In New York City, a TMC for traffic management functions for 10,000 traffic signals has been in operation since 1967. Caltrans' District 7 TMC in Los Angeles dates back to 1970, when it was established to perform freeway management functions with original equipment that has since become outdated *(2)*. Montgomery County in Maryland initially laid the foundation for their current TMC in 1980 as a way to manage their surface street traffic control system through the computerization of 10 traffic signals *(3)*.

In recent years, transportation agencies have been able to purchase more powerful computers and deploy computer and communication technologies first used in military defense and space operations. These technological advancements allowed agencies to deploy advanced techniques for surveillance, detection, and control, as well as for information dissemination.

The capabilities of TMCs have evolved over time partly in response to the demand for access to transportation agencies on a 24-hour basis by citizens and public safety agencies. Earlier TMCs performed primarily static functions, such as data processing, communication, and response activities. These activities required an individual segment of time and could not be performed simultaneously or "as the events happen." Eventually, more advanced technological capabilities allowed TMCs to perform data synthesis, communication, and response activities in actual processing time analyzed by computer, known as real-time. The real-time aspect of the TMC allows responses and modifications to the system to be made as changes in travel conditions occur, thus resulting in more effective management of our transportation systems. As noted above, a number of early TMCs were able to perform some real-time functions.

Opportunities presented by computers, communications, information technologies, and software integration tools have made it possible to upgrade existing TMC facilities and create new ones to efficiently tie together ITS, or more specifically, advanced traffic management system (ATMS) subsystems. Today, response and coordination functions under various types of transportation management and incident management are performed by a combination of hardware, software, and operations personnel located at the TMC. These elements dictate the need for many operational support requirements. Figure 2 shows a typical TMC operation with ATMS functions and requirements based on operational support and cost *(4)*.

Different agencies use transportation management centers for a variety of reasons and for nearly all modes of transportation. The complexity and extent of the center's functions are dependent on each agency's individual needs. Today's high-speed computing and communications systems allow a single agency or a number of agencies to integrate individual management centers to provide wider system coverage. State and municipal agencies are increasingly joining together through system architectures. The USDOT and Federal Highway Administration (FHWA) National ITS Architecture team effort have developed a system diagram depicted in Figure 3. The TMC subsystems covered in the ITS architecture include information service providers (ISP), traffic management, emissions management, emergency management, transit management, toll administration, freight and fleet management, commercial vehicle administration, and planning. These aspects of the TMC will be discussed in detail later in this synthesis.

TYPES OF TMCs

Transportation management centers may be categorized by type of facility. Centers are related to the following areas:

- Highways, for coverage of high-speed and limited-access highways and toll roads;
- Surface streets, for coverage of arterial streets and signalized intersections;
- Tunnels and bridges, focusing on these corresponding facilities;
- Surface transit, for controlling bus operations;
- Rail transit, for control of subway and light rail operations;
- Railroads, for commuter, long-distance, and freight rail operations; and
- Integrated centers, for two or more individual types of TMCs within a single facility.

Figure 4 pictures a transit related TMC with several operators working the control desk and monitoring a subway system through a series of workstations and a wall display. The transit (subway) TMC shown is the Metro Atlanta Rapid Transit Authority's (MARTA) central control room in Atlanta, Georgia. Figure 5 shows a modern bridge/tunnel TMC control room layout with an operator seated at the control desk and dispatching station. The control desk has several workstations with computer screens in the desk dashboard panel. Beyond the control desk is a multifunctional wall display that features several panels of video monitors and "hi-tech" map display with various color-coded real-time indicator lights.

Table 2 lists the percentages of the TMCs for each type of transportation system indicated by the survey. The table indicates that 67, or 32.7 percent, of all the surveyed TMCs covered

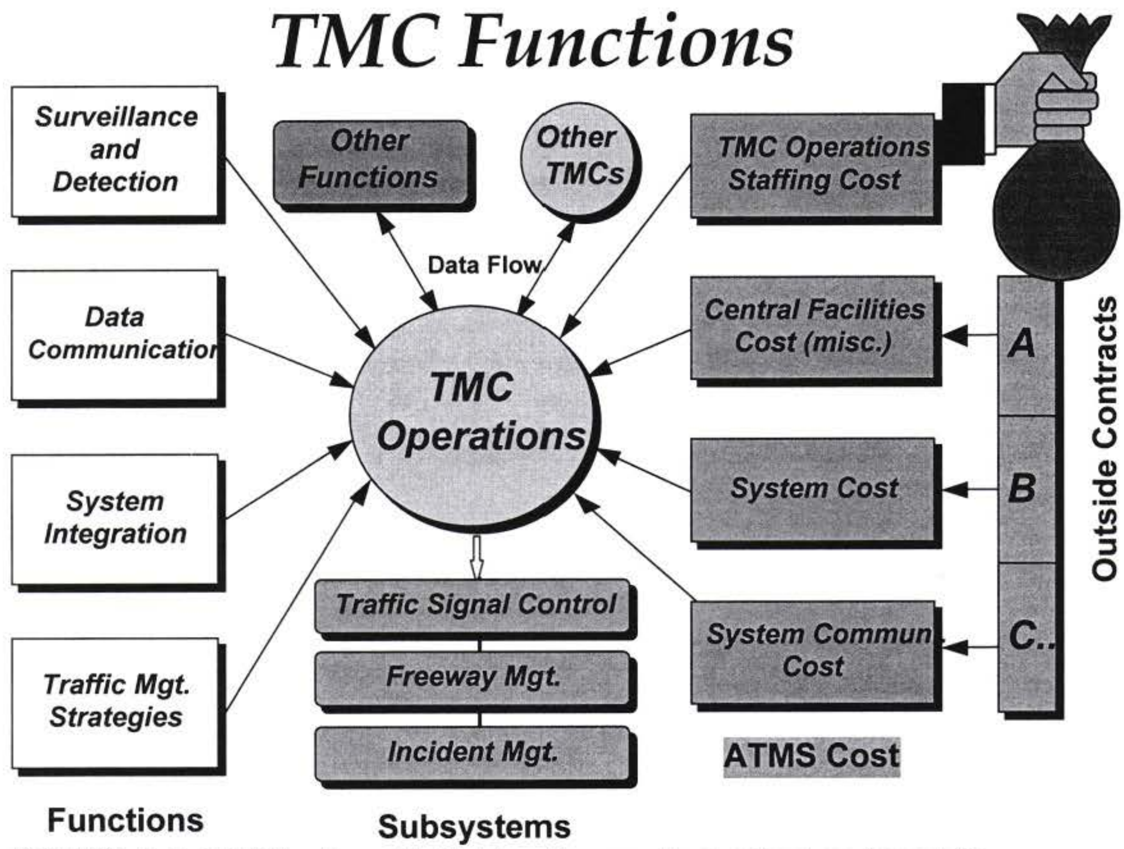

FIGURE 2 Typical TMC functions related to integration, operational, and cost requirements *(4)*.

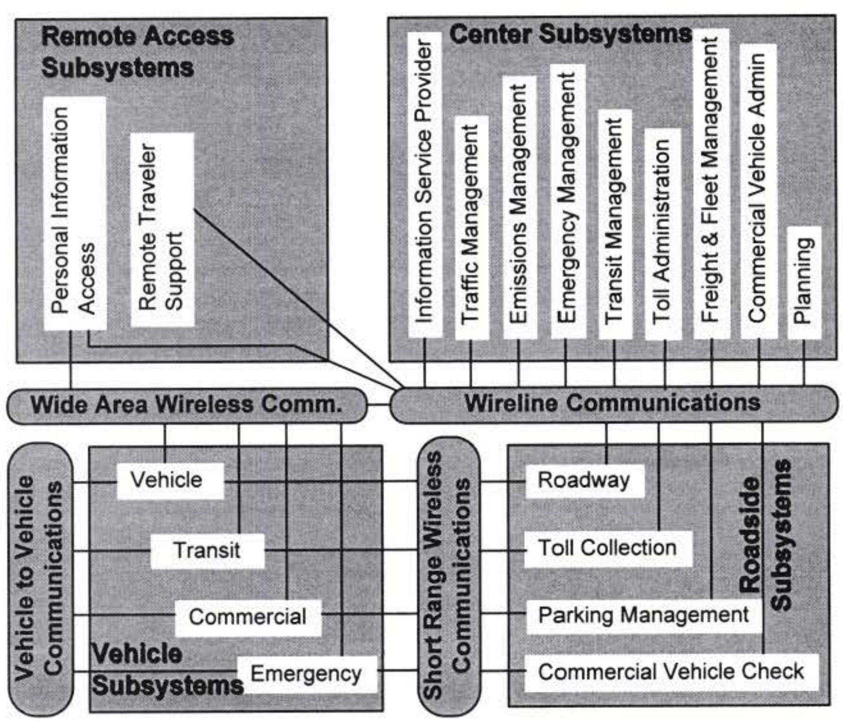

FIGURE 3 National architecture subsystems interconnect diagram *(5)*.

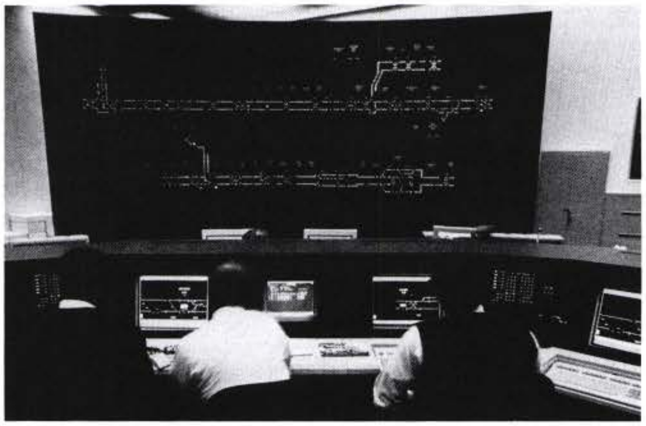

FIGURE 4 Transit (subway) TMC with operators at MARTA central control room.

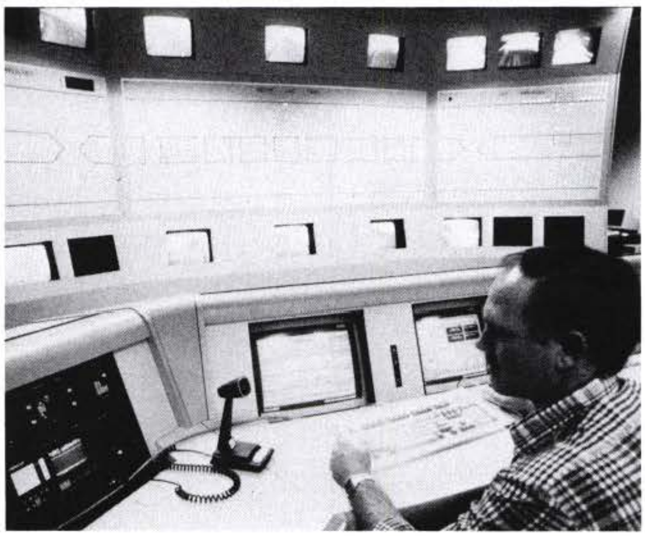

FIGURE 5 Glenwood Canyon Tunnel TMC control room with operator.

TABLE 2

PERCENTAGE OF SURVEYED TMCs WITH EACH TRANSPORTATION SYSTEM

Transportation System Type	Number of TMCs	Total TMCs (%)
Highway	67	32.7
Surface street	65	31.7
Bridge/tunnel	37	18.0
Transit (bus)	15	7.3
Transit (light rail/subway)	13	6.3
Rail (commuter/intercity)	8	3.9
Total	205	100.0

Numbers exceed total response due to duplication of system type covered.

highways. Table 3 presents a breakdown for each type of TMC derived from the survey results. As Table 3 indicates, approximately one-quarter of all the TMCs surveyed were integrated, meaning that they covered more than one type of

TABLE 3

BREAKDOWN OF SURVEYED TMC TYPES

TMC Type	Number of TMCs	Total TMCs (%)
Highway	35	23.8
Surface street	33	22.4
Bridge/tunnel	23	15.6
Transit (bus)	6	4.1
Transit (light rail/subway)	8	5.4
Rail (commuter/intercity)	5	3.4
Integrated	37	25.2
Total	147	100.0

transportation system, such as highways and bus. Additionally, the table indicates that 35 TMCs, or 23.8 percent, were related solely to highways. In total, surveyed information was received for 147 TMCs.

A number of state and municipal agencies have found it advantageous to house the TMC operations of multiple transportation modes and facilities in a single building to foster strong interagency communications and coordination. These types of TMCs, called integrated TMCs, should not be confused with a series of individual TMCs that may be integrated or interconnected through computer or communications networks to provide regional coverage. The definition of an integrated TMC refers to the coverage of multiple transportation modes and systems within a single facility. The TranStar TMC in Houston, Texas, is an example of an integrated TMC type. TranStar covers the highway system, surface street system, and surface transit (bus) system within the city of Houston. There are also cases, such as in Orange County, California, where TMC functions such as control or data synthesis are shared, but the physical facilities are separate.

To a lesser extent, there are also other types of TMCs in use today. Some TMCs, such as those for Illinois DOT in the Chicago area, function solely as communications and dispatch centers or emergency management support centers. Other centers, such as TRANSCOM in the New York City area, function as data storage and retrieval banks, containing information on the condition of transportation systems or their field equipment.

The survey results were also summarized to indicate the types of TMCs found for each type of agency. For most state and province transportation agencies, nearly all the TMCs cover freeways because of their regionwide or statewide jurisdictional coverage. Most municipal or county agency TMCs tend to cover surface streets, which are usually under the local agency's jurisdiction. This is evidenced by the surface street TMCs' more localized coverage. The "other" category (presented in Table 1) included transportation agencies and authorities not part of state or municipal government transportation agencies. These agencies, such as The New Jersey Turnpike Authority, are generally specialized in a particular transportation system (in this case, highways) and complement the state and municipal agencies in providing coverage of the region's transportation network. Nearly half of the respondents in the "Other" category indicated they have bridge and tunnel TMCs, since most of the respondents listed in the "Other" category were toll authorities.

Slightly more than one-third of all state TMCs are integrated, whereas roughly one-fifth of all municipal TMCs and only 12 percent of all "Other" agency and authority TMCs are integrated. This generally indicates that state-operated TMCs perform more comprehensive functions, while municipal and transportation authority TMCs tend to perform more specialized functions.

SYSTEM CONCEPT

For many transportation agencies, the transportation management center represents the central point for which the collection and dissemination of transportation information, surveillance, and control of roadway and transit conditions, and management of congestion, event, and incident related traffic occurs in an area. In a conjunctive effort, government transportation agencies, private industry partners, academia, and city or state emergency departments work together to manage surface, rail, and intermodal transportation through advanced electronic, communications, and computerized components. Managed by the TMC, travel condition information is gathered, synthesized, and then disseminated to allow transportation managers to make appropriate transportation decisions based on the policy of the responsible agency. The travel condition, congestion management, and incident management related information, referred to in this synthesis as data, may then be converted to understandable congestion or incident information and disseminated through a variety of media to the public.

CHAPTER TWO

CHARACTERISTICS OF TMCs

Typical characteristics of transportation management centers (TMCs) are discussed in this chapter. The characteristics studied for this synthesis include the functions of a TMC, the transportation system coverage area it serves, the facility configuration and special requirements, and institutional arrangements. This chapter will show how TMC functions and transportation system coverage are interrelated and interdependent. Institutional arrangements and coordination and their influence on the agencies' TMC programs are also discussed in this chapter.

TMC FUNCTIONS

Transportation management centers perform three basic functions: gathering, synthesizing, and disseminating traffic and travel condition information. The efficiency and effectiveness of the overall transportation system largely depends on how well the TMC performs these three core functions. As a result, it is important that every TMC have the ability to collect and process large quantities of transportation information. The depth to which these functions are applied corresponds to each agency's intent, which may range from assisting in incident management to transit bus tracking.

As information is processed through the TMC's functional cycle (gathering, synthesis, dissemination), the TMC is able to monitor and control the operations of the system. Types of information generated by TMCs include, but are not limited to:

- Location, type, and nature of incidents,
- Details related to road construction,
- Route diversion,
- Traffic condition information,
- Transit system information,
- Data supporting indicators of congestion management, and special event information.

Well-managed TMCs are able to process and synthesize the integration of measurable traffic and transportation evaluation data (e.g., traffic volumes, queue lengths, average delay, headways, weather, etc.) gathered from multiple data collection systems in sustaining a continuous flow of information. While all TMCs are involved in some portion of the functional information flow process, each TMC's objectives—to maintain and expand the flow process—are different. For example, a transit related TMC may have a different methodology (i.e., adherence to routes and schedules) to satisfy their informational flow process than a regional freeway management center or a traffic signal control center (i.e., maintenance of a certain level of peak hour congestion).

For the most part, there are many similarities in TMC operations. Most of this chapter refers to TMCs related to traffic management simply because more information is currently available on these types of TMCs than TMCs related to transit. Nonetheless, findings related to traffic and transit TMCs are presented throughout the course of the synthesis.

As noted, all TMCs must be able to fulfill the three basic functions related to the informational flow process to satisfy justification and fulfill supporting objectives. The TMC's purpose and the type of agency "owning" the TMC drive the process of gathering, synthesizing, and disseminating information. Transportation management centers process data obtained from various field devices as well as from radio and telephone communications with other staff and, on occasion, with the public. Additionally, incident detection information synthesized by many TMCs is often gathered by sources outside of and not controlled by the TMC, such as radio communications, phone calls, and fax transmissions with other agencies or private organizations. To create a self-supporting informational flow process, TMCs use a variety of detection and surveillance devices to gather as many different types of data as possible. This assists the agency in creating a complete "snapshot" of the travel conditions for the agency's operational jurisdiction at any given moment.

Each type of device controlled by the TMC and used to gather data on the transportation system has its advantages and disadvantages. For example, the use of video cameras can help in the verification, and sometimes, the identification of traffic build-ups. The chief functions of closed circuit television (CCTV) and its cameras are verification and monitoring. Thus, cameras are an excellent resource for verifying the type and location of an incident, monitoring the incident scene (once the incident has been positively identified and verified) and any delays or back-ups caused by the incident. These functions are greatly enhanced if the TMC's cameras have pan-tilt-zoom capabilities.

In an effort to battle urban traffic congestion, federal, state, and local funding for ITS deployment has increased significantly through the Intermodal Surface Transportation Efficiency Act (ISTEA) in recent years. As a result of this funding, many TMCs have been able to deploy reliable surveillance, detection, verification, and data analysis systems. These systems utilize a variety of inputs and algorithms to filter and process raw detector data to report real-time conditions of the transportation system. The combination of detectors, video, and other information sources provides quick, accurate incident detection, verification, and classification. As a result, TMCs use the data to adjust ramp metering controls, prepare variable message sign (VMS) messages, generate graphical displays (for TMC and public use), present data in text form to describe conditions, and in some TMCs, prepare the data for fusion with data from other sources, such as vehicle probes and weather conditions.

The ability to evaluate system performance in real-time can be part of the TMC function. In addition, data can be archived by the TMC into a reliably accessible, computerized historical database, rather than retained in cumbersome paper formats. The TMC can also update electronic databases of historical data that are already in use and manage their storage effectively. With the amount of data available, coupled with the highway operations experience of transportation agency personnel, information collected by the TMC can assist in planning and operations activities, such as identifying and prioritizing bottlenecks and evaluating the effectiveness of high-occupancy vehicle (HOV) systems and congestion pricing initiatives not typically conducted through a TMC.

TMCs monitor incident related conditions as well as normal traffic conditions. When incidents occur, TMCs of any type play a significant role in any or all of the three basic incident management functions: detection, response, and monitoring. Although the TMC does not physically respond to an incident, the facility performs duties related to logistical and emergency support, communication, dispatch, and monitoring. Upon positively identifying, verifying, and classifying an incident, a TMC may coordinate with the public service media, information service providers (ISPs), and emergency response and clearance organizations to implement response and monitoring procedures to clear the incident and return the system back to normal operating conditions. Response may be the activation, coordination, and management of appropriate personnel, equipment, and communication links. Response also includes dissemination of information directly to motorists and transit travelers, ISPs (mostly private sector entities), and the media. TMCs typically disseminate traffic information through VMS and highway advisory radio (HAR) and have traditionally passed many types of transportation condition information to the traffic reporting media for their use. TMCs will continue to operate most highway-based information sources, such as VMS and HAR, but an emerging role of the TMC in widespread information dissemination to the public is to pass this information to an ISP (whether free or with a fee) for packaging and dissemination for specific customer uses. Rapid detection and notification, continuous monitoring, and active communication with field personnel are critical to the timely removal of an incident and amount of time that the facility operates at reduced capacity.

In many locations, the incident management and response process is initiated by motorists who call into a public safety answering point, which is usually staffed by police, fire, or medical agencies, with a description and location of an incident. The emergency service agencies needed to respond to the incident are notified and the information is relayed to the TMC. In some locations, where there is permanent police presence or dedicated incident "hotline" operators in the TMC, the public safety answering point may be consolidated under the TMC; it can also be contracted out to a private organization. The ISPs usually obtain information from the TMC. In cities with minimal or developing traffic management programs, the public safety answering point may send relevant incident data simultaneously, or in sequence, to an ISP and a TMC, depending on the needs of each and on the availability of the information that may be released. While the incident management process described is fairly common, the individual steps may vary due to a number of factors. The incident management process may be affected by:

- The ability of the involved parties, including the TMC, to confirm incidents based on the level of ITS equipment deployed,
- The severity of the incident and need to divert traffic,
- Local agency information dissemination and incident management procedures, and
- The relationship of transportation agencies, emergency agencies, ISPs, broadcast media, and other parties involved in regional incident management.

Typical activities conducted by the TMC in contributing to the response and clearance of an incident are:

- Receipt of initial information on incidents if such operators are employed at the TMC,
- Verification of incidents through surveillance, monitoring, and data collection equipment,
- Communication with appropriate agencies and personnel responsible for clearance and emergency services,
- Provision of information to other appropriate entities (internal and external) responsible for traffic management on the affected or adjoining facilities,
- Control of traffic management devices such as traffic signals, HAR, VMS, lane use signals, variable speed limit signs, and other components that can be programmed and controlled individually,
- Coordination with other agencies whose facilities may experience additional congestion or may be used for diversions,
- Dissemination of incident related information to the public through highway-based information sources such as VMS, HAR, and motorist call-in services, or through ISPs for the preparation of information for radio and TV media, and other end users, and
- Supply of on-site emergency management support.

Similarly, during periods of recurring congestion unrelated to specific incidents, TMC personnel will evaluate system conditions through network condition displays, video surveillance, and other information sources. This analysis allows the TMC managers and operators to prepare information for dissemination to travelers and media sources. Some TMCs use data fusion techniques to combine the data—originating from different sources—to make determinations on travel indicators for various transportation facilities. One example of data fusion, which is gaining popularity, is the use of data from vehicle probes to estimate speeds and travel times through the use of a small sample of vehicles in the traffic stream. Vehicle probe technology, tested in Houston and in the New York/ New Jersey metropolitan region, allows speed and travel time

TABLE 4

COMPARISON OF CURRENT VERSUS FUTURE PERCENTAGES OF EACH FUNCTION BY TYPE OF TMC

	Highway		Surface Street		Bridge/Tunnel		Transit (Bus)		Transit (Light Rail/Subway)		Rail (Commuter/ Intercity)	
Function	C (%)	F (%)	C (%)	F (%)	C (%)	F (%)	C (%)	F (%)	C (%)	F (%)	C (%)	F (%)
Surveillance	81	94	73	**97**	**87**	94	67	75	60	70	50	63
Incident Mgmt.	88	**97**	60	84	**90**	**97**	58	75	70	90	75	88
Public Information Dissemination	66	**83**	40	73	58	65	**67**	75	40	60	50	75
Private Information Dissemination	67	86	31	68	**74**	81	50	67	40	60	50	**100**
Interagency Inf. Sharing	84	95	47	77	81	87	75	92	60	80	**88**	**100**
Environmental Monitoring	27	42	11	27	**48**	**61**	33	42	20	30	13	25
Special Event Management	75	88	74	87	**81**	81	75	**92**	70	90	75	88
Coordination with Emergency Agencies	86	95	61	82	**90**	97	75	92	50	70	88	**100**
HAZMAT	45	56	21	27	**71**	74	50	58	20	30	63	**75**
Emergency Management	55	67	45	61	77	87	75	83	60	70	**88**	**100**
HOV Operations	27	**47**	10	24	**35**	39	25	33	0	0	0	0
Planned Track/ Lane Closure	78	86	68	84	**90**	**97**	67	75	30	40	38	38
Data Fusion	34	**64**	24	45	45	52	**50**	58	30	30	38	38
Ramp Metering	**28**	**59**	15	34	13	26	25	33	0	0	0	0
Traffic/Track Signal Control	47	73	**89**	**97**	26	42	50	67	30	60	25	38
Lane Signal Control	22	47	34	47	**68**	**77**	33	33	0	0	0	0
Toll Management	11	16	3	8	**48**	**48**	0	17	0	0	0	0
Risk/Liability Management	19	20	23	24	**45**	**45**	42	42	30	30	25	38
Other	23	30	11	16	16	48	8	25	20	40	25	38

Note: C% = Current percentage; F = Future percentage
Bold values indicate the highest reported current and future percentage of the performed function for each TMC type.

data to be collected from vehicle probes as they are tracked at roadway checkpoints. The data collected from the vehicle probes can be used to determine the presence of traffic congestion or incidents on specific roadway links (between checkpoints). Currently, many TMCs are able to supply these data to traveler information subsystems and system graphics display boards. In the near future travel conditions may be conveyed to in-vehicle route guidance systems *(6)*.

The survey for this synthesis asked respondents to indicate from a list of TMC functions those performed at their facility. Table 4 indicates, by TMC type, the percentage of TMCs that perform each function. For example, it was reported by the survey respondents that 73 percent of the surface street TMCs currently perform surveillance functions. The survey results also indicate an anticipated 97 percent of the surface street TMCs will perform surveillance functions in the future. The value of 97 percent in Table 4 is in boldface to indicate that the highest percentage of TMCs (by type) performing surveillance functions in the future will be surface street TMCs. The following lists the types of functions identified in the survey and a brief description of each function:

- Surveillance includes detection, visual, and vehicle probe techniques.
- Incident management includes any activities related to incident detection, response, or monitoring.
- Public and private information dissemination includes sending data and other travel related information to private and public organizations whether for profit or as a service.
- Interagency information sharing includes sharing of data and travel condition information among agencies involved or interested in TMC operations (information may be used for data synthesis and analysis).
- Environmental monitoring includes the observation and detection of air quality, noise, and weather conditions.
- Special event management includes the control, surveillance, monitoring, and response to traffic conditions during special events.
- Coordination with emergency agencies involves the communication, dispatch of personnel, and control of traffic devices for emergency vehicles.
- Hazardous Materials (HAZMAT) management includes the response to incidents involving hazardous materials and communication with or dispatching of appropriate personnel.
- Emergency management includes any activities related to the dispatching and direct involvement of TMC personnel dedicated for on-site emergencies due to catastrophes and disasters.

• High-occupancy vehicle (HOV) operations include the control, surveillance, and data collection of high-occupancy vehicle facilities; may also include bus priority operations or exclusive bus lane operations.

• Planned lane/track closure management includes coordinating and monitoring scheduled maintenance and construction activities related to the maintenance and protection of traffic or transit.

• Data fusion includes the combination of data sources (collected by the TMC and outside the TMC) in data synthesis and analysis activities.

• Ramp metering includes the control of ramp metering devices for highways, HOV facilities, or toll facility approaches (not at plazas).

• Traffic/Track signal control includes the control, modification, or preemption of surface street traffic signals in response to changing traffic conditions; also includes actual control of track signaling operations.

• Lane control signals includes the control, modification, or emergency priority operation of lane use signals on streets and highways in response to traffic conditions, construction, emergency, or reversible lane usage.

• Toll and traffic management includes the surveillance, data collection, control, or in some cases, toll operations (for tunnel or bridge agencies) of traffic conditions.

• Risk/Liability management includes a standard set of procedures, internal regulations, or dedicated personnel whose object is lowering risks and the potential for liabilities or dealing with the effects of a liability situation.

• "Other" includes activities not specifically listed in the survey, such as taking calls from the public, issuing permits, law enforcement dispatching, snow removal operations, radio broadcasting, maintenance operations and dispatching.

As the survey results in Table 4 indicate, those functions found most frequently across all types of TMCs were:

• Coordination with emergency agencies,
• Special event management,
• Incident management,
• Interagency information sharing, and
• Surveillance.

Larger, integrated TMCs can perform many functions that cross transportation modes and systems.

FACILITY CONFIGURATION VERSUS FUNCTION

Spatial Requirements for TMCs

Depending on the functionality and extent of activities, physical size and configuration of TMCs may vary significantly. For example, the TranStar center in Houston, Texas covers approximately 50,000 sq ft. In the TranStar TMC, as well as in other larger TMCs, a wide variety of functions and activities are performed. As is typical for large TMCs, several transportation modes are integrated and many operate around the clock.

Medium-sized centers, such as the TMC in Milwaukee, Wisconsin and the state transportation department TMC in Newington, Connecticut measure roughly 7,000 sq ft and 5,400 sq ft, respectively. Many of the same basic functions are performed in the medium-sized TMCs as in the larger-sized TMCs, but are generally reduced in terms of the magnitude of central equipment in the TMC or the extent of the activities to support those primary functions.

Some smaller-sized TMCs, particularly a number of the Maryland State Highway Administration's (SHA) TMCs, act as satellite centers and report to a larger statewide or regional center. Additionally, smaller-sized TMCs like the I-4 center in Orlando, Florida, or the traffic signal control center in Santa Ana, California, typically concentrate on a single or a few limited specialized functions. In some areas these TMCs communicate localized information to a larger, regional TMC.

Regardless of the size of the TMC facility, a typical layout includes:

• Space for the control room (housing operator workstations, consoles, and CCTV monitors),
• An equipment room (computers, communications, peripherals),
• Conference media rooms and visitor/tour facilities, and
• Offices and personal facilities.

The major differences among small, medium, and large-sized TMCs are based on a number of considerations, such as *(6)*:

• Size and functionality of the transportation system. Generally, it has been the design approach that the larger the transportation system coverage (e.g., number of highway miles, intersections, railroad track miles, etc.), the larger the TMC.

• Additional systems or functions co-located at the TMC. These can include police presence, equipment dispatching, HOV operations, and transit coverage.

• Number of operators on duty at any one time or within one shift, with each operator requiring a console or terminal.

• The type and layout of any video/graphic displays. Television monitors and large screen displays require a significant amount of vertical and horizontal space, particularly if projection systems are used.

• Office spaces. In some locations, TMCs include offices only for staff involved with TMC management. In other TMCs, offices are also provided for additional staff with adjunct or unrelated duties.

• Number and type of specialized areas such as conference facilities, reception areas, press room(s), kitchens, restrooms, and equipment and lighting rooms.

Expansion of any of the TMC's primary functions may warrant additional operators/dispatchers and monitors or workstations. The potential reallocation of space can be costly and operationally disruptive. Specialized central equipment requirements, such as master controller hardware, complex signal systems, or specialized workstations for field hardware programming and control may also lead to reconfiguration of the facility. For more complex, integrated TMCs, the spatial requirements depend not only on the above factors, but also on the level of integration between transportation systems; the degree to which the TMC functions as an information and coordination center among agencies; and the relationship between the TMC and transportation agencies and emergency responders. Room for expansion should be considered in every initial TMC design *(7)*. However, no correlation was found between the physical size of the TMC and the size of the transportation coverage area (i.e., highway centerline miles, number of signalized intersections, or transit route miles) served.

Equipment for TMCs

In a typical TMC, equipment is required for computer storage and processing, communication, and information displays. On-line computers, performing the active functions of the TMC, are typically connected through either a mainframe or a local area network (LAN). Both configurations must be capable of transferring data and video images at exceptionally high speeds. For TMCs using a modular LAN computer network design alternative, the addition of equipment and hardware components can be easily accomplished. Likewise, a LAN, which is the more preferable computer configuration for a TMC, can serve more devices located in the center, interface with additional field devices and controllers, and provide a faster means of communication with additional transportation providers, agencies and data users *(6)*. Generally, systems that can be readily upgraded are preferable.

A critical element in TMC deployment will be the integration of the emerging National Transportation Communications for ITS Protocol (NTCIP) to provide interoperability and standardization among TMCs with existing communications protocols. The NTCIP profiles will enable the exchange of data between TMCs and from TMCs to other centers. NTCIP allows ITS field devices, such as variable message signs, traffic controllers, and environmental sensor stations, to exist on the same communication channel, thus providing interoperability for ITS devices. It also allows a device from one vendor/manufacturer to be switched with one from another vendor/manufacturer, thus providing interchangeability. Until these standards and protocols are incorporated into TMCs on a widespread basis, incompatibility among components and systems may prevent TMCs from sharing databases and "seamlessly" informing and controlling various types of hardware and software systems.

Communications

The TMC typically communicates with the field equipment through communication servers that receive data from the computer through the LAN and distribute it through the TMC communication channels. These channels may be grouped functionally. Although the exact communication configuration system usually differs from center to center, one group of channels may service signal controllers, ramp meters, detection stations, and variable message signs remotely through fiber optic cabling. These functional services may include radio networks (for HAR), modems providing varied public traveler information outlets, and modems exchanging information with other TMCs and transportation providers and agencies. Increasingly, high-speed phone lines and modems, spread spectrum radio and even microwave communications are becoming commonplace *(6)*. For voice communication among personnel, ordinary telephone lines and two-way radio still remain the most common forms. In fact, some TMCs still use ordinary telephone lines for data transmission.

Computer Servers and Operator Workstations

Typically, one or more servers act as the central point of computer activities. Each server comprises a large disk drive for storage and a real-time operating system. Some TMCs may have multiple servers, one performing its activities online and the other(s) acting as back-up. The back-up servers may perform other off-line functions, such as program development and database backup and updating, and can be used for emergencies in the event that the primary server is inoperable. The individual operator workstations, which are connected directly to the mainframe or are part of a LAN, typically are personal computers or comparably sized terminals controlled by the computer keyboard and mouse. The workstations also include color display monitors and feature graphical user interfaces (GUI). The software applications used in the TMC are operated from the workstations and output is sent either to a local printer on-site or through a network of off-site printers *(6)*.

Printers

A sufficient number of printers, connected to the printer server and the operators' workstations through the mainframe or LAN printer server, must be able to serve a wide variety of software output. Printed output in TMCs can include hard copy reports, faxes, e-mail, failure/malfunction logs, graphical representations of the transportation system, travel conditions based on summarized data, database status summaries, logs of system operations and activities, and special operator reports. Depending on the volume, TMC printers can be expected to be used heavily and for this reason back-up units are frequently kept on-hand. Additionally, color printers, once expensive hardware, are useful for color-dependent output, such as maps and graphical indicators and are becoming more reasonable in price *(6)*.

Display Components

In some TMCs, a large wall display (map or video) is commonly used to show travel conditions. Wall displays may use a variety of backdrops for travel condition information. Some displays are of the older map display type where various indicators (e.g., light-emitting diode (LED)) are raised onto a mounted paper map. Similarly, aerial photos may be used as a background with LEDs to provide greater perception of the TMC's coverage area.

Widespread use of video has resulted in the less frequent use of graphic wall maps, while more advanced wall displays incorporate geographic information systems (GIS) to graphically and descriptively provide travel condition information in a more accurate fashion. The GIS graphically displays the geometry of the highway/street network and its spatial data and combines this information with geographically referenced highway/street network attributes, such as traffic, to perform analyses. From these analyses, the GIS integrates the two data sets and can display the attributes (descriptive level) and analysis results on an electronic generation of the highway network in map form (graphical level).

Experimental use of global positioning system (GPS) technology in conjunction with GIS graphical capabilities is growing in popularity in TMCs to provide highly accurate position and speed information as well as a continuous and precise global basis for time keeping. The TMC can collect position, speed, and time-related traffic data from vehicle probes using GPS. The GPS is advantageous in that the system, including the collection and receipt of data, is not affected by weather and is fixed upon a worldwide common grid referencing system. The GPS-acquired data may easily be combined with GIS graphical capabilities to display traffic conditions on an electronic map in the TMC. The downside of using a full-scale GPS application in the TMC is that no performance standards or protocol criteria have been established at this time.

At present, most graphics that typically appear on operators' workstations can be viewed on various types of large screen displays. The displays may consist of a projection video display of the computer screens, a large video screen, or a block of smaller video screens. In terms of adding central system components and field hardware to the TMC, this type of display has the advantage of greater modularity over the older wall map displays. Projecting the workstation's screen onto a large video display allows more personnel to observe field conditions from the control room or an adjacent conference room, allowing the control room to be isolated, if desired. Overall, video can be very cost effective to install and maintain especially when compared to more static types of display, primarily because of the capability to change graphic displays easily. Caltrans' District 12 TMC and Texas DOT's Fort Worth District TMC, for example, use video for their wall display in addition to projecting workstation screens onto wall displays.

In addition to travel condition information, a graphics display can also illustrate the status of a control system's operation. This can include areas under maintenance, installation phases, testing of equipment, troubleshooting and maintenance activities, and field hardware failures and malfunctions. By exhibiting this information, TMC personnel can determine at a glance what field hardware, if any, is off-line or whether there is a geographical concentration of field equipment failures or malfunctions indicating power or communication failure in a grid. Table 5 lists the many video graphics displays that can be shown for roadway related TMCs, particularly those for freeways and surface street systems. Examples of the display capabilities outlined in Table 5 include:

- Caltrans' District 12 TMCs' expert system that logically suggests variable sign messages from an inventory of possible messages based on changing travel conditions.
- Illinois DOT's TMC in the Chicago area plans to display in the TMC alternative incident management response scenarios so that personnel can select the most appropriate response.

TMCs frequently use video monitors to display information on field conditions for surveillance, incident detection,

TABLE 5

EXAMPLES OF GRAPHICS DISPLAY CAPABILITIES FOR HIGHWAY AND SURFACE STREET RELATED TMCS *(6)*

Surface Street	Highway
• Geographic layout of signalized intersections	• Geographic layout of highways and interchanges
• Traffic signal detector locations	• Detector locations, information and status
• System status	• Ramp meter control
• Signal timing	• Lane control signals
• System detector data	• Changeable/Variable message sign operations
• Signal phasing and current operational status	• Traffic condition indicators in a color-coded format for each link:
• Local detector calls	⇒ speed
• Traffic condition indicators:	⇒ lane occupancy
⇒ volume	⇒ level of service
⇒ lane occupancy	• Freeway and incident management/response options and algorithms
⇒ speed	⇒ Congestion/incident location and information
⇒ stops	• Locations of non-detection field equipment
⇒ delay	⇒ Cameras
	⇒ VMS
	⇒ etc.

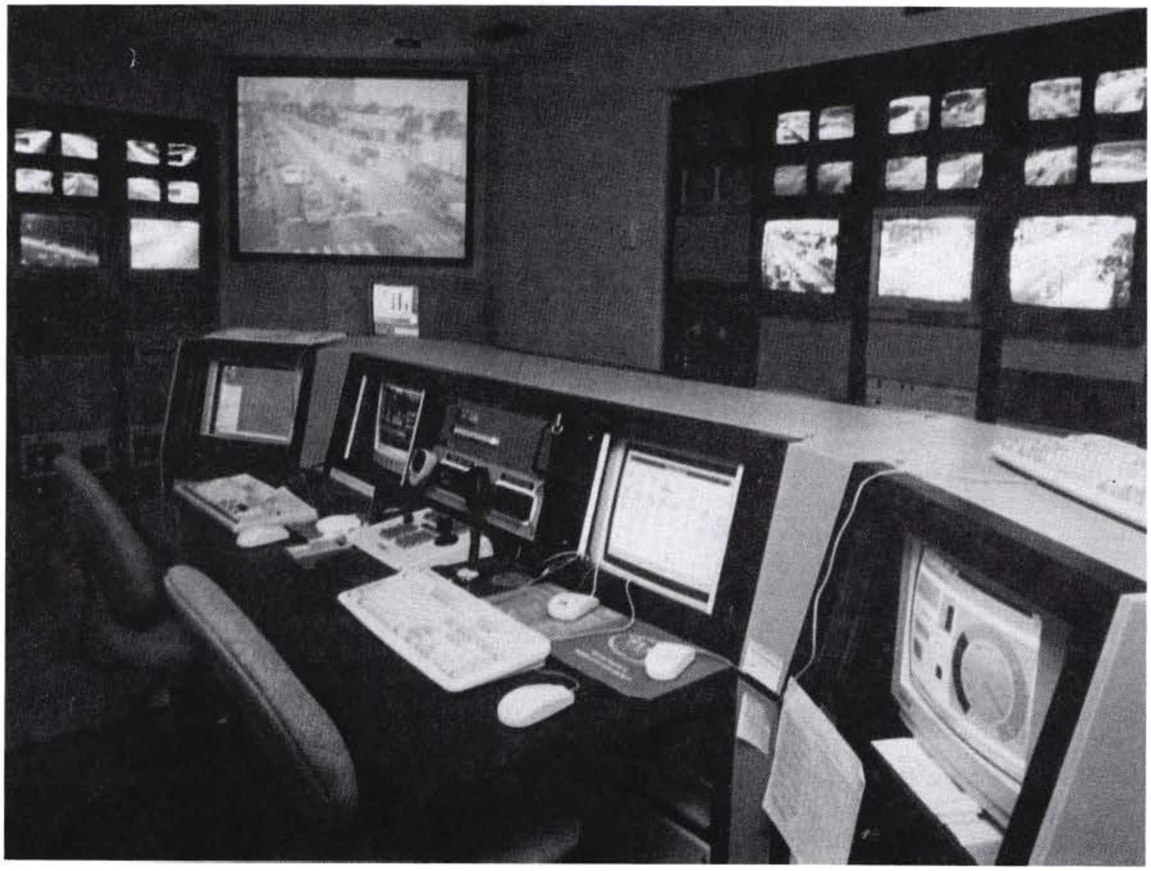

FIGURE 6 Variety of display components in the city of Daytona Beach, Florida TMC.

verification, classification, and incident management. In some systems, operators can use CCTV displays in conjunction with advanced traffic software algorithms to adjust field controls, such as track or street signals, to improve traffic capacity in response to changing (i.e., real-time) conditions. Figure 6 shows that a TMC may have numerous display capabilities. The integrated TMC (highway and surface street) for the City of Daytona Beach, Florida has a wall video projection display (which also projects on-screen displays from workstations) and two video wall panels with multiple full-size color monitors and a series of smaller black-and-white monitors.

Through the use of sophisticated software applications and a GUI, a workstation can project onto the video display a graphics array and/or a CCTV picture. This allows TMC personnel to view real-time pictures concurrently with graphical information and, thus aid in monitoring conditions on both local and network levels.

Software Capabilities

The functions of the TMC and the duties performed at the facility will generally direct the type and complexity of the software to be used. This is especially important when deciding which application best suits the needs of the TMC. Nearly all TMCs use commercially available application-based database software, or paper files to receive, process, and store field condition data and information. Other types of software commonly used by TMCs include management information system software, adaptive control, and expert system software. A number of proprietary advanced software programs are now available that are specifically designed for TMC operation. At this time, there are no database or criteria standards for TMC facilities.

One example of software specifically designed for a TMC is an application that performs real-time data synthesis and reporting functions. The software is part of an advanced traffic monitoring system that combines the surveillance functions of cameras with concurrent detection and data collection functions. There are three versions of this software, depending on the needs of the customer. At a minimum, through video surveillance and detection, the software can perform vehicle detection, tracking, counting, speed determination, turning movement, and stop line detection functions. Another version can determine, in addition to the previous measures, queue length, spatial headway, and lane changes. The most advanced version of the software includes vehicle classification, link travel time determinations, pedestrian and bicycle detection, and application support for mass transit, HAZMAT tracking and management, and other vehicle identification functions. There are increasingly more software manufacturers that offer similar types of software designed for TMC operation, particularly those that can merge surveillance video with detection data *(8)*.

Task Requirements for TMCs

Many important tasks and activities, both technical and nontechnical, are performed in the TMC. Depending on the basic functions of the TMC, the tasks performed will vary. However, a number of essential tasks are common to every TMC in maintaining day-to-day operations. Some of those critically important tasks are discussed in this section.

Documentation

Perhaps one of the most important, although frequently neglected tasks, in the TMC is documentation. Performance of the TMC is in many ways reflected by the completeness, accuracy, and arrangement of its documentation. Detailed procedures for document control and distribution to management are fundamental to the operation and maintenance of the TMC. Documentation of changes and updates is necessary, especially with regard to the TMC's software and hardware components, and operational control parameters. All TMC team members should document changes and updates on computer with paper back-up. Typical documentation tasks at the TMC may include, but not be limited to *(6):*

- Activity log of employees' duties and responsibilities (to determine what percentage of time is dedicated to specific tasks),
- Event logs related to equipment, field conditions, operator commands,
- A ledger of changes, updates, or modifications to TMC equipment, etc.,
- Daily summary reports of field conditions and equipment failures, and
- Incident logs including date, time, type, and location.

Equipment Tracking and Performance

It is important for the TMC to track and record the performance of its equipment. For example, the project manager of the INFORM traffic control center in Long Island, New York continually records and tracks equipment performance. The project manager also provides documentation to the responsible agency and its service and equipment consultants on a bi-monthly basis, the percent of equipment on-line, reporting aspects of the control center that require attention, and resolutions to any problems *(10).*

Reporting of Progress

Progress reports are useful indicators of the operational effectiveness and efficiency of the TMC. These documents are typically submitted on a periodic basis to various managers in the responsible agency. Submission of periodic progress reports is especially important to all organizations to indicate the growth and development of the TMC under the organization's guidance.

Progress reports on the TMC's operation should include a status of activities related to administrative or supervisory matters, system operation, interagency cooperation and communication, and technical issues. Progress reports may be accompanied by tabular or graphical summaries of various indicators to show TMC activity for the period or compared to previous period. For the most part, these progress reports should be automated and simple to produce if the data can be continually stored, reduced, and synthesized. Trends may be drawn from these reports and could be effective in identifying additional staff or system coverage needs at particular times of the year. A sample progress report for the INFORM system on Long Island, New York is contained in Appendix D.

TRANSPORTATION SYSTEM COVERAGE

Typical transportation system coverage includes parameters such as miles of roadway by type, lane and centerline miles, transit miles, and HOV lane miles. Integrated TMCs may include a combination of transit, bridge, toll road, and other facilities coverage, depending on the TMCs sponsorship.

Nearly all of the facilities covered by a highway TMC are high-speed, multilane, limited-access roads and/or toll roads. In some urban areas, agency TMCs also monitor HOV and exclusive bus lane facilities. Many of the TMCs in larger urban areas also monitor long corridor segments, some of which contain multiple parallel highways, beltways, and mainline spurs.

Many urban area highways now use a closed circuit television (CCTV) system and field cameras for surveillance and ramp meters for traffic control. These functions are generally carried out from a highway TMC and in some urban areas are performed on a network of regional highways. One of the largest urban area highway surveillance and control systems to date is controlled by Minnesota Department of Transportation (Mn/DOT) TMC in the Minneapolis-St. Paul area. The Mn/DOT TMC controls approximately 170 CCTV cameras and nearly 400 ramp meters, which covers about 70 percent of the metropolitan area's highway system.

To achieve a maximum level of coverage for monitoring and verification, the TMC's video surveillance system requires pan-tilt-zoom functions and 360-degree rotation. Additionally, camera installations may require wiper blades, self-cleaning fluid, visors, and heating and deicing mechanisms to maintain clear vision in harsh weather conditions. To ensure adequate coverage, in the Minneapolis-St. Paul system cameras were placed at 1-mile spacing along regional highways, and at other strategic locations.

Ramp meters control the number and spacing of vehicles entering the highway and do so to maintain capacity and speed of the highway traffic. These controls can be either manipulated by TMC operators or automated (as is the case at Mn/DOT) and may be activated and cycles changed depending on the freeway traffic conditions. In high traffic volume areas, two lanes may be provided at an on-ramp for more vehicle storage so that traffic queues will not spill back onto local streets and cause decreased safety and traffic flow. Dual-lane ramp metering and bypass ramp metering for HOV on-ramps are also present in some areas around the country and can be controlled remotely from the TMC during periods of HOV operation (*11*).

Advanced information technologies provide greater capability in managing the system. Communication, vehicle detection, and surveillance are basic functions of a freeway TMC. Field equipment used for visually disseminating information on the freeways typically includes variable message signs. Highway TMCs play a key role in providing information to other agencies and to motorists. For example, VMSs alert motorists of freeway conditions ahead by displaying programmed (or in some systems real-time) messages originating from the TMC.

The use of graphical symbols with text messages on VMS is found in a few areas. Public acceptance and understanding of these messages needs further testing. Dedicated radio broadcast frequencies, also known as highway advisory radio (HAR), alert motorists to traffic conditions and incidents, as well as emergency information in the listening area. These broadcasts, sometimes transmitted from the TMC, give more detail on roadway conditions and are usually complemented by TMC-operated HAR signs and VMS on the highways. However, HAR has restricted broadcast range and frequency allocation can be limited. Typical AM radio frequencies used for HAR broadcasts are 530 and 1610 kHz for a localized or short-range coverage area. These are low-powered frequencies and have limited range. Traffic or emergency information broadcasted on HAR may also be transmitted through other frequencies or specific power arrangements, however, the operating agency is subject to the licensing process of the Federal Communication Commission (FCC). Some HAR systems have old equipment and messages cannot be changed quickly. Other TMCs have more up-to-date HAR systems and can update and review broadcast messages more frequently, depending on need. In metropolitan areas with more than one HAR system, there is a strong need for coordination of message content among agencies.

Lane control signals may be used on freeway segments to direct and advise traffic due to downstream incidents. These signals are controlled by the TMC based on conditions downstream and indicate whether traffic lanes are open or closed. In the United States, lane control signal usage is most common at approaches to bridge and tunnel facilities and in reversible lane and HOV lane applications. A freeway management system in the Netherlands uses speed control, and in some cases guidance information, in conjunction with lane control to alert motorists to downstream conditions. There are a few applications in the United States using speed control (i.e., variable speed limit signs) with lane control, but this practice is limited.

Another manner in which agencies can monitor coverage of their transportation system through the TMC is with service patrol vehicle dispatching. In some TMCs, travel condition data can be used and manipulated to warrant the dispatching of service (or motorist assistance) patrol vehicles, which may be stationed at accessible locations or continuously run over a specific route to assist in incident management and disabled vehicle clearance. The service patrol vehicle drivers are in constant communication with TMC operators and dispatchers to obtain and send updated information on the incidents' status and to maintain the clearance operation.

INSTITUTIONAL ARRANGEMENTS AND COORDINATION

Among the most important institutional issues are intrajurisdictional and interjurisdictional coordination. Organization of the TMC depends on two conditions: 1) where it reports within an agency's hierarchy, and, 2) its relationship to regional agencies' TMCs and responsibilities. Regardless of the TMC's location in the agency or regional structure, its organizational relationships should be established before implementation. This avoids confusion for the management and oversight component of the TMC once it is in operation (*1*).

The organizational relationship needs to be clearly understood and well defined to maintain the presence of the TMC within the responsible agency or coalition of agencies when important organizational decisions are made. Administratively, the TMC is best located in its agency's organizational structure where it can receive the bureaucratic and financial support required to maintain operations. This is accomplished at the highest level possible within the agency or organization, which is typically in the operations department. At this level, the TMC administrator would report to a Transportation Operations Director (or similar title) and thus would be able to emphasize the importance of the TMC function and have support to compete for funding, equipment, and staffing. Even in smaller cities, where the responsible transportation agency may not be as structured as in large cities, it is nonetheless important for the TMC to be promoted and its function made known to city officials. This can also be said for newer TMCs that have very limited capabilities. In many past cases, a major step in TMC development has been the appeal of potential capabilities to state, regional, or city officials.

Organizationally, the TMC also needs to be situated within the regional transportation management structure where it can receive and disseminate information directly to other TMCs. In most large metropolitan areas, it is not usually feasible to locate all transportation management functions in a single TMC because of political, jurisdictional, legal, or financial barriers. It should also be noted that a singular, multi-agency TMC may not be warranted for a metropolitan area. While it is extremely difficult to house the transportation management activities of each agency in a single facility, advancing computer, communications, and network technologies make it conceivable to effectively coordinate the activities of a number of TMCs located throughout a metropolitan area or geographic region. For maximum exposure, it may be advantageous to physically house the TMC within a transportation agency's headquarters or regional office. In this fashion, the TMC is perceived by executive management as a visible and active part of the organization. As an example, Washington State DOT found that locating its TMC in the regional headquarters office building in Seattle helped significantly with the coordination of technical and managerial activities. Conversely, other agencies have reported that it is preferable for the TMC to be located away from a regional or main office so that the TMC's activities can be conducted without nearby influence and political interference.

Regional TMCs must be extensively networked with other TMCs to ensure coverage of all highways, surface streets, transit, bridge/tunnel facilities, and emergency operations in the region as well as with the media and private sector information vendors. Such a communications architecture maintains reasonable regional coverage even if one TMC is off line. In any form of regional TMC architecture, the responsibilities for each agency are most effective if they are outlined in signed memoranda of understanding (MOUs) or documented interagency agreements *(1)*.

Although a considerable commitment is required for regional interjurisdictional coordination, a simple and useful solution may be the establishment of an active policy or oversight committee composed of the executive directors of participating regional agencies, such as that established for TRANSCOM or TranStar. Establishment of a policy committee, technical committee, subcommittees and user groups may aid in fostering long-term coordination, cooperation, and consensus building, especially in larger metropolitan areas where there are typically numerous involved agencies and organizations. A technical committee that steers technology, innovation, standards, and technical deployment represented by each regional agency may be highly beneficial to TMC advancement. Additionally, it may be advisable to establish technical subcommittees dealing with specialized TMC topics and any users' group interests to share experiences. As evidenced by the Washington State DOT TMC in Seattle, the interjurisdictional coordination process may be executed on a regular basis through a small group of decisionmakers representing the involved agencies.

The TRANSCOM coalition exemplifies the need for a cooperative and coordinated approach for a TMC to manage regional transportation effectively. TRANSCOM is a coalition of 14 transportation and public safety agencies in the three-state metropolitan region of New York, New Jersey, and Connecticut. The coalition provides a cooperative and coordinated approach to regional transportation management. Its funding and administrative mechanism are guided primarily by its member agencies, with assistance from FHWA. The coalition is governed by an executive committee board and a strong organizational structure consisting of the chief executives of its member agencies. All actions, whether financial, administrative, or technical, taking place within the TRANSCOM coalition require the unanimous approval of the executive board committee. Interjurisdictional coordination within the coalition plays a significant role in its implementation of ITS technologies in a multijurisdictional environment and in the regional construction coordination program.

Multi-Agency Operation

In multijurisdictional or multi-agency TMCs, the primary functions and requirements discussed above are similar, however, the operational structure within the TMC or network of TMCs takes a more integrated approach. Different TMC configurations may be employed, depending on the role of the involved agencies and organization of the TMC. In the operation of a single TMC, computer hardware and personnel for each involved agency in the coverage region usually share space in the TMC's control room. In this system design, the TMC can accept and manage all transportation and equipment status data from the multi-agency coverage region *(6)*.

In regions (mostly large metropolitan areas) with multiple TMCs operated by different agencies, many of the participating agencies house their computer hardware and personnel in their own center and communicate externally with the other TMCs. In this system design, a centralized TMC (if this communications architecture is used), plays roles in each of two scenarios. In one scenario, a centralized TMC carries out its primary field controls through workstations that are networked with a second agency's TMC. In this case, each agency's center provides backup field control and data storage capabilities. In a second scenario, a centralized TMC acts as the overall coordinator of individual TMCs, and the workstations in individual TMCs would have full control of field equipment *(6)*.

CHAPTER THREE

DESIGN CRITERIA

This chapter presents the design criteria for a number of TMC related topics. This information results from the survey responses and is supported by literature on existing systems.

A survey of agencies on various TMC related topics was conducted through correspondence with TMC and freeway/incident management experts. The topics covered in this synthesis through the survey and a separate review of existing systems are:

Justification and feasibility—What are the primary reasons for building a TMC?

Communication among TMCs—What types of communications architecture are used by TMCs?

Staffing and hours of operation—What are the working shifts in a TMC? How many people are employed by the TMC during all working shifts? What type of personnel are employed?

Operations and maintenance—What aspects of the TMC does operations and maintenance include? What are some typical activities?

Costs—How are TMC costs defined? How much does a TMC cost?

Public relations and media involvement—What are the agencies' approaches to communications with the media? Who constitute the media? What are any public relations activities related to the TMC?

Information dissemination and sharing issues—What are TMCs policies regarding sharing information with other agencies and organizations? Are there any issues?

Resource sharing—Does resource sharing involve TMCs? What resources are shared? Which agencies are the resources shared with?

Liability and litigation—Is liability cause for concern by a TMC? How should the responsible agency view its TMC in terms of liability as a part of transportation management?

Procurement procedures—What procurement processes are used for the TMC or for any systems within the TMC? How are the processes utilized?

Software issues—How is software for the TMC's central system obtained? What issues have been raised?

JUSTIFICATION AND FEASIBILITY

An agency's technical manager must secure the support of high-level management when proposing a TMC. This begins with an initial justification of the need for the TMC. Unfortunately, TMC construction has often been set aside not only due to budget constraints but for a lack of understanding on the part of the agencies' decisionmakers of the utility of TMCs. Initial planning for a TMC should address and justify the initial capital and on-going operations, maintenance, and staffing expenses of a TMC.

As a consequence of demand from the public and government agencies, some agencies have reported that a TMC has become a necessary system component for advanced transportation management systems the agencies have planned or installed. In these agencies, the commitment to install advanced technologies provides the foundation for the political and financial support for the TMC. Additionally, TMCs can be also be built based on the support, in part, of the Congestion Mitigation and Air Quality (CMAQ) Program. Under ISTEA, the CMAQ Program is a funding mechanism for projects that will contribute to the attainment of national ambient air quality standards in nonattainment areas.

In addition to being a necessary system component in advanced transportation management system deployment, TMCs may be warranted for a variety of reasons. Many agencies expect that their TMC will serve as a multifunctional and multimodal management facility. Some common expectations of TMCs include:

- Control and management of signal control systems (rail or surface street),
- Monitoring, control, and management of highway systems control and management of corridors,
- Participation and assistance in the incident management process,
- Provision of motorist and traveler aid services,
- Provision of traveler information (traffic and weather conditions) to media, motorists and other travelers, and other private entities,
- Interagency and multimodal coordination,
- Coordination of commercial vehicle ITS user services, and
- Air quality improvements.

While many of these expectations can serve as the backbone of TMC justification, building individual facilities may depend on overcoming institutional obstacles—funding constraints and political pressures, to name two. If the technical feasibility is well justified and has broad-based support, then the TMC is more likely to be developed.

Each agency respondent was asked to provide justification for building their TMC. The survey results were divided by type of TMC to identify common areas of justification. Respondents from highway TMCs cited congestion management most frequently as the primary justification for building a facility. Other justifications included:

- Public service and notifying the motoring public,
- Incident management,

- Centralization of operation, control, and communication with field elements,
- Emergency management and response coordination, and
- Necessary system component.

By far, the most common justification for building a surface street TMC was congestion management. Other justifications included:

- Incident management,
- Need for monitoring and control of the system,
- Information processing and dissemination, and
- Centralization and upgrading signal systems.

Anticipated special events and large long-term construction projects such as the Central Artery/Tunnel Project in Boston, are also frequent justifications cited for the building of a TMC. The Central Artery/Tunnel project has an interim operations center (IOC) which conducts surveillance, incident management, and traffic management advisory functions. The IOC monitors the primary highway and surface street network, including a portion that is affected by the project. The IOC will serve a critical role in the project until a permanent TMC for the City of Boston is constructed. A video surveillance and control system is used in the new TMC at the Third Harbor Tunnel (Ted Williams Tunnel) connecting East Boston to the downtown. According to the survey results, respondents from bridge/tunnel TMCs most regularly cited these reasons for justification:

- Public service,
- Incident management,
- Toll management,
- Traveler safety improvement, and
- Traffic control.

In another example, New York State DOT will deploy an interim TMC for the Gowanus Expressway (I-278) in New York City to facilitate a 10-year, $600 million reconstruction project. The interim TMC covers both freeway management and a coordinated surface street system for the project's regional area.

In parallel with highway and surface street TMCs, bridge/tunnel TMC respondents indicated congestion management as an important consideration in justifying a TMC. Bridge/tunnel coverage tends to be more localized and its congestion management concerns are generally limited to their facilities and any upstream approaches. In some urban areas, bridge/tunnel TMCs complement highway and surface street TMCs, thus eliminating gaps in coverage in an individual corridor or throughout a regional network.

Of the transit related TMCs, transit-bus survey respondents cited TMCs as a necessary component of their vehicle dispatch and tracking system. Other responses included safety, system management, air quality, and interagency coordination. For transit-light rail/subway TMCs, survey respondents also indicated similar justifications, primarily the need for vehicle dispatch. Overall, transit agencies have a strong need for centralized fleet control and monitoring. Survey respondents from commuter railroad TMCs considered centralized management and control of rail and maintenance operations as the primary justification. Additionally, respondents reported the need to upgrade the control system and necessary system components. Although the sample size for each transit related TMC was much smaller than for roadways, the general trend of responses was consistent.

COMMUNICATION AMONG TMCs

It is becoming increasingly rare for an agency to operate a TMC that does not communicate with other TMCs, especially in urbanized areas. For regions with multiple TMC configurations, three types of communications architectures are common: centralized, distributed, and hybrid. These TMC architectures may interconnect multiple TMCs of a single agency or may interconnect the TMCs of several different agencies. In many urban areas, operating agencies are involved in regional transportation management and coordinate their activities through a network of TMCs.

Examples of all these TMC architecture types are in evidence around the country. An example of interagency TMC coordination is a state transportation department that covers freeways and municipal or county agencies that cover surface streets. Expansive coverage and multiple transportation systems and modes require the integration of TMC operations.

Figures 7 through 9 depict the three common types of TMC communications architectures. As shown in Figure 7, Maryland has established a centralized communications architecture for state TMCs. In Maryland, regional TMCs individually communicate with and report to the centralized statewide TMC. The regional TMCs perform all the necessary monitoring and data collection activities, but they report local conditions to the statewide TMC and handle specific events, such as nonrecurring congestion, incidents, and route diversion.

Figure 8 illustrates a distributed (or decentralized) communications architecture for multiple TMCs. In the Chicago area, individual TMCs operated by Illinois DOT perform distinct and separate functions but communicate and report information continually to one another; discuss mitigation options; and act jointly when events occur. In this architecture, there is no central point, and each TMC essentially contributes to assessing and responding to changing conditions.

A hybrid communications architecture for multiple TMCs, exhibited in Figure 9, will exist in Southern California when a new system becomes operational. A hybrid architecture will be used to combine centralized and decentralized communications architectures where a complex and integrated network of TMCs, whether operated by a single agency or multiple agencies, exists. In Southern California, the cities of Irvine, Santa Ana, and Anaheim each operate a localized TMC. Currently, each city's TMC performs its individual functions but the future plan is to communicate and interact only with the District 12 TMC. Figure 9 indicates the centralized portion of the communications architecture to support the exchange

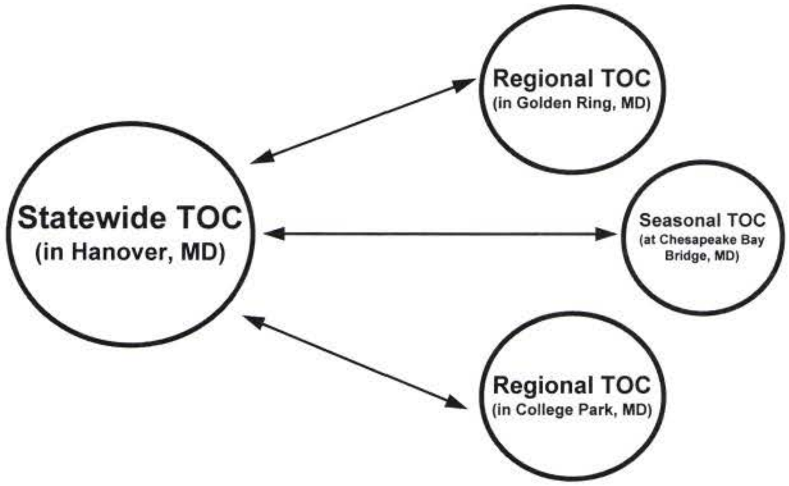

FIGURE 7 Example of a centralized TMC communications architecture in Maryland.

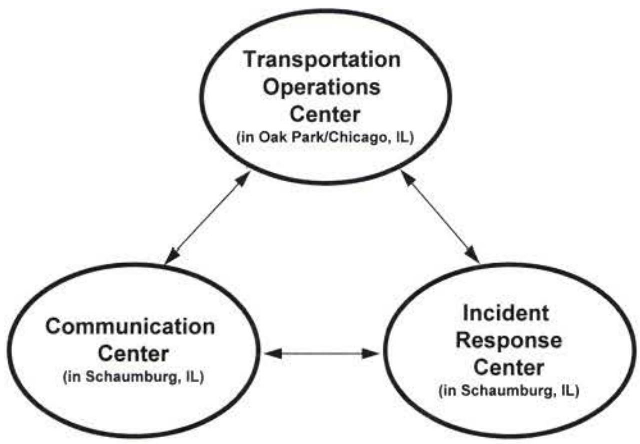

FIGURE 8 Example of a distributed TMC communications architecture in Illinois.

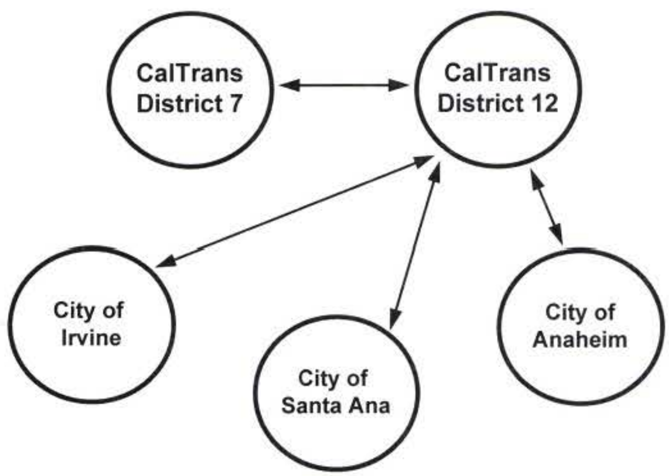

FIGURE 9 Example of a hybrid TMC communications architecture in the southern California region.

of traffic information and performance of traffic management functions. The District 12 TMC will communicate any relevant information obtained from the individual city TMCs, as well as their own data, to the District 7 TMC. In the figure, interaction between the district level TMCs represents the decentralized portion of the communications architecture. In addition, the four Southern California TMCs (District 12, Irvine, Santa Ana, and Anaheim) will be integrated so data can be shared and regional functions assumed when one TMC is inoperable.

Other TMC architectures currently in use are more complex versions of the simplified centralized, decentralized, and hybrid architectures described above. For example, in the tristate region of New York, New Jersey, and Connecticut, a regional coordinating consortium of some 14 agencies called TRANSCOM (Transportation Operating Coordinating Committee) has established a TMC with a regional architecture in which there are no operational or control responsibilities. TRANSCOM's regional operations information center (OIC) is a complex version of a centralized type of architecture. While TRANSCOM does not operate roadways or facilities, it serves as a clearinghouse and coordination hub for the collection and dissemination of real-time incident and construction information 24-hours per day to over 100 member agencies and affiliates. TRANSCOM monitors, with its own deployed technologies, and receives information on multiple transportation systems within the three-state region. TRANSCOM's regional architecture, to be completed in 1999, consists of a central database server linked with workstations located at member agencies' facilities.

While TRANSCOM serves a tri-state area, another TMC architecture is emerging that transcends geographical regions and corridors. To coordinate and share transportation information among TMCs, over 40 agencies have expressed interest in the development of a "virtual" TMC network, called the Information Exchange Network (IEN), to connect TMCs in the I-95 corridor on the East Coast. In this "virtual" network, there is no centralized TMC. Instead, the network connects more than 50 workstations in 12 states with real-time data and graphic displays that include GIS capability to display real-time corridorwide information. Information on any portion of the I-95 corridor may be accessible to any I-95 Corridor Coalition member agency operating an IEN workstation from their own TMC. The I-95 Corridor Coalition member agencies' TMCs currently have their own systems workstation and a separate IEN workstation.

The network connects, in real-time, statewide TMCs and local TMCs to share incident-related and other relevant information. Both the information gathering and information disseminating aspects of TMC operations are deployed to assist operating agencies in traffic management. The IEN extends the capabilities of local operators to reach out to distant TMCs in real-time during the incident management process and broadcasts the relevant information to all agencies involved. The system facilitates connections to existing advanced traffic management systems across all modes, locations, and private sector designs and will soon be able to use expert systems.

The IEN requires technical and operational support to develop, operate, maintain, and evaluate the data being used. The support includes the gathering of information from member agencies and other sources, assessment, and synthesis of the data for dissemination to other member agencies' TMCs. In the future, the IEN will provide integration of software to allow transfer of data to and from agency-specific systems and will have the capability to display the locations and characteristics of all relevant ITS components, such as VMS, CCTV, HAR, and TMCs. It is the intent of the I-95 Corridor Coalition that the network be the cornerstone of the I-95 information system, and is supported by the plan for deployment of 60 interconnected workstations at member agencies' TMCs *(12)*.

The IEN and TRANSCOM regional networks use common system platforms. From a technical and institutional perspective, the TRANSCOM regional architecture may be considered a subset of the Corridor-wide IEN. Accordingly, the requirements of the IEN are established in conjunction with the TRANSCOM Region-Wide ITS Implementation Strategy and vice-versa. In this manner, members of both networks have access to the IEN and the TRANSCOM regional architectures through the workstation in their TMC *(13)*.

Presently, a consortium of transit, highway, surface street, and bridge/tunnel agencies in the New York City metropolitan area is considering draft alternatives for a complex hybrid communications architecture that will tie into existing regional TMC networks (i.e., TRANSCOM and IEN). Currently, the consortium of leading agencies (New York City DOT, New York State DOT, Port Authority of NY/NJ, and Metropolitan Transit Authority of New York) have devised four draft regional architecture design alternatives; in each alternative one of the four leading agencies would act as the regional system TMC server. A TMC system and subsystem structure is in development for each of the four draft design alternatives. The structure for each design alternative will identify which agencies will be operating TMCs and what the flow of information will be. Potential issues and obstacles include conformity by all involved agencies to the multijurisdictional organizational and institutional framework and tying together multiple layers of communication architecture so that members of separate regional architecture can be interconnected.

In this unique hybrid regional architecture, individual TMCs, each managing a portion of the regional transportation system, are connected to a subregional server that is operated by one of the four leading agencies' servers. The subregional agency server is connected to a much larger regional architecture controlled by TRANSCOM and the IEN and can communicate with other agencies outside the New York City subregional architecture. This type of complex, multitiered regional architecture is beneficial because the impact of changing travel conditions may be traced throughout the system and throughout the region, even though there is overlapping of system and agency boundaries.

Among the considerations in the development of a draft regional architecture, there are four architecture alternatives (each with a subregional agency server) that will communicate with and support the regional servers (i.e., TRANSCOM and IEN). The New York City agency subregional server provides coverage over surface streets within the boundaries of New York City and interconnects the New York State DOT advanced traffic management system components within the New York City boundaries, city DOT traffic control system, city DOT operations, city police command center, city mayor's office for emergency management, and other city emergency and response agencies. The New York State agency subregional server primarily covers the highways and priority arterials within the five boroughs of New York and in regions adjacent to the city, such as Long Island and the downstate region. A third agency subregional server controlled by the Metropolitan Transit Authority interconnects transit agencies such as New York City Transit rail and bus, Long Island and MetroNorth commuter railroads, and the Long Island bus system. The final subregional architecture comprises a Port Authority of NY/NJ agency subregional server that interconnects relevant Port Authority facilities including the three major airports, the bus terminal, the George Washington Bridge, the Outerbridge Crossing, the Lincoln and Holland Tunnels, and all waterway ports controlled by the agency. All of these subregional servers will be networked among each other as well as the regional architectures served by TRANSCOM and the IEN.

The survey results for this synthesis reveal that, currently, most TMCs of all types are of a centralized or distributed communications architecture. There are relatively few TMCs with a hybrid communications architecture at this time. However, this type of deployment is increasing as configurations become more complex and more multi-agency integration is necessary. Table 6 lists the frequency of the types of architectures used for each type of TMC. Many of the highway, surface street, and transit TMCs have centralized communication architectures. Most of the bridge/tunnel TMCs are distributed and perform functions that are related to a single facility. Many of these bridge/tunnel TMCs do not communicate with a central external TMC. Examples of distributed communication among TMCs can be found in the Port Authority of NY/NJ and MTA Bridges and Tunnels (Triborough Bridge and Tunnel Authority) facilities in New York.

TABLE 6

TYPES OF COMMUNICATION ARCHITECTURE BY TYPE OF TMC (%)

Type	Highway	Surface Street	Bridge/ Tunnel	Transit (Bus)	Transit (Light Rail/Subway)	Rail Commuter/ Intercity
Centralized	70.5	64.8	22.7	50.0	66.7	85.7
Distributed	15.9	18.5	63.6	50.0	33.3	14.3
Hybrid	13.6	16.7	13.6	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

STAFFING AND HOURS OF OPERATION

Staffing

Staffing of a TMC is based to a great extent on two primary concerns: the number and type of personnel needed, influenced by predetermined budgets, and the knowledge and planning required to fulfill the functions (and corresponding tasks) of the TMC. A detailed analysis of the individual tasks to be performed may be required to determine the exact number of personnel needed for the TMC's full-time and part-time positions. When TMC task assignments have been determined, the responsible agency can begin to organize the staff structure and quantify the number of employees at each level *(7)*. A variety of personnel, from the TMC director or chief supervisory position to the individual technical assistants, play significant roles and perform essential duties in a TMC. Regardless of the type of TMC, effective day-to-day operation requires a number of basic tasks and administrative procedures by the TMC team to: *(6)*

- Ensure the continuity, integrity, and efficiency of operation,
- Obtain, retain, process, analyze, manipulate, and archive data,
- Ensure security, operation, and administration of the TMC's software, hardware, databases, local area computer networks (LAN), communications system, servers, etc.,
- Ensure that the TMC functions are performed by authorized and properly trained personnel,
- To communicate and coordinate with affected agencies and organizations, and
- Document or maintain logs of all TMC tasks and activities.

Depending on the hours of operation and the extent of functions at the TMC, a variety of staffing levels can serve the responsible public agency or private organization (if operated for the agency). Typical full-time positions in the TMC indicated by the responding agencies included:

- TMC manager or director,
- Supervisors (definable for operations, engineering, maintenance, law enforcement, systems, etc.),
- Equipment (field and central) engineer or maintenance coordinator,
- Transportation engineers,
- Electrical engineers,
- Computer programmers,
- Workstation operators and analysts,
- System administrators (for computer hardware, software, and networks),
- Inspectors (e.g., for field equipment, etc.),
- Inspecting supervisor (if applicable),
- Law enforcement personnel (for TMCs with joint operation of a transportation agency and a police department/highway patrol),
- Radio dispatchers,
- Administrative staff, and
- Maintenance staff.

Individual TMCs, depending on the functionality and extent of their activities, may not require each of the positions listed above and are affected by the technical, financial, and institutional concerns of the responsible agency. The following part-time and/or full-time positions have been described by agencies whose specific TMC functions require particular types of personnel:

- Additional workstation operators and analysts,
- Desk operators,
- HAR broadcasters,
- Dispatchers only for motorist-aid patrols (if applicable),
- Emergency planners,
- Maintenance technicians,
- Task-oriented trainees,
- Public information and media relations personnel, and
- Intern employees.

Well-defined qualifications requirements are critical to hiring competent personnel with adequate skills to carry out the TMC's overall function. For many of the TMC positions, the personnel need some understanding of traffic operations and knowledge of the regional transportation system covered by the TMC. Further, the job descriptions and qualifications for various TMC-related positions (i.e. police department or highway patrol officers) should be upgraded as responsibilities at the center are changed or added *(7)*. The need for direct involvement of the responsible transportation agency may be significantly reduced for privately staffed TMCs, such as New York State DOT's Information for Motorists (INFORM) TOC and ConnDOT's Bridgeport TMC.

Need for Maintenance Personnel

As ITS deployment begins to improve the overall level of service of the transportation system, any failure in these systems will be especially obvious to the public and potentially damaging to the responsible agency. Therefore, the responsibility for timely maintenance should be under the control of the TMC and should include any independent information systems that the TMC interacts with. In staffing a TMC, it is important to obtain the necessary maintenance support of field equipment linked to the TMC. Prompt and timely preventive, response, and design modification maintenance of field devices is essential to efficient real-time functioning of the system. Traditionally, through procedures based on long-standing maintenance priorities, it was the maintenance division of the transportation agency that sent personnel to the field to perform a variety of maintenance tasks. This process may not be suitable for the needs of TMCs. Rather, the TMC should have its own permanent maintenance group. To facilitate this, the personnel necessary to maintain TMC field equipment may need to be transferred from the agency's maintenance department to positions directly under the TMC director. Otherwise, there should be a clear understanding between the maintenance division and the TMC for allocation and dispatch of maintenance personnel. In either staffing structure, a dedicated maintenance workforce is essential for TMC related maintenance activities *(1)*.

The maintenance personnel, whether transferred or hired from the outside, will likely require additional training to properly service advanced electronic equipment. Additionally, traffic signal technicians and specialists may need to be hired to diagnose, troubleshoot, or upgrade particular devices such as detectors, signal controllers, and other TMC-controlled field devices. Because of the complexity of equipment and the technical skills needed to maintain the TMC, decisions about hiring and training maintenance personnel are best controlled by the TMC manager. It is important for the responsible agency and the TMC manager to make a commitment to the immediate repair of the system and restoring normal operation.

In addition to hiring staff to carry out various support functions, the responsible agency may wish to contract out personnel for services. Contracting is a customary process for agencies to obtain operations, maintenance, and hardware/software support.

Need for Emergency Personnel

Police and emergency agencies, along with dedicated incident management and motorist-aid patrol services, play a critically important role in coordination and information exchange functions at the TMC. In a number of jointly operated TMC facilities around the country, specifically the I-4 TMC in Orlando, Florida, Caltrans TMC in San Diego, and the Bridgeport, Connecticut operations center, space is provided for police and/or motorist-aid personnel. Emergency management personnel may also be performing specific duties in the TMC. At the Houston TranStar TMC, Harris County and the City of Houston Emergency Management Agency are co-located in the building and they, along with the Texas Department of Transportation and Houston Metro, can manage many of the logistical aspects of both transportation and emergency management from the center in response to a major incident or disaster. These employees communicate and interface with emergency medical service (EMS) personnel not located at the TMC. It should be noted that many TMC facilities, due to a variety of constraints, do not have emergency, law enforcement, or motorist-aid personnel in the same facility with TMC operations personnel. The lack of proximity among agencies does not hinder coordination and information exchange efforts because standard operating procedures and interagency agreements have been established.

Generally, workstations and communications equipment space are provided for police and incident management/motorist-aid patrol personnel within the TMC's operations and control room. If there needs to be a physical separation, an adjacent dedicated room can serve their respective TMC-related functions. This type of configuration can be likened to a virtual linkage, where the agencies involved would not require dedicated space and/or equipment. In this configuration, TMC personnel can provide information and travel condition updates to these agencies and organizations instantly, as well as provide a direct communication link, or "hotline," for the police or motorist-aid patrol to speak to TMC personnel.

Perhaps the most important influence on TMC staffing is funding levels and budget constraints, which have a marked effect on the types of positions and the salaries of both full-time and part-time employees. Headcount and hiring constraints may also have a significant effect on staffing levels. Since there are no national minimum standards for TMCs and TMC staffing, any headcount and hiring constraint issues are tackled by individual TMCs. The constraints are generally dictated by funding, but also the workload of current employees and the function of the TMC.

Operation of the TMC may be maximized through a staffing structure that covers all the primary functions of the TMC at the lowest reasonable cost. Hiring experienced and qualified part-time employees whose contracts may not require fringe benefits is one example. Cost is a particularly critical aspect when staffing TMCs operated by all organizations (public and private agencies) that are limited by contract or budget caps to the amount of funding available for the TMC by the responsible agency *(9)*. As a result, salary ranges vary widely across TMCs and across types of personnel within the TMC. These ranges are primarily dependent on the job responsibilities and titles of each person working in the TMC. In estimating salary ranges, it may be useful to use salaries of technical, administrative, and managerial personnel within the responsible agency as a basis and then tailor them to each employee depending on what portion of the employee's job is dedicated to the TMC. Salary ranges also are dependent on the responsible agency's annual TMC budget (if one has been established), as well as inflationary factors.

Table 7 contains aggregated average salaries of TMC positions provided by Los Angeles County in 1997. Table 7 lists average salaries of 14 TMCs for each position and does not specify the average level of experience or expertise for each employee. The average salaries presented in Table 7 are typical of one urban area and are not intended as suggested hiring wages, as the salaries for each position include averages from a number of different levels.

TABLE 7

AVERAGE SALARIES FOR TMC-RELATED POSITIONS IN THE LOS ANGELES, CALIFORNIA AREA (1997 Salaries) *(2)*

Type of Position	Average Annual Salary ($)
Director/Manager	89,920
Assistant Manager	69,000
Senior Supervisor	61,700
Supervisor	54,299
Transportation Engineer	74,043
Assistant Engineer	46,293
Senior Analyst	67,442
Analyst	50,234
Operator	51,000
Electrician/Technician	44,449
Administrative Clerk	30,682

Notes:
- Salaries are based on reported employee salaries for 14 transportation centers in Los Angeles County, California.
- Salaries may vary by region or city or agency.
- Individual responsibilities for each job type may vary and thus constitute a higher (or lower) than expected salary.
- Salaries shown include annual direct salaries without benefits and overhead costs.
- Types of positions and/or responsibilities may overlap in varying sizes of TMCs or in TMCs in other urban areas.

TABLE 8

TMC-RELATED SALARY RANGES FOR A TYPICAL MIDWEST URBAN AREA*

Type of Position	Annual Salary Range ($)
TMC Manager	47,090–80,400
Computer Unit Manager	44,100–74,400
Civil (Traffic) Engineer	36,240–61,080
Electrical Engineer	36,240–60,780
Senior Equipment Technician	36,960–66,720
Equipment Technician	25,980–45,900

*Information supplied by Illinois DOT from their January 1997 Pay Plan.

Many municipal traffic agencies and state DOTs have structured job descriptions and pay scales for technical positions that are lower than those presented in Table 7. The TMC salaries for a typical Midwest city and Northwest city are listed in Table 8 and Table 9, respectively. Some positions' salaries may be more representative of a private sector operation. As a result, there is a common problem among public agencies that have considerable difficulty in obtaining and retaining highly technical personnel on a public sector salary schedule. In many instances, state and local transportation agencies do not have the flexibility to pay technical personnel at the same level as private sector salaries, so the public agencies end up hiring entry-level personnel who leave the agency after a short time of on-the-job training for higher salaries in the private sector. Also, many of these agencies may have job descriptions that do not match the technical functions to be performed or that adequately describe the technical knowledge needed. Agencies typically match the position to the nearest fit. As a result, many agencies try to hire a person whose technical skills are in high demand (and command a high salary) to fill a position that is not adequately described in personnel job descriptions and which pays a lower salary than the market demands.

TABLE 9

TMC-RELATED SALARY RANGES FOR A TYPICAL NORTHWEST URBAN AREA*

Type of Position	Annual Salary Range ($)
Regional Traffic Operations Engineer	44,879–57,437
Assistant Freeway Operations Engineer	40,640–52,048
Traffic Operations Engineer	36,833–47,153
Assistant Traffic Operations Engineer	33,372–42,704
Shift Traffic Operations Engineer	30,270–38,699
TMC Operator	26,932–34,188
Communications Specialist	21,865–27,550
Traffic Systems Operations Specialist	23,422–29,577
TMC Software Engineer	36,833–47,153
Assistant TMC Software Engineer	30,270–38,699
Computer Analyst/Programmer	30,270–38,699

*Information supplied by Washington State DOT Northwest Region Traffic Division, September 1996.

Public agencies that want to hire and retain qualified personnel may need to develop new job descriptions and classifications that better reflect the duties and responsibilities related to the TMC (in addition to more traditional responsibilities) and the fair market value of the salaries paid for these positions.

Training

Some agencies involved with the operation of TMCs have formal or informal training programs in place. Methods of training vary widely, but most occur on the job. The TMC in the northwest region of Washington State DOT supplements on-the-job training for new operators with a manual. Use of manuals and step-by-step handbooks is a common training method. Other training programs include software simulation programs on demonstration workstations, and training material followed with a course syllabus *(7)*.

Some TMCs also have specialized training programs, such as emergency planning, and procedure training materials for involved personnel on natural and man-made disaster response events *(7)*. Emergency management, response, and dispatch training related to the TMC needs to be compatible with, in compliance with, or designed to achieve existing safety procedures.

Survey respondents from each type of agency were asked what types of training programs they have for TMC personnel. The most common training methods related to highway TMCs include:

- Certification through seminars and/or workshops,
- On-the-job training,

• In-house training,

• Simulation and mock-training (some with simulated workstations),

• Classroom and coursework, and

• Computer-based training (an effective, although expensive, method).

Some agencies indicated that their personnel received training from outside facilities. Only two of the TMC respondents (approximately three percent) indicated that they did not have training available for TMC employees. Some of the most common training areas related to highway TMCs, according to the responses, include:

• Emergency management (related to response and preparedness),

• Computer training and network certification,

• Incident management,

• Radio operations and telecommunications,

• Traffic analysis, and

• Partnership and team building.

Other methods and areas of training related to freeway TMC operation were reported and they may be considered by individual TMCs. For surface street TMCs, the most common training methods indicated by the survey respondents are:

• In-house training,

• On-the-job training,

• Training conducted by private consultants, contractors, manufacturers, installers, and equipment and software vendors,

• Certification through seminars and/or workshops, and

• Classroom and coursework.

Although many areas of training were identified in the survey, one was cited considerably more than others. Signal timing training related to planning, development, and optimization was indicated as a universal and necessary aspect of surface street TMC operation, according to respondents. Approximately 11 percent of the surface street TMC respondents indicated that they did not have training available for TMC employees. For some of these TMCs, the respondents indicated that training was not needed or used by the TMCs' personnel.

For bridge/tunnel TMCs, in-house and outside classroom training methods were the most frequently indicated by survey respondents. Only three percent of the bridge/tunnel TMC respondents indicated that they did not have training available for employees. Areas of training most frequently cited by respondents were desk officer training, supervisor training, and computer and communications training for technicians.

Training methods cited most frequently among the three types of TMCs included on-the-job training, user manuals and standard procedures, certification courses (some of those indicated are offered by the federal government), field training and orientation, and instructional tapes. Training areas were identified from every transit TMC type and only one area was common to all types: dispatcher training courses on emergency services. The survey results indicated that 20 percent of the transit related TMCs did not have training available for its employees.

In addition to providing training for new employees, it is important for agencies to cross-train their existing full-time and part-time TMC staff to defray budget or staffing constraints. Cross-training allows TMC employees to pick up and become proficient in skills other than those required for their primary responsibilities. Due to resource constraints, Caltrans' District 12 TMC initiated significant cross-training efforts between Caltrans personnel and California Highway Patrol officers to perform computer-aided dispatch duties, monitor CCTV cameras, etc. Although law enforcement officers and operations personnel may work within the same TMC facility, cross-training the two groups may be a challenge since there is a notable difference between them. The two groups may be cross-trained to perform similar tasks, however, enforcement personnel may be better equipped and require less training than operations personnel to interact, communicate with, and dispatch emergency personnel agencies. Conversely, operations personnel have more technical skill to analyze or modify system components.

Hours of Operation

In many areas, TMCs operate continuously while others operate only for certain periods. Some TMCs, especially those dedicated to surface streets, may only require operation during peak traffic congestion periods (i.e., during times of ramp metering operation). As TMCs move toward performing a greater number of control and surveillance functions, the time periods of TMC operation will likely be extended (*6*).

Larger, regional TMCs operated by state transportation departments or regional governments are generally the most suitable for 24-hour, 7-day operation because of their larger staffs. For municipal or county operated TMCs, minimum coverage would be two weekday shifts, one each for the morning and evening peak periods. Many municipal and county operated TMCs lack the resources for off-peak hours operations and can only provide on-call staff for emergency or planned events. Some of these TMCs make arrangements to transfer their late night and weekend surface street or transit (surface street as well) control to the regional TMCs (*1*). Naturally, all of these staffing coverage practices should be determined by a needs assessment conducted by the TMC's responsible agency. The needs assessment should take into account the overall function of the TMC, the tasks that will be conducted there, and a variety of local conditions that may affect staffing coverage.

Some agencies, although operating their TMCs continually, do not always have dedicated TMC personnel for the entire operational period. During "off-hours" maintenance personnel may periodically monitor equipment malfunctions or TMC equipment operation. In some cases, the TMC's computers monitor the system automatically during the "off-hours" and "notify" an on-call TMC operator or supervisor when an unexpected event arises. Computers can also perform off-line

TABLE 10

PERCENTAGE OF DAYS AND TIMES OF OPERATION BY TYPE OF TMC ACCORDING TO THE SURVEY (Values in %)

	TMC Type					
Day/Time	Highway	Surface Street	Bridge/ Tunnel	Transit (Bus)	Transit (Light/ Rail Subway)	Rail Commuter/ Intercity
No. of Days of Operation						
7	58.2	31.4	90.0	87.5	50.0	62.5
6	1.6	1.7	0.0	0.0	12.5	0.0
5	36.9	65.3	10.0	12.5	37.5	37.5
Special Event	3.3	1.7	0.0	0.0	0.0	0.0
No. of Hours of Operation						
24	51.6	27.1	83.9	75.0	62.5	62.5
Limited Hours	45.1	72.9	16.1	25.0	37.5	37.5
Special Event	3.3	0.0	0.0	0.0	0.0	0.0
Avg. No. of Hours in Limited Operation	12.8	11.1	10.5	16.0	13.5	11.3

TABLE 11

SAMPLE STAFFING TABLE FOR 24-HOUR/7-DAY WEEK OPERATION *(9)*

Operator Level	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Dispatcher 1	10P-6A	10P-6A	10P-6A	10P-6A	10P-6A	10P-6A	10P-6A
Dispatcher 3	OFF	OFF	6A-2P	6A-2P	6A-2P	6A-2P	6A-2P
Dispatcher 2	OFF	OFF	6A-2P	6A-2P	6A-2P	6A-2P	6A-2P
Dispatcher 1	6A-2P	6A-2P	OFF	OFF	OFF	OFF	OFF
Dispatcher 3	OFF	OFF	2P-10P	2P-10P	2P-10P	2P-10P	2P-10P
Dispatcher 2	OFF	OFF	2P-10P	2P-10P	2P-10P	2P-10P	2P-10P
Dispatcher 1	2P-10P	2P-10P	OFF	OFF	OFF	OFF	OFF

functions during the off-peak hours, such as backing up files or processing traffic data and information from the field hardware. Performing these computer functions during the off-peak hours will allow the components to be up and running during the main hours of TMC operation coverage *(6)*.

Table 10 contains the percentage of days and times of operation for different types of TMCs. According to the survey results, bridge/tunnel and transit (bus) TMCs have the highest percentages of 7-day operation (90.0 and 87.5 percent, respectively) and 24-hour operation (83.9 and 75.0 percent, respectively). Conversely, the days and times of operation noted by the survey results for surface street TMCs revealed that operation coincided with regular business hours. Nearly two-thirds (65.3 percent) of all surface street TMCs were five-day operations, and almost three-fourths (72.9 percent) of surface street TMCs operate on a limited-hours basis. For those TMCs with limited hours of operation, (i.e., not operating around-the-clock), an average number of hours was determined for each type of TMC. The number of hours, based on the survey results, ranged from 10.5 hours (bridge/tunnel TMCs) to 16.0 hours (transit-bus TMCs).

Staffing for 7-day, 24-hour-per-day operation typically entails three assignment shifts, each 8 hours per day. The first and second shifts usually consist of full-time or part-time employees and encompass the daytime hours from Monday through Friday. These shifts include the morning and afternoon peak travel periods. Employees usually report to their full-time position supervisors and assist the supervisors in many aspects of operation during the peak periods. The first and second weekday shift supervisors are usually full-time employees and are present to monitor the TMC operation, perform administrative functions, and ensure that staff are adequately trained to perform their duties within the TMC. Additionally, students and temporary employees may be able to work during any shift. Table 11 contains a sample staffing table that presents various levels of staffing possibilities for a TMC operated by a state DOT. The staffing table is based on 24-hour, 7-day coverage and considers three possible staffing levels, categorized into dispatcher 1, dispatcher 2, and dispatcher 3. In the staffing table, the dispatcher 1 level provides support on weekends and non-peak-hour overnight shifts. The dispatcher 2 level provides full coverage 8 hours per day, Monday through Friday and the dispatcher 3 level provides full coverage and supervision 8 hours per day, Monday through Friday to accommodate increased activity during peak hours *(9)*. Supervisory employees routinely prepare and maintain training documents and reports on the staff, field, and equipment conditions. The supervisors report to the TMC director or manager. For TMCs operated by a private organization, such as the Long Island INFORM TMC, the supervisors and TMC manager may be required to document the TMC's operation on a periodic basis, usually in the form of a progress report (one is provided in Appendix D), to the public agency owner. Full-time weekday supervisors may be required in some centers to carry out on-call duties during off-peak hours to deal with operational problems or special events (*9*).

During the night or "off-peak" hours, and weekend shifts (for TMC's operated 7 days per week), a part-time shift may provide support to and carry out the TMC functions. Although these personnel have limited activity in the TMC, their level of training should be the same as for full-time personnel. This ensures that the effectiveness of the TMC's operation is not compromised during the off-peak periods. Part-time staff, which may include supervisors, may also be scheduled to cover full-time employees and supervisors in the event of sick leave or vacation time. Depending on future plans for the TMC, the agency may wish to promote experienced part-time employees to full-time status to provide for additional coverage of the system *(9)*.

Additionally, there are some important logistical items to consider when developing staffing schedules. TMC scheduling (again depending on size and complexity of operations) may require detailed advanced planning. It is generally most efficient for the TMC if staff shifts do not change during peak hours. All positions related to the TMC's operation should be in place prior to the peak travel periods. This also applies to TMCs that are not 24-hour, 7-day operation centers and those TMCs that are in operation only during weekends or special events *(9)*.

It is important for the TMC's operating agency to develop and maintain in the facility a large, visible staffing schedule that displays the schedules of all employees, both full-time and part-time on a daily or weekly basis. By having a visible schedule, the TMC staff manager can be kept apprised of any foreseeable staff shortcomings or lack of personnel during the overlap in shifts. For this reason, the TMC manager and personnel supervisors should consider part-time employees a valuable asset to the operation of the TMC, particularly for 24-hour operation. Furthermore, it is imperative in larger TMCs to rotate the shifts of the part-time employees on a periodic basis (i.e., monthly) to allow them to become more familiar with the TMC's operating system, procedures, and co-workers *(9)*.

OPERATIONS AND MAINTENANCE

Operations Manual

A number of administrative concerns related to operations and maintenance must be addressed when designing a TMC of any type. For every TMC there should be a management-issued Operations Manual. The manual should be completed, reviewed, and approved by the management of the responsible agency and management of all agencies for joint operations. The manual should cover three basic TMC areas: general TMC information; policies and procedures on internal operations and maintenance functions of the TMC; and policies and procedures involving traffic management. The sub-topics of these three basic areas are presented in Table 12.

The manual can be developed with the above considerations and may include additional materials based on the mission and design of the TMC along with any local considerations. Manuals for future TMCs will be developed with increased emphasis on the standards and protocols of a national ITS architecture and practice in mind.

Division of Responsibility

Regardless of the functions and extent of operations performed within the TMC, a clear division of responsibility for personnel in the center is most important. A detailed, documented, and acknowledged division of staff responsibility, particularly in multi-agency TMCs, eliminates confusion among personnel and clearly establishes lines of authority and communications. As central equipment, specifically computers, begins to perform more complex tasks, the cross-training of personnel to operate virtually every device in the TMC will allow for maximum level of utility from the systems.

Operations and Maintenance Interface

Specific procedures for operations personnel to deal with system maintenance are needed. For example, if daily work orders are generated by the computer, they should be reviewed and supplemented first by an operations supervisor before being handed out. Manual additions to work orders may come from their own observations or from inspectors' reports or other acceptable sources.

In another example, field maintenance personnel who are provided with specific information on operations can assist in trouble-shooting activities. Operational information for trouble-shooting the system needs to be provided and procedures need to be clearly stated. Additionally, operations and maintenance staff must coordinate the time of day in which response maintenance will be performed (i.e., various activities may be restricted to off-peak periods due to regular operations activities) *(7)*.

Emergency Planning

Internal Emergencies

It is important for the TMC to define what constitutes an emergency and to have a corresponding emergency planning procedure. Internal emergencies may be defined as critical events, such as electrical and communications failures and field device failures resulting from natural or man-made disasters, which may severely affect the operations of the TMC. Emergency planning operations activities, of course depending on the TMC's function, may include temporary use of portable variable message signs to supplement permanent signs in the event of equipment failure due to electronic or communication grid outages. An emergency planning operations supervisor is usually responsible for serving as a point of contact to other agencies and possibly to regional media outlets to make them aware that an emergency situation or regionwide disaster

TABLE 12

ISSUES RELATED TO DEVELOPMENT OF A TMC OPERATIONS MANUAL *(1)*

General Information	Policies and Procedures on Internal Operations and Maintenance	Polices and Procedures on Traffic Management
• Mission and functions of TMC • Relationship of TMC to other transportation agencies • Organizational relationship of TMC within responsible administrative agency • Diagrams showing physical layout of TMC • Road network (highway and surface street) geometrics • Equipment location referencing system	• TMC address, main telephone number, fax number, e-mail address • Hours of operation • Contract procedures in case of TMC emergencies • Telephone procedures • Personnel ⇒ Organizational chart ⇒ Description of duties of each position ⇒ Training (required classes & training manuals) ⇒ Rules of conduct • Equipment ⇒ Authorized use ⇒ Maintenance • Facility ⇒ Security procedures and authorized access ⇒ Backup power ⇒ Disaster Recovery Plan (damage to structure) ⇒ Custodial services • Software ⇒ Backup procedures ⇒ Disaster Recovery Plan (system virus contamination to building destruction) • Media ⇒ Access to center ⇒ Media guidelines • General public, transportation professionals, VIPs ⇒ Access to center ⇒ Conduct of tours	• Incidents (accidents, disabled vehicles, spilled loads) ⇒ Identification (vehicle detection, 911 traffic reporters) ⇒ Verification (CCTV cameras, police, DOT personnel ⇒ Response plans (ramp metering, traffic signals, VMS, HAR, telephone advisory systems) ⇒ Incident documentation • Congestion ⇒ Monitoring ⇒ Response plans • Planned and special events (roadway closures & maintenance) ⇒ Obtaining necessary information on planned events ⇒ Response plans • Field Equipment Malfunctions ⇒ Dispatching of repair crews ⇒ Documentation • Interjurisdictional Coordination ⇒ Other TMCs ⇒ Transit Agencies ⇒ Other Agencies (Highway patrol, police, fire, EMS) • Information distribution ⇒ Media ⇒ Value added packages of transportation information ⇒ General public

has prevented the TMC from being able to conduct its normal operations.

External Emergencies

Conversely, planning procedures for external emergencies may need to be developed within the TMC to respond to regional emergencies and disasters should the TMC be capable of conducting normal or limited operations, depending on the situation. TMCs can provide information and logistical support to transportation and emergency agencies affected by disaster or incident. For example, the INFORM center in Long Island, New York functioned as a de facto emergency operations center during two disaster events; the blizzard in 1996 and the Pine Barrens wildfires in the Hamptons in July 1995 *(7)*.

For the operations aspects of the external emergency planning procedures, representative emergency scenarios can be developed and documented according to the types of natural disasters likely within the region, as well as any man-made disasters or accidents. The planning for these disasters should be coordinated with any state emergency planning agencies, the Federal Emergency Management Agency (FEMA), the National Guard, and local fire, police, and rescue agencies in accordance with local emergency plans *(7)*.

Training for Emergencies

Whether responding to internal or external emergencies, training materials and training drills should be updated and facilitated by the emergency supervisor on a periodic basis to familiarize all personnel involved with standard procedures as well as any disaster-specific procedures. Occasional drills, field tests, and "table-top" exercises can help keep the planning procedures fresh and improve intra-agency and inter-agency communications and coordination. Additionally, the emergency procedures supervisor, with the help of other supervising observers, should evaluate the training methods and emergency procedures and techniques developed on a periodic basis *(7)*.

Maintenance

Integral to the functionality of the TMC is the development of a maintenance management system. The individual components of a maintenance management system may differ across types of TMCs, however, there are some basic elements integral to maintenance management of any type of TMC. One important element of a TMC's maintenance management system is an equipment maintenance and inventory system.

Another essential element of the maintenance management system is failure management. These procedures are important to obtain accurate information as to the reasons why equipment has failed, the activity performed to repair it and the equipment used to replace or repair it. In addition, failure management procedures can accurately track equipment that ordinarily is difficult to maintain. Specific procedures within a failure management system should be developed to provide detailed failure and repair information noted above from the field technicians. In some systems, hand-held computers equipped with bar-code readers have aided greatly in this task *(7)*.

Verification of the effectiveness of the TMC's maintenance management system and each of its elements should be performed periodically. These activities may take the form of evaluation analyses and field checks of installed field equipment. Non-technical issues, such as institutional barriers, should be addressed and training requirements should be developed in the planning and conceptual design phases of the TMC's maintenance management system. Additionally, it is important that the maintenance management system (as with other management systems) include the assignment of priorities to specific maintenance practices.

COSTS

The cost of building and maintaining the TMC is an important factor in the design, functionality, and physical aspects of the facility. In essence, there are two categories of costs when considering development of a TMC: central system costs and annual operation and maintenance costs. Generally, central system costs of a TMC consist of:

Physical TMC costs—construction costs to erect and furnish the building, purchase/lease of space or land.

Equipment costs—central hardware components used to perform the functions of the TMC. This also includes support hardware such as the power system and heating, air conditioning, and ventilation systems.

Design costs—funds spent prior to and aside from construction of the building. These costs may include designs related to TMC layout, engineering, and system development.

Software and Integration costs—the operational, control, or detection software products, as well as networking workstations and integration between software components and hardware components.

Costs pertaining to field devices and existing communication lines are not included with the costs listed above when a true accounting of the cost of the facility itself is the goal. Although the infrastructure is critical to the functions that the TMC performs, the deployment of field devices, equipment, and communication usage for field equipment may come under separate contracts or cost pools. For accounting purposes, these costs may be labeled as "other system" costs not directly attributable to the TMC facility itself. Central system costs are usually covered under the responsible agency's capital budget allocation and are amortized over a specified number of years. The sources of funding for the TMC's capital budget vary for each TMC and may be a combination of federal, state, municipal or county, and private funds, depending on the specific financial agreements. For example, for New York City DOT's central TMC, over $5 million in federal funds were spent to develop the agency's central system *(1)*.

Survey data on costs were provided by many agency respondents representing each TMC type. However, due to the wide range of dollar values, it was difficult to correlate them to TMC characteristics such as transportation system coverage (i.e., number of highway miles, intersections, track miles, etc.), number of personnel, or extent of central hardware components (i.e., number of workstations, video monitors, etc.). The survey of cost data for this synthesis provided a correlation between cost and the size of a TMC. For each type of TMC, Table 13 presents a summary of the statistical correlation of central system costs and annual costs for the average size by TMC type. For example, in Table 13 the typical central system cost is $3 million and annual cost for a 5,000 sq ft TMC is $1.45 million. The regression method best applicable to the range of each type of cost and each type of TMC is indicated in the table as well as the range of costs from the survey data. The cost of the central TMC system should be considered throughout the planning and development process in making a determination of characteristics and functions.

The second type of costs, referred to as annually occurring costs, include those related to the day-to-day operations and maintenance of the TMC and may be influenced by a number of different factors. Operations costs may encompass items such as personnel wages, computer usage, vehicle costs, and electrical and communication infrastructure requirements. Infrastructure costs may vary by TMC, but generally comprise costs related to communication lines, installation and hook-up, and any other dedicated electrical and communication transmission lines.

Similarly, 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. Operations and maintenance costs, for the purpose of budgeting, are generally expressed in terms of annual dollars. As with the central system costs discussed above, correlation of operations and maintenance costs with key TMC characteristics was difficult to show because of the wide range of annual dollars spent. Operations and maintenance costs are important aspects in determining the annual budget for the TMC, especially when competing with other transportation department priorities. Funding for annual TMC operations and maintenance costs is typically derived from an annual budget separate from capital funds.

For most TMCs, the burden of annual costs is shouldered by the responsible agency without much outside assistance. There is currently considerable debate on whether a portion of

TABLE 13

SUMMARY (BY TYPE OF TMC) OF STATISTICAL CORRELATION BETWEEN COSTS AND TMC SIZE

TMC Type	Highway	Surface Street	Bridge/Tunnel	Transit (Bus)	Transit (Light Rail/Subway	Rail (Commuter/ Intercity)
Statistical Sample Size	45	37	8	5	5	5
Average Size of TMC (sq ft)	9,200	5,000	20,000	14,000	7,700	1,900
Annual Cost (Estimated $)	1,300,000	1,450,000	1,900,000	1,950,000	590,000	310,000
Operations	950,000	1,150,000	900,000	1,500,000	550,000	295,000
Maintenance	350,000	300,000	1,000,000	450,000	40,000	15,000
Regression Method Used	Linear	Cubic	Cubic	Linear	Inverse	Cubic
Signficance of Data Fit	Low	Medium	Low	High	Low	Medium
Range of Costs						
Low	15,000	1,000	900,000	75,000	75,000	22,000
High	11,000,000	6,250,000	14,500,000	6,250,000	1,350,000	3,100,000
Central System Cost (Est. $)	4,400,000	3,000,000	30,000,000	4,700,000	1,700,000	1,000,000
Physical	1,250,000	1,050,000	4,500,000	2,250,000	700,000	20,000
Equipment	2,250,000	1,300,000	15,000,000	1,175,000	450,000	900,000
Design	500,000	250,000	5,400,000	425,000	225,000	30,000
Software	400,000	400,000	5,100,000	850,000	325,000	50,000
Regression Method Used	Power	Linear	Cubic	Linear	Linear	Series
Significance of Data Fit	Medium	Medium	High	High	Low	Medium
Range of Costs						
Low ($)	10,000	7,000	10,000	125,000	125,000	1,900
High ($)	130,000,000	72,000,000	70,000,000	14,400,00	17,000,000	8,500,000
Ratio of Central to Annual Costs	3.38:1	2.07:1	15.89:1	2.41:1	2.90:1	3.22:1

capital funds from other agencies should be set aside for operation and maintenance of the TMC so that the responsible agency does not absorb most (or all) of the annual cost. As noted above, survey cost data were correlated versus TMC size and the results summarized in Table 13.

PUBLIC RELATIONS AND MEDIA INVOLVEMENT

Many of the agencies responsible for TMCs are involved with the media, whether for access to the center, information dissemination, or communication of traffic conditions. The procedures for communication and dissemination of information to media sources and to the general public vary by agency and are discussed in the *Information Dissemination and Sharing Issues* section. As for access to the TMC, it has proven to be a very popular and useful learning tool for the public and media. Promoting TMC visits can prove to be of great value and tours should be encouraged by the agency. The TRANSCOM operations center has found it very beneficial to inform the media of its activities through direct access to the center *(1)*. This allows TRANSCOM to facilitate coordination with media sources in what can be, in a general sense, an adversarial relationship.

Agencies operating TMCs can also interact with the public by granting guided tours of the facility. Tours for various types of groups can be tailored to the group's interest. Observation areas can be built into the TMC to facilitate guided tours and to avoid disruption of the center's regular operations. Exploiting the real-time monitoring and surveillance aspects of the TMC through live video feeds and "hi-tech" displays of actual conditions may greatly enhance the value of the tour to visitors. Providing access to a demonstration TMC workstation with projection onto a graphics display may assist in enhancing the value of the tour *(1)*. In another respect, many agencies send their decisionmakers to visit other TMCs to learn first-hand how to develop, or better operate, their own TMC. This process is popularly advocated by FHWA as a funded activity in sending public officials to functioning TMCs.

INFORMATION DISSEMINATION AND SHARING ISSUES

Many agencies find that transportation information, such as travel condition information, traffic data, and travel advisory information, is costly to gather. Most of the same agencies, however, believe the information is important because it retains value. Consequently, many agencies provide this information for a charge, especially to "for-profit" private information service providers (ISP) and broadcast media organizations. Agencies that sell information use the revenues to partially cover the costs of operating and maintaining the TMC and its field equipment. In some TMCs, transportation information is passed along to ISPs or nonprofit organizations at no charge, however, some agencies may charge for its packaging and delivery. Often, private-sector ISPs are looking for travel information the TMC has collected so that they can manipulate and customize it for prospective customers. The ISPs count on select markets to whom they can sell specifically packaged information and, thus, earn income on the customized information package.

It is usually difficult for TMCs to maintain a revenue stream from information dissemination when most of the general interest travel information collected in the TMC is transmitted to the public or made available to public agencies free of charge over the phone or fax, mail requests, computer bulletin boards, and recently the Internet. Two transportation management systems with active information dissemination programs are the Smart Route Systems' SmartTraveler information program in Washington, D.C. and the Florida DOT radio traveler information network.

Information sharing can also be an issue within the TMC. In some TMCs, DOT personnel may have restricted access to certain police information or data. A clear and well-defined division of responsibility at the TMC between police and DOT personnel may assist in addressing any issues on restricted information *(1)*. Similarly, in regional transportation management organizational structures where TMC communications link together public agencies, ISPs, and media outlets, the involved parties may not have full discretionary power to access all data. To prevent sensitive TMC information from going to the wrong agencies, or to preserve the operating agency's TMC intellectual property rights, involved parties would only have access to the information and data directly relevant to the parties' needs.

RESOURCE SHARING

Resource sharing may be defined as two or more agencies or organizations utilizing the same personnel, equipment, devices, etc., on a mutually approved schedule and arrangement. The practice of resource sharing vastly reduces the capital costs for these resources imposed on the agencies and, at the same time, promotes partnerships and good relations among agencies (and private organizations). Survey respondents were asked to identify whether they share resources or responsibilities such as:

- Use of field devices,
- Personnel,
- Central TMC equipment,
- Authority,
- Control of field devices,
- Responsibility, and
- Other reasons (defined below).

Table 14 indicates the percentage of survey respondents, by jurisdiction, who share each resource. The table indicates that, generally, agencies share some TMC resources, and that state, county, and transit agencies and bridge/tunnel toll authorities tend to share resources somewhat more often than city agency TMCs. For example, over 50 percent of the state agency-operated TMCs share the use of field devices, whereas only 30 percent of the state TMCs share personnel with other TMCs. Some of the resources that were cited in the "Other Resources" category include:

- Data and information,
- TMC space and facilities,
- Communication system and media,
- Training,
- Maintenance contracts,
- CCTV,
- 2-way radio channels,
- Live video feeds, and
- Computer and communication links to public safety agencies and organizations.

To determine with whom the respondents are sharing resources, a cross-tabulation of responding agencies (aggregated by type) to the types of agencies with whom they shared was performed. The results of this analysis are presented in Table 15. The table lists the type of responding agencies, the resource category being shared, and the type of agency shared with. Listed in each cell of the table in descending order are the types of agencies with whom the responding agencies most commonly share their resources. For example, the state agency-operated TMCs share personnel most frequently with other state transportation departments. To a lesser extent, state agencies share TMC personnel with state police and city agencies. Generally, state agencies share TMC resources most often with state police departments, city agencies, and other state agency departments. City agencies share TMC resources most frequently with the state agency. County agencies share TMC resources most often with their corresponding state agency and to a lesser extent city agencies and other agencies and/or private organizations. Agencies comprising the "other" category, transit agencies and toll authorities, typically share their TMC resources with similar transit and toll agencies, and private organizations. As reported in the survey, these agencies share very limited resources with public agencies, and when they do it is mainly with state transportation departments. These survey results are consistent with previous findings, particularly in that county and city agency-operated TMCs

TABLE 14
PERCENTAGE OF AGENCIES BY JURISDICTION SHARING RESOURCES (%)

	Resource						
Agency Type	Use of Field Devices	Personnel	Central TMC Equipment	Authority	Control of Field Devices	Responsibility	Other Resources
State	53.7	29.6	40.7	27.8	16.7	27.8	40.7
City	19.4	3.2	12.9	9.7	25.8	12.9	16.1
County	40.0	0.0	20.0	13.3	33.3	60.0	20.0
Other	48.4	19.4	16.1	9.7	12.9	6.5	29.0
Average	43.0	18.0	26.0	17.0	20.0	23.0	30.0

TABLE 15
RESOURCE SHARING BY AGENCY JURISDICTION

Agency Type	Use of Field Devices	Personnel	Central TMC Equipment	Authority
State	1) State police 2) Private organization 3) Cities	1) Other departments 2) State police 3) Cities	1) State police 2) Cities 3) Other departments	1) State police 2) Cities 3) Other departments
City	1) State 2) Other departments	1) Other departments	1) State 2) Other departments	1) State
County	1) Cities 2) State	—	1) Private organization 2) State 3) Cities	1) State 2) Cities 3) County police
Other	1) Private organization 2) Cities	1) Private organization 2) State 3) Cities	1) Private organization 2) State	1) Private organization 2) State
	Control of Field Devices	**Responsibility**	**Other**	
State	1) Cities 2) State police 3) Other departments	1) State police 2) Cities	1) Media 2) Other departments 3) State police 4) Cities	
City	1) State 2) Other departments	1) State 2) City police	1) State 2) PD/FD/EMS	
County	1) State 2) Other counties 3) Cities	1) Cities 2) Private organization	1) State 2) Private 3) Other counties 4) Media	
Other	1) Private organization 2) States	1) Private organization	1) City Police	

frequently look to state DOTs for aid in operating and maintaining their TMC.

LIABILITY AND LITIGATION

With TMCs providing an advancement in transportation management strategies, the potential for litigation may be reduced. As standards and protocols for TMCs are developed and as stricter and more comprehensive legal and institutional policies are established among TMCs, the occurrence and effects of liability could be substantially diminished. Nevertheless, liability and the potential for agencies' involvement in litigation does exist. Liability risks may be attributable to TMC design, activities involving coordination with other organizations, system operation, and system maintenance. Specifically, liability, and possible litigation, may likely involve the design, operation, and maintenance of TMC-controlled field equipment. Related to freeway and bridge/tunnel TMCs, potential liability may arise from malfunction of ramp metering signals and lane control signals, misinformation of traveler information systems and highway advisory radio, malfunction of and misinformation on variable message signs, response failure of emergency service vehicles programs and incident management patrols, deficient operation of HOV, and misuse of toll tag information at plazas. A leading professional in the transportation management field indicated that there may be a significant economic and possible legal effect on the business community when traffic is diverted for reasons justified by the TMC. Ultimately, liability issues are agency-specific and are mainly subject to legal interpretation. Hence, common statements about liability across TMCs could not be drawn from the survey results. It should be noted that case law concerning TMCs is in the initial stages of development and will evolve over time *(17)*. As in all traffic engineering programs, it is essential to use standards developed by FHWA, AASHTO, and other agencies, and to support the basis of decisions with factual documentation.

PROCUREMENT PROCESSES

A number of procurement methods are employed to contract for construction services and materials related to TMCs. Among the most common procurement methods in practice are: low bid contract, facilities management, life-cycle costs, design build, privatization, prequalification, and request for proposal (RFP). The survey asked the agency representatives whether they used any of these procurement methods and if any other method was employed related to TMCs. The survey results are described for each of the procurement processes currently in use and are presented in Table 16.

Low Bid Contract

Low bid contracting is the most often practiced method of procurement by public agencies in the United States and survey results show it to be the most common among TMCs as well. It is the process of choosing products and services based on the lowest bid for the costs of the product and services. The purchasing agency issues nonproprietary functional specifications

TABLE 16
PROCUREMENT PROCESSES EMPLOYED BY TYPE OF TMC (%)

Procurement Process	Highway	Surface Street	Bridge/ Tunnel	Transit (Bus)	Transit (Light Rail/Subway)	Rail (Commuter/ Intercity)
Low bid	79.7	64.5	67.8	50.0	60.0	50.0
Facilities management	10.9	9.7	9.7	8.3	0.0	25.0
Life-cycle costs	10.9	11.3	12.9	16.7	10.0	37.5
Design-build	21.9	16.1	45.2	16.7	20.0	12.5
Privatization	4.7	0.0	0.0	8.3	10.0	12.5
Prequalification	45.3	29.0	48.4	33.3	40.0	50.0
Request for proposal	65.6	58.1	61.3	41.7	40.0	75.0

for a specific item or system, specifying quantities. Appropriate "quotes" are then received from interested vendors, distributors, or manufacturers. The agency reviews the lowest bid submitted including item vendor sheets, if appropriate. If the submitted description of the item meets issued specifications, a purchase order or contract is issued by the agency. If for some reason the "offerer" does not qualify to be a responsible bidder, the award may go to the next lowest responsible bidder, or, the purchasing authority altogether may choose to issue a "rebid" *(14)*.

Facilities Management

Facilities management, also known as systems management, is a procurement method using the bid system to install specific facilities, systems, or components within an existing structure or larger functioning system. With regard to TMCs, in this procurement method, a contractor is employed to develop the software and hardware specifications for the management center. The hardware and construction are advertised and bid competitively. The facilities manager also supervises the procurement practices, develops the software, integrates the commercial and applications software with the hardware as it is installed and provides documentation and training for an integrated system *(14)*. According to the survey results, facilities management was among the most seldom used procurement practices, consistently around 10 percent across all TMC types.

Analysis of the survey results indicated that among bus transit, surface street, and highway TMC types, facilities management procurement was employed by generally larger and more complex TMCs. This correlation was not true among rail transit and bridge/tunnel TMC types. Facilities management procurement was not used in light rail/subway TMCs in the survey.

Life-Cycle Costs

Life-cycle cost procurement is a form of competitive bidding where a contract is awarded based on the initial capital cost plus cost of operation over a designated period of time. Life-cycle cost is normally based on the life of the item with initial capital costs capitalized to reflect annual costs. One of the difficulties with this means of procurement is determining when a device becomes obsolete *(14)*. This method of procurement was employed rather infrequently among the TMCs compared to other processes. Overall, the survey results showed that only 12.8 percent of all TMCs use life-cycle cost procurement. The process was used more frequently by transit related TMCs (20 percent) than by roadway related TMCs (11.5 percent).

Prequalifications

Prequalification procurement is most often used when the contracting agency wants to screen equipment, vendors, or contractors to assure that each can meet the preliminary specifications. Prequalification is a two-step process. The first step is to evaluate the bidders' qualifications and experience to determine if they have the ability to undertake the specified project. The second step is similar to the low bid process except that the purchase order goes to the lowest bidder who's qualifications best suit the work *(14)*. According to the survey results, prequalification procurement was a fairly common form used by all TMCs with relatively similar frequency.

Privatization

Privatization, by definition, is the contracting of public services or selling of public assets to private industry. The maintenance requirements are specified and then contracted out to a private firm for performance reviews *(14)*. Use of privatization as a procurement process was the lowest among all the processes indicated in the survey results (3.2 percent of all TMCs). The process was more common among the transit related TMCs (10 percent) than roadway related TMCs (1.9 percent), and in fact, no surface street or bridge/tunnel TMCs used privatization.

Design-Build

Design-build procurement is a bid process in which a contractor is selected to first design and then implement a project. The project is performed in stages and the contractor's design for each stage is submitted for approval before construction can begin. At the same time, design of another project component begins, sometimes with the help of subconsultants employed by the contractor. It is important that these contracts require periodic deliverable products keyed to periodic contract payments so that contract progress can be measured and evaluated (*14*). Design-build procurement was reported by 23 percent of the responding TMCs.

Request for Proposal (RFP)

This type of procurement is common for contracting engineering services, particularly for planning, design, operations, maintenance, or management consulting services. Usually after the qualifications phase, the contracting agency will issue a formal statement that solicits a project proposal from each of the initially qualified consultants. Each consultant then prepares a comprehensive proposal that may include a scope of services, cost estimate, backgrounds of key personnel, and any standard proposal forms. The agency then selects a consultant, based on their proposal package, either directly for the job or as a finalist for the job, which will require further information and possibly personal interviews. RFP procurement remains among the most frequently used methods in engineering today and is often tied in with low-bid procurement for a variety of engineering services *(14)*. The survey results indicate this to be true for TMCs as well: 60.4 percent of all TMCs used RFPs.

SOFTWARE ISSUES

While some of the software used in TMCs is not transportation related (e.g., database software), software products are necessary components to collect, synthesize, and analyze transportation system data and to operate and control various field hardware (e.g., traffic and/or track signals) elements. In addition to using their own copyrighted software products, agencies may obtain software for TMCs from a variety of sources. These alternative sources include the public domain, other public agencies, or proprietary organizations from which the agencies may acquire licensed software copies.

Agencies of all jurisdictions mentioned software issues involving intellectual property rights and the shelf-life of a product versus its re-usability. Agency respondents are seeking resolution of these and other, less dramatic software issues identified by the operational aspects and capabilities of the TMC and its technology.

CHAPTER FOUR

EXPECTED BENEFITS AND EVALUATION CRITERIA

Many benefits are expected from the operational capabilities provided by a traffic management center (TMC). The survey for this synthesis indicates that some expected benefits are common among all types of TMCs while others are agency-specific. In any case, all operating agencies must find a way to measure how well they are achieving their anticipated benefits.

EXPECTED BENEFITS

Regardless of the type of TMC, an anticipated or expected level of benefit can be achieved by the operating agency. Generally, TMC operations have demonstrated benefits in the areas of transportation safety, productivity, efficiency, and environmental impact. While not all expected benefits can be quantified for each operating agency, underlying evidence of tangible improvements in transportation management is present, as the examples below indicate.

In Maryland, significant increases in highway travel (in vehicle miles traveled) over the past 15 years and additional projected increases resulted in the development and implementation of the Chesapeake Highway Advisories Routing Traffic (CHART) system. The CHART system comprises a statewide operations center supported by localized traffic operations centers made possible by the application of ITS technologies and interagency teamwork. The benefits of the CHART system are experienced by highway travelers in the Washington, D.C. and Baltimore metropolitan areas. Commuting motorists, regional travelers, and commercial vehicle operators benefited from *(15)*:

- Quicker clearing of incidents,
- Coordinated travel information and operations between agencies, and
- The combined efforts of local and regional agencies.

In another example, the TMC for Washington State DOT in Seattle has also demonstrated notable improvements to its freeway system. Although demand on area freeways has increased due to regional growth, the TMC has contributed significantly to improved freeway efficiency. Traffic patterns have been more efficiently distributed through the increased use of HOV lanes and as a result of better traffic patterns, accident rates have decreased. Freeway travel times and speeds have improved with ramp metering, while freeway mainline volumes have increased.

In terms of operation, capacity, and efficiency, there are many anticipated benefits for all types of TMCs. Some benefits are common to some types of TMCs and unique to others. For example, bridge/tunnel TMCs have experienced many of the same measurable benefits as freeway and surface street TMCs because their operation in many locations is affected by upstream and downstream highway facilities. However, there is significant added value for bridge/tunnel authorities to assess traffic efficiency and capacity by measuring delay, throughput, air pollutant emissions, and queue lengths, especially for facilities with toll plazas. The use of electronic toll and traffic management (ETTM) techniques such as electronic toll collection (ETC) has not only resulted in considerable benefits in traffic efficiency and capacity, but has also made it much easier to measure benefits.

There are many benefits for TMCs in the areas of information and communication. Information retrieval, processing or synthesis, and dissemination to the public and various public and private sources is significant when considering the need for continuous and productive transportation movement within a region or several regions, such as the I-95 Corridor in the Northeast. Improved communication, both within the agency and among affected agencies, is also a considerable benefit. Effective communication allows for the efficient mobilization and response to particular traffic conditions resulting from incidents and special events.

A tire fire under I-95 in Philadelphia in March of 1996 is an excellent example of how communication and coordination among TMCs provided rapid response to an incident on a heavily traveled roadway. The fire caused structural damage to a bridge section of I-95 requiring an 8-day closure of the entire roadway. This section of roadway has limited electronic instrumentation. Assessments of queues and congestion on alternate routes were based on direct observation of area roadways and extensive communications with field personnel. Center-to-center communication was conducted mostly by phone, fax, and the I-95 Corridor Coalition's IEN. The IEN's effectiveness was limited as not all workstations were installed at the time of the incident. If the entire network had been operational, a significant amount of the interagency communication would have been via the IEN.

On the initial report of the incident and subsequent closure, various TMCs throughout the Philadelphia region and along the I-95 corridor between Connecticut and Washington were notified of the incident. When the severity of the damage was identified, these TMCs assisted PennDOT to minimize the impact on Philadelphia streets and highways. The TMCs quickly mobilized VMS and HAR equipment to inform motorists enroute to the Philadelphia area to avoid I-95. Particular attention was paid to keep through traffic (destined beyond Philadelphia), especially trucks, on parallel routes in New Jersey. That meant mobilizing resources at key diversion points in Delaware and New Jersey.

TRANSCOM, which serves as the interim communications center for the I-95 Corridor Coalition, served as the primary contact between PennDOT and other agencies beyond the core Philadelphia area. Overall, 11 TMCs outside of Philadelphia were involved in this effort. Variable message signs at four different agencies and three separate HAR systems were mobilized. Additionally, traffic reporting services were regularly updated. This provided coverage of the incident and road closure from Washington, D.C. to southern Connecticut, central and northeastern Pennsylvania and the Delaware-Maryland-Virginia (DelMarVa) peninsula. The agencies responded quickly, coordinated their efforts, and maintained good communication. Travelers heeded the posted warnings, and neither gridlock nor significant congestion on parallel or alternate routes occurred.

The importance of considering the unique function of each system is evident when looking at the anticipated benefits for each TMC. The survey results revealed that highway, surface street, bridge/tunnel, transit (bus, light rail/subway, and commuter rail), and integrated TMCs have both common and unique expected benefits. The anticipated benefits for each type of TMC, including benefits related to the system's operational and efficiency indicators and other nonsystem related, or institutional, benefits are listed below.

Highway TMC Expected Benefits

System Related

- Better incident management in terms of reduced incident response times; incident detection times; and incident clearance times to restore normal operating conditions, limiting the possibility of secondary accidents.
- Better congestion management, traffic management, and traffic diversion in response to traffic and weather related incidents; major events; route and alternative route comparisons based on improvement and service level indicators; mitigating the effects of recurring and nonrecurring congestion through various congestion management techniques; large-scale construction activities.
- Improved information dissemination to emergency services and their vehicles; information service providers; traveling public; media; public agencies; private organizations.
- Maintained and/or improved overall safety on the transportation system.
- Reduced travel delays and times related to incidents; ramp metering controls.
- Reduced number of incidents and accident rates (including secondary accidents).
- Improved air quality through pollutant reduction; fewer vehicle emissions.
- Increased highway efficiency through transportation demand management/system management strategies such as HOV lanes.
- Increased energy and fuel savings.
- Enhanced efficiency of the transportation infrastructure.
- More efficient snow removal operations.
- Improved signal coordination, analysis, and timings to create continuous and progressive traffic flow.

As incident management is an important aspect of highway management and the TMC, benefits may be assessed separately to determine which functions are performing well. For example, Indiana DOT recently experienced a 36 percent reduction in secondary incidents and a 4:1 benefit to cost ratio in the incident response portion of their freeway TMC in Gary, serving the Borman Expressway.

Institutional

Additional expected benefits were not directly system related. The other issues, categorized as institutional in this chapter, discovered in the survey of highway TMCs included:

- Efficient use of staffing and resources through better internal and external control; improved employee motivation and involvement; better coordination; reduction of costs.
- Safe environment for emergency personnel.
- Improved customer service through information.
- Improved public relations and interface with the public.

The system related and institutional benefits listed above for highway TMCs represent the most frequently cited benefits. Due to the large number of highway TMCs, several less common benefits were identified, although they were based on local conditions and indicators.

Surface Street TMC Benefits

System Related

Survey results indicated that many of the same benefits were expected for surface street TMCs as for highway TMCs. There were some differences, mainly due to the different aspects of the transportation system coverage. The expected benefits related to system operation and efficiency were oriented more toward local and arterial roads and signal systems. The most common system related expected benefits for surface street TMCs were:

- Reduced travel times and delays related to incidents; signalized intersections.
- Improved information dissemination to emergency services and their vehicles; information service providers; traveling public; media; public agencies; private organizations.
- Reduced number of incidents and accident rates (including secondary accidents).
- Enhanced collection and centralization of real-time transportation data and information.
- Increased energy and fuel savings.
- Better monitoring and correlation of data and information between construction activities and traffic patterns.
- Continuous and real-time monitoring of traffic signals in a central location.
- Improved signal analysis and timings.
- Increased roadway capacity and improved roadway mobility.

• Quicker response to signal failures and knockdowns.

• Reduced time to install, modify, and maintain signal and signal timings.

• Better incident management in terms of reduced incident response times; incident detection times; incident clearance times.

• Enhanced programming of signal timings.

• Enhanced and centralized traffic signal control.

• Better congestion management, traffic management, and traffic diversion in response to traffic and weather related incidents; major events; route and alternative route comparisons based on improvement and service level indicators; mitigation of recurring and nonrecurring congestion; large-scale construction activities.

• Improved air quality through reduced vehicular emissions.

• Maintained and/or improved overall safety on the transportation system.

Institutional

The institutional TMC issues revealed by the survey for surface street TMCs were:

• Efficient use of staffing and resources through better internal and external control; improved employee motivation and involvement; better coordination; reduction of costs.

• Safer environment for emergency personnel.

• Improved customer service through information.

• Improved public relations and interfacing with the public.

Bridge/Tunnel TMC Expected Benefits

System Related

The survey results indicated that the most common expected benefits related to system operation and efficiency among bridge/tunnel TMCs were:

• Reduced travel times and delays related to incidents; toll plazas.

• Better incident management in terms of reduced incident response times to restore normal operating conditions; prevent secondary crashes.

• Reduced number of incidents and accident rates (including secondary crashes).

• Improved information dissemination to emergency services and their vehicles; information service providers; traveling public; media; public agencies; private organizations.

• Efficient transportation service through reduced congestion; increased roadway capacity; increased travel speeds.

Institutional

Analysis of the survey data further revealed that for bridge/tunnel TMCs, the most common institutional (nonsystem related) benefits included:

• Promotion of reliable customer service.

• Promotion of efficient operations and facility management through efficient use of staffing and emergency response resources; greater staffing control.

Transit TMC Expected Benefits

The survey results identified expected system and institutional benefits related to transit TMCs as well. Because of the smaller sample size of transit TMCs participating in the survey, a clearer indication of expected benefits can be realized when the three types of transit TMCs (bus, light rail/subway, and commuter rail), are combined.

System Related

The most common system related benefits included:

• Reduced travel times and delays.

• Better incident management through vehicle tracking and response.

• Enhanced system management and real-time monitoring of construction activities and their impact on service and functioning of traffic and track signals.

• Improved information dissemination to emergency services; information service providers; traveling public; media; public agencies; private organizations.

• Reduced number and rate of incidents.

Institutional

The expected benefits related to institutional transit TMC issues recorded were:

• Improved customer service through information.

• Enhanced interagency cooperation and coordination of resources (especially when responding to problems or incidents).

TMC benefits can be expressed in either quantitative or qualitative terms, depending on the type of TMC and the agency's perception of benefits. In terms of quantitative benefits, recent evaluations of various Caltrans Districts' TMCs (several of which will be integrated and will cover large multimodal systems) have revealed benefit to cost ratios of 3:1 to 14:1. The quantitative benefits presented here are significant and exemplary; however, the value of an integrated TMC may be best demonstrated by the city of San Antonio TransGuide Control Center. In 1995, an industrial plant fire broke out and was captured within view of the TMC's freeway video surveillance. Emergency services were better informed and therefore could more effectively access the fire, possibly saving the lives of several firefighters. Local police and fire agencies were immediately convinced of the value of the city's investment *(16)*.

Telephone Interview Results

Because it is sometimes difficult to quantify the benefits of a TMC in a questionnaire, it becomes necessary to use other means to focus on items that have made an operating agency successful. In a follow-up telephone survey, various types of TMCs were contacted and, in one portion of the telephone interview, agency participants were asked what makes the TMC successful. Presented below are the results of some the TMC interviews.

• At Texas DOT, the local districts, such as San Antonio, Dallas-Fort Worth, and Houston, had all indicated strong interest in establishing and operating TMCs in building their transportation management systems. The enthusiasm expressed at the district level translated into solicitations of state-level financial support and visibility. Despite the fact that higher levels of funding and self-exposure were required from each district than anticipated, the individual district TMCs have managed remarkably well.

• At the Arizona DOT's TMC in Phoenix, a complete hardware and software system was installed with the hope that it could serve the TMC's expanding functions and accommodate fast-growing traffic congestion throughout the city. Despite some technical and institutional problems (typical for a project of large size and complexity), which delayed the opening of the center, the system was installed successfully. To ensure its continued operation, the developers of the system components are located at the TMC to provide technical support for existing and new installations.

• At the Caltrans District 12 TMC in Orange County, a strong interagency bond between the California State Highway Patrol and Caltrans results in timely incident response and detection and the accessibility of data needed to support their operations by both agencies.

• In Bellevue, Washington, management officials supported the concept of a TMC as part of the city's traffic management plan as early as 1975. The city's management officials have been supportive since with adequate resources, up-to-date equipment, and proper staffing to keep the TMC in operation.

• The Pennsylvania Turnpike TMC located in eastern Pennsylvania measures its success by its continuous 24-hour, 7-day operation and ability to respond to incidents and emergencies at all times. During the blizzards in the winters of 1992/93 and 1995/96, continuous operation and coordination were necessary to keep the Turnpike open.

• At the CHART SOC, operated by the Maryland SHA, there is a focus on technology that is bi-functional; the technology supports the existing functions of the operations control center and serves as a backbone for many of the transportation department's activities, such as maintenance and snow removal.

EVALUATION CRITERIA

The utility of an evaluation process and benchmarking criteria can be, in many cases, a critical factor in an agency's management and decision-making process for its TMC program. An evaluative approach may be employed to determine if the benefits meet the agency's expectation. Criteria used for benefit evaluation differ by type of TMC and are commonly expressed in quantifiable measures of effectiveness (MOEs). For many agencies seeking defined and quantifiable benefits, these MOEs may serve as the realized benefits. In most cases it is difficult to separately evaluate the benefits of a TMC and the other components of an ITS because they are closely integrated *(16)*.

In determining the contributory benefit of highway and surface street TMCs, commonly used MOEs are *(16)*:

- Reduction in travel time,
- Increase in travel speed,
- Increase in freeway capacity,
- Reduction in incident/accident rates,
- Decrease in fuel consumption,
- Decrease in air pollutant emissions,
- Fewer vehicle stops,
- Reduction of intersection and link delays, and
- Modal split data (for TMCs providing transit coverage also).

In addition to applying the above listing of MOEs to general traffic management, they can also be applied to evaluate incident management. This is especially helpful for highway management centers (and to a lesser extent for surface street management centers). Evaluation of incident management implementation can also include criteria such as incident clearance times and reductions for various categories of accident severity or types of accidents to reveal measurable incident related benefits.

The evaluation criteria used to assess the transportation system are not the sole means of determining whether a TMC is realizing its expected benefits. The use of before-and-after studies may indicate that the TMC has had a significant impact on the transportation system it covers. Additionally, some agencies use criteria such as benefit-cost ratio analyses to determine if the investment in an alternative or an option was worthwhile. Benefit-cost analyses translate various parameters related to construction, maintenance, and operation to evaluate a TMC in terms of economics. To decisionmakers, the relation of annual benefits to annual costs is meaningful in determining annual budgets. Market research is a technique that has been used for evaluating both TMC and traffic management program effectiveness.

Highway TMC Evaluation Criteria

The survey results for highway TMCs revealed that nearly 40 different criteria are used to evaluate the operation and achievement of expected benefits. The most commonly used measure in evaluating highway related TMCs included:

• Incident (and secondary incident) reduction rates, average incident response times,

• Delay and stops measures (related to corridors, ramp metering, and incidents),

• Before-and-after studies,

• Benefit-cost analyses (from benefit-cost, the typical cost of an incident may be determined),

• Travel time and time lost over freeway links,

• Air quality and noise assessments, and

• Accident records.

In the telephone follow-up survey, specific examples of TMC benefits were noted. They are listed below, in no particular order, to illustrate the criteria that were used to quantify their TMC's benefits. A recent evaluation of the effect of Wisconsin DOT's highway TMC in the Milwaukee metropolitan area on highway operations revealed:

• 30 to 40 percent reduction in peak-period crashes,

• 15 percent reduction in travel time,

• 8 percent reduction in air pollution during rush hour, and

• 5:1 benefit-cost ratio excluding cost savings from crashes.

Maryland SHA recently conducted an evaluation focused primarily on the incident management element of its statewide TOC-based freeway management program. The evaluation, which accounted for time lost, environmental impacts, and secondary accidents, yielded an overall benefit-cost ratio of 7:1.

Surface Street TMC Evaluation Criteria

The most commonly reported evaluation criteria for survey respondents' TMCs were:

• Delay and stop measures (related to corridors, incidents, and signalized intersections),

• Before-and-after studies (intended for timing plan development),

• Benefit-cost analyses (one agency used the analyses over the design life of the TMC),

• Travel time, and

• Incident management measures, such as average response time; incident duration; incident clearance time.

In addition to the above measures, customer service surveys, overall effectiveness evaluations based on performance, and speed studies were also indicated as commonly used criteria for evaluating surface-street TMCs.

Bridge/Tunnel TMC Evaluation Criteria

Many of the criteria used to evaluate highway and surface street TMCs can also be applied to bridge and tunnel TMCs due, typically, to their facilities' connections to adjacent arterials and highways. Some additional criteria are significant when evaluating benefits of bridge and tunnel facilities, especially where toll plazas are present. These MOEs include: queue length, processing delays, and operating expenses (e.g., comparing costs of operating a manned toll lane versus operating an ETC lane, if applicable). The most common criteria cited among bridge/tunnel TMCs were:

• Delay measures at the toll plaza and across bridge/tunnel links,

• Customer satisfaction based on service surveys and evaluation of courteousness,

• Number of incidents reduced,

• Number of accidents reduced, and

• Incident management measures related to incident response times; incident clearance times; safety improvements.

Transit TMC Evaluation Criteria

Transit agencies and operating authorities have used slightly different parameters for measuring the benefits contributed by the TMC. Among the more common MOEs used by transit agencies are reductions in travel time, on-time performance, minimization of incident response time, and percentage return on investment (*16*). The following evaluation criteria were found to be the most common among some or all types of transit related TMCs:

• Operational performance (specifically on-time performance),

• Improvement of expected benefits based on historical data,

• Adherence to train schedules and schedule recovery after an "upset" in operation, and

• Addressing complaints and grievances of employees and passengers.

While the evaluation criteria presented may be useful as a guide to these types of TMCs in the planning stage or under development, the criteria may not be applicable for each individual TMC. Local conditions and functions specific to the individual TMC may dictate which evaluation criteria are most applicable. Additionally, for integrated TMCs, appropriate evaluation criteria may be required to cover multiple transportation modes and the coordination and operation of different transportation systems (e.g., combination of light rail with surface street traffic).

As evidenced in this synthesis, there are many expected benefits for each type of TMC. Expected benefits are realized when thresholds set by predetermined evaluation criteria are met. With these evaluation criteria, the public can visualize more easily the relevance of the expected benefits and importance of the TMC in managing the region's transportation. This, in turn, reinforces the faith that users have in the system, thus improving its effectiveness.

CHAPTER FIVE

CONCLUSIONS

Key conclusions drawn from this synthesis regarding transportation management centers and their functions, characteristics, issues, expected benefits, and design criteria are identified in this chapter.

A TMC can successfully integrate the primary functions of traffic management and can further optimize the operations of the transportation system.

Fundamentally, the TMC is the physical facility where activities are carried out to support transportation management functions and strategies. The research conducted for this synthesis revealed that the most common TMC functions across all types of TMCs were (in no particular order):

- Surveillance,
- Signal control,
- Incident and special event management,
- Information processing and dissemination,
- Information exchange among agencies,
- Emergency management procedures, and
- Coordination with emergency agencies.

The TMC is a useful centralized location for various agencies to convene and coordinate their involvement in traffic management for a region.

In an urbanized area, it is desirable to have a single facility housing personnel from state, county, municipal highway departments, other public transportation agencies, and law enforcement. In another configuration, agencies operate their own TMC and provide communications to a single regional center or to each other's individual TMCs. In either arrangement, effective communication of information among the agencies is an important component to capably manage the transportation system. Communications must also be provided between TMC personnel and response agencies such as fire, police, emergency services, and towing operators. In the TMC, it is advisable to have work stations dedicated to law enforcement personnel to communicate directly with fellow officers and emergency response personnel and to provide additional traffic management support during times of incidents or special events.

The number and types of personnel and the activities conducted may vary depending on the spatial, task, staffing, and functional requirements of the TMC.

Some typical TMC duties include: monitoring the operation of the transportation system, communicating to dispatching services, and disseminating information to various field equipment (e.g., variable message signs), media, and broadcasting services when conditions on the system change. For instance, workstation operators in the TMC may use CCTV to verify (and to a lesser extent, detect) incidents, areas of congestion or backups, and field conditions due to special events. Through video surveillance, the TMC operator can also determine the type of assistance that may be needed at the trouble location and whether emergency personnel should be summoned.

The TMC requires sophisticated hardware and software to synthesize many bits of information and field condition data to determine how the system is operating and to allow for the adjustment of the system's controls to accommodate changing travel conditions.

Computer workstations with various database capabilities retrieve, store, and process a great deal of information that is synthesized and made usable by the TMC's personnel, other TMCs and the public. Advanced database and analysis software is used to perform analyses of peak-period traffic conditions and traffic control patterns, as well as adapt (in real-time) existing control patterns at critical junctions or throughout a network, depending on field conditions. Powerful computer servers perform these analyses and adjust the necessary field controls, while retrieving, storing, and backing up real-time field data.

Some of the most critical issues affecting the TMC design and deployment are policy issues, including jurisdictional, modal, institutional, and administrative concerns.

Overcoming these concerns is often far more difficult than those related to the functional, technical, or equipment requirements of the TMC. These concerns are often addressed in the early stages of TMC development. The process begins with setting goals that are well-defined, realistically attainable, and for integrated TMCs, acceptable by all involved agencies. Once the goal-setting and mission of the TMC are in place, establishing design criteria such as staffing, cost, and procurement begins.

Overall regional traffic and transportation management are not compromised and TMC deployment includes all agencies providing transportation coverage within the region.

Each responsible agency, whether transit, highway, local, or state, supplies input and recognizes that its contribution to the TMC's operation has impacts on all agencies within its regional transportation system.

Institutional policy that restricts any of the primary functions of the TMC may preclude the integration and coordination of any of those functions among the region's agencies, and may lead to disjointed and ineffective operation and control of the transportation system.

Nontechnical policy issues are identified, addressed, and resolved at the earliest possible time before the TMC is functional. Emphasis on the exchange and coordination of usable transportation information among agencies and TMCs can lead to effective technical integration and communication within the TMC and improve regional mobility. If used as an effective transportation management technique, the TMC can reduce liability.

In the near future, it is widely believed that greater use will be made of area-wide and regional transportation management centers. Newer TMCs will likely be more integrated and multimodal to acknowledge and support a regional transportation system. Until now, many integrated TMC configurations have primarily focused on the coalitions of agencies covering highway operations and surface street signal systems. Recently established TMCs have included transit systems. This multijurisdictional and multimodal operation of TMCs is expected to result in the further linking of TMCs in major metropolitan areas in more complex, hierarchical, and hybrid TMC architectures. In addition, wide-area advanced traveler information system databases can be developed to provide a seamless flow of multimodal travel information.

Goals for TMCs that were frequently reported in the synthesis survey include enhancement in customer service, increase in and manipulation of data flow, and reduction in the everyday liabilities tied to roadways and transit. In reaching these and other goals, agencies at all levels will face multi-faceted challenges. This synthesis highlighted many of those issues and this section provides an overview of some solutions to the challenges.

In the future, many TMC managers will face significant political, economic, and institutional challenges. Competition for funding will be one of the primary challenges. It will be important to prioritize and properly appropriate funds for establishing new TMCs as a function separate from funding the operation and maintenance of those already in existence. Further, as more TMCs move toward continuous 24-hour operation, costs will increase significantly because of the need for extra staffing, for additional field and central equipment, and any additional infrastructure. As the TMC assumes a greater role in the management of the transportation system, it may actually be more costly to the system if the TMC is off-line when major incidents or special events occur.

Rapidly evolving technology and continued development of intelligent transportation systems will have, perhaps, the most significant effects on TMC development and capability. Technological advances soon available to vehicles will considerably affect the role that TMCs play in managing future transportation management systems. Deployment of advanced vehicle control systems and automated highway systems will create a greater dependence on TMCs. The integration of national and international initiatives, such as the Model Deployment Initiative, will also serve to enhance the development of TMCs through multimodal transportation management and traveler information systems.

TMCs synthesize many pieces of information to determine how the transportation system is operating and to adjust the traffic controls to accommodate changing travel conditions. New TMCs will have more sophisticated database and analysis software that will perform analyses of peak-period traffic conditions and traffic control patterns and adapt, in real-time, multijurisdictional traffic control devices. Additionally, some of these data can be selected and archived for future retrieval and evaluation. Public expectation will require TMCs to link the information in more complex, hierarchical, and hybrid TMC architectures. Advanced traveler information system user services, such as vehicle navigation and route guidance, with higher technological requirements are expected to link static route mapping with real-time traffic and transit condition information. Under the coverage and support of the TMC, real-time traffic information may be communicated to vehicle navigation systems to provide motorists with real-time route guidance, which could change based on actual travel conditions within the region. Additionally, further installation of VMS, HAR, and even Internet sites can also heighten public expectations. Since most regions cannot build their way out of congestion by adding new roadways, ITS and transportation management systems will be relied on to better manage traffic, detect incidents, and provide response in a timely manner. If properly designed, procured, and maintained, these systems can meet the expectations that so many agencies have promised for years. Internal uses of the TMC have expanded as well. The need for coordination, communication, and transfer of information among agencies is, in many urban areas, critical to the maintenance of traffic. Databases and synthesized data will also assume more significant roles in the TMC as the level of computer capability increases.

Transportation management centers will also require a major investment in human resources. Each TMC will require trained personnel who understand the transportation network as well as traffic and emergency management techniques. As TMCs grow, more individuals will be required for the operator workstation, engineering, and maintenance positions. In most cases, personnel will be cross-trained to maximize staff efficiency during major incidents and off-peak hours. Personnel duties will become more complex, encompassing the operation of detection devices, VMS, broadcasting on HAR, and implementing alternate route plans.

In addition to day-to-day operations, TMC managers will find themselves taking on new responsibilities including records management, technical troubleshooting, and agreement writing. This new breed of manager will need to balance institutional issues with budget constraints and interagency turf battles. Ideally, agencies will need to agree on cost and information sharing agreements. However, it will be up to the TMC managers to maintain these arrangements, make improvements, and ensure regional or interagency consensus. While this is a challenge, TMCs will afford a much broader picture of the regional network allowing more intelligent decision-making, improved communications with other regional entities, and interagency and intermodal coordination.

REFERENCES

1. *Operating and Maintaining Advance Traffic Management Systems (ATMS) Centers,* Institute of Transportation Engineers, September 1996.
2. *Transportation Management Center Coordination Study-Draft Memorandum No. 1,* Meyer, Mohaddes Associates, Inc., April 22, 1997.
3. Sprecher, M.H., Transportation Takes the NEXTEA, *Government Technology,* May 1997.
4. Patel, R. and Daniels, G., *Funding for Operation and Maintenance of Advance Traffic Management Systems,* Annual Meeting of the Institute of Transportation Engineers, Boston, Mass., August 1997.
5. *ITS Architecture-Theory of Operations,* United States DOT and Federal Highway Administration Joint Architecture Team, June 1996.
6. *Traffic Control Systems Handbook,* United States DOT, Federal Highway Administration, February 1996.
7. *Feasibility Study for the Expansion of the INFORM Southern State Parkway: Technical Memorandum Number 38—An Operations and Maintenance Approach for the LI-ITS,* New York State DOT, January 1997.
8. Nestor, Inc., Intelligent Sensors Division, vendor sheet for TrafficVision TOCStation, September 1996.
9. Sussman, E., *Memorandum for the Capital District ITS Early Action Project Management Center Staffing Requirements,* Parsons Brinckerhoff, January 30, 1997.
10. INFORM *Progress Report Number 28,* New York State DOT, January 30, 1998.
11. *A Toolbox for Alleviating Traffic Congestion,* Institute of Transportation Engineers, Washington, D.C., 1989.
12. *Business Plan,* I-95 Corridor Coalition, June 1995.
13. *Information Exchange Network, Requirements Report, Task 1, Project #1,* I-95 Corridor Coalition, January 27, 1995.
14. Kraft, W.H., *NCHRP Synthesis 245: Traffic Signal Control Systems Maintenance Management Practices,* Transportation Research Board, National Research Council, Washington, D.C., 1997.
15. *Intelligent Transportation Systems Action Guide,* ITS America, 1996.
16. *Intelligent Transportation Infrastructure Benefits: Expected & Experienced,* Operation TimeSaver, United States DOT, Federal Highway Administration, January 1996.
17. Pivnik, S.I., *ITE Final Report-Operation and Maintenance of Electronic Traffic Control Systems,* June 1995, White Paper No. 6—Legal Aspects of Traffic Control System and ITS Maintenance.

LIST OF ACRONYMS

ATMS	Advanced Traffic Management System
CCTV	Closed Circuit Television
CHART	Chesapeake Highway Advisors Routing Traffic
CMAQ	Congestion Management and Air Quality
DOT	Department of Transportation
EMS	Emergency Medical Service
ETC	Electronic Toll Collection
ETTM	Electronic Toll and Traffic Management
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
GPS	Global Positioning System
GUI	Graphical User Interface
HAR	Highway Advisory Radio
HAZMAT	Hazardous Materials
HOV	High Occupancy Vehicle
IEN	Information Exchange Network
INFORM	Information for Motorists Traffic Control System (Long Island, New York)
IOC	Interim Operations Center
ISP	Information Service Provider
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITS	Intelligent Transportation Systems
LAN	Local Area Network
MDI	Modal Deployment Initiative
MOE	Measures of Effectiveness
MOU	Memorandum of Understanding
MSHA	Maryland State Highway Administration
NHS	National Highway System
NTCIP	National Transportation Communications
ITS	for Protocol
OC	Operations Center
OCC	Operations Control Center, Central Artery Project in Boston, Massachusetts
OIC	Operations Information Center
RFP	Request for Proposal
SOC	Statewide Operations Center
STP	Surface Transportation Program
TIC	Transportation Information Center
TMC	Transportation Management Center
TOC	Transportation Operating Center
TRANSCOM	Transportation Operatint Coordinating Committee
USDOT	United States Department of Transportation
VMS	Variable Message Signs

APPENDIX A

Survey Instruments

TRANSPORTATION RESEARCH BOARD (TRB)
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Project 20-5, Topic 28-10

Transportation Management Center Functions
Questionnaire

Name of Respondent: ____________________
Agency: ____________________
Title: ____________________
Telephone No.: ____________________
FAX: ____________________
E-mail address: ____________________

INSTRUCTIONS

We would like to collect information from your agency on the functions of transportation management centers in your jurisdiction. The information will be used to develop a synthesis report on "Transportation Management Center Functions."

The purpose of this survey is to increase the state-of-the-practice in the use of transportation management centers. This synthesis will be of direct benefit to agencies.

This questionnaire should be completed by that person(s) with direct responsibilities for planning, designing and operating your center(s). Please answer as many of the following questions as possible. Attach additional sheets if necessary. Note that Pages 2, 3, and 4 of this survey (Questions 1 through 4) need to be completed for each individual TMC location that your agency controls. In these questions, TMC-specific information is required for each TMC location. The remaining questions (Page 5 to end) do not need to be completed for each TMC. Rather, they are general questions related to your agency. Also, please provide copies of any supporting data, reports, photographs, floor plans, or organizational staffing charts. Send your completed questionnaire and supporting documentation to:

Walter H. Kraft
PB Farradyne Inc.
One Penn Plaza
New York, NY 10019

If you have any questions, please contact Walter Kraft at (212) 465–5724 or Rob Canestra at (212) 465–5719.

WE WOULD APPRECIATE YOUR RESPONSE

1. How many TMCs does your agency control? Indicate the number of TMCs by type.

Types of TMCs	Quantity
Freeway	
Surface Street	
Tunnel/Bridge	
Transit (Bus)	
Transit (LRT/Subway)	
Railroad	
Integrated TMC Specify	

2. Use a checkmark to indicate your TMC functions. Use a separate response for each TMC type and location.

TMC type and location____(e.g., freeway, etc.)

TMC Functions	Current	Future
Surveillance		
Incident Management		
Information Dissemination Public (e.g., CATV, etc.) Private (e.g., Media, ISP, etc.)		
Environmental Monitoring		
Special Event Management		
Coordination w/ Police/Fire/EMS		
HAZMAT		
Emergency Management		
HOV Operations		
Data Fusion		
Ramp Metering		
Traffic Signal Control		
Risk/Liability Management		
Other (specify)_______________		

3. Provide the following information for each TMC type and location.

TMC type and location____(e.g., freeway, etc.)

a) Total square footage of TMC facility (i.e., control room, equipment room, offices, etc.)

____

b) Days of operation _______________________

c) Hours of operation _______________________

d) Is the facility: ❑ Owned ❑ Leased

e) Are police assigned to the TMC? ❑ Yes ❑ No

f) Provide the following costs for the TMC facility.
(Note: Do not include field device or communication costs)

Central System costs (Physical TMC, equipment, design, software and integration) ______________

Yearly TMC Operations costs ____________________

Yearly TMC Maintenance costs ____________________

g) Indicate the number and type of personnel employed per shift at the TMC facility (e.g., 2 operators, 1 supervisor, 3 technicians).

WORK SHIFT			
	1	2	3
Weekday Time			
Weekend Time			
Weekday Personnel			
Weekend Personnel			

4. For each TMC facility type and location, provide the following information:

TMC type and location____ e.g., freeway, etc.)

System Coverage	Number
Freeway centerline miles	
Number of traffic signals	
Tunnel/Bridge centerline miles	
Bus Route miles	
Light Rail/Subway track miles	
Railroad track miles	
Hardware for collecting information	Number
Inductive loop detectors	
CCTV cameras	
Ramp Meter locations	
Vehicle probes	
Radar/microwave detectors	
Video image detectors	
Environmental detectors	
Surveillance aircraft	
Satellites	
Other (specify)	
Hardware for distributing information	Number
Variable Message Signs	
Highway Advisory Radio sites	
Information kiosks	
Activity center displays	
Internet connection?	Yes_ or No_
Other (specify)	
Hardware for displaying information	Number
Video monitors	
Workstations	
Map graphic displays	
Video wall	
Other (specify)	

5. Indicate the justifications for building a TMC (e.g., congestion management, public service, necessary system component, etc.)?

____
____
____
____

6. Provide a brief description of your TMC's system architecture (e.g., centralized, decentralized, or hybrid). Include a context diagram, if available.

____
____
____
____

7. How are personnel selected for the TMC?

____
____
____
____

8. What training programs do you have for TMC personnel?

____
____
____
____

9. a) Is your TMC operated by a private entity?

❑ Yes ❑ No

b) If no, are you considering to do so in the future?

❑ Yes ❑ No

10. a) Do you currently sell information to the private sector?

❑ Yes ❑ No

b) If no, are you considering to do so in the future?

❑ Yes ❑ No

11. Please identify any institutional arrangements (if applicable) with regard to the TMC (i.e., especially for interjurisdic tional coordination).

____
____
____
____

12. List the expected benefits of a TMC (e.g., reduced time delays, information dissemination, incident reductions, etc.)?

____
____
____
____

13. Describe the evaluation criteria used for your TMC?

14. The following questions refer to other TMC considerations.

a) With regard to liability:

- How many lawsuits involving TMCs activities or operations have been brought against your jurisdiction in the last year? ____________
- What was the dollar amount?_______
- Is the number of lawsuits increasing? ❑ Yes ❑ No
- Explain your documentation for potential litigation.

b) Please describe your agency's approach to communications with the media (broadcast stations, traffic and transit information organizations, etc.) and public relations activities related to the TMC?

c) Is resource sharing involved in the TMC operation (joint use of devices, personnel, etc.)? Please specify resources you "share" and with what agencies/companies.

Resource Shared	Agency shared with	Comments
Devices		
Personnel		
Equipment		
Authority		
Control of Devices		
Responsibility		
Other (please specify)		

15. What procurement processes do you use for the TMC or any of the systems within the TMC? If possible, please provide samples.

Process	Yes	No	Description/Comments
Low Bid			
Facilities Management			
Life Cycle Costs			
Design Build			
Privatization			
Prequalification			
Other (Please specify)			

a) What legal issues do you associate with the procurement process?

16. Please add any other comments you think we should be aware of.

This synthesis is being prepared to share knowledge about TMC practices. Any further information to assist us will be appreciated. Please send any manuals, photos, and organizational staffing charts that are instrumental in illustrating your transportation management center.

Thank you for your valuable assistance.

12/31/96

TMC SHOWCASE QUESTIONS

(The following survey questions were used in telephone follow-up calls to selected respondents)

Name of Agency ________________________
Person ________________________________
Date & Time ______________________ Surveyor ____________

1. What makes your TMC successful?
2. What were the most significant technical challenges faced in establishing your TMC? Do they still remain? How were they resolved?
3. What are the most significant institutional obstacles (i.e., political pressures) in establishing and sustaining your TMC? Do they still remain? How were they resolved?
4. How does the TMC coordinate beyond your jurisdictional boundaries (i.e., what happens at the border)? How do you resolve interjurisdictional differences?
5. What procedures are in place in the TMC to coordinate construction schedules with special events and/or incidents?
6. Who maintains existing ITS equipment (in TMC & field)? Over next 5 years, what ITS systems will be added? Who will be maintaining it?
7. What is the average hourly/yearly salary of typical TMC operators (in direct cash salary)? (relating performance & professionalism/workload with salary rates). How long does it take for new TMC employees to become fully proficient?
8. How is the performance of the TMC evaluated? Who conducts it?
9. What standards (NTCIP, ITS NA) is the TMC following (if applicable)?
10. What was the most significant event that you can recall? How did the TMC respond?

APPENDIX B

Survey Respondents

LIST OF AGENCIES WHO RESPONDED TO SURVEY

Agencies Sent To	Number of TMCs and Type
Cities:	
Anaheim, California	1 (SS/FR)
Anchorage, Alaska	1 (SS)
Austin, Texas	1 (SS)
Baltimore, Maryland	0
Bellevue, Washington	1 (SS)
Boston, Massachusetts	1 (SS)
Boulder, Colorado	0
Buffalo, New York	1 (SS)
Calgary, AB	4 (SS; TB; BU; LS)
Charlotte, North Carolina	2 (SS)
Columbus, Ohio	1 (SS)
Daytona Beach, Florida	1 (FR/SS)
Durham, North Carolina	1 (SS)
Edmonton, AB	1 (FR/SS/TB)
Greenville, South Carolina	0
Hamilton, Ontario	0
Hartford, Connecticut	1 (SS)
Honolulu, Hawaii	1 (FR/SS)
Houston, Texas	0
Irvine, California	1 (SS/RR)
Jacksonville, Florida	1 (SS)
Los Angeles, California (ATSAC Operations Division)	1 (SS)
Louisville, Kentucky	1 (SS)
Menlo Park, California	0
Minneapolis, Minnesota	1 (SS)
Newark, New Jersey	1 (SS)
Norfolk, Virginia	0
Omaha, Nebraska	0
Orlando, Florida	1 (FR/SS)
Pittsburgh, Pennsylvania	0
Salt Lake, Utah	0
San Antonio, Texas	1 (SS)
San Jose, California	1 (SS)
Santa Ana, California	1 (SS)
Savannah, Georgia	1 (SS)
Sioux Falls, South Dakota	0
St. Louis, Missouri	0
Surrey, British Columbia	0
Toronto, Ontario	1 (FR/SS)
Vancouver, British Columbia	1 (SS)
Washington, D.C.	2 (1FR/SS/TB/BU; 1SS/TB)
Wichita, Kansas	0
Winston-Salem, North Carolina	1 (SS)
City of Winnipeg, Manitoba	0
Number of Agencies 80	% Agencies w/TMCs 65.91%
Counties:	
Ada, Idaho	1 (SS)
Dade, Florida	1 (SS)
Honolulu, Hawaii	1 (FR/SS)
Lexington, Kentucky	1 (FR/SS)
Los Angeles, California	10 (7SS; 1FR; 1SS/LS; 1BU)
Montgomery, Maryland	1 (SS/BU)
Number of Agencies 8	% Agencies w/TMCs 100.00%

TMC Types: FR-Freeway; SS-Surface Street; TB-Tunnel/Bridge; BU-Transit (Bus); LS-Transit(Light Rail/Subway); RR-Railroad.

LIST OF AGENCIES WHO RESPONDED TO SURVEY (Continued)

Agencies Sent To		Number of TMCs and Type	
Other:			
AMTRAK		1 (RR)	
Central Artery Tunnel Project (MHD)		1 (SS/TB)	
Chesapeake Bay Bridge and Tunnel Commission			0
Delaware River Port Authority		4 (TB); 1 (LS)	
Delaware Transit Corporation		4 (TB); 1 (LS)	
Greater New Orleans Expressway Commission		1 (FR/SS/TB)	
Houston TranStar		1 (FR/SS/BU)	
Illinois State Toll Highway Authority		1 (FR)	
Jacksonville Transit Authority		2 (BU; LS)	
Kansas Turnpike Authority		1 (FR)	
Los Angeles County MTA		2 (BU; LS)	
Mackinac Bridge Authority			0
Maryland Mass Transit Administration		3 (BU; 2LS)	
Maryland Transit Authority		1 (FR/TB)	
MTA Bridges and Tunnels		9 (TB)	
MTA LIRR		1 (RR)	
MTA Metro-North		1 (RR)	
New Jersey Highway Authority		1 (FR)	
New Jersey Turnpike Authority		1 (FR)	
New York State Thruway Authority		2 (FR; TB)	
NYC Transit Authority		2 (BU; LS)	
Orange County Expressway Authority			0
PANY/NJ		4 (TB)	
PATH Corporation		1 (RR)	
Rhode Island Turnpike and Bridge Authority			0
South Jersey Transportation Authority			0
Texas Railroad Commission			0
Washington Metropolitan Area Transit Authority		1 (LS)	
Washington Utilities & Transportation Commission			0
West Virginia Port Authority			0
West Virginia Railroad Authority		1 (RR)	
Number of Agencies	50	% Agencies w/TMCs	74.19%
Agencies Sent To		Number of TMCs and Type	
Province of Saskatchewan DOT		0	
States:			
Alabama DOT		0	
Alaska DOT		0	
Arizona DOT		1 (FR/TB)	
Arkansas DOT			0
CALTRANS		8 (6FR; 1FR/TB; 1FR/SS)	
Colorado DOT		3 (2TB; FR)	
ConnDOT		2 (1FR; 1FR/SS)	
Delaware DOT		1 (FR/SS)	
Georgia DOT		1 (FR)	
Hawaii DOT		2 (FR/SS/TB; TB)	
Idaho DOT			0
Illinois DOT		3 (FR; FR/SS; FR/BU/LS/RR)	
Indiana DOT		1 (FR)	
Iowa DOT			0
Kansas DOT			0
Kentucky DOT		1 (FR)	
Louisiana DOT			0
Maine DOT			0
Maryland SHA		3 (FR); 2 part-time (FR)	
Michigan DOT		1 (FR)	
Minnesota DOT		1 (FR/SS/TB)	
Mississippi DOT		1 (SS)	
Missouri DOT		3 (FR/SS/BU/LS; FR/SS/BU; FR/SS/BU)	
Montana DOT			0
Nebraska DOT			0

TMC Types: FR-Freeway; SS-Surface Street; TB-Tunnel/Bridge; BU-Transit (Bus); LS-Transit(Light Rail/Subway); RR-Railroad.

LIST OF AGENCIES WHO RESPONDED TO SURVEY (Continued)

Agencies Sent To		Number of TMCs and Type	
States:			
Nevada DOT			0
New Hampshire DOT		2 (FR)	
New Mexico DOT			0
North Carolina DOT		5 (2FR; 1SS; 1FR/SS; 1FR/SS/TB)	
North Dakota DOT			0
Oklahoma DOT			0
Oregon DOT		1 (FR/SS)	
PennDOT		2 (FR)	
South Carolina DOT			0
South Dakota DOT			0
Tennessee DOT		1 (TB)	
TexDOT		3 (FR)	
Utah DOT		1 (FR/SS/BU/LS)	
Vermont DOT			0
Virginia DOT		3 (FR; FR/SS/TB; ALL)	
Washington DOT		2 (FR; FR/TB)	
West Virginia DOT			0
Wisconsin DOT		1 (FR)	
Wyoming DOT			0
Number of Agencies	52	% Agencies w/TMCs	55.56%
	190		65.87%

TMC Types: FR-Freeway; SS-Surface Street; TB-Tunnel/Bridge; BU-Transit (Bus); LS-Transit(Light Rail/Subway); RR-Railroad.

APPENDIX C

Urban Transportation Monitor Surveys—1995 and 1998

The author would like to acknowledge Dan Rathbone of Lawley Publications (P.O. Box 12300, Burke, Virginia 22009-2300, (tele: 703–764–0512, fax: 703–764–0516), for publication of his Transportation Management Center Surveys in the *Urban Transportation Monitor*. The TMC survey published in 1995 served, in part, as a foundation for the questionnaire developed and used in this synthesis.

The TMC survey published in 1998 was received too late to use the research, data, or results of this synthesis. It is presented here to provide more recent data on selected traffic operations centers.

Editorial

There is no doubt that the quality of information on traffic conditions that will be available for dissemination to the public will improve significantly over the next few years. This is due to the many improvements (added equipment/technologies and, therefore, increased capabilities and function) that respondents to this week's survey indicated will occur at their respective Transportation Management Centers in future.

A major issue associated with this increased capability is the distribution of this information to the public at large. A strong case can be made for encouraging the private sector to use this type of information to provide "value-added"-type services to the public for a fee. For example, a company can consolidate real-time transit and traffic travel times and provide this in a customized format automatically to a subscriber for their particular origin-destination needs. If a pager is used, automatic "alarm" beeps can sound to warn a subscriber that their trip path and mode of choice is operating at an unacceptable level -- alleviating the need for a commuter to make the same travel-condition enquiry twice a day before they travel.

The scenario described here is just one of many possibilities. What is clear, however, is that TMCs will be focal points of future urban transportation systems and that the information they provide will become more and more valuable in financial terms as their capabilities and proficiency increase.

Daniel B. Rathbone
Publisher

This Week's Survey Results

Transportation Management Centers (Part II)

Over the past few weeks, *The Urban Transportation Monitor* has conducted a survey to obtain information and opinions from the directors of Transportation Management Centers (TMCs) in North America.

Questionnaires were sent to thirty-three TMCs. Thirty completed surveys were received. The results are published in two parts. Part I appeared in the previous issue of *The Urban Transportation Monitor* and Part II is shown here. The overall results are summarized below. Characteristics of individual TMCs are shown on the next four pages and are a continuation of Part I.

Equipment/technologies installed, capabilities of TMCs

	% TMCs that have this presently installed	% TMCs that will install this in future
PRESENT, FUTURE EQUIPMENT/TECHNOLOGIES		
For collecting traffic information:		
Inductive loops/loop detectors	79	36
Closed-circuit television	86	46
Video surveillance cameras	71	39
Ramp meters	57	39
Vehicles as probes	18	36
Surveillance aircraft	18	11
Roadside mounted radar detectors	21	14
Satellites	4	4
Cell phone lines	54	25
Radio communication (CB, agency radio)	86	29
Telephone	79	29
Video imaging detection system	36	39
For distributing traffic information:		
Variable message signs	89	46
Highway advisory radio	50	54
Radio broadcast	64	25
Radio--CD, agency radio	57	18
Cable television	43	43
Personal computer/modem	64	39
Information kiosk	25	71
Telephone	68	36
Telephone - auto dialing	39	32
Displays at activity centers	29	61
For display:		
CRT displays	71	36
Map graphics display	79	46
PRESENT, FUTURE CAPABILITIES/FUNCTIONS OF TMC		
Incident management coordination	89	39
Special event coordination	96	36
Data backup	71	29
Media coordination and cooperation	96	39
System software support and maintenance	75	29
Traveler information services	54	61
Video surveillance	75	43
Traffic responsive signal control	50	50
Variable message sign control	89	43
Integrated transit and traffic operations	25	50
Integrated police/fire dispatching	29	43
HOV system coordination and cooperation	39	54
Emergency response vehicle management	32	25

Average number of personnel working at TMCs:

Traffic engineers: 3; Traffic technicians: 5; Dispatchers: 11; Other: 7 (e.g. computer engineers, supervisors, programmers,systems operators)

Averages annual operating and maintenance budget of TMCs: $2.1 million.

Twelve TMCs operate 24 hours/day, 7 days/week and 10 TMCs have a police officer assigned.

Transportation Management Centers

NAME OF TMC	Central Valley Transportation Management Center, Fresno CA		Newington Operations Center, Newington CT		Texas Department of Transportation-Fort Worth District TMC (Official name not yet determined), Fort Worth TX		Statewide Operations Center (SOC), Hanover MD	
NAMES OF ORGANIZATIONS PARTICIPATING IN TMC	Caltrans California Highway Patrol (CHP)		Connecticut State Police		TxDOT Fort Worth/Dallas Cities of Fort Worth, Arlington, Hurst, etc.		Maryland State Police Maryland Transportation Authority	
EQUIPMENT, TECHNOLOGIES INSTALLED:	Presently installed	In future	Presently installed	In future	Presently installed	In future	Presently installed	In future
For collecting traffic information:								
Inductive loops/loop detectors	√				√	√	√	
Closed-circuit television	√		√		√	√	√	
Video surveillance cameras	√		√				√	
Ramp meters	√					√		
Vehicles as probes				√				
Surveillance aircraft							√	
Roadside mounted radar detectors			√				√	
Satellites								
Cell phone lines	√		√			√	√	
Radio communication (CB, agency radio)	√		√		√	√	√	
Telephone	√		√		√	√	√	
Video imaging detection system			√			√		
For distributing traffic information:								
Variable message signs	√		√		√	√	√	
Highway advisory radio	√			√		√	√	
Radio broadcast	√		√		√	√	√	
Radio–CB, agency radio					√	√	√	
Cable television				√				√
Personal computer/modem	√		√			√	√	
Information kiosk		√				√		√
Telephone	√		√		√	√	√	
Telephone - auto dialing			√				√	
Displays at activity centers		√				√	√	
For display:								
CRT displays	√				√	√	√	
Map graphics display		√			√	√	√	
Other (as indicated by respondents):							weather, road sensors, signal systems, maintenance logistics	
PRESENT AND FUTURE CAPABILITIES/FUNCTIONS OF TMC								
Incident management coordination	√		√		√	√	√	
Special event coordination	√		√		√	√	√	
Data backup	√		√		√	√	√	
Media coordination and cooperation	√		√	√	√	√	√	
System software support and maintenance	√		√			√	√	
Traveler information services	√			√		√	√	
Video surveillance	√		√		√	√	√	
Traffic responsive signal control			√			√	√	
Variable message sign control	√		√		√	√	√	
Integrated transit and traffic operations				√				√
Integrated police/fire dispatching				√				
HOV system coordination and cooperation	√							√
Emergency response vehicle management							√	
Other (as indicated by respondents):								
TYPE OF ORGANIZATIONS TO WHICH TRAFFIC INFORMATION IS PROVIDED	Media		State police; media; local police; ride share companies		Commercial traffic services		N/A	
NUMBER OF PERSONNEL AT TMC	2 traffic engineers 5 traffic technicians 2 dispatchers 3 CHP officers		4 traffic engineers 3 traffic technicians 2-4 dispatchers (state police) 15 systems operators		N/A		traffic eng. support staff 18 traffic technicians Emergency Response Technicians (ERT)	
ANNUAL OPERATING AND MAINTENANCE BUDGET	N/A		$3 million		N/A		$2.4 million	
PROVIDE TOURS FOR TRANSPORTATION PROFESSIONALS ?	YES		YES		YES		YES	
DAYS AND HOURS OF OPERATION	5 am to 6 pm, M-F, November '95–24hrs/day		24 hours/day, 7 days/week		13 hours/day, M-F		24 hours/day, 7 days/week	
POLICE OFFICER ASSIGNED TO TMC ?	YES		NO		NO		YES	

Transportation Management Centers

NAME OF TMC	Anaheim Traffic Management Center, Anaheim CA		Georgia Department of Transportation TMC, Atlanta GA		City of Columbus, Division of Traffic Engineering TMC, Columbus OH		Irvine Traffic Research and Control Center (ITRAC), Irvine CA		ADOT Traffic Operations Center, Phoenix AZ	
NAMES OF ORGANIZATIONS PARTICIPATING IN TMC	Caltrans City of Irvine Hilton Multivision Cable TV		Georgia State Patrol Georgia Emergency Management Agency		City of Columbus Radio and TV Stations		N/A		Arizona Department of Transportation Federal Highway Administration	
EQUIPMENT, TECHNOLOGIES INSTALLED:	Presently installed	In future	Presently installed	In future	Presently installed	In future	Presently installed	In future	Presently installed	In future
For collecting traffic information:										
Inductive loops/loop detectors	√		√		√	√	√		√	
Closed-circuit television	√			√	√	√	√		√	
Video surveillance cameras				√	√	√	√		√	
Ramp meters				√		√			√	
Vehicles as probes			√							
Surveillance aircraft				√						
Roadside mounted radar detectors									√	√
Satellites										
Cell phone lines			√				√			√
Radio communication (CB, agency radio)	√		√		√	√	√		√	
Telephone	√		√		√	√	√		√	
Video imaging detection system				√			√		√	√
For distributing traffic information:										
Variable message signs	√			√		√		√	√	
Highway advisory radio	√			√						√
Radio broadcast				√	√	√				√
Radio–CB, agency radio			√		√	√			√	
Cable television	√		√			√		√	√	
Personal computer/modem	√		√		√	√	√		√	
Information kiosk	√			√		√		√		√
Telephone	√		√		√	√	√		√	
Telephone - auto dialing	√			√			√		√	
Displays at activity centers	√			√		√		√		√
For display:										
CRT displays	√				√	√	√		√	
Map graphics display	√			√		√	√		√	
Other (as indicated by respondents):									Video Wall Video Projector	Internet
PRESENT AND FUTURE CAPABILITIES/FUNCTIONS OF TMC										
Incident management coordination	√		√		√	√	√		√	
Special event coordination	√		√		√	√	√		√	
Data backup			√		√	√	√		√	
Media coordination and cooperation	√		√		√	√	√		√	
System software support and maintenance	√			√			√		√	
Traveler information services	√		√			√		√	√	
Video surveillance				√	√	√	√		√	
Traffic responsive signal control		√	√		√	√	√		√	
Variable message sign control	√		√			√	√		√	
Integrated transit and traffic operations	√			√				√		√
Integrated police/fire dispatching	√			√				√		√
HOV system coordination and cooperation			√					√	√	
Emergency response vehicle management			√					√	√	√
Other (as indicated by respondents):									Hazmat advisory Risk management advisory	Area wide traffic coordination
TYPE OF ORGANIZATIONS TO WHICH TRAFFIC INFORMATION IS PROVIDED	State; police; media		Traffic reporting stations; police; Georgia Emergency Management Agency		Media; police		N/A		State police; DOT maintenance; DOT construction; news media; personal computer displays	
NUMBER OF PERSONNEL AT TMC	2 traffic engineers 2 interns		9 traffic engineers 6 traffic technicians 12 dispatchers 8 support staff		3 traffic engineers 3 traffic technicians		3 traffic engineers 6 traffic technicians		2 traffic specialists 2 traffic engineers 2 traffic technicians 8 operators 14 support staff	
ANNUAL OPERATING AND MAINTENANCE BUDGET	$1 million (including signal maintenance)		N/A		N/A (not separated from daily operations)		$1.5 million		N/A	
PROVIDE TOURS FOR TRANSPORTATION PROFESSIONALS?	YES		YES		YES		YES		YES	
DAYS AND HOURS OF OPERATION	7 am to 5:30 pm, M-F (plus events)		24 hours/day, 7 days/week		6 am to 6 pm, M-F		7 am to 6 pm, M-F		24 hours/day, 7 days/week	
POLICE OFFICER ASSIGNED TO TMC?	NO		GDOT enforcement official		NO		NO		YES	

Transportation Management Centers

NAME OF TMC	Traffic Operations Center, New Brunswick NJ		TransGuide, San Antonio TX		Traffic Management Center, Minneapolis MN		Transportation Management Operations Center (TMOC), Portland OR	
NAMES OF ORGANIZATIONS PARTICIPATING IN TMC	New Jersey Turnpike Authority		San Antonio Police, TxDOT, Via Metropolitan Transit, City of San Antonio Traffic Operations, Research Organizations, Police/Fire/ EMS/911/Dispatch		Minnesota DOT/ Metro Division		City of Portland, Metro, City of Gresham, Multnomah County, Oregon State Police, Washington DOT, Vancouver	
EQUIPMENT, TECHNOLOGIES INSTALLED:	Presently installed	In future	Presently installed	In future	Presently installed	In future	Presently installed	In future
For collecting traffic information:								
Inductive loops/loop detectors	√		√		√	√	√	
Closed-circuit television	√		√		√	√		√
Video surveillance cameras	√		√		√	√		√
Ramp meters				√	√	√	√	√
Vehicles as probes				√		√		√
Surveillance aircraft					√	√		
Roadside mounted radar detectors								
Satellites								
Cell phone lines	√						√	√
Radio communication (CB, agency radio)			√		√	√	√	
Telephone	√				√	√		
Video imaging detection system	√		√		√			√
For distributing traffic information:								
Variable message signs	√		√		√	√	√	√
Highway advisory radio	√				√	√		√
Radio broadcast			√		√	√	√	√
Radio–CB, agency radio					√	√	√	
Cable television			√		√	√		
Personal computer/modem	√		√			√		√
Information kiosk		√		√		√		√
Telephone	√					√	√	√
Telephone - auto dialing	√					√		
Displays at activity centers		√	√			√		
For display:								
CRT displays	√		√		√	√		
Map graphics display	√		√		√	√		√
Other (as indicated by respondents):								
PRESENT AND FUTURE CAPABILITIES/FUNCTIONS OF TMC								
Incident management coordination	√		√		√	√		√
Special event coordination	√		√		√	√	√	√
Data backup	√		√			√		
Media coordination and cooperation	√		√		√	√	√	√
System software support and maintenance			√		√	√		
Traveler information services	√		√		√	√		√
Video surveillance	√		√		√	√		√
Traffic responsive signal control	√		√		√	√		√
Variable message sign control	√		√		√	√	√	√
Integrated transit and traffic operations	√		√		√	√		√
Integrated police/fire dispatching	√		√			√		
HOV system coordination and cooperation		√		√	√	√		√
Emergency response vehicle management	√		√					
Other (as indicated by respondents):								
TYPE OF ORGANIZATIONS TO WHICH TRAFFIC INFORMATION IS PROVIDED	Police; media; TRANSCOM		Media; emergency services (fire & police); transit; private transportation companies; general information services		Commercial radio & TV stations; truckers; transit operators; delivery services; utility companies		Media; police; local authorities	
NUMBER OF PERSONNEL AT TMC	13 dispatchers 5 supervisors 1 manager		4 traffic engineers 20 traffic technicians 60 dispatchers		6 traffic engineers 10 traffic technicians 1 computer engineer 1 programmer 1 R & D engineer 27 other		Center is only now being pulled together–no staff is specifically assigned to TMC.	
ANNUAL OPERATING AND MAINTENANCE BUDGET	N/A		$3 million		$4 million		N/A	
PROVIDE TOURS FOR TRANSPORTATION PROFESSIONALS ?	YES		YES		YES		YES	
DAYS AND HOURS OF OPERATION	24 hours/day; 7 days/week		4 am to 12 am; 7 days/week		6 am to 9 pm weekdays; 11 am to 7 pm Saturdays & Sundays		Still to be decided–preference is 24 hours/day; 7 days/week	
POLICE OFFICER ASSIGNED TO TMC ?	NO		YES		NO		Being considered	

Transportation Management Centers

NAME OF TMC	TRANSCOM Operations Information Center, Jersey City NJ		San Francisco Bay Area Interim TMC (California Coastal Region), Oakland CA		District 7 TMC, Los Angeles CA		Golden Glades Interchange Control Center, Miami FL		Colorado Traffic Operations Center, Lakewood CO	
NAMES OF ORGANIZATIONS PARTICIPATING IN TMC	Over 200 agencies provide and receive information through TRANSCOM		Caltrans, California Highway Patrol (CHP), Metro Transportation Commission, Regional MPO		Caltrans California Highway Patrol Freeway Service Patrol		Florida Department of Transportation Florida Highway Patrol		Colorado State Patrol Colorado Office of Emergency Management	
EQUIPMENT, TECHNOLOGIES INSTALLED:	Presently installed	In future	Presently installed	In future	Presently installed	In future	Presently installed	In future	Presently installed	In future
For collecting traffic information:										
Inductive loops/loop detectors			√	√	√			√	√	
Closed-circuit television	√		√	√	√		√	√	√	
Video surveillance cameras	√		√	√	√			√	√	
Ramp meters			√	√	√			√	√	
Vehicles as probes	√		√	√	√			√		√
Surveillance aircraft					√				√	
Roadside mounted radar detectors						√			√	
Satellites					√					√
Cell phone lines			√	√	√		√	√		√
Radio communication (CB, agency radio)	√		√		√			√	√	
Telephone	√				√		√	√	√	
Video imaging detection system				√	√			√		√
For distributing traffic information:										
Variable message signs	√		√	√	√		√	√	√	
Highway advisory radio	√		√	√	√			√	√	
Radio broadcast	√		√		√		√	√	√	
Radio–CB, agency radio	√		√		√				√	
Cable television					√			√		√
Personal computer/modem	√		√	√	√		√		√	
Information kiosk		√		√		√		√		√
Telephone	√				√		√	√	√	
Telephone - auto dialing	√			√	√			√	√	
Displays at activity centers		√			√			√		√
For display:										
CRT displays	√		√	√		√		√	√	
Map graphics display	√		√	√	√			√	√	
Other (as indicated by respondents):	alpha-numeric pager; internet e-mail									
PRESENT AND FUTURE CAPABILITIES/FUNCTIONS OF TMC										
Incident management coordination	√		√	√	√		√	√	√	
Special event coordination	√		√	√	√		√	√		√
Data backup	√			√	√			√	√	
Media coordination and cooperation	√		√	√	√		√	√	√	
System software support and maintenance	√		√	√	√			√	√	
Traveler information services	√			√		√		√	√	
Video surveillance	√		√	√	√			√	√	
Traffic responsive signal control			√	√		√	√			√
Variable message sign control	√		√	√	√			√	√	
Integrated transit and traffic operations	√			√		√		√		√
integrated police/fire dispatching			√	√				√		√
HOV system coordination and cooperation			√	√		√	√	√	√	
Emergency response vehicle management				√	√			√		√
Other (as indicated by respondents):					lane closure coordination; special event coordination		traffic adaptive signals			
TYPE OF ORGANIZATIONS TO WHICH TRAFFIC INFORMATION IS PROVIDED	Transp. agencies; local, county, and state police; media; employers; TMA's; transit agencies		Media–TV and radio		Media; transportation permits; public		Media; state police; public		Media; local fire/police; truck firms/truck stops/terminals	
NUMBER OF PERSONNEL AT TMC	1 traffic engineer 3 traffic technicians 10 dispatchers 2 operations managers		2 traffic engineers 6 traffic technicians 6 CHP/Media Info. Officers		8 traffic engineers 4 traffic technicians 8 dispatchers 6 CHP officers		1 traffic engineer 4 support staff		4 traffic engineers 6 traffic technicians 1 support staff	
ANNUAL OPERATING AND MAINTENANCE BUDGET	$1.9 million		$1.4 million		$10 million		$250 K		$2.1 million	
PROVIDE TOURS FOR TRANSPORTATION PROFESSIONALS ?	YES		YES		YES		YES		NO	
DAYS AND HOURS OF OPERATION	24 hours/day; 7 days/week		24 hours/day; 7 days/week		24 hours/day; 7 days/week		8 am to 5 pm, M-F		6 am to 7 pm; (24 hours/day; 7 days/week as of 11/1/95)	
POLICE OFFICER ASSIGNED TO TMC ?	NO		YES		YES		NO		NO	

Transportation Management Center Survey -- Addition and Correction

The Transportation Management Center survey conducted by *The Urban Transportation Monitor* and published in the September 15 and 29 editions has created a large amount of interest. After our publication deadline we received information for the PennDOT 6-0 Traffic Control Center in St. Davids, PA. The information is shown here. We also received a clarification from the Florida Department of Transportation. Its Golden Glades Interchange Control Center, in Miami, FL, does not presently have traffic adaptive signals as indicated, but there are plans to have this capability in the future.

NAME OF TMC	PennDOT 6-0 Traffic Control Center	
NAMES OF ORGANIZATIONS PARTICIPATING IN TMC	PennDOT 6-0 Traffic Unit; Philadelphia Highway Patrol; Urban Engineers, Inc.	
EQUIPMENT, TECHNOLOGIES INSTALLED:	Presently installed	In future
For collecting traffic information:		
Inductive loops/loop detectors	√	√
Closed-circuit television	√	√
Video surveillance cameras	√	√
Ramp meters		√
Vehicles as probes		
Surveillance aircraft		
Roadside mounted radar detectors		√
Satellites		√
Cell phone lines	√	√
Radio communication (CB, agency radio)	√	√
Telephone	√	√
Video imaging detection system		√
For distributing traffic information:		
Variable message signs	√	√
Highway advisory radio		√
Radio broadcast	√	√
Radio--CB, agency radio	√	√
Cable television		
Personal computer/modem	√	√
Information kiosk		√
Telephone	√	√
Telephone - auto dialing		√
Displays at activity centers		√
For display:		
CRT displays		√
Map graphics display		√
Other (as indicated by respondents):		
PRESENT AND FUTURE CAPABILITIES/FUNCTIONS OF TMC		
Incident management coordination	√	√
Special event coordination	√	√
Data backup		√
Media coordination and cooperation	√	√
System software support and maintenance		√
Traveler information services	√	√
Video surveillance	√	√
Traffic responsive signal control		√
Variable message sign control	√	√
Integrated transit and traffic operations		√
Integrated police/fire dispatching		√
HOV system coordination and cooperation		√
Emergency response vehicle management		√
Other (as indicated by respondents):		
TYPE OF ORGANIZATIONS TO WHICH TRAFFIC INFORMATION IS PROVIDED	Express Traffic, Metro Traffic, Phila. Highway Patrol, PennDOT maintenance, Delaware River Port Authority, TRANSCOM	
NUMBER OF PERSONNEL AT TMC	1 traffic engineer, 1 technician, 1 student	
ANNUAL OPERATING AND MAINTENANCE BUDGET	Not Available	
PROVIDE TOURS FOR TRANSPORTATION PROFESSIONALS ?	Yes	
DAYS AND HOURS OF OPERATION	8 a.m. -- 4 p.m. Monday through Friday	
POLICE OFFICER ASSIGNED TO TMC ?	No	

Newly Developed Satellite-Based Telecommunications System a Success

Serves FHWA's Region 8

A satellite-based telecommunications system dedicated to transportation, called TEL8, has been developed to serve the Federal Highway Administration's Region 8. This region consists of the states of Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming. The 10-site TEL8 links the state DOTs and four state universities.

Each TEL8 site consists of in-room audio and video equipment which receives and transmits live sound and pictures. Each site is capable of sending and receiving signals from any other site in several modes of conferencing from broadcast to multi-point, two-way interaction.

On June 13 and 14 of this year, TEL8 was used for the first time to provide simultaneous training at the various locations. NHI Course No. 15255, "Access Management, Location and Design" was presented by Ron Giguere of FHWA's Office of Technology Applications and Bud Koepke of S/K Transportation Consultants, Inc. The course was co-sponsored by the Wyoming DOT and the University of Wyoming which served as the host site for the TEL8 transmission.

Two-way communication was available at each site so that questions could be asked and answered in real-time. The instructor and questioner could both appear on the screen while their dialogue was taking place. Over 80 individuals at the six DOTs in Region 8 as well as North Dakota State University and the University of Wyoming participated in the workshop. Instructors adapted the course to enhance interaction with the eight sites.

The course and the TEL8 system received high marks from the attendees. In future, TEL8 will provide regional graduate education credit courses at the four MPC Universities; North Dakota State University, Colorado State University, Utah State University and the University

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Editorial

When asked "what do you consider to be the best features of your Traffic Operations Center," respondents to this week's survey mentioned aspects such as "real time control;" "control of emergency route pre-emption;" "on-line monitoring of hardware and control of field devices," and "real time control of ramp metering." These responses indicate that the ability to react to a particular situation in a meaningful way rather than, more passively, just collect and distribute information, is considered to be a very positive attribute.

Presently, a Traffic Operation Center's response to congested traffic conditions usually takes the form of some signal timing adjustments and ramp metering. Both of these techniques are cost-effective, but their ability to significantly increase capacity in a particular corridor is limited.

To provide Traffic Operations Centers with additional "tools" to react to congested conditions, it is proposed that they should seriously look at applying the concept of "dynamic capacity." Dynamic capacity can be defined as the ability to change roadway capacity in response to prevailing traffic conditions. Although reversible lanes are a major component, dynamic capacity is a broader strategy. At intersections, for example, applying dynamic capacity differs from reversible lanes in three ways: 1) in addition to reversing the direction of one or more through lanes, nearly all geometric components of the intersection can be changed; 2) the equivalent of regular pavement markings can be maintained; 3) left-turn lanes can be maintained while the flow of a through lane is reversed. Dynamic capacity is made possible at intersections when regular pavement markings are replaced with intelligent pavement markers which can emit white or yellow light and can be switched on or off.

This will give Traffic Operations Centers the ability to respond to traffic congestion in a meaningful way in many corridors. Considering the staggering cost of congestion, any new strategy that has the ability to squeeze more efficiency out of the highway system should be considered.

Daniel B. Rathbone, Ph.D., P.E.
Publisher

This Week's Survey Results

Traffic Operations Centers (Part 2 & 3)

Earlier this month, *The Urban Transportation Monitor* conducted a national survey to obtain information and opinions on Traffic Operations Centers. Questionnaires were faxed to centers that concentrate on surface street/arterial operations. The results of the survey were published in the previous issue and also appear in this issue of *The Urban Transportation Monitor.*

Traffic Operations Center Contacts

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Traffic Operations Centers (Part 2)

LOCATION	Los Angeles, CA	Bridgeport, CT	Orlando, FL	Minneapolis, MN	Boise, ID
YEAR TOC FIRST OPENED	1984	1994	1987	1972	1978
YEAR OF LAST MAJOR UP-GRADE OF TOC	1997	1994	1987	1998	1990
MAJOR COMPONENTS OF LAST MAJOR UP-GRADE	Projection video system; physical space expanded from 1,500 to 5,000 sq. ft.	Some modules of construction project are still being developed.	Computer system (mini), free standing map displays.	New control room layout and furnishings	Replaced main frame HOneywell UTCS system with a PC based Honeywell system. Added 8 Traconet closed loop systems.
NEXT MAJOR UPGRADE OF TOC	1999	1998	2000	2003	1998
MAJOR COMPONENTS OF NEXT MAJOR UP-GRADE	Start retrofitting the existing traffic management operating system form fixed time to fully adaptive system	Installation of highway advisory radio system	Computer system (micro), video wall	New TOC facility, integrated with state police and traffic signal group	Replace the downtown Boise Honeywell signal system (80 controllers & cags). Will install new signal software, will install CCTV cameras. Will do a total remodeling of existing TMC.
TOTAL SQUARE FOOT-AGE OF TOC	5,000 sq. ft.	2,000 sq. ft.	1,600 sq. ft.	10,000 sq. ft.	450 sq. ft.
TYPE OF EQUIPMENT CONTROLLED, MONI-TORED:					
Signalized intersec-tions	2,240	300	400	12	198
Ramps with ramp me-tering signals	0	0	0	400	0
Total length of road sections with direc-tional control/lane con-trol signals (feet)	6,702 ft.	0	0	3,000	0
Intersections with pre-emption capability	22	150	100	N/A	56
HOV priority signals	0	0	0	49	0
Overheight vehicle control signs/signals	0	0	0	0	0
Other	124 signals at freeway on/off ramps	0	0	54 changeable message signs	0
TYPES OF DATA COLLEC-TION EQUIPMENT/SERV-ICES USED					
Inductive loop detec-tors	8,211	200+	300	3,170	800+ /20
Radar/microwave de-tectors	2	216	0	0	0
Video image detectors	0	0	0	80	6
Vehicle probes	0	0	0	30	0
Environmental sensors	0	91	0	0	4
CCTV cameras	157	91	0	180	0
Cellular phone (911) calls	0	1 system	0	0	0
CB radio	0	0	0	0	0
Helicopters	0	0	0	0	0
Spotters	0	0	0	0	0
USE DATA FUSION TECH-NOLOGY	yes	Yes	No	Yes	No

Traffic Operations Centers (Part 2, continued)

FUNCTIONS DATA FUSION TECHNOLOGY USED FOR	Systems graphic display	News media video	N/A	Systems graphics display; route guidance; motoristis information systems; ramp metering control.	N/A
SIGNAL TIMING SOFTWARE PROGRAMS USED	Urban Traffic Control System (UTCS)	N/A	None. Signal timing is performed at another site.	In-house and SCATS	TRANSYT 7F, PASSER
ONLINE NETWORK TRAFFIC CONTROL TECHNIQUES USED	None	N/A	None	In-house metering algorithms and SCATS based corridor program	Current signal systems are Honeywell and Traconet
MEASURES OF EFFECTIVENESS USED	Total travel time; total travel; delay; average speed; throughput.	Average speed	Number and percentage of stops; delay; total minute-miles of congestion; average speed; throughput (per lane).	Average speed; accident rate; througput; fuel consumption; vehicle emissions; user costs.	Delay; average speed; accident rate; fuel consumption; vehicle emission.
HOW GRAPHICS ARE DISPLAYED AT TOC	At workstations; on a large screen	At work stations	On a wall map	At workstations; on a large screen; on a wall map	At workstations; on wall map (1998)
FUNCTION OF CCTV SYSTEM	Monitoring traffic conditions; detection, confirmation of incidents and incident management	Monitoring traffic conditions; detection, confirmation of incidents and incident mgmt.; monitor ramp spillback conditions.	Detection, confirmation of incidents and incident mgmt.	Monitoring traffic conditions; detection, confirmation of incidents and incident mgmt.; monitor ramp spillback conditions; adjust ramp metering rates.	Monitoring traffic conditions (1998); detection, confirmation of incidents and incident mgmt.(1998)
TYPES OF DISPLAYS AT TOC	Projection video	Array of smaller video screens	Array of smaller video screens	Projection video and array of smaller video screens	Projection video and array of smaller video screens (1998)
WHAT GRAPHICS DISPLAY SHOW AT TOC	Controller online status: by group, individually; for each intersection: operation of detectors, geographic layout, detector locations, signal phasing, signal timing, system detector data; parameters: volume, occupancy, speed, stops, delay, pulse.	Controller online status:individually; operation of traffic signals; for each intersection: operation of detectors, geographic layout, detector locations, signal phasing, signal timing, system detector data, local detector calls; parameters: volume, occupancy, speed.	Controller online status: individually; operation of traffic signals; for each intersection: detector locations,system detector data; parameters: volume, occupancy, speed, stops, delay.	Controller online status: by group; operation of traffic signals; for each intersection; operation of detectors, signal phasing, signal timing, system detector data; parameters: volume, occupancy, stops, delay, ramp meter queueing data.	Controller online status: by group, individually; operation of traffic signals; for each intersection: operation of detectors, geographic layout, detector locations, signal phasing, signal timing,local detector calls; parameters: volume, occupancy.
FUNCTIONS DISPLAYED AT TOC	Control and mgmt. of traffic signal systems; lane controls; control and mgmt. of corridor control systems; participate in the incident mgmt. process; provide motorist aid services; special event mgmt.; planned lane closure mgmt.; provide traffic information to outside organizations.	Control and mgmt. of traffic signal systems; participate in the incident mgmt. process; provide motorist aid services; environmental monitoring; special event mgmt.; planned lane closure mgmt.; provide traffic information to outside organizations.	Control and mgmt. of traffic signal systems; participate in the incident mgmt. process; planned lane closure mgmt.; complaint response (the TOC has a dedicated telephone line, listed in the telephone directory, for traffic signal problems).	Control and mgmt. of traffic signal systems; lane controls; ramp metering signals; control and mgmt. of corridor control systems; participate in the incident mgmt. process; provide motorist aid services; provide in-vehicle route guidance information; special event mgmt.; provide traffic information to outside organizations; changeable message sign systems.	Control and mgmt. of traffic signal systems; participate in the incident mgmt. process;special event mgmt. (1998); planned lane closure mgmt.; provide traffic information to outside organizations; coordinate traffic controls and motorist infromation with other operating agencies.
METHOD OF DISTRIBUTION OF INFORMATION TO OUTSIDE ORGANIZATIONS, MEDIA	Through media (radio, TV, press); changeable message signs	Through media (radio, TV, press); VMS; highway advisory radio (in 1998)	N/A	Traffic control signals; highway advisory radio; information kiosks; internet connection; through media (radio, TV, press), changeable message signs.	Internet connection; through media (radio, TV, press)
COSTS OF TOC:					
Capital cost, excluding field equipment and communications	$7 million	N/A	$385,000	Present value, $3 million	$150,000

Traffic Operations Centers (Part 2, continued)

Operational cost/yr	$350,000	$900,000/yr	$239,000	$4 million	N/A
Maintenance cost/yr	$645,000	$400,000	$81,000	$1 million	N/A
HOW COORDINATION BETWEEN DIFFERENT AGENCIES IS ACHIEVED	Each agency has workstation in own control center, with overall coordination conducted by the TOC.	Each agency has workstation in own control center, with overall coordination conducted by the TOC.	TOC provides overall coordination for four agencies with telephone contact being used for changes.	We are mostly under one agency. We communicate information to others.	We control all signals (state, city) within ADA county TMC (298 signals)
NUMBER AND TYPE OF PERSONNEL EMPLOYED PER SHIFT AT TOC	5 engineering assistants, 1 engineering associate	6a.m.- 2 p.m. 2 operators, 1 service patrol dispatch, 3 transp. engineers, 1 operations supervisor; 2 p.m. - 10 p.m. 2 operators, 1 service patrol dispatcher; 10 p.m. - 6 a.m. 1 operator	5 a.m. - 3 p.m. 1 computer operator; 10 a.m. - 7 p.m. 1 computer operator; 7 p.m. - 5 a.m. 1 computer operator	6 a.m. - 2:30 p.m. 8 engineers, supervisors, 4 highway technicians, 4 computer technicians, 9 repair technicians, 4 motorist info persons, 8 motorist aid persons; 10:30 a.m. - 7 p.m. 2 engineers, supervisors, 4 highway technicians,2 repair technicians, 4 motorist info persons, 7 motorist aid persons; 7 p.m. - 9 p.m. 2 motorist info persons, 2 motorist aid persons.	7 a.m. - 6 p.m., 1 traffic operations engineer
WHAT DO YOU CONSIDER TO BE THE BEST FEATURES OF YOUR TOC?	On-line monitoring of field hardware as well as congestion The system provides a second-by-second monitoring and control of all field devices.	CCTV coverage of I-95, co-location with state police	Location	On-live ramp metering, FM-band radio broadcast, loop detection network, changeable message sign network.	Large windows to allow tour groups a good vantage point without having to enter the TMC.
WHAT DO YOU CONSIDER TO BE THE WORST FEATURES OF YOUR TOC?	The operating system (UTCS) is over 20 years old. LADOT is in the process of developing a new system that will replace the UTCS (Adaptive Traffic Control System, [ATCS]).	Need more floor area and console area.	Lack of technology. The signal system is outdated and not very flexible. PC bloat is another bad feature, each upgrade or new feature added to the TOC means another PC to be operated rather than using one PC for several functions.	Short staffing of computer support/programming	Not enough space. As the county grows and we add more signals, CCTVs, we will need larger TMC to house expanded staff.
RECOMMENDED AS IMPORTANT ASPECTS TO TAKE INTO CONSIDERATION BY OTHER AGENCIES WHEN PLANNING A NEW TOC	Define requirements; select a second-by-second control system; build a communication infrastructure with high bandwidth (fiber optics).	Co-location with police who receive 911 cell phone calls. Provide as much video coverage of roadway as possible.	Establish paths of communication (personal and physical) between other agencies in the area. Sharing of data is very important to the success of a TOC. If several agencies need to work together, that effort should, at least, appear seemless to the public.	Internal communications/coordination; ramp metering on-line algorithms; flexible room layout -- will need to adjust months after opening.	Before planning a TOC, agencies need to tour other TMCs. It was very helpful for us to see other TMC layouts and talk to staff.
DAYS OF OPERATION OF TOC	240 days/yr plus additional 30 days of planned events	7 days/wk	7 days/wk	7 days/wk	Monday - Friday
HOURS OF OPERATION OF TOC	6:30 a.m. - 6:30 p.m.	24 hrs/day	24 hrs/day	6 a.m. - 9 p.m. M-F; 10 a.m. - 8 p.m. Sat. & Sun.	7 a.m. - 6 p.m.
ARE POLICE ASSIGNED TO THE TOC	No	Yes (located in state police barracks)	No	No	No
ARE LOCAL AGENCIES NOTIFIED WHEN TRAFFIC ON REGIONAL HIGHWAYS ARE DIVERTED TO A LOCAL STREET SYSTEM?	Yes	Yes, all detours off I-95 have been pre-planned and local police departments have copies of maps.	In theory	If possible, yes.	Not usually. We find out about freeway incidents on radio. We are in process of forming an incident mgmt. team (county, DOT, state patrol) to form strategies for incident detection & coordination of detours.

Traffic Operations Centers (Part 3)

LOCATION	Edmonton, Alberta	Vancouver, BC	San Jose, CA	Toronto, ON	Charlotte, NC
YEAR TOC FIRST OPENED	1978	1986	1991	1994	1992
YEAR OF LAST MAJOR UPGRADE OF TOC	1993	1986	N/A	1997	On-going
MAJOR COMPONENTS OF LAST MAJOR UPGRADE	Replaced central mini computer with PCs; "new" enhanced UTCS software (CRC1500 system)	Centralized computer conrol system (MTCS); microprocessor based controllers	N/A	Traffic Mgmt. display system providing near real-time GIS display/monitoring of traffic signal control operations and traffic congestion along arterials and expansion of traffic adaptive control	TOC building, fiber optic communication system, incident detection, CCTV incident verification
NEXT MAJOR UPGRADE OF TOC	2000	1998-2000	1998	1998	1998
MAJOR COMPONENTS OF NEXT MAJOR UPGRADE	Begin gradual replacement/upgrade of field equipment; modify central system to support new controllers.	New central distributed control system; multi-protocol and remote wireless communication.	EV-link, smart corridor, light rail terminals	Focus will be on enhancing integration of work flow process between office engineering staff and the newly developed situation and control room and expansion of CCTV feeds from Urban Traffic "hot spots" and traffic adaptive control.	Tie in to reversible lane section of US 29 (non-freeway arterial)
TOTAL SQUARE FOOTAGE OF TOC	800 sq. ft. (+ 1,200 sq. ft. of office)	250 sq. ft.	405 sq. ft.	39,000 sq. ft.	13, 000 sq. ft.
TYPE OF EQUIPMENT CONTROLLED, MONITORED:					
Signalized intersections	484 (200 isolated, 85 timebased coord.)	650	516	1,787	0 (future)
Ramps with ramp metering signals	0	0	0	0	0
Total length of road sections with directional control/lane control signals (feet)	5 (500 m)	0	0	6,000	0 (future)
Intersections with preemption capability	Whole system is preempt; add local preempt as required	150	39	54	0 (city)
HOV priority signals	44 (37 bus/ped & 7 bus "jump")	20	0	67	0 (future)
Overheight vehicle control signs/signals	3	0	0	0	0
Other	10 variable message signs; 4 variable speed signs	0	4 changeable message signs, 1 HAR	14 APS (audible pedestrian signals), 2 arterial to freeway ramp gates (time of day closures)	0
TYPES OF DATA COLLECTION EQUIPMENT/SERVICES USED					
Inductive loop detectors	75	240	741	4,661	Approx. 35 stations
Radar/microwave detectors	0	0	0	56	26
Video image detectors	0	0	0	2	0
Vehicle probes	0	0	1	0	0
Environmental sensors	0	0	0	0	0
CCTV cameras	6	0	18	37	26
Cellular phone (911) calls	0	0	0	0	0
CB radio	0	4	0	0	0
Helicopters	0	0	0	0	0
Spotters	10 (3 permanent; 7 temporary/seasonal)	0	0	0	0

Traffic Operations Centers (Part 3, continued)

Other	3 piezo strips	0	0	9 high frequency radio	0
USE DATA FUSION TECHNOLOGY	No	N/A	Yes	No	Yes
FUNCTIONS DATA FUSION TECHNOLOGY USED FOR	N/A	N/A	Systems graphic display; motorists information systems	N/A	Systems graphic display; motorists information systems
SIGNAL TIMING SOFTWARE PROGRAMS USED	CCG CALC, SINTRAL, INTERCAP, TRANSYT, PASSER 4, COORD/SP	TRANSYT 7F, PASSER II	Series 2000 (Transcore)	HCS, PASSER, TRANSYT 7F, TSD, PRDG, HCM Cinema	Traconex, Econolite
ONLINE NETWORK TRAFFIC CONTROL TECHNIQUES USED	Fixed time, semi-actuated, time of day	MTCS	N/A	SCOOT (15% of Network), owner developed system	None
MEASURES OF EFFECTIVENESS USED	Total travel time; delay, average speed, accident rate; volume/capacity ratio	Delay, average speed, fuel consumption	Total travel time; average speed, accident rate; fuel consumption; vehicle emission	Travek tunel bynber abd oercebtage of stops; delay; average speed; accident rate; throughput; fuel consumption; vehicle emissions; incident response time	Average speed, accident rate
HOW GRAPHICS ARE DISPLAYED AT TOC	No graphics	At workstations and on a wall map	At workstations and on a large screen	At workstations and on a large screen	At workstations, on a wall map, and on a large screen
FUNCTION OF CCTV SYSTEM	Monitoring traffic conditions; detection, confirmation of incidents and incident management.	N/A	Monitoring traffic conditions; detection, confirmation of incidents and incident mgmt., monitor ramp spillback conditions.	Monitoring traffic conditions; detection, confirmation of incidents and incident mgmt., monitor ramp spillback conditions.	Monitoring traffic conditions; detection, confirmation of incidents and incident mgmt.
TYPES OF DISPLAYS AT TOC	Array of smaller video screens	Display map	Projection video, array of smaller video screens, split-screen display	Projection video, array of smaller video screens, large video screen	Large video screen and array of smaller video screens (video wall)
WHAT GRAPHICS DISPLAY SHOW AT TOC	N/A	Controller online status: individually; operation of traffic signals; for each intersection: operation of detectors, geopgraphic layout, detector locations, signal phasing, signal timing, system detector data, local detector calls; parameters: volume, occupancy, speed, delay.	Controller online status: by group, individually; operation of traffic signals; for each intersection: operation of detectors, geopgraphic layout, detector locations, signal phasing, signal timing, system detector data, local detector calls; parameters: volume, occupancy, speed.	Controller online status: by group, individually; operation of traffic signals; for each intersection: operation of detectors, geopgraphic layout, detector locations, signal phasing, signal timing, system detector data, local detector calls; parameters: volume, occupancy, speed, delay, communications link.	Contoller online status: individually; for each intersection: none -- city signal control center
FUNCTIONS DISPLAYED AT TOC	Control and mgmt. of traffic signal systems; lane control signals; special event management; planned lane closure mgmt.	Control and mgmt. of traffic signal systems; control and mgmt. of corridor control systems; special event mgmt.	Control and mgmt. of traffic signal systems;special event mgmt. In May 1998, the Silicon Valley Smart Corridor Project will have:control and mgmt. of corridor control systems; participate in the incident mgmt. process; provide motorist aid services; provide traffic information to outside organizations.	Control and mgmt. of traffic signal systems; lane control signals; control and mgmt. of corridor control systems; participate in the incident mgmt. process; special event mgmt.; planned lane closure mgmt; provide traffic information to outside organizations; coordinate traffic controls and motorist information with other operating agencies; roads dispatch, (pothole repair, debris & snow removal, maintenance & emergency closures), 911 emergency (fire, ambulance, police), provincial roads operations.	Special event mgmt.; participate in the incident mgmt. process; provide motorist aid services; provide traffic information to outside organizations; planned lane closure mgmt.; coordinate traffic controls and motorist information with other operating agencies.

Traffic Operations Centers (Part 3, continued)

METHOD OF DISTRIBUTION OF INFORMATION TO OUTSIDE ORGANIZATIONS, MEDIA	Through media (radio, TV, press); variable message signs.	Traffic control signals; media (radio, TV, press).	Highway advisory radio, Internet connection, media (radio, TV, press).	Traffic control signals, information kiosks, web site development pending, through media (radio, TV, press), variable message signs, automated fax system, call-in automated voice information system, dedicated dial-in computer info system.	Highway advisory radio, Internet connection, media (radio, TV, press), changeable message signs (overhead and portable)
COSTS OF TOC:					
Capital cost, excluding field equipment and communications	$750,000 (construction)	$2 million Canadian	$1.5 million	$15,000,000	Approx. $3 million including building
Operational cost/yr	$600,000/yr	$150,000 Canadian	$120,000	$5,500,000	Currently $410,000; $660,000 future
Maintenance cost/yr	$10,000/yr	$95,000 Canadian	$50,000	$800,000 (building only including security, parking, storage)	Currently $90,000; future $685,000
HOW COORDINATION BETWEEN DIFFERENT AGENCIES IS ACHIEVED	Only one agency involved	Stand alone center	Each agency has workstation in own control center, with overall coordination conducted by the TOC.	Separate work areas/work station in shared control room	Each agency has workstation in own control center, with overall coordination conducted by the TOC.
NUMBER AND TYPE OF PERSONNEL EMPLOYED PER SHIFT AT TOC	6:30 a.m. - 3 p.m., 1 TOC technician; 9 a.m. - 5:30 a.m., 1 TOC technician; 8 a.m. - 4:30 p.m., 4 engineering staff.	7 a.m. - 5 p.m., 1 operator, 6 field crew, 1 engineer, 1 design technician; 5 p.m. - 7 a.m., 2 field crew.	7 a.m. - 3 p.m., 1 technician; 3 p.m. - 11 p.m., 1 technician.	6 a.m. - 2 p.m. 2 rescue operators; 6 a.m. - 6 p.m. 2 dispatch operators; 8 a.m. - 6 p.m. (flex) 18 analysts/techs; 9 computer systems; 6 mgmt./admin.; 5 electronics; 2 rescue operators; 6 p.m. - 6 a.m. 1 dispatch operator; 2 a.m. - 10 a.m. 2 rescue operators.	5 a.m. - 1 p.m. 4 operations, 2 maintenance; 1 p.m. - 9 p.m. 4 operations, 2 maintenance
WHAT DO YOU CONSIDER TO BE THE BEST FEATURES OF YOUR TOC?	System reliability; control emergency route pre-emption.	Real-time control; uploading/downloading function, back-up EPREM for operation; on-line communication assures efficient call/services to problem locations.	The ability to view incidents and provide information to motorists in real-time.	Integration of services (signal systems/freeway operations/maintenance & road operations/emergency services). Building includes TOC and Police Department's 922 operations.	Communication, cooperation of all first response and support agencies in the area. Freeway service patrol integration with TOC, integrated systems and services.
WHAT DO YOU CONSIDER TO BE THE WORST FEATURES OF YOUR TOC?	Communication costs are high	Lack of CCTV	Some technical difficulties with our large screen monitor	Limited urban CCTV monitoring, limited access for large tours	Have not yet worked out issues of providing video, data to other agencies at remote locations
RECOMMENDED AS IMPORTANT ASPECTS TO TAKE INTO CONSIDERATION BY OTHER AGENCIES WHEN PLANNING A NEW TOC	Communication costs; flexibility/multi vendor support (avoid single source).	Flexibility to intergrate new technology and new controller.	Ease of operation, comfort.	Future directions – properly sized & scoped to match community; Ideal vs. conceptual layout of work areas (accoustic qualities – multiple radios & phones, work flow).	Funding issues, staffing/personnel issues, establishing scope of TOC fundings, establishing operations concept early on, information sharing issues (other agencies and the media)
DAYS OF OPERATION OF TOC	24 hrs/day (staffed weekdays)	Weekdays except holidays	7 days/wk	Monday - Fridays & special events /construction needs	7 days/wk
HOURS OF OPERATION OF TOC	staffed 11 hrs/day	7 a.m. - 5 p.m.	12 hrs/day	6 a.m. - 10 p.m.	16 hrs/day (6 a.m. - 9 p.m.)
ARE POLICE ASSIGNED TO THE TOC	No	No	No, but interact directly with staff	No, but are provided with feed to field CCTV camera	Yes
ARE LOCAL AGENCIES NOTIFIED WHEN TRAFFIC ON REGIONAL HIGHWAYS ARE DIVERTED TO A LOCAL STREET SYSTEM?	Not a concern here; only one agency involved	N/A	They will be when Smart Corridor is completed in May 1998.	Yes but not necessarily timely. Working on agreements for greater cooperation and better notification.	Yes, via two-way radio or telephone

APPENDIX D

INFORM Progress Report No. 28—December 1997

SUMMARY

- Equipment performance improved slightly this month
- Cable plant balancing started this month

SYSTEM PERFORMANCE

In December, HELP vehicles provided assistance to 898 vehicles, the I-800 ROADWORK number was called 1,580 times, VMS messages were used to support 86 roadway incidents and 436 traffic signal maintenance calls were made.

There were no major new deployments of PVMS but there are currently ten signs being used to provide information to motorists on Long Island.

EQUIPMENT PERFORMANCE

Figure 1 illustrates the percent of equipment on-line for the past 12 months. Performance this month improved somewhat for the more critical subsystems of CCTV, VMS, and detectors.

MAINTENANCE

Maintenance meetings continue to be conducted on a regularly basis and a number of problems have been either resolved or action has been planned to resolve them.

RF training was provided to the maintenance contractor's electricians, and cable balancing was initiated following the training. Progress has been slow but it is expected to pick up as procedures become more streamlined. Also, additional equipment has been ordered and when it becomes available in the next few weeks a second cable balancing crew will start work.

The interactive reporting program, that allows remote access of equipment status, has been satisfactorily tested. It wil be operational in January and a remote site will be installed at the maintenance contractor's office.

CONTROL CENTER

An existing inventory program is being modified to allow tracking of critical INFORM spares. It is expected to be operational in January.

The Failure Management Tracking System (FMTS) has been modified to include additional equipment items and online statistics of equipment performance.

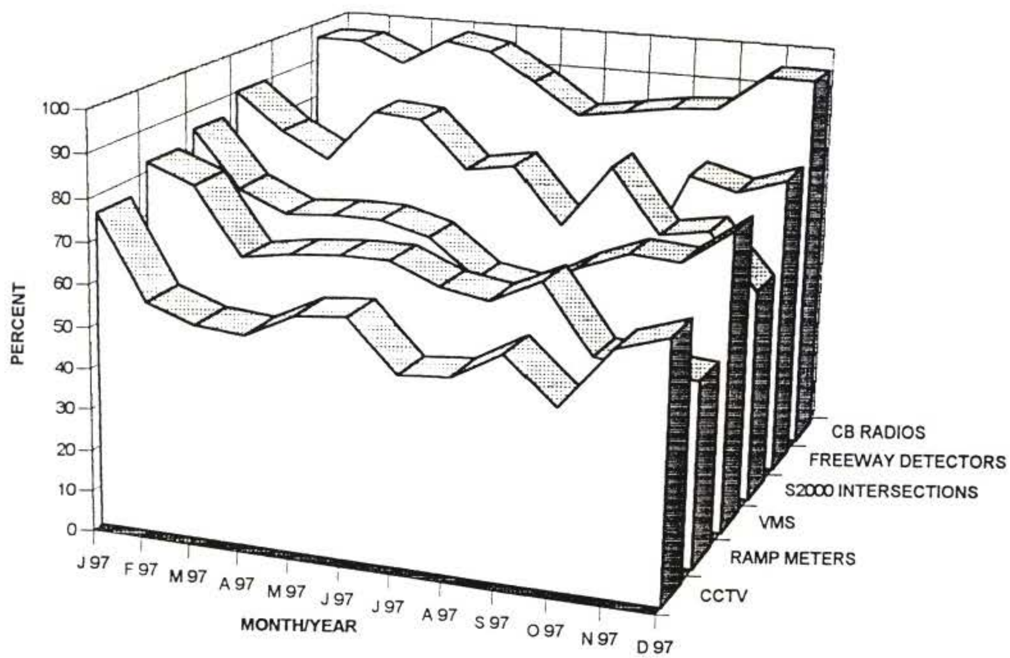

FIGURE 1 Percent of equipment on-line.

THE TRANSPORTATION RESEARCH BOARD is a unit of the National Research Council, a private, nonprofit institution that provides independent advice on scientific and technical issues under a congressional charter. The Research Council is the principal operating arm of the National Academy of Sciences and the National Academy of Engineering.

The mission of the Transportation Research Board is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research findings. The Board's varied activities annually draw on approximately 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encouraging education and research, and recognizes the superior achievements of engineers. Dr. William A.Wulf is president of the National Academy of Engineering.

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The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

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