Organizing for Intelligent Transportation Systems

Case Study of Emergency Operations in San Francisco Bay Area

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Computer-integrated transportation (CIT) is envisioned as an integrated network of public and private transportation organizations, each with unique responsibilities but working toward a common mission of facilitating travel across all modes of transportation. Research on CIT is extended to emergency operations (EOs) and presented. EOs in California are examined and their role in gathering and using traffic incident information is identified. The basis of coordination between EOs and transportation management centers is established. Intelligent Transportation System (ITS) services and technologies that may be beneficial to EOs are identified, and the similarities and differences between California EOs and the emerging ITS national architecture are compared.

The effect of incidents on congestion has been well-documented. A widely cited study indicates that incidents account for 61 percent of all congestion delay in the United States (*1*). On a similar scale, the California Department of Transportation (Caltrans) reported that 50 percent of motorist delays on freeways are related to incidents (*2*). Therefore, it is critical to coordinate incident response procedures to minimize these delays. In fact, because of this need, large metropolitan areas initiated incident response programs as early as the 1960s. For example, in 1961 Chicago started the Minutemen Program, which consisted of tow trucks that patrolled the freeway system and offered assistance to vehicles in trouble (*3*). California's Freeway Service Patrol (FSP) is a similar program serving the same purpose.

The National Intelligent Transportation System (ITS) Program Plan (*4*) also recognized the importance of providing effective emergency management. It highlighted the need for service and technology provision. What the plan did not address, however, was how these technologies may be used by the emergency agencies responsible for the various aspects of emergency operations (EOs).

Effective incident management requires the coordinated effort of many participants, including transportation management centers (TMCs), traffic management teams (TMTs), law enforcement, FSP, Caltrans' Maintenance Branch, hazardous material teams (HMTs), ambulances, fire departments, and even coroners. How will communication and database technologies assist in this process? Will these technologies serve as a catalyst for promoting and facilitating interagency coordination?

In an earlier paper (*5*), the concept of computer-integrated transportation (CIT) was proposed, which is envisioned as an integrated network of public and private transportation organizations, each with unique responsibilities but working toward a common mission of facilitating travel across all modes of transportation. CIT is designed to achieve effective coordination of the transportation system while respecting the individual responsibilities of the participating organizations. The earlier study examined the concept of CIT from the perspective of arterial and highway TMCs. Among other findings, the study identified institutional impediments and opportunities for inter-TMC coordination. However, the paper only touched on how transportation agencies interact with related nontransportation agencies.

This study, as a follow-up, examines the coordination between TMCs and EOs and investigates whether an appropriate level of coordination can be determined. The research presented here was completed in parallel with two studies, one on commercial vehicle operations (*6*) and the other on transit agencies (*7*). These three studies together provide a comprehensive view of how transportation agencies at the state and local levels can improve their coordination with other, nontransportation organizations.

This paper is divided into four sections. First, the study's objectives and survey design are stated. Then, on the basis of interview results, state-of-the-practice EOs in California are described and the coordination between EOs and TMCs is discussed. Next, the value of the ITS user services as perceived by the emergency agencies is depicted and the California emergency management system is compared with the one proposed by the National ITS Architecture Program. Finally, the study is summarized with concluding remarks.

STUDY OBJECTIVES AND DESIGN

The objectives of this study are to (*a*) survey the operations of emergency agencies; (*b*) identify their potential roles as traffic or incident information providers or users; and (*c*) identify ITS user services that may be beneficial to the emergency agencies.

The scope covers EOs in Northern California that deal with traffic-related incidents, including Caltrans TMCs and Maintenance Branch, the California Highway Patrol (CHP), FSP, and the local 911 centers, also known as the public safety answering points (PSAPs). The survey was administered through site visits that covered four major aspects:

- Functions performed,
- Channels of communication,
- Use of technologies, and
- Desirability of ITS user services.

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EXISTING PRACTICES OF EMERGENCY OPERATIONS

EOs are organized into two levels—disaster mode and day-to-day incident mode. The former addresses disastrous situations such as a major earthquake, flooding, and fire, and it involves the management of major resources such as personnel and equipment across multiple jurisdictions. Disaster mode occurs only a few times a year. The day-to-day mode refers to the daily operations that handle freeway incidents and occurs many times a day.

Disaster Mode

To provide organization to handle major disasters, California S. 1841 required establishment of a statewide Standardized Emergency Management System (SEMS) and development of an approved course of instruction for all emergency response personnel. Specifically, the legislation required that by December 1, 1993, the Governor's Office of Emergency Services would establish a SEMS and by December 1996, all state agencies would use the adopted SEMS to coordinate multiple-agency emergency and disaster operations.

In response, CHP proposed an Incident Command System (ICS) approach and proposed the establishment of emergency operations centers or emergency resource centers (ERCs) to serve as sites for coordinating actions. An ERC was established with the new Caltrans TMC in Oakland and was activated during the 1995 floods, before the TMC became operational.

Incident Command System

ICS is proposed as the foundation for developing California's SEMS. The development of ICS can be traced back to 1970 after a disastrous fire season in Southern California. In November 1988, Governor Deukmejian sent a memorandum to all state agencies to encourage full-scale implementation of ICS at the state level. In 1989 CHP approved the use of ICS for all emergency incidents occurring within the CHP jurisdiction.

ICS is proposed as an emergency management system that enables emergency response personnel to manage incidents effectively through the proper use of resources, common organizational structure, and common terminology. Specifically, ICS is designed to provide a management structure with the following attributes:

- Common terminology,
- Modular organization,
- Unified command structure,
- Consolidated action plans,
- Manageable span of control,
- Predesignated incident facilities,
- Comprehensive resource management, and
- Integrated communications.

Through a common organizational structure based on functions, as illustrated in Figure 1, personnel from each involved agency and jurisdiction can coordinate according to their task assignments.

Following are the major functions of each component:

- *Incident command*. Makes all emergency operational and tactical decisions.

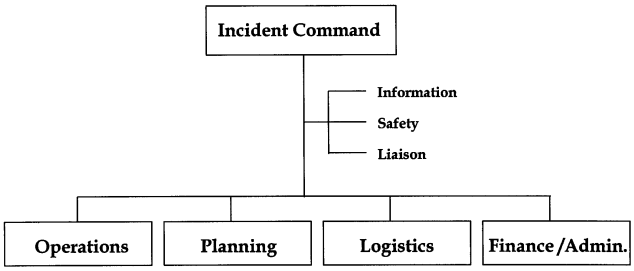

FIGURE 1 Major components of incident command system.

- *Operations*. Implements the strategy and tactics directed by the Incident Commander.
- *Planning*. Analyzes information and provides intelligence to the Incident Commander to develop strategies for mitigating the emergency.
- *Logistics*. Procures all resources necessary to support the incident objectives.
- *Finance*. Ensures the collection of financial cost data.

Caltrans TMCs and Maintenance Branch are developing a parallel management structure in support of ICS. ICS is intended as a management structure for multiple jurisdictions as well as for single jurisdictions, but it remains unclear whether this will become a standard internal management structure for Caltrans TMCs and Maintenance Branch.

Emergency Resource Centers

The establishment of ERCs in California is a recent event. For example, the ERC in Oakland consists of a conference room and communications equipment that can use auxiliary power sources and uses microwave for transmitting signals (hence avoiding the use of conventional phone lines, which may be down in catastrophic situations). However, it is unknown whether there are plans to link the databases and computer systems of the different agencies to coordinate resource allocation and dispatch. It also is unclear how new automation, database, and communication technologies may be used for ICS or SEMS. At present, ERCs provide a meeting place for the emergency agencies.

Day-to-Day Incident Mode

Day-to-day incident mode pertains to mitigating congestion through quick response to traffic incidents. It is apparent from interviews that EOs understand their responsibilities well. In the following subsections, EO operations are discussed from three perspectives: initiation of emergency services, jurisdictional responsibilities, and utilization of communication technologies.

Initiation of Emergency Services

There are two major ways to initiate emergency services. The first is by citizen calls. Citizens may report an incident through three channels: call box, cellular phone, and ground-line phone. In the San Francisco Bay Area, except for calls from the toll bridges and tunnels, which go directly to Caltrans maintenance dispatch centers located

near the facilities, all call-box calls go to the CHP Communication Center (CHPCC) in Vallejo.

In addition to receiving call-box calls, CHPCC receives all cellular 911 calls in the nine-county Bay Area. It is a common practice to grant higher priority to cellular 911 calls than to call-box calls. Thus, it is not uncommon for call-box calls to encounter a long delay. Through a computer-aided dispatch (CAD) system, CHPCC relays highway incident information to CHP field units, TMC, and FSP. Information on non-traffic-related incidents is forwarded by CHPCC to the local PSAP, which in most cases is either the local police or the fire dispatch center.

The PSAP receives direct ground-line 911 calls within its district and relays information to police, medical, or fire units, depending on the situation. Traffic-related freeway incident information received by the PSAP is forwarded to CHPCC. Normally, each city has its own PSAP. Countywide PSAPs cover small cities and other regions that do not have their own PSAP. Since July 1988, California has provided coverage of PSAPs for the entire state.

Emergency services also may be initiated by field units or closed-circuit television operated by TMCs. Loop detector information will alert the operators at the TMC but will not automatically initiate emergency services; a confirmation by a field unit is required. Figure 2 summarizes the process of initiating emergency services.

During the study, two remarks regarding the initiation of emergency services were notable. According to the Alameda County sheriff's department, 40 percent of all cellular 911 calls are non-traffic-related and are transferred from CHPCC to the PSAP. These calls would avoid waiting time if they could connect directly with the proper PSAP. This requires the development of a positioning method—each call can be transferred automatically to the PSAP for the calling region. Moreover, this change may involve reallocating staff and communications equipment for both CHP and the PSAP. The sheriff's department further indicated that Pacific Bell (the regional telephone company) has contacted them to examine the technology of positioning within the current cellular network.

The second remark regards the reception of automatic and manual MAYDAY notifications. Should these signals or calls be received by CHPCC directly or by an independent service provider (such as the American Automobile Association) that screens these signals before relaying the emergency calls to CHPCC?

Jurisdictional Responsibilities

The emergency agencies established a set of clearly defined responsibilities in clearing incidents and managing traffic around the scene, as summarized in Figure 3.

FSP and CHP scene commanders coordinate directly with CHPCC, whereas TMTs, Caltrans Maintenance Branch, and HMTs coordinate with TMCs. TMCs and CHPCC communicate mainly through the CAD system operated and maintained by CHPCC, although radio communications between CHPCC and CHP field units are audible to TMCs. Radio contacts between field units coordinated by CHP and those by the TMC are not encouraged. CHPCC and Caltrans TMCs are thus aware of any information obtained from and decisions made by their field units.

For historical reasons, Caltrans Maintenance Branch has its own dispatch and communication centers. They communicate with field units directly without necessarily informing TMCs, especially for incidents on the toll bridges and in tunnels because call-box calls from these facilities go directly to Caltrans Maintenance. Caltrans headquarters personnel indicated that they plan to streamline communication among TMCs, Maintenance dispatch, and field units. This plan has been implemented partially in the new Caltrans TMC in San Diego. The goal is to set up an efficient communication system so that relevant information is channeled to all

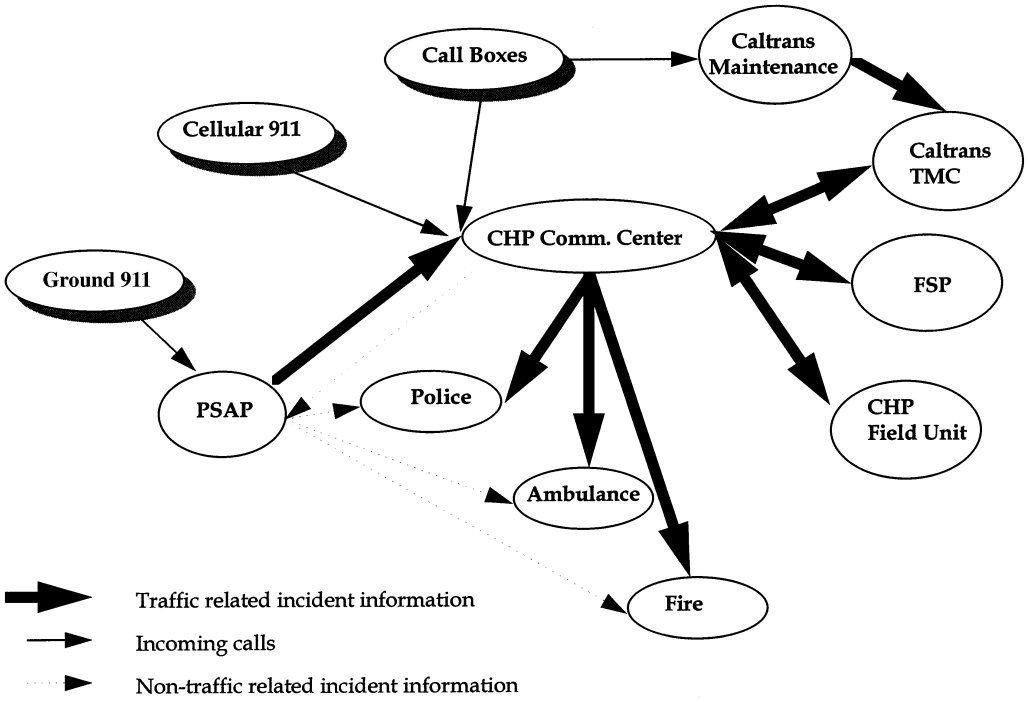

FIGURE 2 Initiation of emergency services.

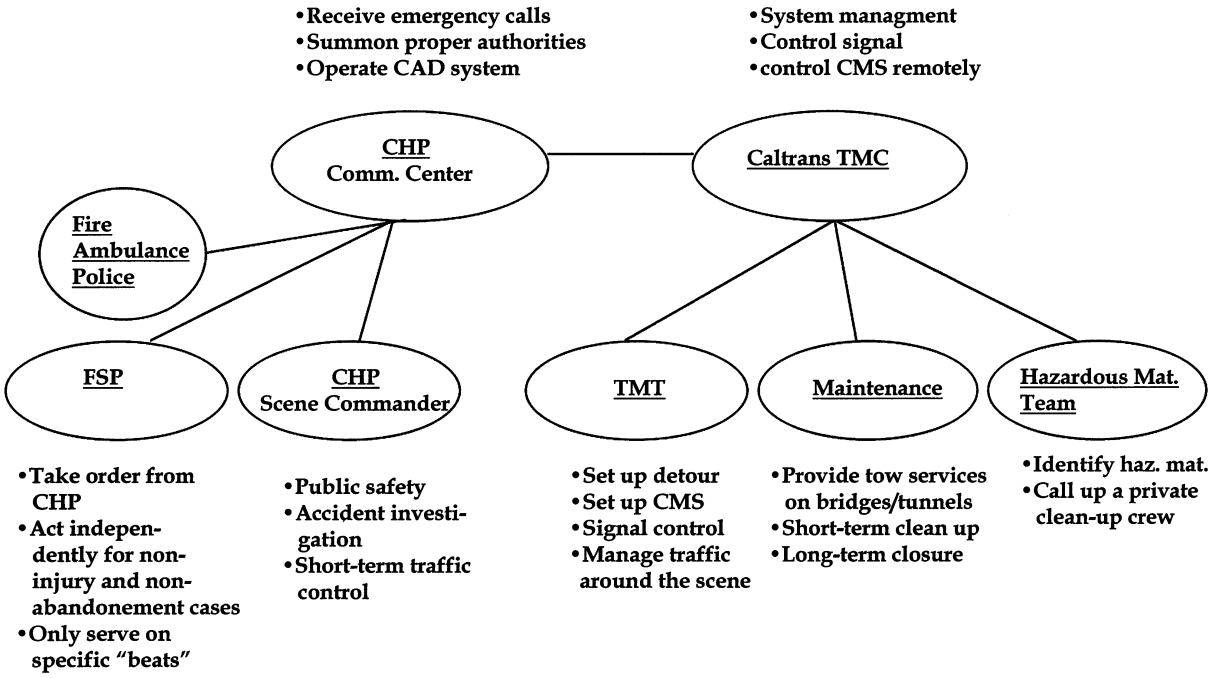

FIGURE 3 Agency responsibilities.

involved parties. The plan is to combine all dispatch functions (TMT, Maintenance) into one district dispatch communication center.

Use of Communication Technologies

Emergency communications can be classified into four categories: caller-to-center, center-to-center, center-to-field, and field-to-field. These represent different modes of communication, each adopting a different technology.

Caller-to-Center Communications California uses an E-911 system for all ground-line calls with these features (*8,9*): (*a*) selective routing, which routes calls to the PSAP serving that area; (*b*) automatic number identification (ANI), which shows the caller's phone number; (*c*) automatic location identification (ALI), which shows the caller's street address; and (*d*) automatic call distributor, which allows calls to be answered in the order received. For cellular 911 calls, the system is at the basic level. According to CHP and the sheriff's office, the technology to introduce an E-911 system for cellular calls with ANI and ALI capability already exists. This may be a direction in which the cellular 911 system will head.

Center-to-Center Communications The CAD system is used to maintain real-time communications between the centers. It registers and updates incident information as it comes in. CHP's CAD can automatically code the incident location according to a geofile. After incident information is gathered and coded by a call evaluator, the CAD system assigns the case to the dispatcher in whose region the incident occurred. The CAD system also keeps track of field unit assignments so that idle units will be assigned new cases.

Caltrans TMCs, Caltrans Maintenance Branch, and the media are granted access to the CAD system through remote terminals. However, only incident location and severity information are released; personal information (such as the names of the involved persons) is concealed.

Despite the CAD system's importance for interagency communications, there is no uniform standard governing its design. Four vendors supply CAD systems in the Bay Area. Without a standard, these different city and county systems cannot be linked directly.

Center-to-Field Communications These communications are accomplished through various means: radio, scanner, pager, and cellular phone. In addition, two new modes are being tested: automatic vehicle location (AVL) and mobile data terminal (MDT). Four FSP vehicles in the Bay Area are equipped with AVL devices to determine their locations. Transmitters on board these vehicles transmit their real-time locations to CHPCC. This information is used to assign the nearest FSP to an incident.

MDT is being tested in Southern California. It receives digital information directly from CHPCC's CAD system, thus reducing miscommunications between the dispatcher and the field units. Assignment of field officers to an incident still is directed from CHPCC, however.

Field-to-Field Communications Field units use radio to communicate with each other. These communications are audible to the dispatch centers, which remain informed of developments. CHPCC updates the CAD system accordingly and directs additional resources as necessary.

Figure 4 summarizes the use of communication technologies between the emergency agencies in the Bay Area. Emergency agencies face these technological issues and opportunities: (*a*) introducing

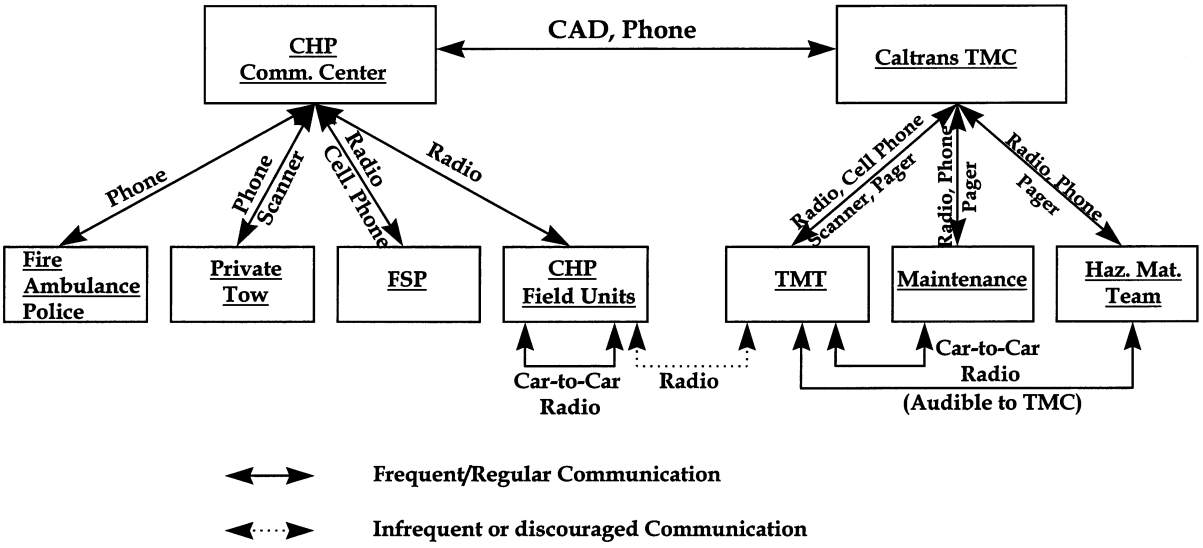

FIGURE 4 Use of communication technologies.

E-911 capabilities for cellular 911 calls; (*b*) routing cellular 911 calls directly to the appropriate PSAP instead of indiscriminately to CHPCC; (*c*) standardizing CAD designs for increased coordination and data sharing; (*d*) introducing AVL to aid dispatch; and (*e*) installing MDT to reduce verbal communications and miscommunications.

COORDINATION WITH TMCs

The most important coordination between emergency agencies and TMCs is information exchanges pertaining to incident locations and severity and dispatch. To this end, the CAD system and phone and radio communications are sufficient. The emergency agencies do not see the need for any higher level of coordination between CHP and the TMC. In many situations, the colocation of CHP and the Caltrans TMC assists in this coordination effort significantly.

For disaster mode coordination, TMCs may reorganize themselves or simply designate personnel to form an ICS structure in the near future. The goal is to allow personnel from different agencies to work together on short notice.

Regarding the use of real-time traffic information collected by Caltrans, most emergency response agencies use only detour and lane-closure information. Only the Bay Bridge TMC uses speed and volume data to alert the operator to a potential incident. CHP mentioned that it would be beneficial to their operations if TMCs could provide routing services to their response vehicles, supply road condition information, and disseminate incident information to the public. Other than these comments, the emergency agencies expressed no strong desire for real-time traffic information. Even if real-time data were made available, it is not clear how the agencies could use them.

DESIRED ITS SERVICES

Based on the user services defined by the ITS National Program Plan (*4*), emergency agencies were polled on these six services: incident management, emergency vehicle management, emergency notification and personal security, public travel security, hazardous materials incident response, and advanced vehicle safety systems.

Unlike the interviews on existing practices, in which the emergency agencies provided a consistent view, each agency responded differently to this set of questions. This is not surprising since they have different roles in handling incidents. Also, perhaps, there is no long-term plan to articulate an official view. It also should be noted that, during the interviews, cost and benefit estimates of these ITS services were not available to the agencies. Their responses may have been different and perhaps more realistic if they could trade the value of these services in light of their budgetary constraints. Their responses are summarized in Table 1.

The views of Caltrans and CHP are similar in many areas. They expressed great interest in incident management and hazardous materials incident response, some interest in advanced vehicle safety systems, and little interest in the other emergency services. Caltrans is very interested in speeding up the detection of incidents. Although CHP expressed the same interest, it was skeptical of the improvement. According to CHP, the present response time was acceptable—average waiting time for a call to be answered was about 56 sec, and average FSP response time was about 8 min (*10*). In a similar way, Caltrans had doubts about the value of emergency vehicle management. It believed that the existing system already performed close to what the ITS technologies could deliver. On emergency notifications, CHP was undecided on their usefulness. They were also concerned about false alarms that would burden their resources. CHP and Caltrans expressed high interest in hazardous materials incident response. However, CHP raised questions about liability and public safety risks if the devices misidentify or miscommunicate the nature of the spill.

The county sheriff's department expressed interest in every service except emergency notification and personal security. It did not think this service is important to the PSAP and was concerned that such automatic notifications could not provide sufficient information to aid in response. It appears that the service of emergency notification and personal security especially is not well received by the public emergency agencies interviewed. None of them expressed the desire to receive such notifications.

TABLE 1 Value of ITS Emergency Services as Perceived by Emergency Agencies

ITS Services	Caltrans Maintenance and TMC	California Highway Patrol	County Sheriff's Department
Incident Management	"Most important"	"Extremely valuable"	"Very important"
Emergency Vehicle Management	"Not of interest"	"Not of immediate interest"	"Very high interest"
Emergency Notification and Personal Security	"Not of interest"	"Undecided"	"Not very important"
Public Travel Safety	"Not of interest"	"Not interested"	"High interest"
Hazardous Materials Incident Response	"Great interest"	"Great interest"	"High interest"
Advanced Vehicle Safety Systems	"Moderate interest"	"Of interest"	"Moderate interest"

Overall, the emergency agencies interviewed appeared to have reservations about the ITS services. They are hesitant to add the new services and believe that the new technologies cannot improve their operations substantially.

NATIONAL ITS ARCHITECTURE

In 1993, the U.S. Department of Transportation chartered four teams (subsequently reduced to two—Loral and Rockwell—in 1995) to develop a national ITS systems architecture (NISA). Emergency management, along with traffic management and 28 other user services (*4*), were included in this NISA development effort. It is timely and appropriate to compare the California Emergency Management Systems (CEMS) with the proposed NISA.

Figure 5 presents a simplified national ITS national architecture framework, which portrays how the various components may be linked (*11*). The framework divides transportation-related entities into four subsystems, center, roadside, vehicle, and (traveler) remote access, with the communications between them highlighted in Figure 5. The emergency management center is linked via wireline communications to the other centers and via wide area wireless communications to the emergency vehicles. At this level, the CEMS is entirely consistent with NISA.

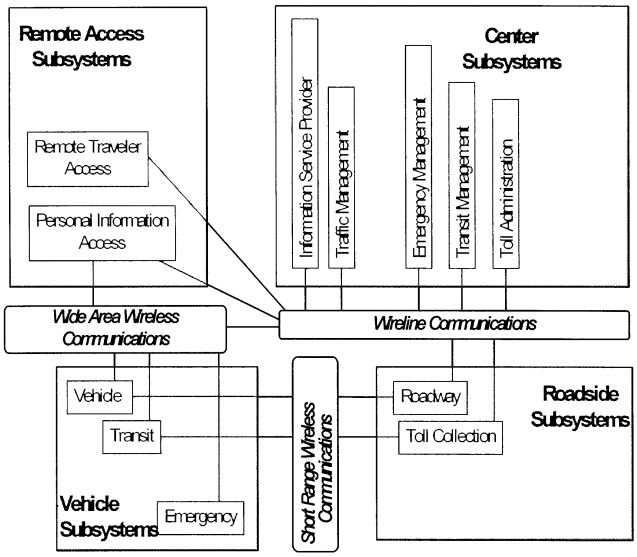

FIGURE 5 Simplified national ITS architecture framework.

Regarding the information flow between the Emergency Management Center (EMC) and related entities, the CEMS is consistent with NISA, although in general the latter delineates stronger linkages. For most situations, telephone contacts rather than electronic data sharing remain the major mode of communication in the CEMS.

The comparison illustrates three aspects that are relevant for system design. The first pertains to the reception of automatic MAYDAY notifications by EMC. NISA represents such a connectivity in its framework, whereas CHP is skeptical of its value and is concerned about resource requirements. It would seem that the private sector could provide this service on a cost recovery basis. For example, the private sector could receive and screen these automatic MAYDAY notifications before forwarding them to CHP. For regional and national interoperability, a standard for MAYDAY notification is needed.

The second aspect pertains to the provision of routing services to emergency vehicles. The NISA indicates that these requests can be handled by either the traffic management center or the independent service provider. This is consistent with interview results indicating that emergency agencies do not have a strong inclination to process real-time traffic information. Moreover, since emergency vehicles are authorized to preempt traffic signals and other vehicle movements, it appears that routing services are not a priority item for them. However, historical records on traffic and accidents could be used to aid the planning of new facilities to minimize response times.

The third aspect regards standardization of the channels for data sharing among emergency agencies. For interoperability, NISA encourages the establishment of communication standards. In California, the CHP CAD system has become the de facto coordination means among the emergency agencies. Yet there is no standard established for inter-CAD communications. It is beneficial to have these standards established.

SUMMARY REMARKS

California leads the nation in developing its emergency management system. California was the first state to provide ubiquitous coverage of E-911 service in 1988. The state is streamlining a unified command-and-control structure for all its emergency agencies and

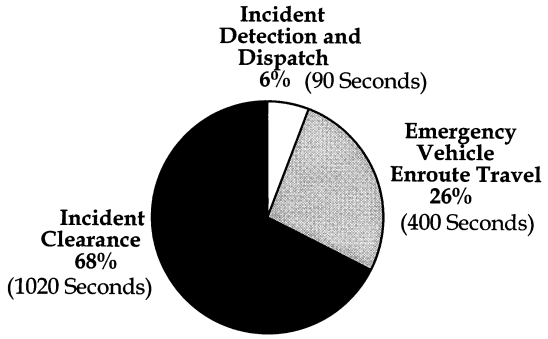

FIGURE 6 Time duration of incident response components.

is establishing emergency operations centers. For day-to-day traffic incident management, CHP, Caltrans, and FSP work together closely. New technologies, such as automatic vehicle location and mobile data terminals, are being tested.

On the basis of the ITS implementation plan (*11*) and interviews, Figure 6 was developed to illustrate the performance of the incident response procedure in the San Francisco Bay Area. Three time durations are depicted: (*a*) incident detection and dispatch, defined as the time between an incident's notification (mainly through cellular 911 calls) and dispatch; (*b*) emergency vehicle en route travel, defined as the time between dispatch and the arrival of the emergency vehicle; and (*c*) incident clearance, defined as the time between the arrival of the emergency vehicle and incident clearance. Although these estimates are rough averages with high standard deviations, they can be used to highlight areas for improvement. Incident detection and dispatch already perform quite well. On the other hand, emergency vehicle en route travel and incident clearance have higher potentials for improvement.

Dispatch of heavy equipment via Caltrans Maintenance Branch is a critical element for incident clearance. This procedure is initiated after emergency personnel arrives at the scene and determines the equipment need. Streamlining communications between Caltrans Maintenance Branch and TMCs, perhaps by unifying their dispatch/communication centers, would be instrumental in reducing the incident clearance time. Caltrans has started to implement this concept in its new TMCs.

Because of the lack of a standard communication protocol, CHP's CAD system is not connected to the county or city CAD systems, nor are the city CAD systems connected to each other. The same is true for agency coordination. An example quoted during the interviews was a recent chemical spill on the Bay Bridge. Caltrans and CHP did not inform the city of San Francisco so that it could redirect traffic; traffic headed for the Bay Bridge was gridlocked in city streets for hours. Since then, Caltrans and the city of San Francisco have established a protocol to improve communications. The coordination between highway-oriented emergency agencies and city emergency agencies can be improved substantially simply by agreeing to a set of communication procedures, which does not have to involve advanced technology.

Communication between TMCs and emergency agencies exists primarily for updating incident status. The existing CHP CAD system can perform this task more than adequately. Higher levels of communications involving real-time traffic information are not perceived as necessary by the emergency agencies. The agencies do not want to handle large quantities of traffic data and do not believe this information can improve their operations substantially.

Interviews indicated that emergency agencies are very cautious in expanding existing functions. They expressed great concern for receiving automatic emergency notifications from vehicles. Similarly, although they are experimenting with new technologies, they are cautious in deploying them broadly.

In summary, effective emergency operations require the coordination of multiple agencies and jurisdictions, who are largely independent yet share similar goals. This is a natural place for contemplating the concept of CIT. An ultimate objective is to streamline and define the coordination process so that the information collected and decisions made are distributed effectively to the party that is empowered to act on the information. This may involve changes in intra- and interorganizational structure as well as employment of advanced database and communication technologies. From the results, it appears that CIT is indeed a trend toward which the emergency operations in California are heading.

ACKNOWLEDGMENTS

The author thanks Art Aclaro, Ralph Blackburn, Bob Bassett, Bob Guinn, Kin Ho, Jim McCrank, Jim Pursell, Alex Skabardonis, and Bon Yee for participating in this study, and Holly Rybinski for collecting the data. This project was funded by the California Department of Transportation.

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The views expressed in this paper are those of the author.

Publication of this paper sponsored by Committee on Transportation System Management.