Title

Data Utilization At California Transportation Management Centers

Authors

Chan, Shirley
Chang, Elbert
Lin, Wei-hua
et al.

Publication Date

1998-11-01

CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Data Utilization at California Transportation Management Centers

**Shirley Chan, Elbert Chang,
Wei-Hua Lin, Alexander Skarbardonis**

California PATH Research Report
UCB-ITS-PRR-98-34

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation; and the United States Department of Transportation, Federal Highway Administration.

Report for MOU **266**

November 1998

ISSN 1055-1425

CALIFORNIA PARTNERS FOR ADVANCED TRANSIT AND HIGHWAYS

ACKNOWLEDGMENTS

This study was performed as part of the California's PATH Program (MOU-266) at the Institute of Transportation Studies, University of California at Berkeley. We wish the thank Caltrans staff at the Transportation Management Centers for the information provided to us throughout the study.

Data Utilization at California Transportation Management Centers

S. Chan, E. Chang, W.H. Lin, A. Skabardonis

June **1998**

ABSTRACT

This study examined the operations and functions performed at the Caltrans Transportation Management Centers (TMC) with emphasis on the data sources, data processing and performance measures. Currently, much of the investment at the TMCs in real-time data collection primarily from loop detectors. Much of this data are archived without further analysis due to the **staff** and budget limitations. Recommendations are provided for establishing a performance monitoring system, usig the existing data to estimate performance measures, and procedures for data processing and dissemination.

Keywords:

TMC, Freeways, Evaluation Techniques, Incident Management, Traffic Delay, Traffic Flow

EXECUTIVE SUMMARY

Objectives and Methodology

In recent years, engineers, planners and political leaders have focused much attention on Intelligent Transportation Systems (ITS) as a means to reduce roadway congestion in an era in which the construction of new roads is prohibitively expensive and/or politically infeasible. **ITS** promises to more effectively use the existing transportation system with advanced technology that allows high-quality data collection, rapid processing and responsive control systems. At the focal point of **ITS** is the Transportation Management Center (TMC), seen as the nerve center for coordinating a wide variety of transportation management methods. The California Department of Transportation (Caltrans) operates nine TMCs that are designed to manage the state highway system.

TMCs collect a vast amount of data fiom several sources (loop detectors, closed circuit television cameras, cellular phone calls for incidents, airborne reports, fieeway service patrol logs). The objective of this study is to evaluate how data is currently acquired, processed, used, and stored by the Caltrans TMCs and to assess the potential to improve efficiency in data utilization. A literature review was performed to obtain information on the role and functions of TMCs in California and throughout the country. Additional information was gathered through interviews with the staff of ITS America, Metropolitan Planning Organizations, as well as field visits to various Caltrans TMCs. Next, the research explored the role of information fiom the new technologies and data processing algorithms in supporting TMC operations

Findings

TMCs are an important means for managing the transportation system by collecting information in a centralized location and developing coordinated action plans. However, much of the investment is in real-time data collection and information dissemination. Little investment has been made for off-line applications (e.g., data analysis for predicting traffic growth). According to TMC staff members, much of this data are stored in the computer system or archived unanalyzed. With the limited manpower and budget, priority is given to overseeing the operation of the system rather than to analyzing the data.

Maintenance and integration of the traffic operation system elements is an important aspect for TMC operation. Loop detector data are subject to error, because of detector malfunctions. Most TMCs do not have the manpower available for systematically checking and maintaining the detector infrastructure. Thus, often the data collected are not reliable. Data fiom other existing (video cameras) and emerging sources (e.g., electronic toll collection) need to be efficiently integrated into the database to assist in the data checking and verification.

Improved software and hardware will permit TMC operators to more efficiently manage the system. The new expert systems being implemented at several Caltrans TMCs will allow the operators to have access to all system elements fiom a single workstation. The new software system is more intelligent than the existing ones and *can* potentially reduce the amount of human intervention needed. It is expected that the software will analyze and interpret the data and recommend an action to the TMC operator.

Currently, measures of performance standards do not exist for any of the TMC functions. For example, the ramp metering plans often are not systematically examined, or re-evaluated. Most of the adjustments **are** performed in response to **user** complaints. Ideally, performance would be measured by the accuracy **of** traffic information disseminated, and amount of congestion delay reduced **as** a result of TMC actions.

Recommendations

There is a need to develop and implement a practical analysis tool to estimate the transportation system performance based on the TMC collected data and actions. This tool **will** permit the Caltrans TMC operators and system managers to have estimates of the quality and quantity of travel in the transportation system, amount and extent of congestion delay on individual **links** and the total system. Such system would also help substantiate the benefits and **costs** of having a TMC in place.

Given the enormous amount of resources being invested in data collection, it should be seen that the data be used to the fullest extent possible. This would require a data management team, to be in charge of the data storage, processing and dissemination. Examples include aggregation of raw loop detector data into different timescales (e.g., 5 minute counts) in suitable formats so it *can* be read and manipulated by most off-the-shelf software packages. The data may be disseminated through the Internet, **CD-ROMs** and other electronic formats dependmg on the needs **of** interested parties.

There is a need to incorporate recent research findings on the possibility of usig the data fi-om the existing surveillance infrastructure to calculate lirk travel times, detect the occurrence of incidents, and construct origin-destination tables. Examples include "vehicle matching" techniques that match individual vehicles based on their characteristics measured fi-om successive loop detectors or video cameras.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Problem Statement

In recent years, engineers, planners and political leaders have focused much attention on Intelligent Transportation Systems (*ITS*) as a means to reduce roadway congestion in an era in which the construction of new roads is prohibitively expensive and/or politically infeasible. ITS promises to more effectively use the existing transportation system with advanced technology that allows high-quality data collection, rapid processing and responsive control systems. In January 1996, the US Department of Transportation introduced "Operation TimeSaver," an initiative designed to put into place the infrastructure necessary for ITS in all major metropolitan areas in the US by 2001 (ITS America, 1996). Four public/private partnerships were designated as showcases for the Intelligent Transportation Infrastructure (ITI) Model Deployment: Phoenix, Seattle, San Antonio, and New York- New Jersey-Connecticut. In addition, Southern California, Houston, and Gary-Chicago-Milwaukee have been designated ITS Priority Corridors.

At the focal point of ITS is the Transportation Management Center (TMC), seen as the nerve center for coordinating a wide variety of transportation management methods. The California Department of Transportation (Caltrans) operates nine TMCs that are designed to manage each district's state highway system. There have been several reports assessing the existing capabilities of these TMCs (Lo *et al.*, 1993; Hall *et al.*, 1994) and future visions of TMCs throughout the US in performing transportation management functions. However, little evaluation of the type and amount of data needed to support these operations has been done.

TMCs collect a vast amount of data, ranging from loop detector data (occupancy, speed, and flow) to motorists' cellular phone calls (incident reporting). The prevailing sentiment among TMC operators appears to be that "more data is better" (Lo *et al.*, 1993); data is often collected and stored without consideration of its usefulness or cost. However, such practices are inefficient and costly. As transportation management becomes more complex, it will become essential that efficiency sought after in the transportation system be also brought into the TMC operations. In light of ITS deployment, efficient utilization of data resources should not only improve current TMC operations, but also extend the capabilities of TMCs to support future Advanced Traffic Management Information Systems (ATMIS) development.

1.2 Objectives of the Study

The objective of this study is to evaluate how data is currently acquired, processed, used, and stored by TMC operations in California and to assess the potential to improve efficiency in data utilization. More specifically, the research aims to:

- identify the weak links and information "gaps" in data utilization that support each of the TMC operations so as to enhance the current performance under the existing information resources;

- explore the value of the data that might be available in the near future through new technologies and assess how these data can be integrated into the existing data framework to improve TMC operations and support future ATMIS deployment.

1.3 Project Overview

The research study is built on an earlier study (Lo *et al.*, 1993) and consists of two phases. In the first phase, all the operations in TMCs that require data are identified. A literature review was performed to obtain information on the role and functions of TMCs in California and throughout the country. Informational interviews were conducted with the staff of ITS America, Metropolitan Planning Organizations (MPO) such as the Metropolitan Transportation Commission (MTC) in Caltrans District 4, TMC staff, as well as visits to various Caltrans TMCs. These personal correspondence and phone calls allowed us to identify the data required for each of the TMC operations. The research focused on the most common TMC operations. For each of these TMC operations, the following questions were addressed:

-- Is the data sufficient to support the operation?
-- Is the data source reliable?
-- Is the data format appropriate?
-- Is the data efficiently collected, processed, and maintained?
-- Is there a need to introduce additional data sources, which are currently available within the existing hardware device?
-- Is there a need to integrate data sources, which care currently not available but can be available with new technologies into the existing system?

The second phase of the research explored the role of information from the new technologies and data processing algorithms in supporting TMC operations. The objective was to determine whether the performance of TMC operations would be enhanced with better quality data. For example, travel time prediction is an important component of ATMIS applications. Currently, travel time estimation relies heavily on the speed data from single-trap loop detectors, which are both unreliable and unstable. Ongoing research has proposed methods for accurate travel time estimation using the existing loop detector infrastructure.

1.4 Report organization

Chapter 2 of the report reviews the status of TMCs traffic management methods available to freeway TMCs. In Chapter 3, the data sources currently used by the TMCs are identified, and questions of whether the data is of sufficient quality, is reliable, and is efficiently collected, processed, and maintained are addressed. The data utilization for each of the TMC functions are discussed in Chapter 4. Chapter 5 summarizes the study findings along with recommendations for improving the data utilization for TMC operations.

CHAPTER 2

BACKGROUND

The purpose of TMCs is to provide a central location for surveillance and control of the transportation system. TMCs are receiving real-time information fiom various sources, and develop/implement actions to respond to changing traflic conditions. Examples include dispatching proper authorities to clear incidents, activating fieeway ramp metering, and changing the signal settings along arterials and networks. It should be noted that there are two types of TMCs in California: Caltrans TMC and local TMCs. Caltrans TMCs primarily focus on the management and control of the state highways (primarily fieeways) while the cities' TMCs' major concern are the arterial systems. Although local TMCs are an integral part of the system, this report focuses on the Caltrans TMC.

In the following sections, the origins of TMCs in the US are discussed as well as the development and status of TMCs in California. The various traflic management methods TMCs utilize are presented. Finally, the future of TMCs is discussed.

2.1 TMC Evolution in the United States

Traffic management projects in the US began as early as the 1950's when the growth in traffic demand began to outpace the construction of new highways. The first of such efforts is the John C. Lodge fieeway project in Detroit, a joint research effort by the city of Detroit, Wayne County, Michigan DOT, and the U.S. Bureau of Public Roads (BPR) (Witheford, 1987). It started with one closed circuit television camera (CCTV) in 1955 and had 14 cameras covering 3.2 miles by the end of the project in 1971. A number of traffic management methods were tested, including lane control signals, ramp metering, automatic incident detection, and changeable message signs (CMS). In 1961, Chicago began its fieeway management program, installing 25 ultrasonic detectors on five miles of the Eisenhower Expressway. During the 1960's, Caltrans studied the need for ramp control on Los Angeles fieeways and began the design of the downtown 42-mile loop freeway surveillance system.

Other related efforts include: Illinois Department of Transportation (IDOT) initiated the Emergency Traffic Patrol (ETP) in Chicago to assist stranded motorists 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) ride-sharing program in the early 1970s, consisting of high-occupancy vehicle (HOV) lanes and park-and-ride lots (Jacobson, 1989).

Success in these early efforts led to their expansion of scope and eventually these fieeway traflic management programs evolved to into TMCs. The earliest examples of these are the IDOT Traffic Systems Center (TSC) in Chicago (formed in the early 1970's), the MnDOT Traffic Management Center for the Twin Cities (built in 1972) and the Traffic Operation Center (TOC, since renamed Transportation Management Center) in Los Angeles in 1971. Table 2.1 summarizes some of the traffic management systems implemented in the 1960's and 1970's.

Table 2-1: Traffic Management Projects Summary (1973)

Project Location	Year Started	No. Ramps Controlled	No. of Cameras Installed
Chicago	1963	39	
Dallas	1971	35	8
Detroit	1955	8	14
Houston	1965	8	14
Los Angeles	1967	9	1
New York	1970	3	111
San Francisco		--	4
Seattle	1967	--	10
Washington, DC		--	46

Source: Everall, P.F, 1973, "Urban Freeway Surveillance and Control: The State of the Art," Federal Highway Administration, U.S. Department of Transportation.

During the 1970's, TMCs nationwide expanded their surveillance and control capabilities by installing additional detectors, ramp meters, and cameras on the roadway. There was a noticeable change in operations in the early 1980's. The TMCs began to focus on the dissemination of traflic information to the public. Providing accurate and timely information on traffic conditions (e.g. locations of traflic incidents), enables the traveler to make informed decisions regarding mode choice, route choice, as well as departure time.

Advancements in computer and information technologies, and reduction in costs, has resulted in expansion of TMCs nationwide. Currently, over 40 TMCs have been deployed, are under construction, or are in the planning stage in the US by state transportation agencies (Oak Ridge National Laboratory, 1996). Existing systems monitor more than 3,800 centerline miles of roadways, which are instrumented with ramp meters, changeable message signs, and closed-circuit TV cameras. Table 2.2 provides a summary of the inventory for some of the major metropolitan areas.

The increased access to the Internet World Wide Web (WWW) has greatly facilitated the dissemination of real-time traffic information to the public. Many of the TMCs around the nation have set up websites, which display the locations of incidents and the real-time status of various links on a schematic diagram of the transportation network. Cities such as San Antonio and Phoenix also have linked their website to several of their cameras, providing the viewer a live image of the roadway. Most of these websites are not necessarily operated by the TMC themselves; there is an increasing trend toward giving this information to a private company to process and display the information on the Web. These websites have become a popular source of traffic information; for example, the Southern California site (operated by Maxwell Labs) receives an average of 400,000 hits per day.

Table 2-2: Status of Operational TMCs in the United States (1996)

LOCATION	CENTERLINE MILES COVERED	NUMBER OF RAMP METERS	NUMBER OF CCTVS	NUMBER OF CMSES
Atlanta, GA	50	5	452	41
Chicago, IL	136	n	3	20
Columbus, OH	115	⊠	129	33
Dallas and Ft. Worth, TX	13	n	46	51
Denver and Boulder, CO	7	28	19	21
Detroit, MI	33	57	157	57
Los Angeles, CA	750	891	89	99
Minneapolis, MN	160	490	210	80
New York, NY	92	⊠	⊠	⊠
Philadelphia, PN	34	48	37	4
Phoenix, AZ	42	54	299	35
Portland, OR	103	⊟	⊟	14
San Antonio, TX	57	n	302	122
San Francisco Bay Area, CA	347	257	306	75
Seattle and Tacoma, WA	91	223	375	71
St. Louis, MO				
Virginia Beach and Newport News, VA	17	n	99	133

Source: Oak Ridge National Laboratory. Deployment of Advanced Traffic Management Systems in the U.S. by State Agencies - Fact Sheet. ITS America Clearing House, 1996.

Note: ⊠ indicates technology employed at site, but figures unavailable.
n indicates technology not employed by the system.

2.2 TMC Status in California

While traffic management schemes have been used in California for over 20 years, the practice of bringing traffic information to a centralized location for surveillance and control is a relatively recent one. With the exception of **Los** Angeles (Caltrans District 7) and the Bay Bridge Traffic Operations Center in District **4,** the rest of TMCs were established in the early 1990's. Caltrans and CHP jointly adopted a Master Plan to be used as a guideline for the development and operation of all California TMC facilities (TMC Master Plan, **1993).** The objectives of the Master Plan are to standardize the systems and operations in order for resources are used efficiently, to identify the management structure for integrated TMC operation, and to strengthen the public/private partnerships to best serve the traveling public.

In order to meet the above objectives, the Master Plan established three regional TMCs within the State: Coastal, Valley, and Southern (Figure 2.1). The regional TMCs coordinate the efforts of Urban **TMCs** and Satellite Operations Centers (SOCs) within their respective region.

TMC Locations By Region

	Regional TMC	Urban TMC	SOC
Coastal	S.F. Bay Area		Eureka San Luis Obispo
Valley	Sacramento	Fresno Stockton	Redding Kingvale
Southern	Los Angeles	San Bernardino San Diego Orange County	Bishop

FIGURE 2.1 CALIFORNIA TMCs (Source: Caltrans, June 1998)

2.2.1 Organization and Staffing

Typically, the TMC falls under the division of Office of Traffic Management in each Caltrans district. Other departments under the Office of Traffic Management include: Traffic Management Team, Special Event Handling, HOV and FSP, and Ramp Metering. Figure 2.2 shows the organizational chart of the division of Office of Traffic Management for Caltrans District 7.

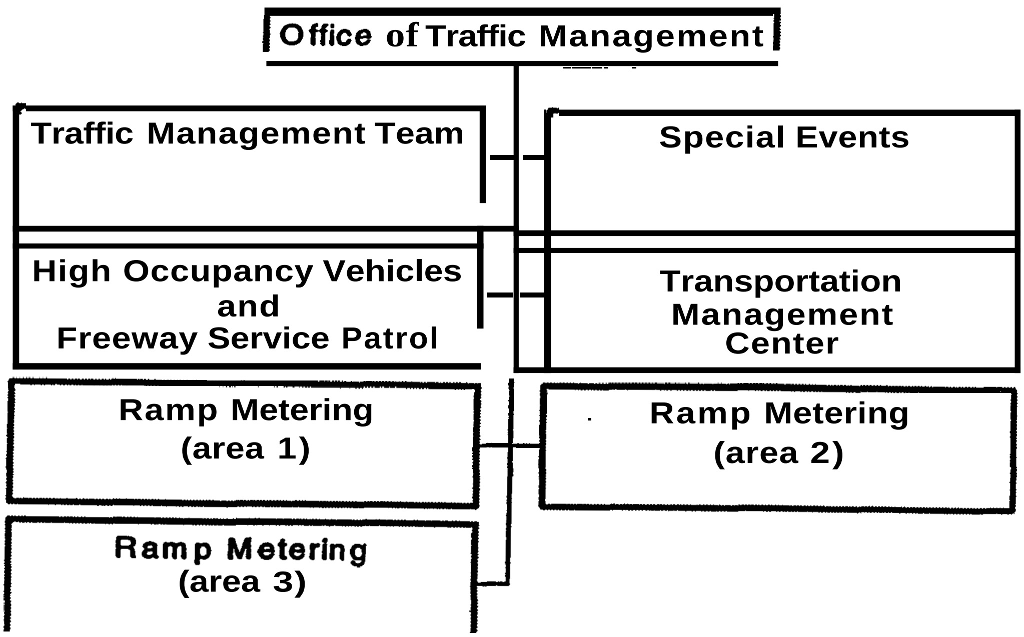


FIGURE 2.2 Organizational Chart–District 7 Office of Traffic Management

All TMCs in California are jointly staffed by Caltrans and CHP employees. As a team, the two departments are able to better coordinate their efforts to manage the state highway system while improving incident response times and sharing resources. To ensure compliance with the Master Plan's objectives, two standing committees were established: Statewide Policy Committee and Local Policy committee. The purpose of the Statewide Policy committee is to develop TMC policies such that the statewide TMC system is efficient and workable. The Local Policy Committee develops policies and procedures that are within the guidelines established by the Statewide Policy Committee and the Master Plan to meet local needs. Each committee consists of management, supervisory, operational, and technical representatives from both Caltrans and CHP.

In the Joint Operational Policy Statement *(General Order 100.43, Annex C)*, Caltrans and CHP agreed to collaborate their efforts and are jointly responsible for incident detection, incident verification, system incident management, operational control of the changeable message signs, and highway advisory radio (HAR) systems. It is still, however, Caltrans' main responsibility to manage the freeway system, while the CHP is primary concerned with fieeway management at the incident scene.

2.2.2 TMC System Elements and Functions

A comprehensive assessment of Caltrans TMC capabilities is included in a PATH report by Lo *et al.* (1993). Eleven specific functions performed at TMCs were listed in the report:

surveillance
provision of information to travelers
arterial signal/ramp metering control
emergency vehicles dispatching
law enforcement
incident management
emergency evacuation/catastrophe plan
special event handling
hazardous material routing
transit scheduling
intermodal coordination

Most Caltrans TMCs, however, only focused on the following five functions: surveillance, ramp metering, incident management, traveler information, and special events handling. Table 2.3 shows a summary of the traffic operations systems elements by district that are primarily employed in carrying out the system functions.

Surveillance: Loop detectors and CCTVs are the most commonly used surveillance methods among the Caltrans TMCs. Over 1, 500 freeway miles are under surveillance with loop detectors. CCTV coverage is rapidly expanding with over 450 cameras currently in operation. In addition, the CHP and private traffic reporters use helicopters to spot congestion and located incidents and provide the information to TMC operators.

Ramp metering: controls access to the freeway mainline. Ramp metering is employed at all Caltrans TMC, although District 7 (Los Angeles) has, by far, the largest system (859 locations). Some metered ramps have HOV by-pass lanes. Metering of freeway connectors is limited to a few critical locations.

Incident management: Incident detection is accomplished through information from CHP officers, FSP drivers, 911 cellular calls and roadside call boxes. This information is first routed to the CHP/CAD system and transmitted to TMC. Currently, there is no implementation of automatic incident detection algorithms based on loop detectors. Incidents are cleared by FSP trucks and rotational tow truck companies. Caltrans districts also employ traffic Management Teams (TMTs). The incident response procedure is not standardized nor documented in all districts. TMTs are usually dispatched for major incidents, when there is damage to the roadway and traffic needs to be diverted for an extended period of time. Severe, multi-vehicle accidents with loss of life are also to likely require dispatching of a TMT unit.

TABLE 2.3. CALTRANS TRAFFIC OPERATIONS SYSTEM ELEMENTS SUMMARY (June 1998)

TRAFFIC OPERATIONS	District												TOTAL
SYSTEM ELEMENTS	1	2	3	4	5	6	7	8	9	10	11	12	
TMC			X	X		X	X	X		X	X	X	8
CHP/CAD			X	X		X	X	X			X	X	7
C C N Cameras	0	3	23	117	1	11	142	70	0	0	14	71	452
Surveillance (dir mi)	0	0	75	212	0	10	748	119	0	14	152	225	1555
Surveillance (stations)	0	0	98	333	0	18	1100	215	0	34	150	310	2258
Ramp Meter Locations	0	0	49	119	1	18	859	120	0	0	171	281	1618
Metered Connectors	0	0	0	11	0	0	21	0	0	0	8	0	40
Ramp Meters--HOV Bypass	0	0	15	35	0	11	349	47	0	0	74	105	636
Call Boxes	21	0	619	3204	451	527	5940	2773	0	553	1663	1018	16769
FSP Coverage (centerl mi)	0	0	47	264	0	10	439	28	0	17	149	96	1050
Traffic Management Teams (TMT)	1	1	2	6	3	2	9	3	1	1	3	3	35
CMS–Fixed	1	8	11	58	1	27	91	26	5	17	34	39	318
CMS–Portable (TMT)	2	5	9	14	9	21	27	11	8	26	23	6	161
HAR–Fixed	2	6	16	10	0	9	10	4	1	3	4	2	67
HAR–Portable	1	2	3	2	0	6	1	1	0	2	1	1	20
HOV Lanes (dir mi)	0	0	15	243	0	0	270	54	0	0	26	154	762

Source: Caltrans

Traveler information: Although all Caltrans TMCs have some means of disseminating trafiic information to travelers, the information and method varies fiom district to district. For example, Sacramento, Fresno, and San Bernardino often provide weather information because many motorists in the area pass through the mountains and Central Valley. Changeable messages signs (CMSs) as well as Highway Advisory Radio (HAR) are also used to disseminate information to the public.

Special events: TMCs are often involved with the planning and implementation of trafiic management schemes for major special events. Fixed and portable HAR and CMS units are used to provide information on the location of special events, road closures and other information.

2.4 Future Directions

Several enhancements are underway in the Caltrans TMCs. Most of the enhancements are concerned with better utilization and interaction of the system elements. For example, in District 12 the system allows all the CMS units, CCTV, and loop detectors to be operated fiom one workstation. In the old system, separate units were required to operate each element (e.g., multiple computers were used to operate the CMSs: one PC controlled 10 CMSs in the south county while another PC was used to change messages on CMSs in the north county. Thus, a TMC operator may now sit down at one computer and handle an incident fiom beginning to end without having to leave his workstation or requiring any assistance. District 12's system automatically records and produces a log of all the activities. These logs are summarized on a daily, weekly, and monthly basis. The type of information recorded includes: number of CMSs used, length of CMS up, and the loops, which were used in providing traffic information. It should be noted that the new system does not allow ramp metering control fiom the TMC; changes must be performed manually in the field.

District 7 TMC is also being upgraded. It would incorporate software for efficient data storage and manipulation, and perform system-wide analysis of fieeway operating conditions based on surveillance data. *Also*, the operator will have control of the CMS's, the CCTVs, and ramp meters fiom his workstation. He will be able to activate or deactivate multiple CMSs at one time, select and display up to two CCTV images on one monitor, and change ramp metering rates on-line. By running on a UNIX platform, the user will be able to simultaneously run multiple programs on the new system. Each workstation will also have two monitors to allow the operator to view more than one screen at any one time. An expert system would recommend appropriate CMS messages to the operator, or alternate routes. The recommended actions will have to be approved by the operators before implemented, according to the policy adopted by the District.

Future developments for TMCs are likely to be in the information dissemination and data processing area. Perhaps the role of TMCs will be to provide a public information resource that the private sector *can* add value to and market to the general population. Currently Maxwell Laboratories get all of the loop detector and CAD data fiom Southern California Districts. TravInfo gets similar data in District 4. The data dissemination would be also provided to institutions and other organizations. Shipping companies have expressed interest in obtaining such information, as well as emergency vehicle dispatch centers. In San Antonio, for example, hospitals receive current traffic reports for dispatching their ambulances. There is an effort toward a "multi-modal" modal transportation center (Henley, 1996) to integrate data collection and data processing across various transportation jurisdictions (e.g., local streets vs. freeways) and with transit agencies, such a bus companies.

According to Jay Bockisch of ITS America, the two most pressing needs for TMCs nationwide are the revision of agency procurement rules and the creation of working algorithms and models. Most state transportation agencies are finding that their procurement rules are not flexible enough to deal with the rapidly changing nature of communication technology, in terms of both upgrading and buying new equipment. In addition, the managers of these contracts may also lack an understanding of how technology works or how to choose it. And even when the hardware is in place or available, the needed algorithms are lacking. Most software currently used by TMCs has been produced in-house for local conditions and has never been subject to rigorous evaluation. There is a need for software to analyze the data fi-om various sources, and for robust simulation models to evaluate the impacts of TMC actions.

CHAPTER 3

DATA SOURCES

Surveillance of and monitoring conditions on the freeway system form the foundation for all other TMC actions. TMCs either directly feed information to support the action, or act as a monitoring tool to evaluate the effectiveness and efficiency of the action. In the following section, each of the current data sources is described and the operations it supports are identified.

3.1 Loop detectors

Loop detectors are normally placed in each freeway lane, often at **1/3** or **1/2** mile spacing to automatically record vehicle counts and occupancy (the portion of time that the detector is occupied). Vehicle speeds are estimated from the occupancy and assumed average vehicle length. Double loop detectors, or speed-traps (spaced about **14 ft** apart) permit the direct measurement of speeds.

The sensors are embedded in the roadway and connected to a detector station (typically a 170 signal controller). Each controller processes the data locally into **30** sec average values and then transmits it back to the TMC via leased phone lines. The data is then displayed graphically on a freeway map where the color **of** the light represents a particular traffic flow status; traffic flow status is based on vehicle loop occupancy.

The reliability and accuracy of loop detector data is the major issue facing TMC operators. Loops placed in the freeway pavement are susceptible to many problems (e.g. too many splices, bad connection) and are very sensitive instruments. They also require intensive maintenance. Loop repair could be difficult since it requires freeway lane closures. Thus, often a sizeable proportion of loops is not working properly, reducing the effectiveness **of** the surveillance system

3.2 Closed Circuit Television (CCTV)

Closed-circuit television (CCTV) cameras are used for freeway surveillance and incident verification. They provide law enforcement officials a means for verifying incidents from the TMC and deciding on the proper response (i.e. tow truck, ambulance, fire truck) in a timely manner. **As** Kin **Ho,** the CHP's TMC supervisor, remarked, "Technically, an officer sitting here in Oakland looking at an image of an incident in San Jose -- 50 miles away -- can be the first officer on the scene" (MTC Transactions October/November **1996).** CCTVs provide a reliable bird's eye view of the area, and are especially useful in screening out false alarms, i.e., warnings generated by the loop surveillance system when no incident has occurred. Without CCTVs, the verification process is prolonged because a CHP officeror other official must arrive on the scene before proper response is taken. It should be noted that the CHP in District **7** requires that incidents be verified on the scene and that they have the exclusive responsibility for managing incidents. Thus, use of CCTV does not affect the duration of the incident. In order to improve the effectiveness of CCTV and reduce the incident duration, current verification policies need to be changed.

The CCTV system primarily supports the function of incident detection and verification. However, it can be also used for the following fieeway management functions **(JHK, 1993):** monitoring traffic movements on the mainline, HOV lanes, and the entrance/exit ramps; verifying proper operations of TMC field devices such as CMS, and observing weather and hazardous conditions.). Currently, none of the TMCs utilize their system to perform any law enforcement activities nor do they have plans to do **so.**

It is essential that the CCTV cameras are able to produce a picture of sufficient clarity for incident verification; operators should be able to identify vehicle types, view the full roadway (both inbound and outbound directions), and **discern** particular details. In the past, monochrome cameras provided better resolution under low-light level conditions, but recent advances in video image processing technologies have improved the performance of color video cameras. Table **3.1** below shows a comparison of features between monochrome and color cameras. Monochrome cameras require one-tenth the faceplate illumination level to achieve a full video image and cost one-third **as** much **as** color cameras. Although monochrome cameras also have a higher resolution, color cameras are predominantly used in TMCs.

Table 3-1: Monochrome vs. Color Cameras

Feature	Camera Type	
	MONOCHROME	COLOR
Lighting for full video	**0.13** foot-candles	**1.3** foot-candles
Horizontal Resolution	**580** TV lies	**460** TV lines
Vertical Resolution	**350** TV lines	**350** TV lines
Cost per Camera	**$750**	**$2,450**

Source: JHK & Associates. *CCTV* ***Design Requirements Technical Memorandum: San Francisco*** *Bay* ***Area Traffic Operations System," preped for Caltrans District 4, Draft Document No. 036, July 1993.***

Another important feature (independent of the camera type) to consider is the camera's field-of-view, which is determined by the length of a lens. **As** the focal length of a lens decreases, the wider the field-of-view becomes and the more details are shown. Camera lenses with longer focal lengths will provide views of distant targets. Two methods to increase the effective focal length of the lens include placing extenders between the camera and the lens using a larger format lens on a smaller format camera. Most CCTVs can provide a field-of-view of up to five lanes wide and several hundred feet in length **(JHK, 1993).**

3.3 CHP/CAD System (Call boxes, 911 Cellular, Public entities)

Currently, the California Highway Patrol's Computer Aided Dispatch (CHP/CAD) system serves as the most important source of information on fieeway incidents. Eighty percent of the information used in the Bay Area's TravInfo comes fiom the CAD. The CAD *system* receives incident information fom CHP officers and fiom the following detection sources:

(1) **Call boxes:** Call **boxes** are installed on the right shoulder at about 1/4 mile spacing. **They** are wireless cellular phones utilizing solar panels atop 14-foot poles to recharge the batteries. Each call **box has** a unique identification number which permits the operator to know the location from which the call is made, and a built-in detection *system* to notify the CHP if the unit **has** failed (or vn)— Call **boxes** are used by motorists to request **assistance** and report incidents.

(2) **Cellular 911 calls:** When motorists use their cellular phone to report fieeway incidents, these calls are directly routed to the CAD center. **These calls** are referred to **as** MO911 **calls** and *can* be identified by the caller's name and phone number, which are automatically registered in the CAD system.

(3) **Public Entities' calls:** Personnel fiom public organizations (e.g., Caltrans maintenance crews, **local** police departments, fire departments, **county** medical services, etc) often report fieeway incidents to the CAD center. These **calls** are usually made via phone **lines** (hot numbers).

(4) **Other** ***calls:*** Citizens *can* report fieeway incidents by dialing 911 on regular phones. **These** non-cellular 911 calls are first routed to the precinct in which the call is made. The precinct then reroutes calls about fieeway incidents to the CAD center. Citizen band (CB) calls are routed to the CAD center through their corresponding **radio** communications center, but **only** those **calls** fiom tow trucks are identified **as** CB **calls** in the CAD **database.** Other CB calls (e.g., fiom **tractor trailers**, other commercial vehicles or private two-way communications) are **also** not identified **as** such in the CAD *system.*

Phone operators who answer calls fiom the CHP and other sources record the information directly into a computerized **database** using a **standardized** format (CAD log.) The entered information includes: the time and source of the *call,* incident location, incident **type,** vehicle description, CHP/FSP or **tow** truck arrival and departure.

3.4 Freeway Service Patrol (FSP) Units

The Freeway Service Patrol (FSP) is a traffic management strategy which helps remove disabled motorist fiom the fieeway either by either assisting in the field (supplying a gallon of gasoline, changing a flat tire, recharging a dead battery), or towing the vehicle to a designated drop location **off** the freeway. The program, which is a cooperative effort between the CHP, Caltrans, and the local metropolitan transportation organization, is intended to augment the call box program. **A** special team of tow truck drivers continuously patrol selected fieeway segments, usually during the morning and afternoon peak hours (5:30 a.m. - 9:30 a.m. and 3 p.m. - 7 p.m.[1]) on weekdays (excluding specified holidays).

FSP's communication system serves as an interface between the CHP/CAD and Caltrans' TMC (Figure 3.1). The tow truck driver uses it to inform the dispatcher of an incident on the fieeway that may require additional assistance while the dispatcher uses it to send a tow truck to the incident site. The system utilizes the following:

- ***Voice Radio***: communication between FSP drivers and dispatchers
- ***CHP CAD system:*** California Highway Patrol's computer-aided dispatching system
- ***Microwave CAD system (MicroCAD)***: handles all data transmission between vehicles and FSP dispatchers.
- ***Automatic Vehicle Locator (AVL)***: monitors the location of each tow truck
- ***Mobile Data Terminal (MDT)***: allows transmission of text messages between tow truck drivers and FSP dispatchers.
- ***Management Reporting System (MRS)***: software to summarize activities of tow trucks.

Data such as the truck's speed, direction, and location can be obtained fiom the AVL subsystem. By knowing each truck's location, dispatchers are able to better manage the fleet and assign the nearest available tow truck to the incident site. In District 4, the speeds of the FSP trucks are displayed on a monitor in real-time; data is updated either every one mile traveled (or every three minutes). No reports are generated fiom this information.

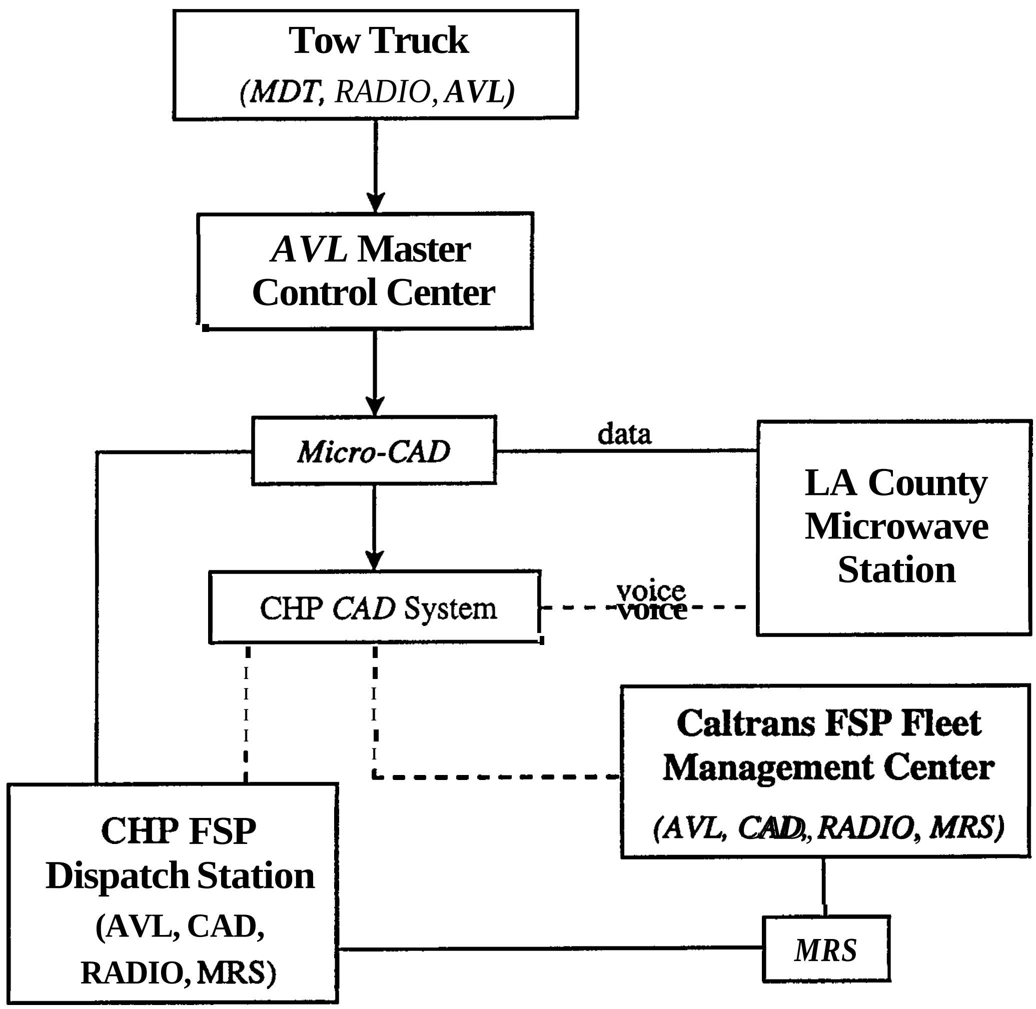
Currently, the TMC does not use the speed data received fiom the FSP trucks. The data is considered unreliable since the trucks may stop to assist disabled vehicles. Research is currently being conducted to determine how data fiom FSP trucks may be used in combination with loop data to estimate average travel speeds (Moore, 1997). When drivers are not attending to incidents and are cruising along their assigned beats, they can operate as probe vehicles. To mark the *start* of this period, FSP drivers can report their status when operating as probe vehicles. However, because FSP drivers are contractors, their labor agreements do not include this activity and will need to be amended it this method is adopted. Another issue which may restrict the use of the FSP truck speed data, is that the trucks do not necessarily match the ambient speed of traffic. Also, it is unclear how the probe vehicle data will be integrated with the loop detector data.

3.5 Airborne Reports

In the San Francisco Bay Area (Caltrans District 4), airborne reports are provided by Metro Networks during the morning and afternoon peak periods. Reporters in aircraft and helicopters fly over the Bay Area reporting on the traffic conditions. The information s entered by the operators into the TravInfo database. No verification of the information is required.

[1] The times are only approximate and may vary between areas.

Figure 3.1: Interface Between the CHP Communication System and Caltrans Traffic Management Center



3.6 Emerging Technologies for Data Acquisition

This section describes some of the emerging data sources which would become available for use at TMCS.

3.6.1 Satellite data

Since the 1970s, a number of satellites have been launched into orbit to provide global coverage of the earth. Information collected by the satellites provide forest inventory data as well as a means to monitor wildlife and to identify water pollution. Currently, research is being conducted on the feasibility of using satellite data for traffic surveillance. Satellite imagery **is** equivalent to snapshots taken over a large area at an instant in time. Measures of density can be calculated fiom the photos. Loop detectors placed in the ground count the number of vehicles passing a point in space across a time period and yield traffic volumes and occupancy times from which speed can be estimated.

It was shown that 1-m resolution was sufficient to count and classi vehicles at 90 percent accuracy level of highway segments tested in the Columbus, Ohio **(Merry, et** al. 1996). These images, however, were only aerial photographs which were scanned to produce the equivalent of 1-m ground resolution digital images. *Also,* the simulated data were produced under specific lighting occasions and required significant image processing work (i.e. maximizing contrast between the vehicles and pavement and edge enhancement of vehicle edges). Before satellite imagery *can* become feasible for traffic data collection, a more automated process which requires less human intervention as well as works under more diverse environmental conditions would first need to be established (Merry et. al., 1996).

3.6.2 Video Image Processing

Vehicle detection through video cameras offer several advantages over loop detectors. Since video cameras are mounted on poles, it *causes* little traffic disruption and are easily moved. In addition to the commonly collected flow and occupancy data from loop detectors, video monitoring systems are also capable of estimating vehicle classifications, link travel times, vehicle trajectories, and queue lengths at urban intersections. The basic steps of video image processing include *(Hartman,* 1996): capturing the image via camera system; converting the signal from analog to **digital** form; and processig the image (eliminating unwanted noise and enhancing edges and contrast). This equipment is either located adjacent to the cameras or centralized at the TMC. Operators may then perform further computations and analysis back at the TMC. Most of the deployed video image processing **(VIP)** systems are in Europe and Japan. In the **US,** operational **VIPs** have been installed in Atlanta and Minneapolis.

A number of methods have been developed to process video images. One such process detects vehicles by "subtracting" the incoming background image from the current background estimate. ***An*** example of this approach is the Image Processing for Automatic Computer Traffic Surveillance (IMPACTS) system. This method, however, does not work well under congested conditions or lighting conditions which *cast* strong shadows. The detection strategy currently used in Belgium and France requires that vehicles appearing in the video be continuously identified and tracked in each frame. Another related approach attempts to only track sub-features of the object (i.e. part of the rear bumper, fi-ont tires) since features on a vehicle **wll** always move together **(Malik,** 1997). The trajectory of each vehicle can be plotted with each update of the vehicle's position. Back at the TMC, vehicles appearing at two or more camera sites are matched and a record of the route taken by the vehicle through the fieeway system is constructed. From these records, the TMC can compute origin/destination (O/D) counts as well as link travel times. Typically, only a subset of the vehicles appearing in the video are matched.

Video image processing, although not widely used at TMCs, can be a feasible source of data to help monitor and control traffic and detect incidents. Data may be collected manually or automatically in conjunction with the loop detector data. Because VIP has not been fully developed and subject to vandalism and excessive shaking, there are no plans to use it extensively (Esquenazi, 1997).

3.63 Electronic Toll Collection

Electronic toll collection (ETC) was first introduced on one lane of the Carquinez Bridge in August 1997, allowing vehicles to pay their toll without stopping at a toll booth. As the vehicles pass through the ETC equipped toll lane, the system reads the small plastic transponder mounted to the inside of the windshield and automatically deducts a toll fiom a prepaid amount. These tags may be purchased fiom a customer service center which was set up primarily to issue tags, manage customer accounts, and handle customer inquires. The center maintains a list of valid tags, transmits this information to an on-site computer, as well as collects the transaction information taking place on each lane. Since each transponder has an individual code, the system has the capability of tracking individual vehicles. By the end of 1999, all seven Caltrans toll bridges in the Bay Area will be equipped with an electronic toll collection (ETC) system. By detecting the entrance of a vehicle on one bridge and the entrance of the same vehicle on a different bridge, link travel time estimates may be calculated. In addition, O/D tables may also be constructed using the information fiom the ETC system.

CHAPTER 4

DATA UTILIZATION IN SPECIFIC TMC FUNCTIONS

The data sources used to support TMC operations were presented in the previous section. In this section, the data sources used for each of the TMC operations are identified. The flow of data is presented next. Finally, the measure of performance(s) employed to evaluate the functions are discussed.

4.1 Incident Management

There are three parts to the incident detection and response: data sources, verification/ assessment, and incident response. Figure 4.1 shows the flow of incident data through these stages as envisioned by Caltrans District 4 engineers. The dotted lines represent data flows and the solid lines indicate actions.

4.1.1 Data sources

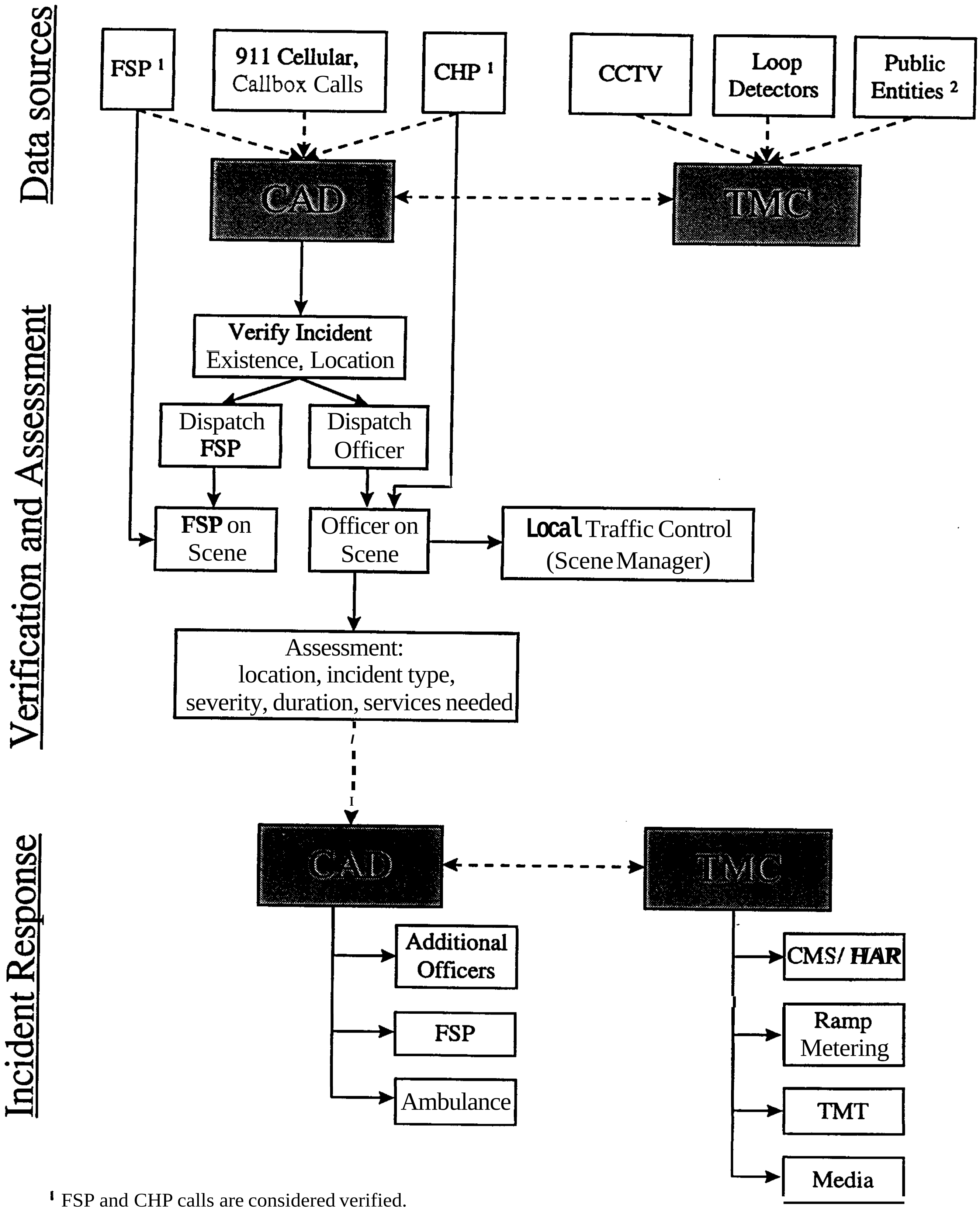
There are two types of TMC data sources. The first type consists of those that are first routed through the CHP/CAD center, while the second type goes directly to the TMC. The CAD detection depends primarily on reports received fiom CHP officers, FSP drivers, and the public via 911 cellular calls and call boxes along the highway. The TMC also receives reports from Caltrans roadside maintenance crews. A data link exists between the TMC and the CHP/CAD which allows the TMC staff to monitor the feed that comes out of the CAD center. The presence of CHP personnel at the TMC ensures that the CAD center receives any incident related information at the TMC in a timely manner.

Several incident detection algorithms have been developed to detect the occurrence of an incident based on loop detector data. An incident is detected when there is a significant change in the traffic pattern. The system then triggers a warning in the control center. Unfortunately, present detection algorithms often are unable to reliably detect incidents, or produce too many false alarms. Many TMC operators have had bad experiences with the "California" algorithm and its variations which have caused them to mistrust the algorithm's usefulness, and they do not rely on loop detectors to identify incidents. The loop detector data are often used in the incident verification stage.

4.1.2 Flow of data

Once an incident has been reported to the CAD center, the incident must be verified by trained staff (e.g. CHP officers, FSP drivers, or Caltrans maintenance crews). Figure 4.1 shows the two stages in this process. If the incident report is fiom the public, the CAD operator collects information on incident location, incident type and incident severity. Incident location data includes road and direction of the incident. Incident type data relates to its nature. This is particularly important because the CHP is required to serve as a scene manager for all injury accidents, while the local fire department serves as the scene manager for any type of chemical spill. For incidents such as vehicle stalls, the assistance of the FSP is usually sufficient. Information related to the severity of the incident, i.e. number of lanes blocked, are also necessary data.

Figure 4.1: Data in Incident Detection and Response in District 4



[1] FSP and CHP calls are considered verified.
[2] Public entity calls are considered verified if at the scene.

At this stage, the location of the reported incident is the most important data. An officer is dispatched to the scene to confirm the location of the incident. (If it is an FSP or CHP that makes the initial report, then, by default, the aforementioned steps are bypassed.) At the scene, the officer reassesses the incident type and severity. This newly assessed data is passed along to the CAD, and an appropriate course of action is decided upon. This is also the first opportunity to estimate the duration of the incident

The CHP officer serves as the scene manager, directing local traffic. If he deems it necessary, he may request additional officers to assist in local traffic control, FSP trucks to clear the road, and an ambulance or coroner to attend to injured persons. Requests are relayed to the CAD Center and carried out fiom there. It should be noted that if a coroner is needed, the minimum duration of such an incident is about two hours.

Following the incident verification and assessment, the TMC uses various traffic management techniques to avoid congestion built up at the incident location. These involve activating CMSes and/or HAR to alert the public, and/or activating ramp metering along the corridor. In cases of severe incidents (e.g. motorist death, permanent damage to the roadway), the TMC may dispatch a Caltrans response team to close off the road and divert traffic away fiom the site, using portable message signs. The TMC will also inform the media of the incident. In many cases, however, the media have their own sources and sometimes learn of incidents before the CHP or TMC.

4.1.3 Measures of Performance

Incident response and clearance times are typically used to assess the effectiveness of the incident management program. For example, FSP beats and number of tow trucks are determined such as to achieve an average of 10 minutes response time. Procedures to automatically evaluate the effectiveness of incident management on the traffic stream are not currently available. The detection rate and false alarm rate are typically used for performance measures regarding automatic incident detection algorithms.

4.2 Traffic Information Dissemination

One of the primary TMC goals to disseminate information on current traflic conditions to the traveling public. TMC operators analyze and distribute timely travel information to travelers such that they are able to *make* more informed decisions about their departure time or route choice. In most districts, information about road conditions and incidents are commonly disseminated to the public via CMSes, voice recorded messages for broadcast on HAR, and notification to the media and local cities. In District 4, however, TravInfo, a Traveler Information Center (TIC), gathers, organizes, and disseminates traveler information for the nine-county region in the Bay *Area.* TravInfo operators work closely with the TMC operators for data to provide reports on traffic conditions on the fieeways, bridges, and major roads, information on public transit schedules and routes, as well as information on ridesharing, park-and ride lots, bikeways, and van and taxi services for disabled travelers.

4.2.1 Data sources

The data sources for traffic information dissemination are S i a r to those for incident management. They include: CAD data, CCTVs, aerial surveillance, loop detectors, cellular calls, and calls from Caltrans field units. Table **4.1** (below) summarizes the type and source of information used by the TravInfo/TIC system in Caltrans District **4.** The content of the table is also valid for most TMCs, dependent on the availabiity of the source. Note that the sources, which are shaded in the Table, are used less often than the unshaded ones.

Table 4-1: Summary of TIC Information Type and Source

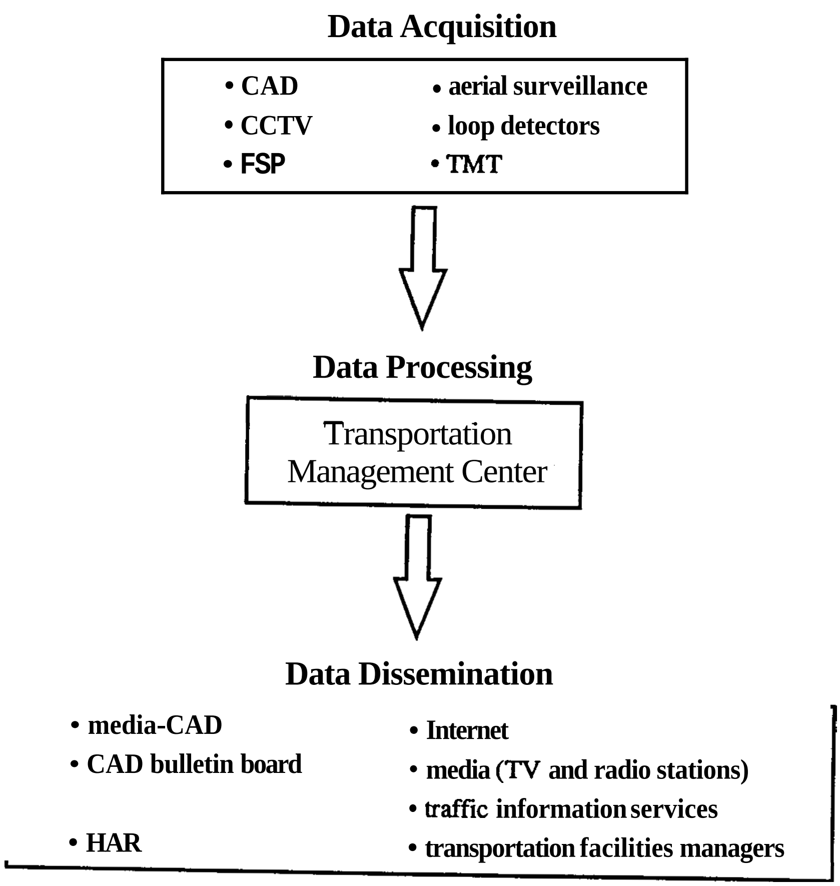
TYPE OF INFORMATION	SOURCE
Incidents	CHP Computer Aided Dispatch System
Speed, location, heading, vehicle ID	Freeway Service Patrol Automated Vehicle Location System
Speed, volume, congestion	Caltrans mini-Traffic Operations System (TOS)
Incident verification, congestion	Closed Circuit Television camera
Incidents, congestion, delay	Airbome reports (Metro Networks)
Routes, schedules, stops	Regional Transit Database (MTC)
Incidents, congestion, delay	Cellular callers
Speed, congestion, incidents, roadway closures, maintenance	California State Automobile Association and Caltrans fleet dispatches
Delays, incidents	Transit Agencies
Weather data	Internet
Major events, lane closures, roadwork, incident, parking, congestion	Event operators and Local agencies
Events, parking	County Offices of Public Information
Incident, closures, events	City Police Agencies
Delays, conditions, travel advisories, parking	Airport Towers and Offices of Public Information
Road closures due to storm damage	California Dept. of Emergency Services

4.2.2 Data Flow

All TMCs are directly linked to the CHP/CAD system. Currently, each TMC operator sits in front of a CAD terminal and continuously monitors it for incidents that pertain to their region. The operator interprets the data and decides whether the incident is of relevance based on its significance and impact on the roadway. In District **4,** if the information is of interest, the operator manually inputs the data from the CAD into the TravInfo/TIC system, specifying the location, description, impact, and time of incident. This process takes approximately **2-3** minutes. Afterwards, the operator records the incident messages on the traveler advisory telephone system's (TATS) voice processing system. In general, verification of the incident is not required and CAD information is assumed to be valid. It should be noted that part of the process is automated in District **4.** Loop detector data and CCTV images are automatically transmitted to the TMC, which is then transmitted to the TIC.

TMC operators in District **4** are also responsible for updating the database as information changes. Operators at other districts take similar action when relevant information is identified. For example, operators may activate or deactivate CMSes or record a message for broadcast via HAR. At present, no prescribed course **of** action exists between the TMCs. Figure **4.2** below shows the general flow of information to the public.

Figure 4.2: Flow of Traffic Information



The most common methods used to disseminate TMC-generated traffic information to the public include:

- media- CAD[1] information available on the Internet, to the radio and TV stations
- Average speed data available on the Internet
- TMC displays information on CMSes
- TMC faxes information to subscribes, TV networks, and media
- TMC posts closures on CAD bulletin board

Loop detector data (once every 30 seconds) are used by traffic reporting services and other private entities such as Maxwell Laboratories in Southern California to provide information on traflic conditions (speeds at the detector locations) via the Internet WWW. The data is delivered real-time and automatically with approximately a minute delay (due to processig time). Other methods of disseminating information in the near future include cable channels and smart kiosks.

4.2.3 Measures of Performance

Ideally, the TMC would be able to measure the timeliness and accuracy of the information. Also, the benefits (in terms of delay or travel time reduction) as a result of disseminating traffic information. However, this is difficult to quantify. None of the TMCs interviewed had existing performance measures for this operation.

4.3 Ramp Metering

Ramp meters in California are initiated either by a time-of-day schedule or traflic responsive (i.e. rates are determined by prevailing volumes and occupancies on the roadway). Ramp meters are controlled on site by a 170 signal controller.

4.3.1 Data sources

The decision for metering a specific ramp is based on analysis of data collected on the freeway mainline and the ramps. The analysis is performed off-line using manual techniques or computer models. The ramp metering rates are set up by the ramp metering group in each District's office of traffic operations. Normally, ramp metering rates are changed in the field, and not remotely by the TMC operators.

Loop detector data in the vicinity of metered ramps (on-ramp, off-ramp, and main lane volumes, and occupancy) are sent from the 170 controllers to the TMC every 30 seconds and are kept for 36 hours real-time. Five minute data, or ten cycles of 30-second data combined, are stored for 4 days in real-time. Both the 30-second data and the 5-minute data are then stored indefinitely on tapes. Data for the ramps are kept for only about a year.

---

[1] The media-CAD filters out confidential information before disseminating it to the public.

4.3.2 Flow of data

Fixed-Time Metering: The meters are *set* up to meter by a time-of-day schedule (e.g. *6* am to 9 am, 3 pm to *6* pm). **A** maximum of **15** metering rates, which are tailored to each location, are available at each controller. Thus, adjacent meters do not necessarily have the same **15** rate codes. The rates increase linearly. If the conditions do not *call* for metering, the signal heads **will** rest in green (for meters *set* up on the time of day schedule), and *can* change to a cycling mode at any time. *An* end-of-queue detector is placed at the entrance of the on-ramp to determine possible queue spillovers to the local streets. In District **7,** if such a *case* occurs, the ramp meter is programmed to "green ball," allowing the vehicles to enter the freeway. However, in District 11, queues are allowed to build on the on-ramps.

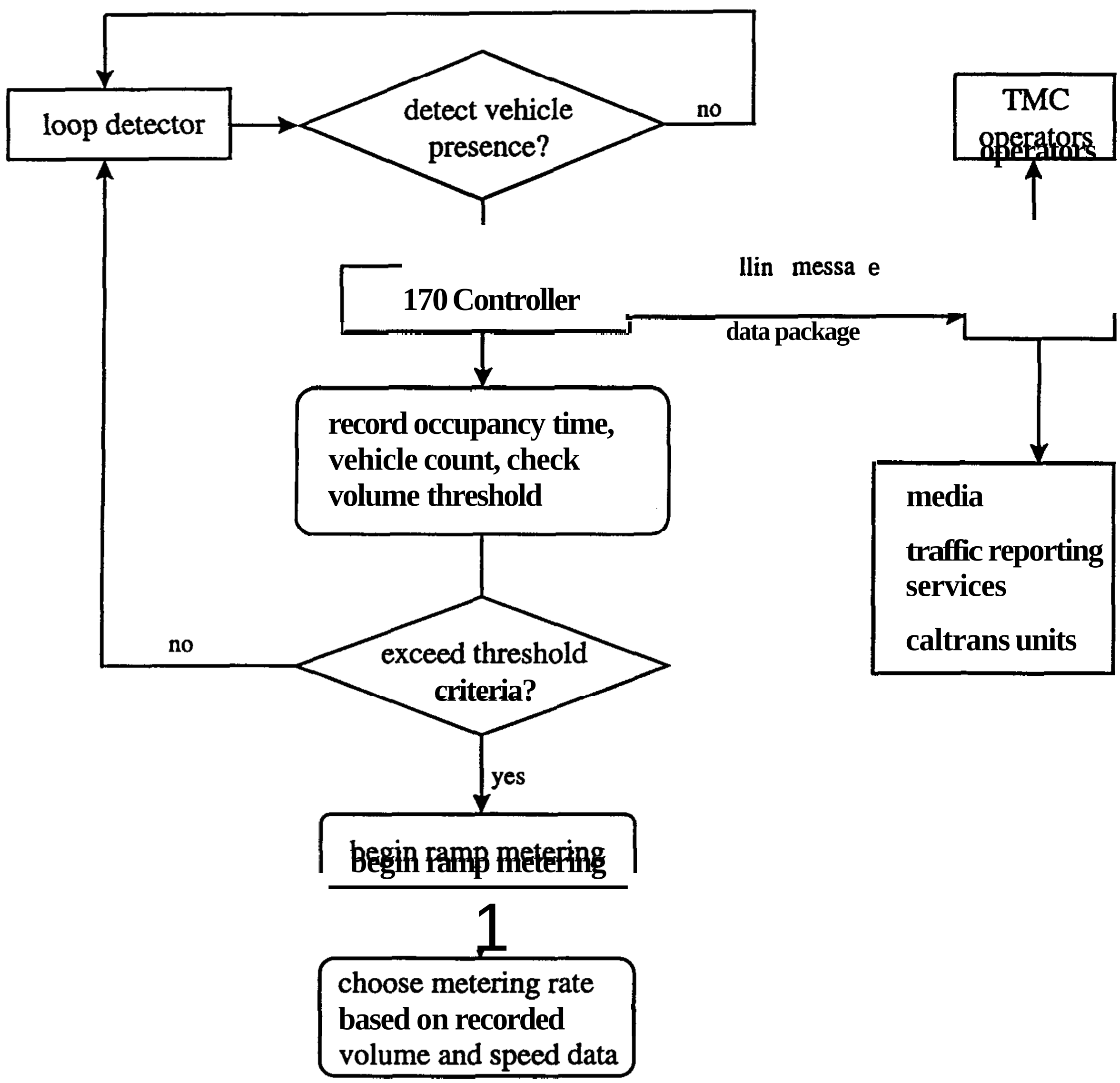
Traffic responsive metering: District **7** has also implemented local traflic responsive metering. When the volume on the main lane **has** reached a pre-set threshold, traffic responsive meters are activated (Figure **4.3.**) If the traflic condition allows the metering rate to be less restrictive (i.e. if the traflic is light enough), it will over-ride the preset time of day metering rate. Local mainline responsive **runs** in the background and will not *set* the metering rate to be more restrictive than the metering rate *set* by the time of day schedule. Currently, ramps are controlled locally; algorithms to coordinate corridor-wide ramp metering have not yet been implemented.

4.3.3 Measures of performance

Vehicle throughput and delay along the specific freeway corridor are the **performance** measures typically used for assessing the need and effectiveness of ramp metering. However, no formal "before" and "after" studies are performed following the installation or changes in ramp metering, and there is no mechanism in the TMC to quantitatively assess the performance of ramp control. TMC staff relies on qualitative observations to assess performance.

In general, the operation of a newly installed ramp meter is closely monitored for about two weeks following activation. Field observation **of** mainline volumes and ramp queues are made, and the metering rates are adjusted **as** appropriate. Thereafter, adjustments are made only under compelling circumstances due to a shortage in staff. The TMC responds reactively and relies on the public for feedback since they are usually the first to call and complain when they perceive a problem exit (i.e. when they think something isn't right). *Also,* the TMC receives feedback fiom maintenance groups in the field. Currently, the system will not allow operators to change metering rates, but will allow operators to turn individual ramp meters on or off. In the future, the metering rate *can* be changed on-line.

FIGURE 4.3 DATA FLOW FOR TRAFFIC RESPONSIVE RAMP METERING



4.4 Special Events

Special events include occasions, which generate large enough crowds to and fiom a site that transportation facilities are severely impacted. Examples include ball games, state fairs, auto races, parades, demonstrations, concerts as well as planned maintenance and construction lane closures. Caltrans Traffic Management Teams[2] (TMT) provide assistance for special events which impact the State highway system and incidents which cause extensive traflic backups. They help coordinate efforts between the CHP (ramp closures), Caltrans (signage), local city or county law enforcement (local routes), public works department, transit agencies, andor event sponsors and develop a traflic management plan. The plan generally includes signing, traffic control, and command-post elements, but *can* also employ other measures such as ramp-metering, signal-timing modification, and HAR broadcasts.

The TMC's main goal is to inform the public of the special event, usually through the **use** of CMSes. Detour directions are rarely given, except if the detour is to from one parallel fieeway to another. TMC rely heavily on the advisory aspect rather than controlling the ramp metering rates. Other methods, which the TMC uses to disseminate information to the public, include CHP bulletin board, HAR, and the media (i.e. news radio).

4.4.1 Data sources

Type of information acquired before handling a special event include:

- ***start*** and end times of the event;
- event type;
- capacity of the roadway;
- site characteristics;
- expected number of people attending the event;
- available transportation modes; and
- alternate routes available.

Most of the data described above comes fiom the event organizers and the operators' past experience. In addition, meetings are set up leading to the event between Caltrans and the main players (i.e. the vendors and ticket sales) to try to identify where the people are geographically located and how many people to expect. These meetings allow the vendors to share **their** experience from past years. In District 7, volume data from records and tubes counts on fieeways are also sometimes taken for usage in the handling of a special event.

Currently, the TMT in District **4** is in the process of establishing a **database** which would record information such as the location and time of the planned activities as well as the **size of** the crowd attracted. The database will also contain information on construction and maintenance work such as the project's schedule.

---

[2] **The TMT is also responsible for managing traffic around the scene of an incident.**

4.4.2 Flow of data

Event sponsors are not required to inform the TMT about planned special events, but they often go to the local police seeking assistance with traffic coordination. Event information is then passed onto the TMT who helps plan and implement traffic management schemes. The TMT uses both fixed and changeable message signs to help manage traflic at special events. CMSes are sometimes used for pre-event-warning, alternate-route, or informational purposes to prevent end-of-queue accidents as well as encourage voluntary detouring of traffic. The signs can help balance traffic volumes on the various routes to the special event. As a result, the end-of-queue is monitored. When the volume of traffic on one approach becomes too heavy, the TMC operator changes the message on the CMS accordingly.

4.4.3 Measures of performance

Past experience is most helpful for predicting the behavior of these events (i.e. duration of planned events) while consulting vendors help predict the number of participants expected. After the occurrence of the special event, the traffic response team fills out a critique form which documents the specifics of the events, time of day, traffic management plan in place/used, how many lanes were blocked, agencies involved, and any delay that was caused by the traffic on the fieeway mainline.

A more formal critique is sometimes prepared in a memo or report format, which includes recommendations for improving future response. The TMT also meet regularly before and after major special events to discuss the traffic management plan. The success of the plan is determined by the overall performance and is dependent on all the parties involved in the coordination effort, the amount of congestion developed, and the limitations of the given system (bounded by capacity). There are, however, no specific rules or standards for evaluating the performance of the handling of the special event. It is difficult to quantify the level of effectiveness and thus only estimates of the delay reduction are used.

4.5 Changeable Message Signs

Changeable message signs (CMSs) are traffic control devices used to manage the traffic impacts caused by major incidents, special events, or highway construction/maintenance activities. CMSs help to reduce traffic congestion and delay and improve motorist safety by providing motorists with real-time highway related information. Typically, these signs display early warning, alternative-route signing, and informational signing to the traveling public. This type of information enables motorists to become aware of the approaching situation so that they may adjust their driving habits or choose an alternate route to bypass the bottleneck. In some cases, CMSs are used to guide and inform motorists, both visitors and local traffic, to the correct access points or to display fieeway speeds ahead. Both Caltrans Districts 4 and 7 have adopted the policy of activating CMSs only during an incident, but other Districts use them for planned events.

There are two types of CMSs available for use: portable and permanently installed. The portable CMSs are usually truck or trailer-mounted and can be transported to specific locations. For example, a portable CMS is moved to a congested area (e.g. parade, holiday traflic congestion at a bridge, a major accident) to display an advisory message to the motorists. Use of the permanently installed

CMSs, on the other hand, is dependent on their location. Thus, some fixed CMSs are used more often than others. Messages on both types of CMSs are changed based on varying traffic conditions. Most of the fixed CMSs *can* be remotely controlled and operated fiom the TMC while the sign messages displayed on portable CMSs are changed on-site.

Typically CMSs display what has happened and where the problem is but do not necessarily recommend an action to the motorist, letting the motorist decide what to do. If a detour is suggested, it will most likely be a detour from a state highway to another state highway. Traffic diversion onto local streets is usually avoided. Messages must also make *sense* no matter which message is read first.

Normally, for a single special event, two CMSs are used (one in each direction) to advise the motorist plus an additional one or two portable CMSs to warn the motorists about the traffic conditions. Thus, at least three or four CMSs are used for a special event.

4.5.1 Data Sources

It is important that CMSs displays are reliable and accurate because the highway agency will lose credibility if the information is erroneous. Once motorists lose confidence in the system, they will not respond appropriately in the future. Data sources Caltrans **TMCs** use for their CMS system primarily include CAD and CCTVs. Incident response teams out in the field will sometimes call into the TMC to provide information. The type of information acquired before updating a message include:

location of incident/planned event
nature of incident (e.g. auto accident, smoke, high winds)
type of special event (e.g. concert, ball game)
time of special event and expected number of people

4.5.2 Flow of Data

The TMC is responsible for handling all requests for TMT assistance. Upon evaluation of the request, when necessary, the TMC staff notifies/dispatches the appropriate TMT members. The TMT and TMC work closely to coordinate all work with respect to activating portable/permanent CMSs. CHP officers and maintenance staff in the field (e.g. to close a lane) may sometimes request to have a CMS activated or a CMS message changed.

Computer algorithms are not used to process data; rather, TMT staff members use past experience **as** the basis for their decision making process. Most of the portable CMSs cannot be operated remotely and require a person to be physically on-site to change the sign's message. **A** traffic engineer or a person familiar with the signing requirements usually enters the messages. On the other hand, all the fixed CMSs are controlled remotely from the TMC. The operator **has** the capability of selecting a message from the message library. The messages *can* be classied into the following categories:

End of queue protection (e.g. prepare to stop **flagman** ahead, speed 25 mph next 1 mile)
Alternate detour routing (e.g. all traffic must exit, fieeway closed, use Frontage Road)
Bridge/Tunnel closures (e.g. Bay Bridge closed, **use** San Mateo Bridge)
Specific location closures (e.g. Devils Slide closed, use Hwy 92)

Special events (e.g. air show parking, use next exit)
Miscellaneous (e.g. right arrow; dense fog ahead, no passing; wet oil ahead, keep left)

4.5.3 Measures of Performance

The TMC keeps a record of the use of the CMSs. Information recorded include location and time of use, message(s) employed, party which requested the activation of the CMS, and if the message was changed, the party which requested the change. The TMC may receive calls from the public regarding misguiding/confusing messages. The TMC responds to and records these calls. The TMCs do not have a method of verifying the status of a CMS unless a CCTV was placed in the same area. The system does keep track of which signs are still active. The use of portable CMSs is recorded on a log sheet. The information includes the location of the CMS, messages displayed, and the times each message was turned on and off

The effectiveness of a CMS sign depends on how quickly a message is put up and how accurate the message is. Currently, there is no mechanism to evaluate the CMS effectiveness as a traffic management or information tool.

CHAPTER 5

CONCLUSIONS

5.1 Summary of the Study Findings

TMCs are an important means for managing the transportation system by collecting information in a centralized location and developing coordinated action plans. However, much of the investment is in real-time data collection. Loop detector and ramp metering data are continuously being collected. Little investment has been made for off-line applications (e.g., data analysis for predicting traffic growth). According to TMC staff members, much of this data are stored in the computer system or archived unanalyzed. With the limited manpower and budget, priority is given to overseeing the operation of the existing system rather than to analyzing the data for trends.

Improved software and hardware will permit TMC operators to more efficiently manage the system. The new expert systems being implemented at TMC Caltrans Districts 7 and **12** emphasize centralized operations, ***so*** the operators will have access to all system elements from a single workstation. The new software system is more intelligent than the existing ones and *can* potentially reduce the amount **of** human intervention needed. It is expected that the system will be more automated ***so*** that it *can* analyze and interpret the data and recommend an action to the TMC operator.

Maintenance and integration of the traffic operation system elements is an important aspect for TMC operation. Loop detector data are subject to error, because of malfunctioning detectors. Most TMCs do not have the manpower available for systematically checking and maintaining the detector infrastructure. Thus, often the data collected and the information displayed on traffic maps are not accurate or reliable. The use and importance of CCTVs were emphasii during the TMC visit to District 7. Although CCTVs provide valuable information, the costs **of** purchasing and installing them *can* be prohibitively high. Other emerging data sources (e.g., electronic toll collection) need to be efficiently integrated into the database.

Currently, measures of performance standards do not exist for any of the TMC functions. For example, the ramp metering groups will often not examine and reevaluate the timing plan of a ramp meter until the public brings it to their attention. They react, rather than taking on a proactive approach, to the situation. Ideally, performance would be measured by the amount of congestion delay reduced as a result of TMC actions. Clearly, there is a need to establish some type of performance measures and mechanisms for estimating them, which will help substantiate the benefits and costs of having a TMC in place.

5.2 Recommendations

5.2.1 Estimating System Performance

A practical tool to estimate *system* performance based on the TMC collected data and actions is needed. This tool will permit the Caltrans TMC operators and system managers to have estimates of the quality and quantity of travel in the transportation system. Appendix B includes a proposed design of a Practical Performance Management System (PeMS) submitted to Caltrans for implementation in an existing TMC.

5.2.2 Other Ways to Use Data Collected

Research is currently being conducted on the possibility of using the data fiom the existing loop detector infrastructure to calculate link travel times and construct O/D tables. Reliable estimation and prediction of travel times is especially important for disseminating traffic information and designing Advanced Traveler Information Systems (ATIS). Travel times may also be used to detect incidents.

"Vehicle reidentification" techniques is one approach for estimating travel times. *As* a vehicle passes over a loop detector, it produces a disturbance in the electromagnetic field and creates an inductive loop pattern or "vehicle signature (fhgerprint)" (Kühne, 1991). By comparing the fhgerprints available at an upstream detector, the system *can* match the fhgerprints and reidentify vehicles at a downstream location (vehicle reidentification) to derive travel time estimates. Automated vehicle reidentification via sequence matching of vehicle lengths measured from standard Caltrans speed traps has also been examined (Coifman, 1997). This approach would also provide origin/destination data and incident detection (sudden changes in travel times).

Petty et. al. (1996) have developed a method, which accurately estimates travel times directly fiom single-trap loop detector data. The model assumes a common probabiity distribution of travel times between consecutive loop detectors during a given time interval, i.e., vehicles arriving at an upstream detector randomly "choose" their travel times to the downstream detector fiom a common distribution. Detector flow and occupancy data are used to estimate the arrival times at the downstream detector. The actual arrival times observed at the downstream detector are compared with the calculated arrival times. The travel time distribution, which minimizes the discrepancy between the two sets of arrival times, is then found via a measure such as least squares. Lower and upper bounds of possible travel times are set using the occupancy data. Summing up the estimates between individual loop pairs along a freeway segment will give an estimate of the travel time on the stretch of the freeway.

5.2.3 Data Storage, Reduction and Dissemination

Given the enormous amount of resources being invested in data collection, it should be seen that the data be used to the fullest extent possible. This would require a group of individuals, the data management team, to be in charge of the storage, aggregation, and dissemination of the data in a readable format.

It is not possible to identify all the parties, which would be interested in the TMC data. Interested groups may include, but not limited to planning agencies, private traffic information providers, government officials, traffic engineers and analysts, and University researchers. For most purposes, raw data is inconvenient and difficult to use. One can only imagine the amount of storage needed to keep all the 30-second counts collected at each loop detector station each day for all the loop detectors in the District. To reduce the amount of storage, the original data are aggregated by detector stations and into 1-minute and 5-minute counts as time passes. As an example, at District 4, 30-second counts are kept for 1 year before it is aggregated by detector station. The data is maintained in this form for one year, after which it is assembled into 1-minute and 5-minute intervals. The time frame in which the aggregation takes place, however, varies between each TMC.

In general, data compiled into 5-minute intervals will probably provide sufficient detail to most users. Rather than waiting for a minimum of two years before 5-minute counts are made available; the data management team can aggregate the 30-second data within months of collecting it. Not only will data storage facilities be reduced, but also users will be able to work with more current data. However, data fiom incidents, bad weather and special events should perhaps be kept in it raw form indefinitely. Researchers and engineers fiom Caltrans and consulting firms would be interested in this data for developing automatic incident detection algorithms

Regarding real-time information, Caltrans District 7 has already made CAD information available on the Internet (http://www.maxwell.com/caltrans/). The service is available 24 hours a day, 7 days a week. The growing popularity and accessibility of the Internet makes it a feasible means of information dissemination. Many public organizations, research facilities, and schools are connected to the Internet making it possible for them to download data fiom the World Wide Web (WWW).

Groups within the organization can access the database via an Intranet. An Intranet is a private Internet that facilitates internal communications and computing within organizations. However, by doing this, the TMC loses control of the data and its use. Because users (within the organization as well as outside) will not need to first request for the data, they remain anonymous to the TMC. To prevent this, the TMC may put up a "firewall" that requires the user to submit information such his affiliation and the organization's name before access to the data is granted. Such measures may help to prevent misuse of the data.

CD-ROMs provide another viable means of dissemination in compact form. Interested parties may place orders for pre-packaged data. By having the users make a formal request, the TMC can better keep track of their users and have more control over who receives the data. The costs of each method have not been examined but needs be considered, as each method will require different resources.

More importantly, the format in which the data will be made available should be established, as raw data counts will probably be of little use to most users. Since not all users will necessarily be proficient with computers, the data should be available in a format that can be read and manipulated by most off-the-shelf software packages.

REFERENCES

1. Intelligent Transportation Society of America, *National Goal for Deployment of Intelligent Transportation System*, Sixth Annual ITS America Meeting, Houston, Texas, April 1996.

2. Hall, RW., H.K. Lo, E. Minge. *Organizing for ITS: Computer Integration Transportation Phase I: Results for Arterial and Highway Transportation Management Centers.* PATH Research Report UCB-ITS-PRR-94-24. University of California, Berkeley, Institute of Transportation Studies, November 1994.

3. California Department of Transportation (Caltrans) and California Highway Patrol (CHP). Transportation Management Center (TMC) Master Plan, June 1993.

4. JHK & Associates. *CCTV Design Requirements Technical Memorandum: San Francisco Bay Area Traffic Operations System (draft).* Prepared for California Department of Transportation, District 4, Document No. 036, July 1993.

5. Kühne, RD. Freeway Control Using a Dynamic Traffic Flow Model and Vehicle Reidentification Techniques. In *Transportation Research Record 1320*, TRB, National Research Council, Washington, D.C., 1991, pp. 251-259.

6. Coifman, B.A. *Automated Vehicle Reidentification and Travel Time Measurement Using Effective Vehicle Lengths from Loop Detector Speed Traps - Part II: Automated Travel Time Measurement Using Vehicle Lengths from Loop Detector Speed Traps, a Pilot Study and Research Proposal*, working paper, UCB-ITS-WP-97-1, University of California, Berkeley, Institute of Transportation Studies, March 1997.

7. Lo, H.K., RW. Hall, and J.R Windover. *California Transportation Management Centers, Part 1: Assessment of Existing Capabilities.* PATH Working Paper, UCB-ITS-PWP-93-17. University of California, Berkeley, Institute of Transportation Studies, December 1993.

8. Wei, C., P. Hsu, and S. Leung. *A Working Freeway Service Patrol Program: Its Role in Traffic Management.* Proceedings of the Annual Meeting of ITS America, 5th Meeting, Vol. 1, 1995.

9. Merry, Carolyn J., McCord, Mark R, Bossler, John D., Jafar, Fatmeh, and Perez, Lesley A. *The Feasibility of Using Simulated Data Coordinated with Traffic Ground Counts.* Final Report. FHWA/OH-96-014. The Ohio State University. Prepared for Ohio Deparment of Transportation, August 1996.

10. *Malik*, J. and S. Russell. Measuring Traffic Parameters Using Video Image Processing, *Intellimotion*, Vol. 6, No. 1, 1997.

11. Hartman, D., D. Middleton, and D. Morris *Assessing Vehicle Detection Utilizing Video Image Processing Technology.* Texas Transporation Institute, Research Report 1467-4, September 1996.

12. Henley, W. *Presentation: Cast, Benefits, and Visions of California TMCs*, May 23, 1996 MTC Transactions October/November 1996.

13. Differt, D. and Stehr, R. "Reflections on Traffic Management Experience in Minnesota," *ITE Journal,* March 1992, pp. 43-46.

14. Esquenazi, S. Personal interview, District 7 TMC, August 4, 1997.

15. McDermott, J., C.H. McLean, and A.T. Smith. Three Decades of Progress: Freeway Traffic Management in Illinois, *ITE Journal*, March 1992, pp. 27-31.

16. Witheford, D.K. The Historical and Research Framework for Freeway Traffic Management, *Transportation Quarterly*, Vol. 41, No. 4, October 1987, pp. 503-518.

17. Everall, P.F. Urban Freeway Surveillance and Control: The State of the Art. Federal Highway Administration, U.S. Department of Transportation, June 1973.

18. Oak Ridge National Laboratory. ***Deployment of Advanced Traffic Management Systems in the U.S. by State Agencies - Fact Sheet.*** ITS America Clearing House, 1996.

19. Brubaker, M.M. Transportation Data Issues in the San Francisco Bay Area with National Applications and Recommendations, Paper No. 970738, Presented at the 77th Annual Transportation Research Meeting, Washington, D.C., January 1997.

20. Jacobson, L.N. Freeway and Arterial Management Effort in Washington State, ***ITE Journal,*** Vol. 59, No. 11, November 1989.

21. MacCalden, M.S. A Traffic Management System for the San Francisco-Oakland Bay Bridge, ***ITE Journal,*** May 1984, pp. 43-46.

22. Goode, R. and M. Blackwell. The Information Age Comes to Bay Area Travelers, Metropolitan Transportation Commission, In *Transactions,* October/November 1996.

23. Moore, J.E., S. Cho, and A. Basu. Use of Los Angeles Freeway Service Patrol Vehicles as Probe Vehicles, Interim Report, University of Southern California, 1997.

APPENDIX A

Contacts/Correspondence

Caltrans Headquarters
Wayne Henley

Caltrans - District 4 (Oakland)

Sean Nozzari	(510) 286-4544
Sean Coughlin	(510) 286-4804
Barry Loo	(510) 286-6910
Cyrus Mashoodi	

Caltrans - District 7 (Los Angeles)

Sam Esquenazi	(213) 897-4385
David Lau	(213) 897-4385
Peter Wong	(213) 897-0254

District 11 (San Diego)

Tarbell Martin	(619) 467-3204
Max Wickham	(619) 467-3029
Susie Martin	(619) 467-3064
Ross Cather	(619) 467-3022

District 12 (Orange County)

Joe Hecker	(714) 724-2659
Mahesh Bahtt	(714) 756-4952

ITS America
Jay Bockisch (202) 484-4540
jbockisch@itsa.org

California PATH
Dimitri R. Loukakos (510) 231-9511
loukakos@uclink4.berkeley.edu

Metropolitan Transportation Commission
Michelle M. Brubaker (510) 464-7700

SPECIAL EVENT HANDLING

1. How many special events does the TMC handle a year?
2. Special team that handles special events at TMC? which division?
3. Type of information acquired before handling a special event (i.e., start and end times, event type, time of day, location, capacity, and expected number of people):
4. Type of data used for handling a special event and source of data:
5. Type of information
6. What does the TMC do for these events? (CMS, ramp metering, coordinating special buses, etc.)
7. How do they predict the behavior **of** these events? (database of previous events?)
8. What information is stored? For how long is the information stored?
9. How is performance measured?
10. Expected future improvements? more data? different data needed?

CHANGEABLE MESSAGE SIGNS (CMS)

1. Where are they usually used? What is their relationship to special event handling?
2. How many CMSs are active, usually?
3. Type of information acquired before updating a message:
4. How is data processed? are there any computer algorithms, expert systems?
5. Who changes the CMSs? What are the procedures for changing **a** message? who controls them?
6. Classification of messages (delay, incident, construction, etc.)
7. Besides use of CMS, what other methods are used to disseminate information to the public?
8. What information is recorded? how long is the information kept?
9. How is performance measured?
10. Expected future improvements? more data? different data needed?

RAMP METERING

1. What triggers the initiation **of** ramp meterindsignal control? (time of day, special data/conditions, manual)
2. Type of data acquired before ramp meterindsignal control is initiated.
3. Who activates it? (automatically, manually)
4. When activated, how often **is** the pattern changed?
5. Who changes the pattern? (TMC, local unit)
6. What triggers the end of ramp meterindsignal control?
7. Is the status of the control device sent to the TMC?
8. If ***so,*** what information is sent, and how often?
9. How is performance measured?
10. What information is recorded/stored and for how long?

APPENDIX B

Proposal to Implement a Practical Performance Management System (PeMS)

P. P. Varaiya and A. Skabardonis

June 5, 1998

Abstract

This document describes a proposal to implement a Practical Performance Management System (PeMS) at a Traffic Management Center. The overriding goals of this implementation are flexibility, modularity and simplicity.

1 Introduction

We propose to build a transportation accounting system, called TransAcct, that will allow easy access to summary statistics of how a transportation system is operating. The TransAcct system will be a tool for Caltrans employees to use to assess the performance of the transportation system. TransAcct will also be a flexible and expandable tool for researchers to use to dig deeper into the concept of transportation system performance. In many ways, TransAcct will be a highly specialized data mining tool.

TransAcct will have two different ways of interacting with the user, based on two different types of users. The first type of user is a casual user. This individual will want to know general, predefined statistics that have been generated over various links and/or regions. It is assumed that this type of user will not want to know anything about the TransAcct system and will only want to perform simple queries. The second type of user will want to perform more complex queries. They would be frequent users of the system and would want to invest the time to learn about it's capabilities and features. The second type of user would want to be able to expand the types of queries that the system can perform. A person who is interested in the broad measure of how the transportation system performed yesterday would fit into the first category whereas a researcher who is attempting to develop algorithms for assessing system performance would fit into the second category. To address the needs of these two users TransAcct will have two different types of interfaces: 1) a web-based interface, and 2) a shell-based interface.

The web-based interface will allow users to user their WWW browser to access the system. Typical users of this interface could be Caltrans managers, and members of the press and public. Users will be able to point and click on various regions and see summary statistics on each region. They will be able to pull up predefined graphs and see comparison among days and/or locations. The shell-based interface will allow users to perform more detailed queries. They will be able to write their own programs to assist them in performing repeated queries of the database. The design of the TransAcct system is essentially dictated by these two types of users.

A portion of TransAcct will consist of a collection of performance evaluation routines which will be invoked on the request of users via either their web browsers or a specialize shell. These routines will perform predefined tasks which will display evaluations of the transportation system to the user.

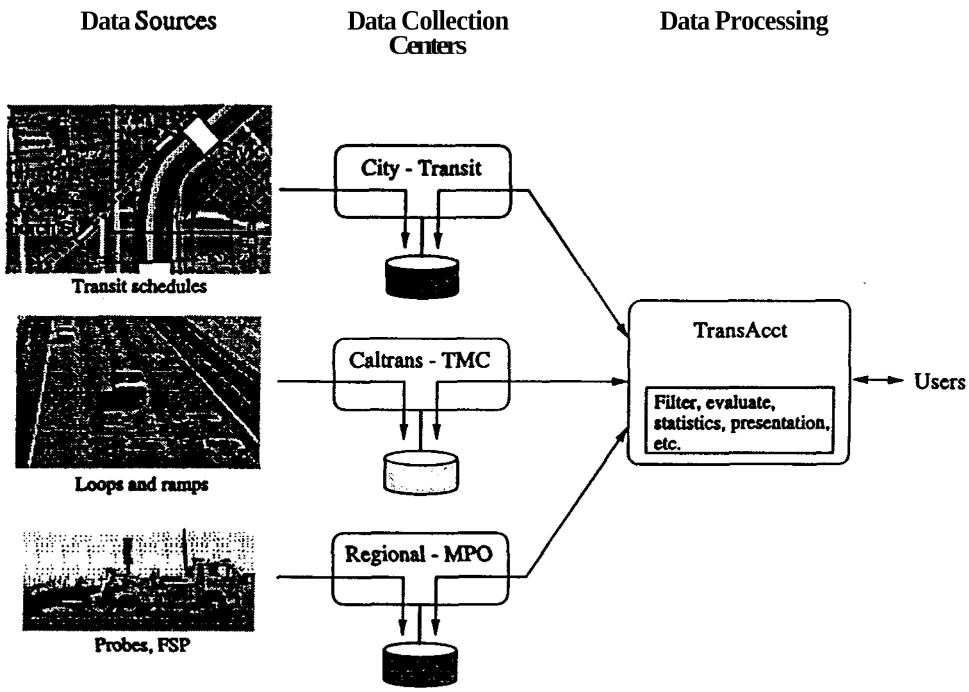


Figure 1: The future: disparate entities will collect and store information about the transportation system. TransAcct will mine through this information as needed to extract valuable performance data.

This set of routines, along with the routines that filter and process the loop detector data, has been developed by the independent firm Berkeley Transportation Systems, Inc. We plan on purchasing their software to implement our system.

The system that we are designing will consist of four parts: 1) the evaluation routines, provided by BTS, 2) the structures in the database to facilitate these routines, 3) the web interface to these routines, and 4) the shell interface to allow different routines to be developed. The rest of this document describes the design of these various pieces of the system. Before we begin, we take a slight detour to provide a short preview of the future of TransAcct. We then return to our task at hand and spelling out how we will design a prototype system that will get us there.

1.1 'The Future

The vision of TransAcct in the future is large and all encompassing. It will be a complete transportation system evaluation tool. Figure 1 provides a rough view of the future of TransAcct. There will be multiple sources of data. These data sources will range over modalities, time scales, fidelities, and geographic location. Most of the data sources will be collected by independent. entities. We will have local transit schedules, like buses, light rail, and subway; inter-area schedules, like airport arrival and departure times, high speed trains, and ships; and intra-area information from loop detectors, ramp meters, ATC tags and CHP automated dispatch. TransAcct will have routines that will process these sources of data to filter errors, fix holes, and extract salient features. It will allow users to perform simply calculations like mean levels of congestion and average speeds. But it will also allow users to calculate more detailed measures like link travel times from a variety of estimates, like loops, probe vehicles, and historical data, and to combine them into a single, viable estimate. It will allow incident detection algorithms to be tied seemlessly into incident management and response scenarios.

This type of system would be the foundation for many different ITS applications: incident detection, traveler information systems, route guidance, flow control, etc.

1.2 The Current Prototype

Although the above scenario is nice, it is, at this moment, unrealistic. To implement such a system from scratch would take years of planning. Worse yet, it would probably involve building quite a few systems that at first didn't work, or didn't live up to expectations, and then starting all over again. The amount of money spent on trying to achieve everything at once would be astronomical. Any project that attempts to do all of this in one shot would likely end in failure.

Instead, we start small and work our way up. We take a small, focused, specific problem and solve it very well. The problem that we are addressing with this software is the problem of performance evaluation of the freeway system based on loop detector data. The software system that we are proposing will be based upon the loop data collection infrastructure that is already in place at the Caltrans District TMC. Hence we are proposing to take one data source and to produce one type of calculation. The distinction that we are making is between the universal performance measurement system as described above in Section 1.1, and a practical one that we plan on implementing.

The question is how do we implement such a system. It would be easy to have a single, canned routine which would extract the loop data that we want from the database and to compute some performance statistic. The program would be quick, simple and easy. But, it wouldn't be modular, it wouldn't be expandable, and it wouldn't be very useful. Hence, we propose to take a little more time and to develop a simple platform on which to create data processing tools like the loopbased performance evaluation routines. This platform will also allow users to view results via the Web. We feel that taking the time to build the proper foundation will pay off almost immediately in terms of algorithm development and product deployment.

2 Design Guidelines

In designing this system, we are adhering to a few simple concepts: use the Internet, leverage existing hardware and software, implement the system in an incremental manner, ensure modularity, use off-the-shelf technology. In holding to these tenets, we feel that we can easily and cheaply design and build a system that will implement the functionality described in the previous section. In addition, these tenets will enable the software to become the foundation of the future system described in Section 1.1.

2.1 Use the Internet

The Internet has become the communication medium of choice and is now the standard for deploying distributed networked applications. Web-based applications use the standard browsers as universal clients, and the Java programming language has enabled developers to utilize legacy machines to their full extent. This has translated directly into lower development costs and greater interoperability between legacy systems.

TransAcct is essentially a distributed networked application. In order to get information, the users need to communicate with the TransAcct server. The TransAcct server then needs to turn around and communicate with the database containing the requested information. This database might be on the same machine as the TransAcct system. But then again, for a complex query, there might be multiple databases involved which are scattered over many machines and administrative

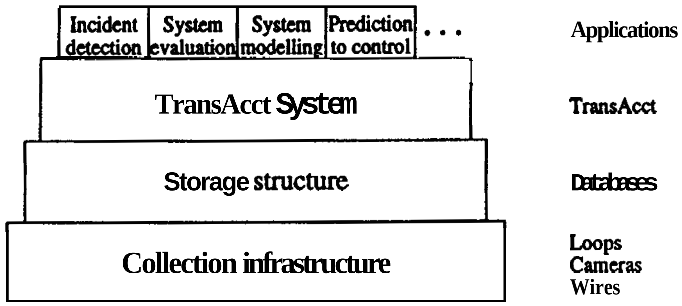


Figure 2: The foundation of the TransAcct system rests upon a good collection and storage infrastructure. With the TransAcct system in place to manage this information, many useful applications can be implemented.

domains. In any case, both queries, the users' and TransAcct's, are done between different machines. Hence, it makes sense to go through the Internet.

2.2 Leverage Existing Hardware and Software

From a cost standpoint, the most important concept to adhere to is to use existing hardware and software as the base of the system. There is no reason in this day and age for a software design to dictate hardware purchases. Since TransAcct is essentially a piece of middleware (meaning it sits in the middle of a flow of information), there are two sides to it: the side which collects and stores the data, and the side which talks to the users and generates graphs for them. Therefore it is important that we specify exactly what we mean when we say that we are going to leverage the existing hardware.

The first set of hardware is the existing data collection infrastructure. The most common example of this is the system which collects freeway flow information. This includes the loop detectors, the communication links that transmit the information back to the Caltrans TMC, and the computers which then store the information in a database. It is obvious that TransAcct should be designed to operate with this infrastructure. In addition, TransAcct should be able to operate with any *future* data collection infrastructure with minimal additional work. As illustrated in Figure 2, the various data collection and storage structures are the foundation that TransAcct will rest upon.

The second set of hardware are the individual machines that will access the TransAcct system. It is essential that individuals be able to access the core functionality of TransAcct with their existing hardware base. This will be achieved by designing TransAcct to operate over the standard Internet connections. This means that the primary interface to TransAcct needs to be via the Web. This will allow users to access the system through freely available web browsers. There will also be a secondary interface that will allow users to perform more complex operations. The shell-based system will also leverage off of the existing hardware and software base. To achieve this the shell will be written in a manner that will run on all of the common computing platforms. This means that it will either be written in Java or it will piggy back on top of another application.

2.3 Incremental Implementation and Modularity

The system should be designed to be able to take advantage of additional data sources as they come on-line. When CAD data are available, we should be able to incorporate them with little programming effort. When link travel times become available from tagged vehicles, we should be able to compare these to the loopbased estimates. Indeed, as incremental data become available, the TransAcct platform will be able to incorporate them. This will allow researchers to slowly but surely develop routines to mine through this data and extract useful information.

Closely related to the concept of incremental implementation is the concept of designing the software in a modular fashion. Specifically, the introduction of a new type of data shouldn't require that the entire system be redesigned. Indeed, one of the main attributes of TransAcct will be the ability to incorporate multiple types of data as they become available. We should also be able to upgrade the various components of the system and still have the system be functional.

2.4 Use Off-the-shelf Technology

The world of computer hardware and software is quick moving. The product cycles for computer hardware are less than a year and for software it is even less. Therefore it is important to be able to utilize standard software products. Specifically in the areas of database programming, web servers and transaction processing. Therefore it is important that we use off-the-shelf technology for:

1. the web server,
2. the database **API,**
3. the application server (if any),
4. the shell language.

This will allow us ensure the survivability of the software through many industry cycles.