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EXECUTIVE SUMMARY

Transportation Management Centers (TMCs) are focal points for monitoring and operating traffic management systems. As new technologies are developed through research in Intelligent-Vehicle-Highway Systems (IVHS), these TMCs will assume increasingly more importance **as** command and control centers for transportation operations.

This study is aimed at developing visions for how the TMC of the future will exploit the capabilities of IVHS. Part 1 of this study, reported herein, is an assessment of existing TMC capabilities in the State of California. Part **2,** to be reported later, will develop the future visions, considering present capabilities, ongoing research and transportation needs.

The Part 1 report includes a brief overview of TMC development efforts, and results of in-depth interviews with personnel at all seven Caltrans TMCs, as well as interviews with three city TMCs (Anaheim, Los Angeles and San Jose). The interviews assessed: existing TMC functions, coordination among TMCs, coordination with other agencies, facilities, software and databases, and communication media. Detailed survey results are provided in Appendix B, on a site by site basis.

Major study conclusions include:

(1) California has made great strides in developing its TMCs, especially through the close coordination of the California Highway Patrol (CHP) and Caltrans. These efforts have laid the groundwork for major advances in traffic management.

(2) Despite California's accomplishments, the TMCs have not yet fulfilled their potential for being the nerve centers for the vast array of traffic management functions. Effort is needed to determine the best way to integrate a greater scope of advanced IVHS functions into TMC operations.

(3) Effort is needed to develop California's TMCs into a distributed network of closely coordinated agencies, to ensure that their combined talents can **be** applied in the most effective manner.

1. INTRODUCTION

Many major US cities are confronted by the problem of traffic congestion. It is estimated that urban travel is increasing at a rate of 4% per year, and new facilities can only accommodate less than one-fourth of this additional demand (Davies et al., 1991). If this trend continues, it is obvious that the problem of urban traffic congestion will only grow in the future. The situation in California's metropolitan areas, such as Los Angeles (LA) and the San Francisco Bay Area, is even worse than the national average. Congestion levels in the Bay Area rose 25% between 1985 and 1988 (Bay Area Economic Forum, 1990). Furthermore, because constructing new highways is an unpopular solution, recent efforts have focused on developing better management strategies for the transportation system.

A focal point for operating and monitoring traffic management systems is the Transportation Management Center (TMC). The TMC provides a site where cooperative and coordinated efforts to manage the transportation system can occur. The TMC monitors conditions of the transportation system and responds to them either reactively, as in incident management, or proactively, as in adaptive traffic signal systems. Additional functions of the TMC might include disseminating weather and roadway conditions to the public, implementing emergency evacuation plans, monitoring hazardous material routing, or coordinating inter-modal transportation.

Given the active state and federal programs to develop new traffic management technologies, it is an opportune time to strategically assess TMC capabilities, and form a vision for how TMCs may evolve in the future to incorporate these new technologies. Critical issues include: (1) comparison of distributed to centralized operating strategies; (2) TMC functions, and assignment of functions to different types of TMCs; (3) coordination among TMCs; (4) system integration and standardization; and (5) incremental deployment strategies.

The goal of this study is to examine and explore issues that impact TMC design and organization. Some of the elements to be examined include existing TMC facilities, TMC expansion plans, and Intelligent Vehicle Highway Systems (IVHS) research and development activities. The intent is that by providing a comprehensive assessment of these issues, TMC development will be guided along a direction that serves both today's needs and the needs 20-30 years in the future.

This study is divided into two parts. The first part, reported herein, surveys California TMCs with the goal of ascertaining baseline conditions. The second part, to be reported later, will define a set of visions for future TMCs. Functional analysis will be performed, and aspects regarding regionalization, coordination, and automation will be examined.

2. BACKGROUND

Traffic management is not a new concept. The earliest traffic management projects in the US began in the 60s and the 70s when the construction of new highways had already been out-paced by the growth of traffic. Illinois Department of Transportation (IDOT) initiated the Emergency Traffic Patrol (ETP) program in Chicago to assist motorists with vehicle trouble in 1960 (McDermott et al, 1992); Minnesota Department of Transportation (MnDOT) implemented isolated ramp metering on Interstate 35E in 1970 (Differt and Stehr, 1992); Washington State Department of Transportation (WSDOT) established a program to encourage ride-sharing and other transportation system management (TSM) measures in the early 1970s, such as high-occupancy vehicle (HOV) lanes and park-and-ride lots (Jacobson, 1989). Many of these projects originally focused on hot spots, and electronic surveillance at the system level was minimal, if it existed at all. Success in these early projects led to bigger projects which enhanced the management system with more capabilities. Eventually, these early projects evolved themselves into TMCs. For example, the IDOT Traffic Systems Center (TSC) in Chicago was formed in the early 70s; the MnDOT Traffic Management

Center (TMC) was built in 1972; and the Freeway and Arterial Management Effort (FAME) was established by WSDOT in 1987.

The California experience was similar. One of the earliest efforts started at the Bay Bridge. In 1971, an experimental closed circuit television (CCTV) project was initiated at the bridge to reduce detection time for stalls and accidents (MacCalden, 1984). Around the same period of time, when peak period traffic demand continued to increase, an HOV and bus lane was introduced. In 1974, a computer controlled ramp metering system was devised. This was among the earliest ramp metering systems in the U.S. The Bay Bridge TMC continued to grow over the years. Presently, magnetic vehicle detectors are installed in each of the five lanes at 1200 foot intervals along the bridge and optical queue detectors at 600 foot intervals for incident detection. And there are plans to further extend the scope of surveillance, particularly along the lower deck via CCTVs.

In Southern California, a 3-year federally funded project started a TMC in 1971, which electronically monitored 42 miles of portions of the Santa Monica, San Diego and Harbor Freeways via loop detectors. Real-time traffic flow data were transmitted to the TMC and displayed on a hard-wired wall map. This early program also funded three California Highway Patrol (CHP) helicopters and a freeway service patrol program. Over the years, the TMC has expanded tremendously. To date, it currently monitors over 340 center-line miles of freeways via more than 20,000 loop detectors and operates over 800 ramp meters (California Department of Transportation (Caltrans) District 7, 1992). In addition, Changeable Message Signs (CMS) and Highway Advisory Radio (HAR) are among the equipment installed to disseminate incident information to travellers. The TMC has installed other functions too, as will be indicated later.

Equally important are the TMCs run by cities or local governments, which are more concerned with arterial traffic surveillance and control. The first city TMC in California, the Automated Traffic Surveillance and Control (ATSAC) System, was introduced by the Los Angeles Department of

Transportation in **1984** for controlling arterial traffic during the Olympic Games. The initial installation encompassed **118** intersections and **396** detectors in an area of **4** square miles. Information was transmitted to the ATSAC System for monitoring and actuating the adaptive signal timing plans (Rowe, **1990).** Currently, there are **860** signalized intersections under ATSAC computer control. Their plan is that by **1998,** all 4,000 signalized intersections in the city will be put within the ATSAC System. Favorable evaluation of the ATSAC System stimulated similar work in the cities of Anaheim and San Jose; both TMCs were initiated in **1988.**

While traffic management schemes in California have been performed for over **20** years, the practice of bringing traffic information to a centralized location for surveillance and control is relatively recent. For example, District 11 (San Diego) has been operating ramp metering as a centralized system since **1978,** but the TMC was only formed in **1990** (Caltrans District **11, 1993).**

Table 1 indicates that most California TMCs started in the late **80s** or the early **90s.** Currently, many of them are in the process of planning expansion. This effort is partly stimulated by the **1992** Memorandum of Understanding (MOU) on the development and operation of CHP and Caltrans collocated TMCs (Caltrans, **1993).** This effort also reflects a trend across the United States due to developments in **IVHS,** and Intermodal Surface Transportation and Efficiency Act (ISTEA) legislation. In **1990** alone, there were **105** freeway operations projects reported in the US (TRB, **1991).** Most of them were operating in a TMC setting or had potential to become one.

Table 1 Starting year of California TMCs.

TMC	**Starting Year**
Caltrans District 3 (Sacramento)	1990
Caltrans District 4 (Bay Bridge Hub)	1974
Caltrans District 6 (Fresno)	1991
Caltrans District 7 (Los Angeles)	1971
Caltrans District 8 (San Bernardino)	1991
Caltrans District 11 (San Diego)	1990
Caltrans District 12 (Santa Ana)	1990
City of Los Angeles (ATSAC)	1984
City of Anaheim	1988
City of San Jose	1988

Given the current high level of research and development activities in IVHS, in particular Advanced Transportation Management and Information Systems (ATMIS), TMCs could easily become the nerve centers for implementing an array of traffic management schemes, such as incident detection and response, freeway ramp monitoring and control, surveillance and dissemination of traffic information. Presently, many existing TMCs are already performing in that capacity to different extents. There are other longer term functionalities which might be incorporated in TMCs, such as route guidance and automatic toll collection. It is, therefore, important that TMCs should be designed with a bigger concept in mind. The following are some questions that need to be examined: what functionalities should be included in a TMC; how TMCs and other systems should be coordinated; and how TMCs should be designed so that future functionalities can be incorporated?

3. STUDY DESIGN

The objective of Part 1 of this study is to survey California TMCs to assess their existing functions, coordination, capabilities, and facilities. After a few brainstorming sessions on TMC functions, which were attended by systems researchers from PATH, Caltrans, and Lawrence Livermore National Laboratory, we drafted a survey. It was then refined through in-depth discussions with engineers of Caltrans' Traffic Operations Branch. The final version of the survey is included in Appendix A. Surveys were administered in interview format through on-site visits.

The focus of the survey was on strategic issues, including functionalities, coordination among TMCs and with other systems (such as emergency agencies) and, to a lesser extent, facilities, hardware and software components. Questions in the survey fell in seven major categories, as listed below.

(A) Functionalities

This category refers to functions performed at the TMC. Instances where a particular function exists and is performed outside the TMC, for example signal control function executed by the Signal Operations Group, are not counted in this category. Functionalities were further divided into 12 types, as indicated below.

(i) Surveillance
(ii) Provision of information to travellers
(iii) Arterial signal/ramp metering control
(iv) Emergency vehicles dispatching
(v) Law enforcement
(vi) Incident management
(vii) Emergency evacuation/catastrophe plan
(viii) Special events handling
(ix) Hazardous material routing
(x) Transit scheduling

(xi) Intermodal coordination

(xii) Other functionalities

(B) Coordination with other TMCs

This category captures the coordination among different TMCs, the type of data exchange, and the means of doing so. This information provides insights on the required communication media, and assists in defining the concept of regionalization.

(C) Coordination with other systems

This category examines the relationship between the TMC and related agencies other than TMCs. Survey responses provide information on the existing management and communication structure. Seven types of systems are included:

(i) California Highway Patrol

(ii) Police

(iii) Ambulance

(iv) Fire

(v) Central 911 dispatcher

(vi) Major trip generators

(vii) Weather services

(D) Facilities

Office space, budget, installation cost, personnel, and computers are included in this category. This information indicates monetary and human resources and equipment needed to operate the TMC.

(E) Information input/output and communication means

This category examines communication in detail. The existing communication network and bottlenecks are identified in this category.

(F) Traffic database

The content of the TMC database is recorded in this category. In addition, this category also records the kind and content of data that are archived regularly.

(G) Computer software

This category examines the software that supports each of the TMC functions, for example, signal control and ramp metering.

All seven Caltrans TMCs were visited, including District 3 (Sacramento), District 4 (Vallejo and the hub at the Bay Bridge), District 6 (Fresno), District 7 (Los Angeles), District 8 (San Bernardino), District 11 (San Diego), District 12 (Santa Ana). In addition, we visited three city TMCs at Anaheim, Los Angeles (ATSAC), and San Jose.

Prior to our visits, we sent the survey to the TMC supervisors and requested that suitable personnel, such as engineers, be present during the visit so that technical questions could be answered. We went through the survey with the TMC staff during the visit. To maintain accuracy, we mailed the responses back to the supervisors for review and incorporated their comments. After we had finished the draft report, we sent it out for another round of review. Through this process, we hope to have removed any inaccuracies.

4. SURVEY RESULTS

Tables B-1, B-2, B-3, and B-4 in Appendix B summarize the detailed responses fiom each TMC. These tables follow the same structure as the survey itself, with Table B-1 focuses on TMC functionalities, Table B-2 on coordination (both among themselves and with other systems), Table B-3 on facilities and communication means, and finally Table B-4 on database and computer software. The presentation of results in this section will follow the same order.

For ease of exposition, we divide California TMCs into two classes: Caltrans TMCs and local TMCs. Table 2 summarizes the functionalities of each class. (It is important to note that if a particular function is absent in a TMC, it does not necessarily indicate that the District does not have it; it might be performed outside the TMC). It can be seen that Caltrans TMCs focus almost exclusively on highways and city TMCs on arterial systems.

4.1 Functionalities

Caltrans TMCs

All Caltrans TMCs have a surveillance capability. The most widely used means include loop detectors (5 of 7) and CCTVs (3 of 7). At the time of the survey, the San Bernardino TMC was still installing the communication links between the detectors and the TMC, and the Fresno TMC was in the planning stage. In the near future, it is expected that all Caltrans TMCs will have on-line surveillance systems. The use of newer detectors, such as microwave, optical, and magnetic, is not common, though the Bay Bridge hub (District 4) has been using optical and magnetic detectors for around 10 years. Most of the detectors are single-looped; therefore they can only directly measure traffic occupancy and volume. All Caltrans TMCs have installed Call **Boxes** for emergency situations along major highways. And all have an aerial surveillance capability to spot congestion and incident locations.

All Caltrans TMCs have some means of providing;traffic information to travellers. The information content is mostly limited to locations of incidents and severe congestion, construction detours, or lane closures. Sometimes, information regarding roadway conditions, such as fog and snow, is also disseminated by the Sacramento, Fresno and San Bernardino TMCs. This happens most often along highways passing through the mountains and the Central Valley. For general information, the means of dissemination include Changeable Message Sign (CMS) (7 of 7) and Highway Advisory Radio (HAR) (7 of 7), via the broadcast media (7 of 7) and to a lesser extent via third party devices (such as TeleText and Easylink in Southern

Table 2 Functionalities of California TMCs.

Functionalities	**Caltrans TMCs (7 total) Occurrence**	**Local TMCs (3 total) Occurrence**
Surveillance	7	3
Loop detectors	5	3
CCTVs	3	3
Magnetic detectors	1	0
Microwave detectors	1	1
Optical detectors	1	1
Call boxes	7	0
Traveller info.	7	1
Output means:		
CMS	7	1
HAR	7	1
3rd Party Device	4	1
Media	7	1
Arterial signal control	0	3
Ramp metering system	7	0
Law enforcement	0	0
Incident management	7	1
Detection means:		
CCTV	3	0
Call **box**	7	0
Detector/algorithm	3	0
Aerial Surveillance	7	0
Reports	7	1
Emergency evacuation	1	2
Special events' handling	7	3
Hazardous mat. routing	1	0
Transit scheduling	1	0
Intermodal coordination	0	1

California) (4 of 7). Recently, District 7 (Los Angeles) has started a Cable TV service that broadcasts real-time traffic information. The Fresno TMC provides a public-access computerized dial-up service, which is unique in California. Some TMC supervisors mentioned Caltrans Highway Information Network (CHIN) and Caltrans Highway Information Broadcasting Network (CHIBN) for disseminating traffic information. However, limited publicity certainly impairs their intended functions.

All Caltrans TMCs (7 of 7 have ramp metering systems, with a total of 1201 ramp meters. District 7 (Los Angeles) is the largest; it has installed 722 ramp meters. All ramp meters use the Type 170 controller. The majority of the ramp meters are operating in a dynamic but isolated mode, which means there is no coordination between neighboring meters. The only exception is District 11 (San Diego), where there is coordination between meters along a given route, but not between routes. Also, coordination between ramp meters and neighboring arterial signals does not presently exist in California.

Dispatching of emergency vehicles, such as fire, ambulance, and police, to an incident scene is mostly conducted via the CHP Communication Center (7 of 7). In the Bay Area, the CHP Computer Aided Dispatch (CAD) System is a recent tool developed to assist in this task, which provides an on-line "live" database to facilitate communication as the events are occurring. In Southern California, a similar system, called the CHP Bulletin Board (BB), enhances the communication of emergency and dispatching information among the districts and the media. The CHP BB in Southern California is not a CAD system and is not used for emergency vehicle dispatching, however.

Law enforcement, defined as the use of surveillance equipment such as CCTV to report crime or traffic violations, is not performed at any Caltrans TMC (0 of 7). The impression obtained during the visits was that this is an area that TMCs do not want to get involved, even though it is technically feasible.

Incident management is a very important function in all Caltrans TMCs (7 of 7). In fact, this might be one of the major reasons for the existence of some TMCs. Most Caltrans TMCs apply a multitude of ways to obtain incident information, including call boxes (7 of 7), aerial surveillance during rush hours (7 of 7), drivers' reports using cellular phone calls (the calls always go to CHP Communication Centers first) (7 of 7), reports by Caltrans or CHP field personnel via 2-way radio (7 of 7), and to a lesser extent, loop detector information **(3** of **7)** and CCTV **(3** of *7).* In frequently used highways, cellular phone calls are often the first source of incident information. Multiple but independent calls often help to affirm the occurrence of an incident. Nevertheless, a CHP or Caltrans staff verification is required to start the incident management procedure. Loop detectors can flag flow anomalies to indicate the occurrence of a possible incident. However, such data alone are not perceived as a primary source; often, verification by CCTV's or field personnel reports is required to confirm an incident. On the other hand, CCTVs are often considered as a quick and easy means of detecting and verifying incidents, if they are available.

The procedure to respond to incidents is far from standardized. For example, the condition or severity of the incident to warrant the dispatch of the Traffic Management Team (TMT), which is responsible for managing the traffic around the scene, is not documented in all districts. (District 7 has recently started to document this procedure, Caltrans District **7, 1993).** The dispatch of heavy equipment is often handled by Caltrans' Maintenance branch, which is often not located at the TMC. And the kind of equipment to be dispatched is highly dependent on the experience of the dispatchers or the maintenance supervisors. There is ample room for improvement regarding the standardization of the dispatching procedure.

Freeway Service Patrol (FSP) is used as an element to reduce incident response time. In District 7, there are **138** tow trucks patrolling the Los Angeles highways and responding to incidents. Success in Los Angeles initiated similar FSP projects, such as in the Bay Area in **1992** and in San Diego in **1993.** Other districts, such as San Bernardino, also recently started a small FSP program. Incident management in all districts also involves the broadcast or dissemination of incident information to the public.

The majority of Caltrans TMCs do not have emergency evacuation planning; neither is it perceived as a highly desirable function. Only one TMC claimed that they have an emergency evacuation plan: the Vallejo TMC and its hub at the Bay Bridge. The Bay Bridge hub has a plan to detour traffic from going onto the Bay Bridge during emergency situations, such as an earthquake. Vallejo has contended that "emergency evacuation could be handled by local agencies involved;" the role of the TMC is not clearly defined, however.

All Caltrans TMCs have some degree of special events handling. Special events are defined as occasions which generate a lot of traffic to and from a site, such as ball games, state fair, and the alike. They also include planned maintenance and construction lane closures. This function is not performed frequently. When it occurs, TMCs disseminate event timing and sometimes general congestion information via available means, such as the broadcast media, HAR, and CMS. For major events, the TMT is often involved with the planning and implementation of traffic management schemes such as setting up detour or alternate routes. Other means to control traffic flow, such as adjusting ramp metering rates, are not practiced.
Other functions listed in our survey are rarely performed, including hazardous material routing (1 of 7), transit scheduling (1 of 7), and intermodal coordination (0 of 7). Summarizing, the following functions are found commonly in almost all Caltrans TMCs: surveillance, provision of information to travellers, incident management, special events handling, and ramp metering. Presently, the capabilities of these functions are limited, especially regarding special events

handling and provision of information to travellers. New developments in **IVHS** activities would be able to enhance many of these function capabilities.

City TMCs

All city TMCs have a surveillance capacity, which is essential for arterial network signal control. Loop detectors are the major surveillance devices (3 of 3). Loop detector information is used both for monitoring and sometimes for selecting the appropriate timing plans. To a small extent, newer types of detectors, such **as** microwave and optical, are being installed at isolated intersections for testing purposes. CCTVs are also often deployed at critical intersections (3 of 3) to check for the actual effects of the timing plans. Remote manual adjustments of signal plans are possible if detector information or CCTVs suggest severe congestion at a particular approach.

Provision of information to travellers is not common at city TMCs. Anaheim is the only city TMC that provides congestion information via CMSs, HARs, the media, and third party devices, such as kiosks located at major commercial and shopping centers. Traffic information disseminated is mostly related to the area surrounding Disneyland.

Arterial signal control is the major function for all three local TMCs. The TMCs act as central controllers to the signal systems. All three systems can be run under a fully traffic responsive mode (though it was reported that this mode was seldom used). Instead, the normal mode of operation involves the using of a combination of time-of-the-day plans and frequent manual override during rush hours. All of them have aggressive plans for expansion. LA (ATSAC) has plans to increase control from 850 intersections today to 1300 by the end of 1993, and **to** 4000 by 1998; out of a total of 255 intersections in Anaheim, the TMC controls 209, and there is an immediate plan to cover 40 more soon; San Jose has been working hard to connect all 630 intersection controls to the TMC, up from the present 150. The aggressive expansion plans stress the existing computer and communication software and hardware, and innovative ways of connecting the system are required. The Anaheim TMC will also be the site of a demonstration project to install the new generation of signal control systems (commonly known as the 1.5 Generation). In addition, Anaheim is also planning to install a "SCOOT" system. In terms of coordinating with Caltrans ramp metering system, although it was generally perceived as desirable, no specific plan was mentioned.

Emergency vehicles dispatching and law enforcement are not performed at any city TMC. Incident management receives little attention, despite its extreme importance for Caltrans TMCs. The San Jose TMC mentioned that it plans to broadcast incident information via CMS and HAR in 1 year.

About emergency evaluation, Anaheim and LA have special signal plans to "flush" traffic along selected directions. For example, LA's ATSAC System has a plan to evacuate traffic around the airport (LAX) region. All three city TMCs have signal plans prepared for special events, such as ball games and construction. However, none is performing hazardous material routing and transit scheduling, though San Jose has some intermodal coordination capability by providing signal preemption for light rail. As a summary, surveillance, signal control, and special events' handling are the three major functions of city TMCs.

4.2 Coordination with Other TMCs

Conceptually, coordination with other TMCs may be achieved at several levels. The simplest level (I) of coordination is achieved via occasional meetings, phone calls, faxes, or electronic mail. The next level (11) is to establish data links among the TMCs, so that the TMCs can observe each other's real-time traffic patterns and controls, such as CMS message or signal plans. At level (111), each TMC responds regularly to surveillance information from both itself and other TMCs. And finally at level IV, there might be a "global TMC" that appropriates controls or advice to each subordinate TMC. Going up the levels, it is expected that the needs for communication and computer processing will increase. But by doing so, each TMC will have more information to make better decisions. For regions that are far apart, such as San Francisco and Los Angeles, such coordination may not be needed. By using the above as a classifying structure, we will examine the existing levels of coordination among the TMCs.

The geographical separation of the TMCs basically divides them into **3** groups (this categorization is adopted from the TMC Master Plan **(1993)):** Valley (Sacramento and Fresno), Coastal (Bay Bridge, Vallejo, and San Jose), and Southern (Los Angeles, San Bernardino, Santa Ana, San Diego, ATSAC, and Anaheim). Existing coordination among these three groups is infrequent. When it occurs, it is at level I. The exception is between Fresno and the Southern group; real-time incident information, such as major incident on Highway ***5*** or **99,** is shared via the CHP Bulletin Board (see below). Weather information in the Central Valley, such as dense fog, is transmitted from Fresno to the Southern group via modem when conditions warrant, and vice versa.

Within the Valley group, Fresno maintains level I coordination with Sacramento on a daily basis. Phone calls are the major means of communication. For the Coastal group, the Vallejo TMC maintains a close tie with the hub at the Bay Bridge, video images collected from CCTVs are first compressed and then transmitted from the Bay Bridge hub to the Vallejo TMC; so is loop detector information. Moreover, the Vallejo TMC can monitor every kind of information that is available to the Bay Bridge hub, including CMS messages. In the near future, the capability of controlling CCTVs and ramp metering rates from Vallejo will also be added, so a level II coordination will be maintained between them. Coordination between the San Jose TMC and Caltrans TMCs is lacking at this moment. However, during our visit, the San Jose TMC expressed a strong interest in establishing such a link.

For the Southern group, level II coordination exists among Caltrans and city TMCs. Caltrans TMCs include Los Angeles, Santa Ana, San Bernardino, San Diego, and Fresno, and city TMCs include Anaheim and ATSAC. They exchange incident information via the CHP Bulletin Board, which is a modem-accessible real-time on-line database system. The San Bernardino TMC contended that this system serves as its main communication tool. In addition, Caltrans Los Angeles and Santa Ana TMCs, city of Anaheim TMC, and ATSAC recently developed a direct data linkage, which allows them to retrieve real-time graphic displays of traffic and control information among themselves. Information such as CMS messages are also included. Via high speed modems, their systems can transmit and receive information from each other. The Smart Corridor project, which is planned as a coordinated effort between Caltrans and city TMCs to manage traffic along the Santa Monica freeway, will examine the benefits of having level III coordination.

As discussed above, level II coordination exists within each of the Coastal and Southern group. At this moment, the data transmitted are solely for monitoring, though major incident information theoretically could invoke responses from neighboring regions. Higher level coordination is still being developed, and its goals have yet to be defined clearly. As mentioned above, the Smart Corridor project should be an important milestone for establishing such coordination. Given the proximity of these TMCs, particularly among Los Angeles, ATSAC, Santa Ana, San Bernardino, and the city of Anaheim, a higher level of coordination would be possible and beneficial.

4.3 Coordination with Other Systems

Seven types of systems are included in the category of other systems: (i) California Highway Patrol; (ii) police; (iii) ambulance; (iv) fire; (v) central 911 dispatcher; (vi) major trip generators; and (vii) weather services. Table 3 lists the occurrences of coordination.

All seven Caltrans TMCs collocate CHP and Caltrans staff. This arrangement facilitates better communication between Caltrans and CHP for managing incidents. At the Bay Bridge hub, which responds to incidents by adjusting ramp metering rates and controlling CMS messages; dispatching is done by the Maintenance Tow Service (MTS) located outside the TMC.

Table **3** The coordination between the TMCs and the other types of system.

Type of System	Caltrans TMCs Occurrence (7 total)	Local TMCs Occurrence (3 total)
CHP	7	1
Police	5	2
Ambulance	3	0
Fire department	4	1
Central 911 dispatcher	0	0
Major trip generators	6	2
Weather services	3	0

Coordination between Caltrans TMCs and emergency units, such as fire, ambulance and police, is often through the CHP Communication Center, though most of the TMCs have direct lines accessible to these units. Most Caltrans TMCs, via the TMTs, coordinate with organizers of major events to manage traffic. For TMCs that oversee traffic around major trip generators, such as Disneyland in Anaheim, this coordination happens much more frequently. The TMCs located in the Central Valley, including Sacramento, Fresno, and San Bernardino, often coordinate with the weather services to obtain potential hazard information, such as snow conditions.

Coordination between the city TMCs and other systems is not strong. They will inform the police if their CCTVs spot accidents; or, during special events, they will coordinate with the police and the event organizer to manage traffic.

4.4 Facilities

Table **B-3** in Appendix B shows the facilities of the TMCs in terms of office space and installation cost. For the Caltrans TMCs, space ranges fiom 200 sq. ft. (San Bernardino, which was started recently) to 4000 **sq.** ft (Santa Ana). Six are operating in a space of less than 1000 **sq.** ft. TMC installation costs obtained fiom this survey are rough. For one reason, many TMCs have been developed over many years, and the TMC personnel have lost track of the total installation costs. The other reason is that some of the costs of installing the communication and surveillance system were incorporated in other accounts. This is reflected in the wide range of estimates obtained: $50,000 (Sacramento) to $1 million (Santa Ana). For the local TMCs, their office space ranges fiom 800 **sq.** ft. (Anaheim) to 2200 **sq.** ft. (ATSAC). Installation costs have similar estimation problems; they range from **$3** million (Anaheim) to $20 million (San Jose).

Concerning computing facilities, Personal Computers (PCs) are used in **a** variety of ways, including the display of information, communication with other TMCs via modem, the control of CMS messages, logging incident information, and other miscellaneous office work. Major computation work, such as running ramp metering systems, is still performed on mainframe computers or workstations. Table 4 summarizes computer usage in each TMC.

Table 4 The usage of mainfiame computers or workstations in the TMCs.

Computer	Usage - Caltrans TMCs (8 total)	Usage - local TMCs (3 total)
SUN SPARC	Bay Bridge & Vallejo	0
Data General	Sacramento & San Diego	0
MODCOMP	Los Angeles & Santa Ana	0
Concurrent	0	Anaheim & ATSAC
VAX	0	Anaheim & San Jose

Mainframe computers or workstations are used by Caltrans TMCs to derive appropriate metering rates and communicate with the type 170 controllers to control ramp meters. A variety of computers are used, including SUN SPARC, Data General, and MODCOMP. Fresno and San Bernardino are still in their planning phase of centralizing ramp meter control. For local TMCs, mainframe computers work in a similar fashion, except that they deal with intersection signals instead of ramp meters. Anaheim and ATSAC use the Concurrent mainfiame computer, and San Jose uses the VAX 4000 mini. Anaheim has recently added a VAX computer for installing a new adaptive signal control system.

For staffing needs (see Table B-3 in Appendix B), most Caltrans TMCs are directly operated by a staff of less than 10, including engineers and technicians. The city TMCs are operating at a similar scale – around 10 staff members are required.

4.5 Information Input/Output and Communication Means

The lower portion of Table **B-3** (Appendix B) shows the information input/output and communication means of each TMC. For the Caltrans TMCs, a combination of means is used to transmit information. Loop detector data is mostly transmitted via dedicated phone lines. The only exception is the Bay Bridge TMC, which uses twisted pair and fiber optic cables. CCTV video images are transmitted via a variety of means: coaxial cable, leased phone line, microwave, radio frequency, fiber optics, and twisted pairs. Apparently, many TMCs are experimenting with different means to cope with the higher data volume requirements of video images. Voice-based information, such as drivers' reports, is always transmitted through the phone and radio. The exchange of data between TMCs within the same group, as mentioned earlier, is achieved by modem via phone lines.

Ground-based and cellular phone lines are used almost exclusively for remotely controlling signal controllers and CMS from the TMC. The exception is again at the Bay Bridge, where twisted pair is used. And to a small extent, San Diego is experimenting with the use of radio links between the signal controllers and the TMC.

For the local TMCs, loop detector information is transmitted via a combination of leased phone lines, twisted pair, and fiber optics. Video images are transmitted via coaxial cable, microwave, leased phone lines, fiber optics, twisted pair, and even laser (at ATSAC). To send control signals to the output devices, a combination of twisted pair, fiber optics, spread spectrum radio, and leased line are used.

At this time, there seems to be no common design pattern as to how the communication system is connected. Many TMCs are experimenting with many modes, and they often install the devices on a case by case basis.

4.6 Traffic Database

Table B-4 (Appendix B) indicates the database required to operate the software and the content of the archived database. The information collected for this section was very sketchy. This indicates that the software is treated as a "black box"; operating staff does not need to look into what runs the software — as long as it "works". Often, for each TMC, we had to make a few follow-up calls to obtain this information. The database of Caltrans TMCs normally contains occupancy, volume, speed (which is derived), and device status. Data come in every **6** seconds and are then aggregated at **30** seconds. (This is by no means a standard procedure for all TMCs). Similarly, we did not obtain definite information about the archived database during the visits. Follow-up calls found that volume, occupancy, and incident logs are kept at some TMCs. The storage duration varies from ***36*** hours (Santa Ana and Los Angeles — data remain in the computer's active memory for ***36*** hours and are then downloaded on tapes and stored for ***3*** years) to 2 years (Bay Bridge and Vallejo). At other TMCs, the operators could not provide definitive answers as to whether data are archived.

For local TMCs, in addition to real-time volume and occupancy data, historical traffic patterns are used by the software to adjust the signal plans. Data come in every second and are aggregated to the system's cycle length. The details of what are archived were not clearly defined during the visits, though volume and occupancy data were mentioned.

4.7 Computer Software

For Caltrans TMCs, ramp metering is the only major task that requires heavy computation and communication. There are ***3*** versions of ramp metering software currently in use. The first one was developed by Caltrans District 11's Ramp Metering Operations Branch in **1978** and is commonly known as the San Diego Ramp Meter System (SDRMS). The system is used in

Sacramento and San Diego TMCs and planned for Fresno and San Bernardino TMCs. The second version was developed in-house by District 7 (Los Angeles), which is also used by the Santa Ana TMC. Finally, the Bay Bridge TMC developed its own software back in 1974. The San Diego and Los Angeles TMCs, and the Bay Bridge hub also claimed that they have software for incident detection. The software derives speeds along major highways based on occupancy and volume data. It then color-codes the speeds on the display based on pre-specified ranges, so that the operators are alerted to a potential incident occurrence.

As mentioned earlier, arterial signal control is the major function of local TMCs. All three local TMCs share a very similar software platform: graphical display software developed by JHK & Associates, UTCS (Urban Traffic Control System) developed by the Federal Highway Administration (FHWA) to handle database and communication, and TRANSYT-7F to develop timing plans based on historical traffic patterns. All three systems can be run under fully traffic responsive mode (though it was reported that this mode was seldom used).

5. PLANNED UPGRADES

The present moment is a vantage point for many TMCs – most have plans for expansion. The plans focus mainly on expanding what they have been performing rather than widening the scope. Therefore, in terms of functionalities, they are quite similar to today's TMCs. The following are some examples of these expansion plans:

DISTRICT **4 -** *SAN* FRANCISCO BAY AREA

The proposed TMC will cover **460** miles of freeway. Traffic surveillance will be done by **68** CCTVs, as well as dual inductive loop detectors and magnetometers at a half mile spacing. FSP will cover **188** miles of freeway. The TMC will control ramp meters and selected connector meters for 208 miles of freeway. The TMC will transfer information to motorist information systems (154 CMS, 8 HAR and the media). The communication network will consist of digital lines, spread spectrum digital radios and fiber optic cables.

DISTRICT *6* - FRESNO

The District *6* TMC will be fully implemented by the end of the decade. The TMC will ultimately cover all freeways in the Fresno and Bakersfield metropolitan areas including all of Interstate 5 and State Route 99. The TMC will incorporate traffic surveillance (inductive loop detectors; Caltrans, CHP and other agency field personnel; CCTV; commercial television and commercial traffic reports), traffic management systems (ramp meters and TMT), motorist information systems (CMS, **HAR,** CHIN/CHIBN system and local media), motorist service patrols, environmental sensors, motorist call boxes and a full communication network. District *6* has also prepared a 10-year and a 20-year Ramp Metering Development Plan which covers 131 ramps.

DISTRICT 7 - LOS **ANGELES**

District 7 plans to have a fully operational traffic operations system around the year 2000, To accomplish this, a master plan consisting of 31 projects has been developed. The master plan proposes the implementation of the following facilities: 99 CMSs, 400 CCTVs, 500 miles of freeway covered with electronic loop detectors, 1200 ramp meters, 24 HARs, 349 miles of freeway covered by FSP and 439 miles of communication lines with a fiber optic trunk line, and also 434 miles of HOV lanes.

DISTRICT **8 - *SAN*** BERNARDINO

District 8 has proposed a 47,000 sq. ft. facility with an operation center of approximately 6000 **sq.** ft. The TMC will receive input from 1500 loop detectors, 300 CCTVs, police and drivers' reports, motorist call boxes, and 13 environmental sensing units. The TMC will coordinate special events and control signal actuators, **288** ramp meters, ***65*** CMSs and 1 HAR. The TMC will communicate with CHP, ambulance, media and other TMC's (Los Angeles, Orange County and San Diego). The communication network will primarily be 300 miles of fiber optic cables.

DISTRICT 11 - SAN DIEGO

District 11 has proposed a **42,000** sq. ft. TMC building. The fully operational TMC will cover 211 miles of freeway. The TMC will contain the following facilities: **4,000** under-pavement incident detectors with a half mile spacing, 300 ramp meters, at least 30 CCTV, 35 CMS, and 5 HAR. The TMC will control signal actuators and the I-15 reversible HOV/Express lanes and will coordinate special events. The communication network will be formed from state-owned networks and leased commercial lines. District 11 TMC will also use Automated Vehicle Location (AVL) equipment to aid dispatch in deploying TMT personnel and resources.

6. OBSERVATIONS

Our observations are posed as questions and sometimes as suggestions in this section. The purpose is to stimulate discussion and awareness, which hopefully would lead to more comprehensive design and operation concepts.

i. Functional analysis is needed in TMC design. We have included eleven types of functionalities in the survey. Many of them have not received attention in the past. Some TMC personnel frankly mentioned that they had not thought about many **of** the potential functions at all. The questions that need to be investigated include: "What functionalities should be included in the TMC?", "What would be their impacts on the transportation system?", and "What would be the infrastructure requirements for installing them?"

ii. Many TMCs have aggressive expansion plans. These plans mainly focus on infrastructure installations, such as deploying hundreds of CCTVs and thousands of loop detectors. The general belief is that the system will operate better if more information is available. However, more attention is needed to defining the information requirements and developing efficient means of using them. Likewise, many more CMSs and HARs are proposed, but questions like "How would they be used?" and "What kind of message is effective?" should be examined first.

iii. Even under the existing incident management system, there is room for improvement. The recent addition of the CAD System in the Bay Area and the Bulletin Board in the Los Angeles region are big steps toward automating the communication among Caltrans TMCs, CHP, and the media. (Even though the Bulletin Board in the Los Angeles region is not used for dispatching purpose.) Incidents would potentially involve many emergency agencies, such as fire, ambulance, CHP, Caltrans Traffic Management Team (TMT), Caltrans Maintenance (for dispatch of heavy equipment), FSP, and hazardous material handling team. Therefore the coordination procedure needs to be standardized and streamlined for quicker response. At this moment, coordination procedures are highly dependent on the operators' experience. Such coordination, instead, could be automated by an expert system that invokes a check list of responses based on the type and severity of incident. (District 4 and District 12 have started to investigate this direction.)

iv. Since many TMCs will be expanded in the near future, this may be the best time to examine TMC design standards and interfaces. The purpose is to ensure that data exchange follows standard protocols or interfaces, so that the new TMCs can communicate and coordinate seamlessly with each other.

V. California TMCs show quite a diversity in computer software and hardware. This may be due to their relatively independent earlier development efforts. To achieve economy of scale, it would be beneficial to coordinate the procurement efforts, so that software developed at one TMC would be portable to others.

vi. On-line or off-line performance evaluation of the signal plans or meter rates are not done frequently. The TMCs often compensate for this by providing frequent manual control override instead of fixing the software by fine-tuning the parameters. Such problems can be easily mitigated by providing training to the operators or engineers.

vii. The highest level of coordination between TMCs at this moment stops at real-time data exchange for display purposes. Instead, such data could be built into the software to provide better control systems, such as an integrated arterial signal and ramp metering system. The coordination between the local TMCs and Caltrans TMCs is important since they often are located within the same region, and traffic congestion that occurs on the freeways often spills to the arterial system, and vice versa. Active coordination between them, other than the Smart Corridor project, is rarely seen, though this is often expressed as desirable during the visits. Of course, the institutional issues have to be resolved first.

viii. As it stands now, the communication networks of many TMCs have been developed on a case by case basis. Over the years, they have used whatever is convenient or available. And the expansion plans of many local and Caltrans TMCs require huge efforts in building the communication system. It might be beneficial to set up a committee to oversee the entire communication network restructuring task, so that duplication in effort can be avoided, and local and Caltrans TMCs may share part of the network. The report on the Southern Districts Traffic Operation Systems Communication Study (Caltrans, 1991) is a good starting point.

ix. Finally, IVHS research and development activities have opened up many new traffic management functionalities, such as vehicle route guidance, automatic toll collection, automatic incident detection, and maybe even road pricing. What is the role of the TMC in these functionalities? If a TMC is to be the nerve center for all these activities in the future, what does it imply for TMC design today? These are open questions and certainly deserve more examination and research.

7. CONCLUSIONS

The purpose of this study is to understand the characteristics and operations of California TMCs. We visited all of the California TMCs in order to obtain a better understanding of them. This survey examined the TMCs from a broad base and covered a wide spectrum of issues.

As a summary, in terms of functionalities, California TMCs can be divided into two groups: Caltrans TMCs and city TMCs. Caltrans TMCs mainly perform the following functions: surveillance, provision of information to travellers, incident management, ramp metering, and special events' handling. City TMCs mainly conduct surveillance, arterial signal control, and special events' handling. We also briefly covered other issues in this study, including coordination among TMCs and coordination with other systems, facilities, information input/output and communication means, and traffic database and software. Each of these can be a full study in its own right. In addition to providing a status report on existing TMC operations, this study raises many questions concerning future TMC designs.

In the next report, we will focus on some of the issues discussed in the Observations section and examine their implications on future TMC design. Issues such as functional analysis and coordination among the TMCs will be covered, and incorporation of advanced IVHS capabilities will be examined in-depth.

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APPENDIX A

TMC FUNCTIONALITY AND FACILITY QUESTIONNAIRE

TOC/TMC Functionality and Facility Questionnaire

(May 7, 1993 4:35 pm)

Functionalities

1. Surveillance E / P / D / N

	What kind?	How many?	Spacing	Speed detection?
	Loop detectors			
	CCTV			
	Magnetic detectors			
	Optic detectors			
	Others			

Is it effective? why/why not?

____

2. Provision of information to travellers E / P / D / N

E / P / D / N a. Incident information
E / P / D / N b. General congestion information
E / P / D / N c. Transit schedules
E / P / D / N d. Roadway conditions
E / P / D / N e. Route guidance
E / P / D / N **f.** Others ______________________

via what means?
E / P / D / N a. Changeable message signs
E / P / D / N **b.** Highway advisory radio
E / P / D / N c. Dial-in
E / P / D / N d. Third **party** private devices
E / P / D / N e. CB Radio
E / P / D / N f. Media: which ______________ and how ________________
E / P / D / N g. Others ______________________

Is it effective? why/why not?

____

3. A. Arterial signal control system E / P / D / N
E / P / D / N On-line monitoring system? ______________
E / P / D / N what area scale? ______________________
E / P / D / N Covers how many intersections? ______________________
E / P / D / N Uses real-time data? ______________________
E / P / D / N Coordinated/Synchronized signal control? ______________________

E I P I D I N Fixed cycle length? ______________________
E I P I D I N Changes in signal plans introduced by:

i. Selecting fixed plans by time of day
ii Selecting a fixed plan throughout the day
iii Operator intervention
iv others ______________________

E I P I D I N What types of software? ______________________
E I P I D I N What types of computer hardware? ______________________
E I P I D I N What types of surveillance hardware? ______________________
E I P I D I N Existence of distributed control? ______________________

Is it effective? whylwhy not?

____

B. Ramp metering system E I P I Dl N

E I P I D I N On-line monitoring system? ______________________
E I P I D I N What is its daily operating time? ______________________
E I P I D I N What area scale? ______________________
E / P / D/ N Covers how many ramps? ______________________
E I P I D I N Uses real-time data? ______________________
E I P I D I N Coordinated ramp metering control? ______________________
E I P I D I N What types of software? ______________________
E I P I D I N What types of computer hardware? ______________________
E I P I D I N What types of surveillance hardware? ______________________
E I P I D I N Existence of distributed control? ______________________

Is it effective? whylwhy not?

____

C. Coordination between ramp metering/arterial signal control E / P / Dl N

E I P I D I N What area scale? ______________________
E / P / D/ N Covers how many rampslintersections? ______________________
E I P I D I N Uses real-time data? ______________________
E I P I D I N What types of software? ______________________
E I P I D I N What types of computer hardware? ______________________
E / P / D/ N What types of surveillance hardware? ______________________
E I P I D I N Existence of distributed control? ______________________

Is it effective? whylwhy not?

____

4. Emergency vehicles dispatching E / P I Dl N

What kind?

E I P I D I N a. Police
E I P I D I N b. Fire
E I P I D I N c. Ambulance
E I P I D I N d. Others ______________________

E **/** P **/** Dl N Does it provide routing guidancelinstructions?

If yes, via what means? ________________________________

Is it effective? whylwhy not?

____

5. Law enforcement E **/** P **/** *Dl* N

What kind?

EIPIDIN a. Traffic violation
EIPIDIN **b.** Crime
EIPIDIN c. Others ___________________________________

via what means?

EIPIDIN a. CCTV
EIPIDIN **b.** Drivers' reports
EIPIDIN c. Aerial surveillance
EIPIDIN d. Others ____________________________________

Is it effective? whylwhy not?

____

6. Incident management E **/** P **/** *Dl* N

What kind?

EIPIDIN a. Broadcast of incident information
via what means?
EIPIDIN 1. Changeable Message Signs
EIPIDIN ii. Highway Advisory Radio
EIPIDIN iii. Others ____________________________
EIPIDIN **b.** Inform CHP/police
EIPIDIN c. Inform fire department
EIPIDIN **d.** Inform ambulance
EIPIDIN e. Dispatch tow trucks
EIPIDIN f. Adjust signal plans
EIPIDIN g. Send crew to set up detourlclosure of lane
EIPIDIN h. Inform hazardous material handling crew
E / P / D/ N i. Dispatch of heavy equipments
EIPIDIN **j** Expert system to suggest incident response to TMC operator
EIPIDIN **k.** Others ___________________________________

Incident detection means:

EIPIDIN **a.** CCTV
EIPIDIN **b.** Drivers' reports
EIPIDIN c. Police reports
EIPIDIN d. Roadside emergency telephone
If ***so,*** where is call relayed to? ____
EIPIDIN e. Aerial surveillance
EIPIDIN f. loop detectorslincident detection algorithm
EIPIDIN g. Others ___________________________________

Incident confirmation means:

E I P I D I N a. CHP/Police report
E I P I D I N b. Send out crew
E I P I D I N c. CCTV
E I P I D I N d. Others ______________________________

Is it effective? whylwhy not?

____

7. Emergency evacuation/catastrophe plan E / P I Dl N

E I P I D I N Under what conditions will the plan be invoked?
E I P I D I N a. Earthquake
E I P I D I N b. Others ____________________________

Is it a:

E I P I D I N a. Fixed plan
E I P I D I N b. Real-time adjustable plan
E I P I D I N C. Others ______________________________

Means of executing plan

E I P I D I N a. General media broadcast
E I P I D I N b. Signal coordination
E I P I D I N C. Changeable message signs
E I P I D I N d. Others ______________________________

Is it effective? whylwhy not?

____

8. Special events handling (e.g. construction, football, baseball, etc.) E / P / Dl N

Via what means?

E I P I D I N a. Signal control
E I P I D I N b. Routing
E I P I D I N c. Others ____

Is it effective? whylwhy not?

____

9. Hazardous material routing E / P / Dl N

Means of enforcement:

E I P I D I N a. Truck route tracking
E I P I D I N b. Pre-trip route approval
E I P I D I N **b.** Others ______________________________

Is it effective? whylwhy not?

____

10. Transit scheduling E / P / Dl N

If yes, means of participation:

Is it effective? why/why not?

11. Internodal coordination (eg. with light rail) E / P / D/ N
If yes, means of participation:

Is it effective? why/why not?

12. Other functionalities not described above.

Is it effective? why/why not?

Coordination Among Other TMC's

Is there any coordination among neighboring TMC's?
C ordination exists for what kind of functionality:

	Functionality	With which TMC's	Means (eg, voice phone call, data link, automated control,etc.)
	Surveillance		
	Information provision to travellers		
	Signal Control/Ramp metering		
	Emergency vehicles dispatching		
	Law enforcement		
	Incident management		
	Emergency evacuation plan		
	Special events handling		
	Hazardous material routing		
	Transit route and schedule planning		

	Intermodal coordination		
	Others		

Coordinati ith Other Systems

1. *CHP* E / P / D/ N

If yes, information content

E / P / D/ N a. Incidentlaccident information
E / P / D/ N **b.** Others ________________

Means of coordination

E / P / D/ N a. CHP located at TMC
E / P / D/ N **b.** Dial 911 - provide information
E / P / D/ N c. Direct communication link
E / P / D/ N d. Alter signal plan to facilitate dispatching
E / P / D/ N e. Others ______________________

2. Police **E** / P / D/ N

E / P / D/ N If yes, with police of which cities? ______________________________________

Information content:

E / P / D/ N a. Incidentlaccident information
E / P / D/ N **b.** Others ________________

Means of coordination:

E / P / D/ N a. Dial 911 - provide information
E / P / D/ N **b.** Direct communication link
E / P / D/ N **b.** Alter signal plan to facilitate dispatching
E / P / D/ N c. Others ______________________

2. Ambulance **E** / P / **D/** N

If yes, information content

E / P / D/ N a. Incidentlaccident information
E / P / D/ N **b.** Others ________________

Means of coordination

E / P / D/ N a. Dial 911 - provide information
E / P / D/ N b. Direct communication link
E / P / D/ N c. Alter signal plan to facilitate dispatching
E / P / D/ N **d.** Others ______________________

3. Fire E / P / D/ N

If yes, information content

E / P / D/ N a. Incident/accident information
E / P / D/ N **b.** Others ________________

Means of coordination

E / P / D/ N a. Dial 911 - provide information
E / P / D/ N b. Direct communication link
E / P / D/ N c. Alter signal plan to facilitate dispatching
E / P / D/ N d. Others ______________________

4. Central 911 dispatcher E / P / D/ N

If yes, information content

E / P / D/ N a. Incidentlaccident information
E / P / D/ N b. Others _________________

Means of coordination

E / P / D/ N a. Dial 911 - provide information
E / P / D/ N b. Direct communication link
E / P / D/ N c. Alter signal plan to facilitate dispatching
E / P / D/ N d. Others ______________________

5. Major trip generators E / P / D/ N

If yes, information content

E / P / D/ N a. Events' timing
E / P / D/ N **b.** Estimated traffic volume
E / P / D/ N c. Others _________________

Means of coordination

E / P / D/ N a. Provide information
E / P / D/ N b. Direct communication link
E / P / D/ N c. Alter signal plan to facilitate dispatching
E / P / D/ N d. Others ______________________

6. Weather services E / P / Dl N

If yes, information content

E / P / D/ N a. Weather conditions
E / P / D/ N b. Roadway conditions
E / P / D/ N c. Others ______________________

7. Others not listed above.

____

____

Facilities

Office Space (square feet) ______________________________

Annual Operating budget ______________________________

Installation Cost estimate _____________________________

Computers:

Type	Function	No.

Personnel:

Job Title	Job Nature	Existing (no.)	Desirable (no.)
Traffic Engineer			
Technician			
Computer operator			
Computer programmer			

Information Sources/Sinks and Communication Means

Information Sources	Communication Means
Loop detectors	
CCTV	
Police reports	
Drivers' reports	
Weather services	
Other TMC's	
Others	
Information Sinks	**Communication Means**
Signal actuators	
CMS	
HAR (from TMC to broadcast sites)	

CHP/Police	
Ambulance	
Radio/TV Stations	
Other TMC's	
Dial-in	
Private devices	
Others	

Traffic Database

1. Content
   a. Size of time slice
   b. occupancy
   c. Current link volume
   d. Current link speed
   e. Archived link volume
   f. Archived link speed
   g. Link characteristics
   h. Accident/incident status and duration
   i. Detectors' status
   j. Signal plan status
   k. CCTV status
   l. Current O D flows
   m. Archived O D flows
   n. Others ______________________________

   ____

2. If traffic operation/control uses data in a "rolling horizon" way, how big is the time window?

   ____

3. Traffic database archived?

   Yes No

   If yes, what type?
   a. Time slice
   b. Link speed (t)
   c. Link volume (t)
   d. Incident report
   e. Failure rate of detectors

f. **Others** ____
____

Computer Software

Type	**Software**
Signal Control	
Ramp Metering	
Incident detection	
Database management	
Communication	
Others	

Documentation

Reference : ____
Documents available :__________________________________

Contact Persons

Name: ______________________
Position: ______________________
Phone: ______________________
Address: ____

Name: ______________________
Position: ______________________
Phone: ______________________
Address: ____

APPENDIX B

TMC SURVEY RESULTS

LIST OF ABBREVIATIONS

1.5G	1.5 Generation Signal System
BBS	CHP Bulletin Board System
CAD	Computer Aided Dispatch
CCTV	Closed Circuit Television
CHIBN	Caltrans Highway Information Broadcasting Network
CHIN	Caltrans Highway Information Network
CHP	California Highway Patrol
CMS	Changable Message Sign
CX	Coaxial
D	District
FO	Fiber Optic
FSP	Freeway Service Patrol
GPS	Global Positioning System
GUI	Graphical User Interface
HAR	Highway Advisory Radio
HOV	High Occupancy Vehicle Lane
IR	Infra-red Detector
LAN	Local Area Networking
LD	Loop Detector
MIS	Management Information System
MW	Microwave Detector
OD	Optical Detector
Oper.	Operator
PC	Personal Computer
Prog.	Programmer
RM	Ramp Metering
Rd	Roadway Condition
S	Signal Plan
SDRMS	San Diego Ramp Metering System
SIG. OP	Signal Optimization
Supp.	Support
TMT	Traffic Management Team
TMC	Transportation Management Center
TP	Twisted Pair
UTCS	Urban Traffic Control System
accid.	accident information
algor.	incident detection algorithm
char.	characteristics
comm.	communications
cong.	general congestion information
const.	construction
coord.	coordinated
dev.	device
dissem.	disseminate
emerg.	emergency
incid.	incident information
info.	information
maint.	maintenance
min.	minute
misc.	miscellaneous
sec.	second
surv.	surveillance
sys.	system
temp.	temperature
veh.	vehicle
w.	with

TABLE B-1 TMC FUNCTIONS

TMC LOCATION	District 3 SACRAMENTO	District 4 VALLEJO	District 6 FRESNO	District 7 LOS ANGELES
Surveillance via devices	Yes	Yes	No	Yes
- Means	LD/CCTV	(info. transmitted from Bay Bridge)		LD/CCTV
Information Provision	Yes	Yes	Yes	Yes
- Kind	Incid./Cong./Detour/Rd	Incid./Cong./Rd/Detour/maint.	Incid./Cong./Detour/Rd/maint.	Incid./Cong./Rd. Closure
- Means	14 CMS/7 HAR/Media	14 CMS/1 HAR/3rd Party Dev./CHIN/Media	24 CMS/9 HAR/Media/Public Dial-up	71 CMS/6 HAR/Media/3rd Party Device
Control	Yes	Yes	No	Yes
- Arterial signal	No	No	(by SIG. OP. GROUP)	No
- Ramp metering	17 ramps, dynamic, isolated	62 ramps, dynamic, isolated	No	722 ramps, dynamic, isolated
- Coordination S/RM	No	No	No	No
Emergency Veh. Dispatch	Yes via CHP Comm. Center	Yes via CHP Comm. Center	Yes via CHP	Yes via CHP
- Kind	Fire/Ambulance/TMT/FSP	Police	TMT	Police/fire/ambulance
Law Enforcement	No	No	No	No
- Kind/Means				
Incident Management	Yes	Yes	Yes	Yes
- Means	Broadcast/Inform/Dispatch	Broadcast/Inform/Dispatch	Broadcast/Inform/Dispatch	Broadcast/Inform/TMT/Media interface
- Detection Means	CCTV/Reports/Aerial surv./Call box	Reports/Call box/Aerial surv.	Reports/Aerial surv./Call box	CCTV/Report/Call box/Aerial surv/algor.
Emergency Evacuation Plan	No	Yes, via media/CMS	No	No
- Invoke Condition		Earthquake		
Special Events Handling	Yes, construction/maint.	Yes, sporting events	Yes, construction/ball games	Yes, construction/ball games
- Means	Via Media/set up detour	Suggest routes/TMT/CMS/CHP	CMS/HAR - suggest routes	CMS/TMT/Media Interface
Hazardous Material Handling	No	No	Yes	No
- Means			Detour plan prepared	
Transit Scheduling	No	No	No	No
- Means of participation				
Other Functions	No	No	Emerg. Broadcasting system	No

TABLE B-1 (CONT'D) TMC FUNCTIONS

TMC LOCATION	District 8 SAN BERNARDINO	District 11 SAN DIEGO	District 12 SANTA ANA	District 4 BAY BRIDGE HUB
Surveillance via devices	No (not connected yet)	Yes	Yes	Yes
- Means		LD	LD	LD/CCTV/MW/OD/Magnetometer
Information Provision	Yes	Yes	Yes	Yes
- Kind	Incid./Cong./Rd	Incid./Cong./Rd	Incid./Rd	Incid./Cong./Rd/Detour
- Means	13 CMS/2 HAR/3rd Party Dev./Media	19 CMS/5 HAR/Media	18 CMS/2 HAR/CHIN/Media	CMS/HAR/Media
Control	Yes	Yes	Yes	Yes
- Arterial signal	(by SIG. OP. GROUP)	(by SIG OP. GROUP)	(by SIG. OP. GROUP)	No
- Ramp metering	29 ramps, dynamic, isolated	122 ramps, dynamic, partially coord.	260 ramps, dynamic, isolated	Yes, isolated
- Coordination S/RM		No	No	No
Emergency Veh. Dispatch	Yes via CHP CAD	Yes Via CHP	Yes via CHP	No
- Kind		Police/fire/ambulance/FSP	FSP	
Law Enforcement	No	No	No	No
- Kind/Means				
Incident Management	Yes	Yes	Yes	Yes
- Means	Broadcast/Inform/Dispatch	Broadcast/Inform/Dispatch	Broadcast/Inform/Dispatch	Broadcast/Inform/Adjust signals
- Detection Means	Reports/Call box/Aerial surv.	Reports/Call box/Aerial surv./algor.	Reports/Call box/Aerial surv.	CCTV/Call box/LD
Emergency Evacuation Plan	No	No	No	Yes, via media/CMS/HAR
- Invoke Condition				Earthquake
Special Events Handling	Yes, construction	Yes, Maint. lane closure/ball games	Yes, construction/ball games	Yes, construction/ball games
- Means	Dissem. info via Media interface	CMS/TMT/Signal change	CMS/HAR/TMT/Media Interface	Staff up TMC hub
Hazardous Material Handling	No	No	No	No
- Means				
Transit Scheduling	No	No	No	Yes
- Means of participation				Lower metering rate
Other Functions	Earthquake notification sys.	Earthquake monitoring sys.	No	HOV lanes
		Surveillance by TMT		

TABLE B-1 (CONTD) TMC FUNCTIONS

TMC LOCATION	CITY OF ANAHEIM	CITY OF LOS ANGELES	CITY OF SAN JOSE
Surveillance via devices	Yes	Yes	Yes
- Means	CCTV/LD	CCTV/LD/MW/IR	LD/CCTV
Information Provision	Yes	No	No
- Kind	Planned event/construction		
- Means	CMS/HAR/Media/3rd Party Device		
Control	Yes	Yes	Yes
- Arterial signal	209 intersections, UTCS, 1.5G	1566 intersections, UTCS, 1.5G	Yes
- Ramp metering	No	No	No
- Coordination S/RM	No	No	No
Emergency Veh. Dispatch	No	No	No
- Kind			
Law Enforcement	No	No	No
- Kind/Means			
Incident Management	No	No	Yes
- Means			Adjust signals
- Detection Means			Caltrans/Drivers' reports
Emergency Evacuation Plan	Yes, via signal plans	Yes, via signal plans	No
- Invoke Condition	Emergency	Emergency/riots	
Special Events Handling	Yes, construction/ball games	Yes, ball games	Yes, construction/sporting events
- Means	Suggest route via CMS/signal plan	Signal plans	
Hazardous Material Handling	No	No	No
- Means			
Transit Scheduling	No	No	No
- Means of participation			
Other Functions	No	No	Partial preempt signals for light rail

TABLE B-2 TMC COORDINATION

TMC LOCATION	District 3	District 4	District 6	District 7
	SACRAMENTO	VALLEJO	FRESNO	LOS ANGELES
Coordination with Other TMC's	No	Yes	Yes	Yes
- Types of information shared with other TMC's (means)		-Incident info. w. D3 -Video/LD data/CMS/civil disturbance w. Bay Bridge HUB	-Incident info. w. D7,8,11 & 12 (CHP Bulletin Board) -Special events timing w. D10 (phone) -Weather information eg. fog (phone)	-Incident info. w. D6,8,11 & 12 (CHP Bulletin Board) -Special events timing w. D8,12 (phone) -Signal/ramp meter info. w. D12, cities of LA and Anaheim (direct datalink)
Coordination with other Systems	Yes	Yes	Yes	Yes
CHP - Means of coordination	Incident/accident info. CHP located at TMC	Incident/accident CHP located at TMC/direct comm. link	Incident/accident CHP located at TMC	Incident/accident CHP located at TMC/direct comm. link
Police, Ambulance, Fire - Means of coordination	Incident/accident Dispatch via CHP Comm. Center	No	Incid./accid./maint./const. Phone/scanner	Incident/accident Phone
Major Trip Generators - Means of coordination	Events' timing Suggest routes via media broadcast	No	Events' timing & traffic volume Radio link/alter signal/setup detour	Events' timing & traffic volume Provide info. via CMS
Weather Services - Means of coordination	Daily weather conditions	No	Temp./visibility/wind speed Contact media/arrange staffing	No

TMC LOCATION	District 8	District 11	District 12	District 4
	SAN BERNARDINO	SAN DIEGO	SANTA ANA	BAY BRIDGE HUB
Coordination with Other TMC's	Yes	Yes	Yes	Yes
- Types of information shared with other TMC's (means)	-Incident info. w. D6,7,11 & 12 (CHP Bulletin Board) -Special events timing w. D7,12 (phone)	-Incident info. w. D6,7,8, & 12 (CHP Bulletin Board) - CHP CAD & MIS	-Incident info. w. D6,7,8, & 11 (CHP Bulletin Board) -Special events(meetings) -Signal/ramp meter info w. D7, cities of LA and Anaheim (direct datalink)	-All info. & CCTV w. TMC at Vallejo (modem)
Coordination with other Systems	Yes	Yes	Yes	Yes
CHP - Means of coordination	Incident/accident CHP located at TMC	Incid./accid./planned event Direct comm link/fax/phone	Incident/accident CHP at TMC/radio/phone	No
Police, Ambulance, Fire - Means of coordination	Incident/accident Phone	No	Incident/accident CMS/HAR	No
Major Trip Generators - Means of coordination	No, handled by TMT	Events' timing & traffic volume Direct link/radio	Events' timing & traffic volume Phone	Events' timing & traffic volume Alter signal plan
Weather Services - Means of coordination	Weather/roadway conditions	No	No	No

TABLE B-2 (CONT'D) TMC COORDINATION

TMC LOCATION	CITY OF ANAHEIM	CITY OF LOS ANGELES	CITY OF SAN JOSE
Coordination with Other TMC's	Yes	Yes	Yes
- Types of information shared with other TMC's (means)	-Signal/ramp meter/CMS/HAR/Video info. w. D7, 12, and city of LA (datalink) -Special events(meetings)	-Signal/ramp meter/CMS/HAR/Video info. w. D7, 12, and city of LA (datalink) -Special events(meetings) -Incident info. w. D6,7,8, & 11 (CHP Bulletin Board)	-Intermodal coordination w. the county
Coordination with other Systems	Yes	Yes	Yes
CHP - Means of coordination	No	Incident/accident Via CHP bulletin board/alter signal	No
Police, Ambulance, Fire - Means of coordination	Police for special events Direct phone link to dispatch	Police - incident/accident Phone	Fire - pre-emption (testing) GPS
Major Trip Generators - Means of coordination	Events' timing & traffic volume Direct radio link/meetings	Events' timing & traffic volume	No
Weather Services - Means of coordination	Air quality info. broadcasted Radio message from AQMD broadcast	No	No

TABLE B-3 TMC FACILITIES

TMC LOCATION	District 3	District 4	District 6	District 7
	SACRAMENTO	VALLEJO	FRESNO	LOS ANGELES
FACILITIES				
Office Space (sq. ft.)	400	1300	550	1000
Installation Cost ($)	50,000			Unknown; over a period of years
COMPUTERS	NUMBER - FUNCTION	NUMBER - FUNCTION	NUMBER - FUNCTION	NUMBER - FUNCTION
386/486/PC	4 - CHP MIS and office misc.	3 - communication, FSP, misc.	3 - CMS control, misc.	11 - communication, misc.
Other	Data General S130 - ramp meters	2 - SPARC II - datalink	no	MODCOM - ramp meters/HP - CMS
PERSONNEL	NUMBER	NUMBER	NUMBER	NUMBER
Traffic Engineer	3	3	1	6
Technician	2	5	5	4
Computer Oper./Prog./Supp.	1	0	0	0
Electrical/System Engineer	3 (at 50%)	0	1	0
Other	0	CHP officers - 8	TMC Supervisor - 1	3 (part-time)
FROM INPUT SOURCES	COMMUNICATION MEANS	COMMUNICATION MEANS	COMMUNICATION MEANS	COMMUNICATION MEANS
Loop Detectors	dedicated phone line	leased phone line	no	phone line
CCTV	CX cable	leased phone line	no	MW
Police Reports	radio	via CAD	phone	phone
Drivers' Reports	cellular phone via CHP	cellular 911 via CAD	cellular phone	cellular phone via CHP,radio
Weather Services	CHIBN: modem	no	phone	no
Other TOC's	phone	phone	phone & BBS	phone, datalinks
Others		no	CHIN, CHIBN & CHP MIS	FSP - radio
TO OUTPUT DEVICES	COMMUNICATION MEANS	COMMUNICATION MEANS	COMMUNICATION MEANS	COMMUNICATION MEANS
Signal Actuators	dedicated phone line	no	no	dedicated phone line
CMS	via Maintenance	no	cellular phone & modem	phone line
HAR	via Maintenance	no	dial-up & cellular phone	phone line
CHP/Police	co-located	co-located	co-located	co-located
Ambulance	via CHP	no	via CHP	phone
Radio/TV Stations	fax, phone, MW	phone, CAD	live camera and phone	phone - fax
Other TOC's	phone	phone - fax	phone, BBS	phone, BBS
Dial-in	(not frequent)	no	public access BEE line	phone
Private Devices	no	CAD	no	phone

TABLE B-3 (CONT'D) TMC FACILITIES

TMC LOCATION	District 8 SAN BERNARDINO*	District 11 SAN DIEGO	District 12 SANTA ANA	District 4 BAY BRIDGE HUB
FACILITIES	* TOC just started recently			
Office Space (sq. ft.)	200	900	2000	300
Installation Cost ($)		100,000	<1,000,000	
COMPUTERS	NUMBER - FUNCTION	NUMBER - FUNCTION	NUMBER - FUNCTION	NUMBER - FUNCTION
386/486/PC		5	9 - CMS control, logs, misc.	2 - communication
Other		Data General - ramp meters	MODCOM - ramp meters	SPARC II-info. display,ramp meter
PERSONNEL	NUMBER	NUMBER	NUMBER	NUMBER
Traffic Engineer		1	3	1
Technician		2	6	2
Computer Oper./Prog./Supp.		0	0	0
Electrical/System Engineer		0	0	0
Other		Maint. Supervisor - 1	Dispatch - 8	Dispatch - 1
FROM INPUT SOURCES	COMMUNICATION MEANS	COMMUNICATION MEANS	COMMUNICATION MEANS	COMMUNICATION MEANS
Loop Detectors	"not connected yet"	leased phone line	dedicated phone line	TP, FO
CCTV	no	no	No	TP, FO
Police Reports	phone	phone/radio	phone/2-way radio	no
Drivers' Reports	via CHP	via CHP	cellular phone/call boxes	no
Weather Services	phone	no	no	no
Other TOC's	phone, BBS	phone, BBS	phone,BBS, datalink with D7	modem
Others		Caltrans staff with radio	FSP	
TO OUTPUT DEVICES	COMMUNICATION MEANS	COMMUNICATION MEANS	COMMUNICATION MEANS	COMMUNICATION MEANS
Signal Actuators	(BEING PLANNED)	phone line, radio link	dedicated phone line	TP
CMS	(BEING PLANNED)	phone line	dedicated phone line	TP
HAR	(BEING PLANNED)	phone (reversible lanes)	dedicated phone line	TP
CHP/Police	co-located	collocated	co-located, CHP CAD	no
Ambulance	via CHP	phone, via CHP	via CHP	no
Radio/TV Stations	"Easylink" - media interface	phone/fax/Traffic Reporting Services	phone	phone
Other TOC's	phone, BBS	phone, BBS	BBS, phone	phone
Dial-in	no	no	CHIN	no
Private Devices	phone	no	no	no

TABLE **B-3** TMC **FACILITIES**

TMC LOCATION	CITY OF ANAHEIM	CITY OF LOS ANGELES	CITY OF SAN JOSE
FACILITIES			
Office Space (sq. ft.)	800	2200	1000
Installation Cost ($)	3,000,000	5,000,000	20,000,000 (includes CMS,HAR)
COMPUTERS	NUMBER - FUNCTION	NUMBER - FUNCTION	NUMBER - FUNCTION
386/486/PC	6 - CMS, remote terminal, misc.	13 - LAN, misc.	5 - CMS/CCTV control,graphic display
Other	Concurrent - UTCS/VAX - 1.5G signal	Concurrent - UTCS	mini. VAX 4000 - signal control
PERSONNEL	NUMBER	NUMBER	NUMBER
Traffic Engineer	4	5	2
Technician	4	1	3
Computer Oper./Prog./Supp.	4 (part-time)	0	
Electrical/System Engineer	1	3	
Other	0	0	Maintenance - 4
FROM INPUT SOURCES	COMMUNICATION MEANS	COMMUNICATION MEANS	COMMUNICATION MEANS
Loop Detectors	TP	copper wire, FO, phone line	TP, leased line
CCTV	CX cable, MW, FO	FO, TP, phone line, laser	FO
Police Reports	CAD	no	phone
Drivers' Reports	phone	no	phone
Weather Services	no	no	no
Other TOC's	direct datalink: D7&12, phone	phone, datalink via FO, BBS	
Others	air quality information		
TO OUTPUT DEVICES	COMMUNICATION MEANS	COMMUNICATION MEANS	COMMUNICATION MEANS
Signal Actuators	TP	FO,phone line,spectrum radio	TP
CMS	TP	FO	TP, FO
	copper wire	broadcast from TOC	TP
CHP/Police	local police *CAD*, phone	phone	phone
Ambulance	phone	no	no
Radio/TV Stations	dedicated phone line	no	no
Other TOC's	dedicated phone line	phone, datalink	phone
Dial-in	no (planned)	no	no
Private Devices	**kiosks** (dedicated phone)	no	no

TABLE B-4 TRAFFIC DATABASE AND COMPUTER SOFTWARE

TMC LOCATION	District 3 SACRAMENTO	District 4 VALLEJO	District 6 FRESNO	District 7 LOS ANGELES
TRAFFIC DATABASE				
Size of time slice	30 sec.	6 sec.	5 min.	30 sec.
Contents	Occupancy/volume/speed/accid. & incid. status/detector status	Occupancy/volume/archived volume/link char./accid. & incid. status/CCTV status	In planning stage	Occupancy/volume/speed/accid. & incid. status/detector,CCTV status
Traffic database archived		2 years	In planning stage	36 hours & 4 days
Time slice		1 min.		30 sec. & 5 min.
Contents		Volume/occupancy/incident report		Volume/occupancy (CHP - incident report)
COMPUTER SOFTWARE				
Signal control		No	(by SIG. OP. GROUP)	No
Ramp metering	SDRMS	In-house software (Bay Bridge)	SDRMS	D7 developed
Incident detection	No	In-house software (Bay Bridge)	No	D7 developed
Database management	MIS-CHP database	JHK software	No	MODCOM "infinity"

TMC LOCATION	District 8 SAN BERNARDINO	District 11 SAN DIEGO	District 12 SANTA ANA	District 4 BAY BRIDGE HUB
TRAFFIC DATABASE				
Size of time slice	20 - 30 sec.	30 sec.	30 sec.	6 sec.
Contents	Occupancy/volume/speed/accid. & incid. status/detector,CCTV status	Occupancy/volume/accid. & incid. status/detector,signal plan status	Occupancy/volume/speed/archived volume & speed/accid. & incid. status/detector status	Occupancy/volume/accid. & incid. status/detector,signal plan,CCTV status
Traffic database archived	(planned for future)		36 hours	2 years
Time slice	20 - 30 sec.	30 sec.	30 sec. & 5 min.	1 min.
Contents	Speed/volume/incident report	Volume/occupancy	Volume/occupancy/incident report	Volume/occupancy/incident report
COMPUTER SOFTWARE				
Signal control	(by SIG. OP. GROUP)	(by SIG. OP. GROUP)	Quicknet	No
Ramp metering	SDRMS	SDRMS	D7 developed	In-house software
Incident detection	No	No	D7 developed	In-house software
Database management	Planned ARC/INFO with GUI	D11 developed	MODCOMP "infinity"	Operating system 9-VME system

TMC LOCATION	CITY OF ANAHEIM	CITY OF LOS ANGELES	CITY OF SAN JOSE
TRAFFIC DATABASE			
Size of time slice	1 sec. aggregated to cycle length	1 sec.	1 sec.
Contents	Occupancy/volume/speed/archived volume & speed/link char./detector, signal plan,system elements' status	Occupancy/volume/speed/archived volume & speed/detector,signal plan,CCTV status	Occupancy/volume/speed/archived volume & speed/detector,signal plan status
Traffic database archived	Up to 7 days		
Time slice		15 min. interval	Cycle by cycle
Contents	Occupancy/volume/speed/link char./ detector,signal plan,element status	Speed/volume/occupancy	Speed/volume
COMPUTER SOFTWARE			
Signal control	UTCS, TRANSYT-7F	UTCS, TRANSYT-7F, PASSER II	TRANSYT-7F/JHK series 2000
Ramp metering	No	No	No
Incident detection	No	No	No
Database management	UTCS - SQL format/JHK series 2000	UTCS	JHK series 2000/UTCS