chapter 2

WHAT HAVE WE LEARNED ABOUT FREEWAY, INCIDENT, AND EMERGENCY MANAGEMENT AND ELECTRONIC TOLL COLLECTION?

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EXECUTIVE SUMMARY

The intelligent infrastructure is often the most visible manifestation of intelligent transportation systems (ITS) along the roads, with freeway and incident management often among the first ITS elements implemented in a region or metropolitan area. They can significantly contribute to improving travel conditions by addressing delay caused by both recurring and nonrecurring congestion. Electronic toll collection (ETC) systems similarly aid in reducing congestion on toll roads. In a complementary way, emergency management systems can greatly aid in locating incidents and responding to them in the most rapid and effective manner possible.

Each of the ITS technologies discussed in this paper shows potential benefits; however, only a few of the technologies have reached widespread deployment. Reasons for the limited deployment vary for each technology, but include cost, institutional barriers, uncertainty of benefits, and technological incompatibilities. The following list summarizes the deployment levels of the ITS technologies presented for incident management, freeway management, emergency management, and electronic toll collection.

Widespread: Deployed in more than 30 percent of the largest 78 metropolitan areas.

Moderate: Deployed in 10 percent to 30 percent of the largest 78 metropolitan areas.

Limited: Deployed in less than 10 percent of the largest 78 metropolitan areas.

Incident management systems have proven to be highly successful, and are now found in many major urban areas around the United States. These programs are undergoing and benefiting from significant technological change, particularly that related to the advent of cellular geolocation. Incident management's greatest challenge has been in institutional integration (i.e., in integrating incident management into the mainstream transportation planning and programming processes and in integrating incident management programs across jurisdictional boundaries).

Table 2-1 summarizes the current deployment status for various approaches commonly used in incident management.

Table 2-1. Incident Management Summary Table

Technology*	Deployment Level	Limiting Factors	Comments
Service patrols	Widespread Deployment	Cost, staffing	**Successful**
Common communication frequencies	Limited Deployment†	Cost, institutional issues	**Successful**
Automated incident detection algorithms	Medium Deployment†	Technical performance	**Mixed**
Cellular communication for incident detection	Widespread Deployment	Availability, institutional issues	**Jury is still out**

Table 2-1. Continued

Technology*	Deployment Level	Limiting Factors	Comments
Motorist callboxes	Limited Deployment†	Being replaced by cell phone use	**Successful**
CCTV (ground, airborne, high magnification)	Widespread Deployment	Cost	**Successful**
Cellular geolocation (old generation)	Operational Testing†	Accuracy	**Unsuccessful**
Cellular geolocation (emerging generation)	Operational Testing†	Availability, institution-al issues	**Jury is still out**
Regional incident management programs	Limited Deployment†	Institutional issues	**Holds promise**

** Cross-cutting technologies, such as telecommunications, are addressed in Chapter 7, "What Have We Learned About Cross-Cutting Technical and Programmatic Issues?"*

† Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Freeway management is becoming similarly common, and shares many resources with incident management. Freeway management systems are undergoing significant technological change, and often must accommodate such change in addition to increasing geographic coverage and incorporating additional agencies into the transportation management centers (TMCs), providing their operational foundations. Ramp metering, a major and highly effective component of freeway management, continues to be subject to negative local political pressure, and requires a careful balancing between arterial and freeway flows. Variable speed limits and dynamic lane controls continue to show promise, but are not yet widely deployed in the United States. Portable traffic management systems for use in work zones have proven quite successful. Deployment is now limited, but these systems are expected to become common in the future. Traditional procurement and contracting practices have created challenges in implementing the complex types of systems required.

Table 2-2 illustrates the current deployment status for different freeway management technologies:

Table 2-2. Freeway Management Summary Table

Technology/System*	Deployment Level	Limiting Factors	Comments
Transportation management centers (may incorporate multiple technologies)†	Widespread Deployment‡	Implementation cost, staffing	**Successful**
Portable transportation management centers (may incorporate multiple technologies)	Limited Deployment‡	Implementation cost, staffing	**Successful**
Road closure and restriction systems (may incorporate multiple technologies)	Limited Deployment‡	Institutional issues	**Successful**
Vehicle detection systems (may incorporate multiple technologies)	Widespread Deployment	Cost, maintenance	**Mixed—**depends upon technology
Vehicles as probes (may incorporate multiple technologies)	Limited Deployment	Cost, integration	**Jury is still out**
Ramp metering (includes multiple technologies)	Medium Deployment	Politics, user appear-ance	**Successful**
Dynamic message signs (includes multiple technologies)	Widespread Deployment	Cost, changing technology	**Mixed—**due to operations quality
Highway advisory radio (includes multiple technologies)	Medium Deployment	Staffing	**Mixed—**due to operations quality
Dynamic lane control	Medium Deployment	Not in MUTCD for mainlanes§	**Successful—** especially on bridges and in tunnels
Dynamic speed control/variable speed limit	Technical Testing‡	Not in MUTCD; may require local legislation to be enforceable	**Holds promise**
Downhill speed warning and rollover warning systems	Limited Deployment‡	Cost	**Successful**

** Cross-cutting technologies, such as telecommunications and pavement sensors, are addressed in Chapter 7, "What Have We Learned About Cross-Cutting Technical and Programmatic Issues?"*

† A transportation management center may control several of the systems listed further down the table, and will possibly utilize additional technologies, such as video display systems, local area networks, flow monitoring algorithms, geographic information systems, graphic user interfaces, and database management systems.

‡ Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

§ Mainlanes are freeway lanes that are not tunnels or bridges.

Mayday systems for emergency notification have become quite popular with motorists, although they are still primarily marketed to owners of premium vehicles. Often such systems are combined with supplementary services like driving directions, provided by a commercial call center. Use of computer aided dispatch (CAD) by emergency responders is quite common, although supplementing such systems with vehicle location provided by automatic vehicle location systems has gone slowly because of institutional barriers.

Table 2-3 illustrates the current deployment status for different emergency management technologies.

Table 2-3. Emergency Management Summary Table

Technology	Deployment Level	Limiting Factors	Comments
GPS/Differential GPS on emergency management fleets	Widespread Deployment	Cost	**Successful**
Mayday systems	Widespread Deployment*	Cost, vehicle choice	**Successful**
Mayday processing centers/customer service centers	Widespread Deployment*	Cost	**Successful**
Public safety answering points	Widespread Deployment*	Cost, staffing	**Successful**
CDPD communication	Limited Deployment*	Availability	**Jury is still out**
Onboard display	Widespread Deployment	Cost, user acceptance	**Successful**
Preemption infra-red signal system	Widespread Deployment	Institutional issues, lack of standards	**Successful**
Computer-aided dispatch	Widespread Deployment	Cost, support staffing	**Successful**
Automatic vehicle location	Widespread Deployment	Cost	**Successful**
Networked systems among agencies	Limited Deployment*	Institutional issues, integration cost	**Holds promise**

** Quantitative deployment tracking data not available. Deployment level determined by expert judgment.*

Electronic toll collection has repeatedly been shown to have positive impacts on both the toll facility's financial performance and on traffic flow. Although standards have been slow to develop due to competitive pressure, both standards and interoperability are advancing. Marketing to potential users has proven to be at least as important as selecting the right system/technology in achieving overall system success. Advanced technologies, such as smart cards for use across applications, are showing increased adoption.

Table 2-4 illustrates the present levels of deployment of ETC technology.

Table 2-4. Electronic Toll Collection Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Dedicated short-range communication	Widespread Deployment	Need for standard	**Successful**
Smart cards	Limited Deployment	Commercial and user acceptance; need for standard	**Successful**
Transponders	Widespread Deployment	Privacy	**Successful**
Antennas	Widespread Deployment	Technical performance	**Successful**
License plate recognition	Limited Deployment*	Technical performance	**Jury is still out**

** Quantitative deployment tracking data not available. Deployment level determined by expert judgment.*

To be sustainable, processes for implementing and operating ITS-based programs need to be "mainstreamed," that is, they must be configured to fit within and benefit from the planning and programming processes through which other ongoing programs operate. Mainstreaming also implies broadening acceptance of and building support for ITS-based programs within many functions and at multiple levels of the participating agencies. It also means ensuring that ITS supports the core missions and goals of these agencies. For such support to be solid, the benefits of the programs must be clearly demonstrated, documented, and communicated broadly. Ongoing assessment of system performance is a growing trend.

Most ITS-based programs yield the greatest benefit if deployed on a regional basis; thus, they often cross jurisdictional boundaries. In incident management, for example, many agencies are also involved, even within a single jurisdiction. Success in this environment requires involvement by each stakeholder, achievement of consensus, and thorough understanding of roles and responsibilities by all participants. This approach requires recognizing and addressing the differences between stakeholders, as big differences may characterize what each can afford, staff, or justify. Partnerships between the public and private sectors require a clear understanding of the motivations and capabilities of each side, and of how to best leverage what each partner brings to the bargaining table.

Integration, both technically and institutionally, can yield benefits, but it is a complex undertaking that will eventually need to address linkages across systems, modes, and functions. Although standards and increased interoperability will significantly ease such integration, the standards development process itself is consensus-driven and requires an extended period to accomplish its goals.

The approaches to operations are also changing. Public agencies, traditionally seen as responsible for operating systems that support the public roadways, may experience great difficulty in hiring and retaining technical expertise, also in great demand from the private sector. Thus, trends toward contract operation and maintenance and system privatization are emerging.

ITS project types from which this assessment was prepared range from technology demonstrations to full-scale implementations. They represent hundreds of millions of dollars of investment. Though not every lesson learned is universally applicable, many are relevant across project types. Some technical lessons, such as early problems with geolocation using cellular phones, have been overcome by technological advancement. The greatest impediments to ITS continue to be institutional, but they, too, will begin to diminish as new models of interagency and public-private partnerships are developed. Lessons from operations and management are just now becoming evident.

INCIDENT MANAGEMENT

Incident management provides an organized and functioning system for quickly identifying and clearing crashes, disabled vehicles, debris, and other nonrecurring flow impediments from area freeways and major arterials. Roadways are cleared and flow restored as rapidly as possible, minimizing frustration and delay to travelers while also meeting requirements and responsibilities of the involved agencies. Some jurisdictions and agencies responsible for operations and enforcement have worked together to develop a policy and operations agreement that defines specific incident management responsibilities. Such an agreement includes detection, verification, response, clearance, scene management, and traffic management and operations (ITS Deployment Tracking Database 2000).

Incident management programs can greatly benefit local travel conditions. Maryland's Coordinated Highways Action Response Team (CHART) program has documented a decrease of 2 million vehicle hours per year associated with nonrecurrent delay. Atlanta's NaviGAtor system, implemented in preparation for the 1996 summer Olympic Games, was estimated to have saved the state more than $44.6 million in 1997, its first year of operation. Pittsburgh's service patrol alone nearly reduced by half its response time to incidents, and is credited with a reduction of 547,000 hours of delay per year, valued at $6.5 million (ITS Benefits Database 2000).

Among these technologies, the most successful include service patrols and closed circuit television (CCTV). Service patrols, such as Illinois' Minutemen, Indiana's Hoosier Helpers, or Georgia's Highway Emergency Response Operators (HERO) program, have consistently generated high benefit/cost ratios for their sponsoring agencies, along with extremely positive public perception, documented through many letters received from motorists who have benefited from their assistance. Most of these programs are seen as both responsive and preventive incident management measures, as the situations they clear from shoulder lanes prevent "rubbernecking" delays. The Minuteman program pioneered the use of special service patrol vehicles able to move not only passenger but also commercial vehicles from traveled lanes. More recently, they have begun acquiring vehicles that allow "capture" and removal of disabled vehicles from traveled lanes without the service patrol attendant needing to exit the vehicle—a major step forward in protecting agency employees.

CCTV is widely recognized as the key component that not only allows detailed determination of incident location, but also dispatch of the correct set of response resources, and possibly even the provision of important preparatory information to responders. Although intended primarily for use in managing incidents and freeway flow, CCTV has also proven to be of great value in observing and resolving basic flow problems on both freeways and adjacent arterials. An example of serious efforts being made to address citizen concerns about potential violation of privacy through CCTV systems is the development of a set of privacy principles by the Intelligent Transportation Society of America (ITS America). (The principles are currently in draft form, but are expected to be finalized and approved by the close of 2000.) CCTV images of traffic conditions have proven to be highly popular both with television traffic reporters and traveler information websites.

The broad acceptance of cellular telephones affects two incident management elements: (1) motorist access to cellular phones will likely reduce the need for motorist callboxes except in areas where cellular coverage is unreliable; and (2) as cellular phones, accessed through the emerging cellular geolocation technology, rapidly become the mainstay of incident location, they will replace the use of stationary vehicle detectors and incident detection algorithms. The latter have never been highly effective because of the need to balance false positive readings and slow incident detection.

Regionalization of incident management programs and implementation of common voice communications frequencies among incident responders is likely to increase over time, but, to become widespread, will require participating agencies to overcome many institutional and jurisdictional barriers. The U.S. Department of Transportation (U.S. DOT) has undertaken extensive effort to bring about this result, including sponsoring national workshops, training, and distribution of a broad variety of informative materials.

Incident Management Lessons Learned

Successful incident management programs must have a regional perspective. A good example is Maryland's CHART program, which addresses incidents and congestion both regionally and statewide. Such an approach assures the most effective coordination of response and mitigation of nonrecurring congestion, regardless of incident location. Such programs should have a strategy based on stakeholder consensus, which contains formal agreements on respective roles and responsibilities, so that each participant has realistic expectations of other participants and a full understanding of its own obligations. One model for such a formal program is Milwaukee's Traffic Incident Management Enhancement (TIME) program. Comprehensive operating agreements are needed to achieve full, intermodal, interjurisdictional benefits. Finding the best way to work as a team has been challenging, but sharing information can have benefits well beyond those intended. Such was particularly the case in Atlanta during the 1996 Summer Olympic Games, where the responsible agencies overcame many institutional barriers to work together and successfully manage the tremendous travel demand created by the Games (U.S. DOT, Atlanta Navigator Study, Nov. 1998).

Law enforcement and other emergency services will likely realize measurable benefits from participation in a highly coordinated and formalized regional incident management program. In particular, the right types of partnerships can leverage individual investments, but participants must demonstrate and share benefits with decision-makers on a regular basis. One example of such a partnership is in Milwaukee, where the Wisconsin Department of Transportation (DOT) provided vehicles and the county sheriff provided personnel for a mutually desired freeway service patrol. Outreach to involved agencies and potential partners is key to ensuring program success (U.S. DOT, Regional Traffic Guide, 2000).

Incident management programs face difficulty in sustaining operations because they depend on scarce operations funding, which typically must be reallocated annually, and because they are susceptible to loss of the program champion. Sustainability is much more likely once the program is mainstreamed (i.e., it is part of the normal transportation planning and resource allocation process) (U.S. DOT, Regional Traffic Guide, 2000).

Incident management has been improved through extensive ITS infrastructure. But procurement and contracting issues have complicated acquiring and implementing this intelligent infrastructure. Problems occur when conventional procurement processes, which emphasize only price and offer little flexibility once the contract is signed, are used to obtain systems and software. Examples of such problems and potential solutions can be found in U.S. DOT's guides to innovative ITS procurement and procuring ITS software (U.S. DOT, FHWA Federal Aid ITS, Aug. 1997).

Nonintrusive detectors using technologies such as video image processors, radar, and passive acoustic sensing can provide excellent data when compared to the traditional inductive loop vehicle detector, while offering potential for portability, decreased damage during winter road maintenance, and avoidance of damage during road repair. This result was demonstrated in Detroit, Phoenix, and elsewhere.

Incident management software can significantly increase the speed, thoroughness, and consistency of responses to incidents, and can facilitate sharing of incident information across agency and jurisdictional boundaries. Incident detection algorithms, however, continue to suffer from the need to balance false positive readings with detection sensitivity. Efforts to use more advanced software techniques, such as artificial intelligence, expert systems, and neural networks, have yet to yield major gains in addressing this problem.

Diversionary routing was confirmed in Minneapolis-St. Paul as an effective way to manage traffic congestion produced by an incident, as long as the capacity of the diversion routes is adequate and the traffic flow is controlled by dynamic signal timing adjustments to maintain service levels. Success also requires adequate time for system integration and testing (U.S. DOT, Incident Management, Sept. 1998).

Hazardous Material Incident Response

An estimated 700,000 hazardous material (HAZMAT) shipments occur each day in the United States. The vast majority are packaged properly, meet other stringent requirements, and arrive at their destination safely. The National Academy of Sciences, in its 1993 report, Hazardous Materials Shipment Information for Emergency Response, estimated that between 10,000 and 20,000 motor carrier incidents and approximately 1,000 to 1,500 rail incidents that occur annually involve or threaten release of hazardous materials and necessitate dispatch of emergency response professionals. To provide an appropriate level of safety for the public in the event of an incident, emergency response personnel need timely, accurate information about the contents of HAZMAT shipments. HAZMAT incident response systems improve the accuracy and availability of HAZMAT information provided to emergency response personnel (U.S. DOT, Hazardous Material Response, Sept. 1998).

The use of HAZMAT incident management systems appears to have the potential to reduce the time required to positively identify the hazardous material involved in the incident and to select the appropriate response. Simulations at two rail yards and a truck yard yielded 33 to 41 percent reductions in time required to identify HAZMAT cargoes and select a correct response to the incident situation. Participants in two HAZMAT system field operational tests indicated that this time savings could have several positive impacts. During the tests, users found both systems to be more effective than current systems in determining optimal emergency response and cleanup strategy. Primary implications are that less hazardous material will be leaked, and cleanup procedures can begin sooner. Participants also anticipated a reduction in resources expended to deal with the incident (e.g., by eliminating unnecessary equipment deployment) (U.S. DOT, Hazardous Material Response, Sept. 1998).

Implementation of HAZMAT incident management systems has continued to grow slowly, often supported by general advancement in constituent technologies and overall progress of commercial vehicle administrative ITS programs. Results to date are preliminary, based mainly on simulation and operational tests. Thus, there is limited experience in measuring actual costs and benefits, and in determining the full set of operational issues. In general, slow institutional change has been the main culprit, not faults in the technology.

HAZMAT Incident Response Lessons Learned

HAZMAT incident management systems decrease the time needed to identify the cargo and respond, increasing effectiveness of the response. First responders estimated a 34 percent reduction in time to recognize and identify a hazardous cargo. Operation Respond indicated similar results in Atlanta, Georgia, and in Tonawanda and Buffalo, New York. However, a study of the HAZMAT incident management field operational tests concluded that there must be broad, nearly universal enrollment of carriers for implementing agencies to realize full benefits of such systems. Obtaining participation of smaller or less sophisticated motor carriers is more difficult, as they are both more financially constrained and realize less total benefit from enrollment. Cost was not an obstacle to agencies' interest in participating in the Operation Respond system test, the initial software and training costs totaling less than $700 for the first year and $350 for succeeding years (U.S. DOT, Hazardous Material Response, Sept. 1998).

To date, response from agencies using the systems has been positive. The systems are perceived to be more effective, accessible, and accurate than the paper-focused processes agencies were using. User agencies in the Transit Xpress (TXS) field operational test found the TXS system would be better at maintaining safety and efficiency, tracking HAZMAT loads, accurately reflecting mixed loads, and helping to ensure that motor carriers comply with HAZMAT regulatory requirements. Users also report that they would add the tested systems to their operations (but would not dispose of current systems), and felt that the record-keeping ability of these systems would be an improvement (U.S. DOT, Hazardous Material Response, Sept. 1998).

Where is Incident Management Headed?

Incident management programs are moving more toward formalization, regionalization, and interagency coordination. While no growth was detected from 1998 to 1999 in the number of metropolitan areas with service patrols on freeways, dramatic growth was seen in service patrols on arterials. Metropolitan areas report decreased installation of loop detectors and increased use of nonintrusive detectors such as radar and video imaging detectors (ITS Deployment Tracking Database 2000).

Incident Management Issues

A number of issues must still be resolved in the field of incident management. Effective, long-term relationships among all key players need to be created and sustained, which often involves several agencies working jointly at multiple organizational levels. The challenge of establishing and continuing communications should not be underestimated, though notable successes are being achieved. The proliferation of new technologies, such as cellular 911, mayday systems, and cellular geolocation, may eliminate the need for conventional detection. Similarly, given the heavy cellular phone market penetration and wide E-911 accessibility, motorist aid call boxes and dedicated cellular incident reporting numbers may no longer be justified.

FREEWAY MANAGEMENT

Freeway management allows transportation operations personnel to monitor traffic conditions on the freeway system, identify recurring and nonrecurring flow impediments, implement appropriate traffic control and management strategies (e.g., ramp metering and lane control), and provide critical information to travelers through infrastructure-based dissemination methods (e.g., dynamic message signs [DMS] and highway advisory radio [HAR]) and in-vehicle information systems (ITS Deployment Tracking Database 2000).

Freeway management often includes a freeway management center (or multiple centers where regional responsibility for the freeway system is shared by more than one operating entity) and links to other ITS components in the metropolitan area. Examples of such centers are found in Atlanta, Houston, Seattle, Minneapolis-St. Paul, and elsewhere (U.S. DOT, TMC Cross-Cutting Study, Oct. 1999). From these centers, personnel electronically monitor traffic conditions; activate response strategies; and initiate coordination with intra-agency and interagency resources, including emergency response and incident management providers. The growing presence and sophistication of freeway management centers has generated development of U.S. DOT concept of operations and human factors guides and a multistate pooled funds study of emerging management center issues.

Freeway management is a potent tool for combating recurrent congestion. The first 26-mile segment of San Antonio's TransGuide freeway management system is credited with reducing accidents by 15 percent and emergency response time by up to 20 percent. Studies of the INFORM freeway management system on Long Island in New York indicate that freeway speeds increased 13 percent, despite an increase of 5 percent in vehicle miles traveled during the evening peak period. Ramp metering, a major freeway management tool, was documented as increasing throughput by 30 percent in the Minneapolis-St. Paul metro area, with peak hour speeds increasing by 60 percent. Variable speed limits, a less common technique in the United States, were documented as decreasing traffic accidents by 28 percent during an initial 18 months of operation in the United Kingdom (ITS Benefits Database 2000).

TMCs have become a mainstay of coordinated freeway management in urban areas. California has eight and Texas has six urban TMCs. California also has five rural centers. These centers consistently employ freeway management systems using geographic information systems (GIS), graphic user interfaces, local area networks, and database management systems to control ramp meters, DMS, and HAR. Dynamic lane control is most common in tunnels and on bridges. Although not currently an accepted technique in the *Manual on Uniform Traffic Control Devices* (MUTCD), dynamic lane control has also proven successful over freeway mainlanes in San Antonio and Fort Worth, Texas. Dynamic speed control lacks enforceability in most state legal codes, and is therefore less common in the United States (its primary test having been in Washington State's Snoqualmie Pass); however, it is considerably more common in Europe.

Ramp metering continues to face political challenges (MN DOT, "RFP for Ramp Metering," June 2000) stemming from the complexity of balancing the interests of local (arterial) travelers and through (freeway) traffic, but has been widely proven to have significant benefits when implemented correctly and operated effectively (ITS Benefits Database 2000). Metering rates and algorithms, however, require judgments balancing the priorities of arterial flow against those of freeway flow. These judgments also have safety and infrastructure implications, such as assuring adequate storage capacity and coordinating availability of such storage with release of freeway-bound vehicles at signalized approaches. The Minnesota Legislature's decision to require the Minnesota DOT to evaluate the Twin Cities' ramp metering program by briefly turning off the metering exemplifies the extent of concern by high-level decision-makers.

Portable TMCs were formally studied and proven highly successful in Minnesota's Smart Work Zone field operational test and were later commercialized by that test's private sector partner (U.S. DOT, MN Smart Work Zone Study, June 1998). Almost all work zones now, at minimum, incorporate portable DMS, with increasing use of portable HAR.

Freeway management systems have traditionally relied on stationary detection devices, most commonly the inductive loop vehicle detector. The advent of electronic toll transponders and now of cellular geolocation increase the likelihood of stationary detectors being supplemented or replaced by vehicles serving as traffic probes—reducing the cost of implementation and maintenance and providing much broader coverage, including arterials. Vehicle probe data have been a mainstay in the Houston TranStar freeway management program for several years and were a successful component of San Antonio's TransGuide Metropolitan Model Deployment Initiative.

Road closure and restriction systems, such as the Highway Closure and Restriction System used by Arizona DOT, have proven to be quite popular with motorists and traveler information providers. These systems aggregate information on lane closures and make it widely available over a broad area and an extended time scale. Further integration of such systems is likely, allowing travelers to become aware of expected construction delays, regardless of jurisdictional boundaries.

Two vehicle operation warning technologies—downhill speed warning and rollover warning—have proven to be quite successful. These technologies are typically most applicable to commercial vehicle operation. Both typically use some form of radar to detect vehicle speed and likelihood of rollover through basic computer modeling of vehicle center of gravity. Because commercial vehicle incidents may occur in remote areas, may cause prolonged delay, often block multiple lanes, and can be among the most difficult to clear, the payback from these relatively inexpensive and simple applications can be significant. Results from the rollover prevention systems at the junctions of I-95 and I-495 (the Capital Beltway) in Washington, DC, have been impressive since their initial installation.

En route traveler information provided through DMS and HAR continues to be one of freeway management's most potent tools. HAR has experienced less than universal adoption, owing in part to early negative experiences caused by poor broadcast quality and delayed messages. Increasingly, flashing beacons are used to attract motorists' attention to HAR when critical messages are present.

Freeway Management Lessons Learned

The up-front effort needed for ITS program operation and technology selection is much greater than for traditional transportation infrastructure projects. This circumstance was particularly true in early freeway management implementations such as in Atlanta. Incorporating the experience and knowledge from other implementations increases likelihood of success.

Unfortunately, most early freeway management systems were implemented with little consideration for how they would operate. A U.S. DOT study found that essentially none of the early generation TMCs had prepared a concept of operations while planning or design was under way (U.S. DOT, TMC Implementation Guide, Dec. 1999). Because decisions made in the design/construction phase, such as degree of automation provided to operators and physical proximity of cooperating agencies, have a significant impact on operations and management, only now are operations-related design/construction lessons being fully captured.

Selecting an optimal mix of field devices, such as DMS, CCTV, HAR, and service patrols, requires careful consideration of budget, integration, and operations/management requirements. The system must be flexible as additional agencies/functions come into the TMC and are linked to its systems. For example, although the Texas DOT championed San Antonio's TransGuide transportation management program, local law enforcement, transit, and arterial traffic operations agencies also became interested in joining the program. In a comparable example, several years after the Houston TranStar transportation management program became operational, additional local agencies are joining in. Obtaining training and documentation along with the system is critical to the effectiveness of freeway management systems. Agency staffing policies are often not sufficiently flexible to create the needed positions. Such has been the experience at the California DOT (Caltrans), where an extensive study was undertaken in 1999 of TMC staffing needs.

One finding from the Atlanta experience was that systems engineering management plans are critical to proper integration. Most agencies lack the processes and resources necessary for configuration management, an element of a systems engineering approach. The Georgia DOT is only now undertaking implementation of a formal configuration management program, at considerable cost, over an extended period. A significant component of this cost is the investment in documenting the installed intelligent infrastructure equipment, information which could have been captured at the time of installation at considerably less expense. Atlanta also found that prototyping of key software systems and tools early and often throughout system design and development is critical to software development success. Traditional funding processes that facilitate initial capital investment but may complicate upgrades and system replacements create an attitude that promotes adoption of the latest technologies, encouraging changes to the system late in the implementation process (U.S. DOT, Atlanta Navigator Study, Nov. 1998).

The Minnesota Smart Work Zone project successfully addressed safety in work zones and their congestion impact. For example, it implemented a portable freeway management program that monitored congestion and provided traveler information on a localized basis. The freeway management system moved along the freeway with the construction crews. The Minnesota DOT felt that the system resulted in both increased safety and improved flow of traffic through the work zone (U.S. DOT, MN Smart Work Zone Study, June 1998).

Where is Freeway Management Headed?

Trends in freeway management include increased automation supporting all aspects of operator activity, greater integration of functions within the system and between freeway management centers, preventive action in addition to responsive action, and increased dependence on traveler information. For example, preventive freeway management is being demonstrated in an operational test on I-93 in Boston. Metropolitan areas report no increase in implementation of ramp metering, but show increased interest in active lane control. There is also evidence of increasing contractor operation/management of freeway management systems, such as for Long Island's INFORM system, Northern Virginia's Smart Travel system, and Michigan DOT's system in Detroit (U.S. DOT, TMC Cross-Cutting Study, Oct. 1999).

Freeway management systems will increasingly rely upon standards for communications between centers and between the center and its field equipment, using elements of the National Transportation Communications for ITS Protocol (NTCIP). Having identified a set of "critical" standards, U.S. DOT has had six standards development organizations at work for several years developing and balloting a broad range of ITS standards. U.S. DOT has also initiated a standards testing program whose objective is to document and share the experiences of early users of the emerging standards.

Freeway Management Issues

Even with increased contracting for freeway management services, the extent to which freeway management should be privatized is still being debated. Meanwhile, there is continuing concern that public sector agencies have difficulty hiring and retaining the key technical specialists needed to operate and maintain their freeway management systems. Also unresolved is whether centralized or decentralized systems are superior and which type will come to dominate the field. The density of intelligent transportation infrastructure needed for effective operation has yet to be answered, but is the subject of upcoming U.S. DOT studies.

Privacy continues to be an issue in freeway management. Initial privacy concerns stemmed from the ability of agencies to observe citizens through CCTV systems implemented to monitor traffic flow and incidents, or the mistaken perception that the purpose of these systems was to determine speeds of individual vehicles. Similar concerns arose in those areas where vehicles with electronic toll tags were monitored as traffic probes. In that case, measures were implemented to mask the identity of the vehicle owner from the traffic management agency and achieve anonymous probes. More recently, the ability of agencies and private sector firms to track cell phones in vehicles, allowing them to be used as "wireless data probes," has again raised privacy concerns. In most cases, agencies have implemented outreach programs to explain the safeguards against privacy violations and the procedures used to ensure they are working.

EMERGENCY MANAGEMENT

The purpose of emergency management services is to improve the response time of emergency services providers, thereby saving lives and reducing property damage. To reduce response time, it is necessary to reduce both the time it takes to notify providers and the time it takes for them to arrive at the scene. Emergency notification can be accomplished through cellular telephones, call boxes, and mayday devices (ITS Deployment Tracking Database 2000).

Emergency management systems can have important effects, both on accident survival and on motorist peace of mind. Of drivers testing the Puget Sound Help Me (PuSHMe) mayday system, 95 percent stated that they felt more secure operating a vehicle with the system installed.

Mayday systems have proven to be a significant commercial success for vehicle manufacturers, including General Motors' (GMs') OnStar™ system and the Ford/Lincoln RESCU system, as well as the American Automobile Association's more recent RESPONSE commercial mayday venture. Vehicle manufacturer-installed systems continue to be most common in more expensive vehicle models and in rental vehicles, and are often combined with well-liked, value-added services such as providing travel directions and yellow pages.

In the July 5, 2000, *LA Times*, GM states that its OnStar™ system has grown to a subscriber base of 250,000 in the United States and Canada since its introduction in 1996. The system logs 12,000 to 15,000 calls a day, about 5 percent of which involve emergencies. OnStar™ is available on 29 models of GM vehicles, and will become available on Honda's 2001 Acura models. GM predicts that the system will be available on 1 million vehicles by the end of 2000, and on 4 million by 2003 (*LA Times*, July 5, 2000).

On August 1, 2000, Ford and Qualcomm announced the creation of an alliance called Wingcast to compete directly with OnStar.™ The service will be available, starting with about 1 million vehicles in the 2002 model year. Nissan is also incorporating Wingcast into its Infiniti 2002 models, with Nissan brand cars to follow. Ford officials expect Wingcast to charge users between $9 and $29 per month. Price and level of service will vary by the Ford brand that sells it. OnStar™ charges its users $17 to $33 per month (*USA Today,* August 1, 2000).

In responding to events detected through mayday and other techniques, most emergency response agencies now use CAD systems to effectively manage their fleet resources. Agencies increasingly supplement this information by tracking vehicles with automated vehicle location (AVL) devices (*USA Today,* August 1, 2000). Integration of CAD data across jurisdictional boundaries is being facilitated by development of common location description standards, but will require resolution of institutional issues. Increased AVL implementation will require reducing system cost and successfully addressing organized labor's general dislike of such systems.

The Albuquerque Ambulance Company in New Mexico uses a map-based CAD system that allows the dispatcher to send ambulances to the exact location of an emergency, along with guidance on how to get there. Following installation of the system, the company's efficiency increased by 10 to 15 percent (ITS Benefits Database 2000).

Emergency Management Lessons Learned

The various emergency management systems implemented in field operational tests attained adequate positional accuracy in finding victims' vehicles. In the PuSHMe field operational test, the mean distance error was about 37 meters and the median distance error was about 31 meters from the actual vehicle location. The global positioning system (GPS) experienced difficulties in enclosed spaces or "urban canyons" (in between buildings), but was accurate with vehicles in forested or open terrain. With PuSHMe, the GPS-based systems experienced difficulties in accurately determining locations in enclosed spaces like parking garages. One vendor's product experienced a 37 percent failure rate and the other vendor's had a 29 percent failure rate in updating locations in between buildings. With elimination of "selective availability," announced in May 2000, and increasing presence of differential GPS, obtaining acceptable positional accuracy typically is not a difficult challenge to overcome.

Cellular communication has limitations in areas of marginal or poor cellular coverage. In Colorado's Mayday field operational test—in areas of marginal to nonexistent cellular coverage—the analog cellular system was unreliable in transmitting data (U.S. DOT, Emergency Notification Response, Sept. 1998). Since this test, not only has there been a dramatic increase in the size and density of cellular coverage, but digital cellular systems have made significant inroads on the initially analog-dominated marketplace.

The computer system and mapping database used by emergency call-takers must show and update the map quickly, displaying a wide range of geographic and political attributes in the area surrounding the location of the incident. In both the Colorado Mayday and PuSHMe field operational tests, the map display system and the map database used in the system were problematic. More specifically, in Colorado Mayday, the speed of the computer used for the map display system was adequate for the test but would likely be too slow under real world conditions of multiple, simultaneous mayday calls. The display system needed enhancement to automatically display streets in the vicinity of the incident. The display system also needed the capability to display more than one incident at a time. The map databases and display should have included all roads, road labels, geographic landmarks, and bodies of water, as well as city, county, state, and dispatch region boundaries (U.S. DOT, Emergency Notification Response, Sept. 1998).

Operators of vehicles with the mayday systems found them easy to use and felt more secure with the system available. Using one of the two systems tested in the PuSHMe operational test, 100 percent of users found the device easy to use. The auto redial feature was unanimously viewed as user-friendly. With respect to security and safety, 95.7 percent of users would feel more secure in their vehicle were the system permanently available to them and other members of the family. In situations requiring police, medical, or roadside assistance, 95.6 percent of users thought the system would likely help authorities deliver assistance. In the area of reliability and consistency, 91 percent of respondents reported that only rarely or occasionally were they disconnected when speaking with the response center operator, and 100 percent reported that they were almost always or frequently automatically reconnected (U.S. DOT, Emergency Notification Response, Sept. 1998).

Tests validated the efficacy of using private service centers to screen calls. The PuSHMe operational test helped partners better understand the role of a private response center (PRC) in the deployment of an in-vehicle emergency response system. Private partners felt that a PRC would be a necessary component of any early deployment scenario and pointed to existing PRCs such as those serving the Ford Lincoln RESCU system. Public partners were less concerned, seeing the PRC as a viable and likely scenario but not the only one. Public partners are generally concerned, however, about the potential overload they experience from 911 calls made by motorists observing incidents.

Emergency Management—Computer Aided Dispatch

CAD systems, GIS, and AVL support real-time, traffic-sensitive route guidance for emergency vehicles and promote more efficient use of vehicle and personnel resources. Even though the technology is proven, it is still crucial to train dispatchers before they will embrace it. Packaged AVL systems are widely available, but the absence of standardized map locations remains an obstacle. Technology will enable public safety and traffic agencies to share data, but the agencies need to be aware of one another's resources, and must coordinate plans to address the public's privacy concerns. While integration among systems is feasible, it remains technologically challenging. Integration is time-consuming, costly, difficult to manage, and does not always produce easily quantifiable benefits, because CAD systems are typically proprietary, and no interface standards have been defined.

Emergency Management—Mayday

Mayday systems identify incidents through sensor data such as airbag deployment. They support increasingly accurate location data through improved cellular coverage, GPS formulas, and 10-second history of location prior to impact. Communication coverage and availability of crash data are expanding. Integration with E-911 will continue to develop as E-911 expands, but will lag for cellular 911 callers until auto-location of cellular 911 calls begins to become available. Interface requirements should be built to specific agency requirements.

Where is Emergency Management headed?

The capabilities of emergency response systems will continue to expand as more data on seatbelt use, airbag deployment, and other vehicle functions become available. In addition, cellular coverage will expand and become more accurate. E-911 calls will become integrated with and begin receiving information from data-rich Mayday cellular calls.

On July 19, 2000, U.S. Transportation Secretary Rodney Slater kicked off the National Mayday Readiness Initiative (NMRI). NMRI is a public-private partnership aimed at creating effective, efficient integration between Mayday service providers and the Nation's public emergency responders and incident managers. NMRI brings together all of the key stakeholders to discuss and work toward resolving issues. The initiative is co-sponsored by U.S. DOT and the ComCARE Alliance, with support by a grant from the General Motors Corporation. In a press release announcing NMRI, U.S. DOT said that it expected more than 11 million mayday units to be on the road by 2004 (U.S. DOT, press release, July 2000).

Emergency Management Issues

The primary issues with mayday systems relate to the ability to get location data from all cell phones. The Federal Communications Commission (FCC) has approved two technologies—network-based and GPS-based, leaving the decision on which technology to use for regional cellular geolocation to local authorities. A network-based solution, where location is determined according to triangulation by the cell phone network itself, may require access to information available only from the local carrier, complicating the ability of a privatized mayday center to obtain the information it needs. For GPS-based regions, the Mayday center will receive positional information directly from the calling phone.

The issues with CAD/AVL are both technical and institutional. Reconciling map location referencing problems will make the systems more robust, but it is unclear who will be responsible for carrying out this action. Expanding available resources depends on multiple agencies pooling their needs and funds.

ELECTRONIC TOLL COLLECTION

Electronic toll collection provides for automated collection of toll revenue through the application of in-vehicle, roadside, and communication technologies to process toll payment transactions (ITS Deployment Tracking Database 2000). Participating patrons (vehicles) are identified by the use of roadside hardware and software and an identifier or "tag." In areas with more than a single toll collection authority, compatible tag technologies enhance convenience to the patron and promote "seamless" transaction processing.

ETC systems can provide a number of major benefits. On the Tappan Zee Bridge in New York City, manual toll lanes were documented as having a capacity of 400 to 450 vehicles per hour, while those with ETC systems handled 1,000 vehicles per hour. Florida's Turnpike Authority calculated a 2.03:1 benefit/cost ratio if only 10 percent of the vehicles at a sample toll plaza used ETC, rising to well over 3:1 as the number of ETC-equipped vehicles increased (ITS Benefits Database 2000).

The technologies necessary for successful ETC emerged and matured rapidly, although the industry successfully resisted standardization for many years. Early problems with data errors were overcome, and ETC has repeatedly been shown to be both highly economical and widely popular, particularly with commuters. Major U.S. DOT efforts are improving standardization and interoperability. Further success in this area is likely to result as smart cards are accepted for more than just transportation-related purposes, such as in Los Angeles where McDonalds™ is accepting them.

Electronic Toll Collection Lessons Learned

Poorly designed and poorly implemented ETC systems can be quite costly and can negatively impact traffic and the environment. Lee County reported that with tens of thousands of transactions per day, the problems created from a small percentage of incorrect transactions are significant (Burris 1998). Verifying the system's accuracy before making a selection was critical to the success of many early ETC programs.

Having a detailed marketing plan was key to the acceptance and rapid growth in use of Virginia's FasToll system (Harris and Choudhry 1998). Such outreach must identify and address the diverse audiences who may become enrolled in the program, speaking to the individual needs and motivations of each. In some cases, the majority of patrons are not regular commuters, as in Lee County, Florida (Burris 1998). Therefore, marketing campaigns targeted to the commuting population will miss a significant portion of potential ETC customers.

Public-private partnerships involving industry, financiers, and other private sector partners can reduce or eliminate the price of transponders as an impediment to widespread deployment, although most cases of such partnerships have been outside the United States. The availability of automatic positive balances and exclusive lanes at toll booths are attractive to drivers and draw more ETC users (Harris and Choudhry 1998). The practice of confidential encryption should be promoted to reassure users who have confidentiality concerns, as the E-ZPass program has done (Ascher 1999).

Several toll facilities use license plate recognition technology to identify toll evaders. This technology continues to face challenges in achieving rapid startup, high productivity, and high accuracy owing, in many cases, to the wide variety of license plate placements, formats, and color schemes in the United States. In other applications, agencies still rely on staff to interpret the images captured photographically for enforcement purposes.

Electronic Payment Systems Lessons Learned

Existing proprietary revenue collection systems are limited in their ability to support an "open" architecture; therefore, a technology standard is needed to ensure compatibility. Electronic payment systems can reduce revenue collection and maintenance costs, increase security, allow for increased throughput, and provide more detailed customer information. One study indicated that ETC reduced the cost of staffing toll booths by 43.1 percent, money handling by 9.6 percent, and roadway maintenance by 14.4 percent (Philip and Schramm 1997). The case study for the ETC system at the Carquinez bridge suggests that, overall, the ETC project would realize most of its objectives, although expansion of the system beyond its initial pilot phase has experienced significant delays. The project would provide a higher level of service quality to toll patrons, improve quantity and quality of data collection, increase traffic flow on ETC toll lanes, and reduce vehicle emissions and fuel consumption.

ETC systems also provide an opportunity to partner with other agencies and integrate with other ITS technologies (ITS Deployment Tracking Database 2000).

Earlier generation payment systems, such as bar code tags, have not completely disappeared and are still in use at some locations. Bar codes, however, were subject to degradation by dirt and grime, and were highly sensitive to correct placement on the vehicle.

Where is ETC Headed?

The future for ETC is regional, coordinated multi-use systems, especially as regional and national standards are developed. The potential for smart cards shared with other agencies and the private sector is real and must be pursued. Similarly, agreements between multiple agencies to pool or share "back office" toll processing activities hold potential for cost savings and increased automation. In such situations, multiple toll facilities using a common toll collection system, such as the E-ZPass system in the northeastern United States, can implement common processing facilities for processing transactions.

As usage expands, agencies will have to explore ways to increase conversion of lanes and create faster ETC lanes. Rapid payback supports system upgrading and replacement. Incorporation of vehicle identification technology into the vehicle during the manufacturing process may eliminate the need for add-on devices, should this technology become standard in the future.

Electronic Toll/Payment Issues

It will be important to determine the proper mix of ETC and manual lanes to allow for optimal road use and traffic flow. One key issue is the need for regional architecture standardization, but first the boundaries that constitute a "region" must be determined. The industry is debating the merits of discounting tolls for ETC users to encourage use, or charging them for the convenience of ETC.

CONCLUSION

Significant progress has been achieved in implementing freeway, incident, and emergency management and ETC systems, with many benefits realized from these investments. Some components, such as mayday systems, are being deployed at accelerated rates. Others, such as use of vehicles carrying cellular phones as wireless data probes, are only emerging, but show promise. Integration of technologies within each type of system and between the systems themselves is increasingly recognized as key to achieving full benefit from intelligent infrastructure, but is also known to present both technical and institutional challenges. As implementation expands, as new locations begin implementation, and as systems are updated or replaced, lessons and experiences like those documented in this paper will continue to have value in increasing the likelihood of rapid, successful, and cost-effective deployment, and in planning for generations of technologies yet to come (Pearce 1999).

REFERENCES

Ascher, M., "E-ZPASS–Putting ITS In the Hands of the People," *Proceedings of the 6th World Congress on Intelligent Transport Systems* (Toronto, Ontario, Canada: ITS World Congress, November 1999).

Burris, M., *The LeeWay Electronic Toll Collection System, Florida* (Tallahassee, FL: Leeway Authority, February 1998).

Harris, M. and O. Choudhry, "FasToll: Virginia's Electronic Toll Collection User Survey Response Summary," *Proceedings of the 1998 ITS America Annual Meeting* (Washington, DC: ITS America, May 1998).

ITS Benefits and Costs Database Web Page, Mitretek Systems, http://www.mitretek.org/its/benecost.nsf (Washington, DC: U.S. DOT, 2000).

Los Angeles Times, "Your Wheels" (Los Angeles, CA: LA Times Corporation, July 5, 2000).

Metropolitan ITS Deployment Tracking Database Web Page, Oak Ridge National Laboratory, http://itsdeployment.ed.ornl.gov (Washington, DC: U.S. DOT, 2000).

Minnesota Department of Transportation, *Request for Proposals for Evaluation of Ramp Metering* (St. Paul, MN: Minnesota Department of Transportation, June 2000).

Pearce, V.: untitled presentation, *Proceedings of the 6th World Congress on Intelligent Transport Systems* (Toronto, Ontario, Canada: ITS World Congress, November 1999).

Philip, D. and W. Schramm, "Cashless Tolls Mean Money Saved," *Traffic Technology International* (Dorking, Surray, UL: UK and International Press, 1997).

USA Today, "Ford Plans Challenge to GM OnStar" (Washington, DC: USA Today, August, 2000).

U.S. DOT, *1996 Atlanta Navigator Case Study* (Washington, DC: U.S. DOT, November 1998), EDL No. 9685.

U.S. DOT, *Emergency Notification and Response ITS Field Operational Test Cross-Cutting Study* (Washington, DC: U.S. DOT, September 1998), EDL No. 6326.

U.S. DOT, *FHWA Federal Aid ITS Procurement Regulations and Contracting Options* (Washington, DC: U.S. DOT, August 1997), EDL No. 3029.

U.S. DOT, *Hazardous Material Incident Response ITS Field Operational Test Cross-Cutting Study* (Washington, DC: U.S. DOT, September 1998), EDL No. 6327.

U.S. DOT, *Incident Management: Detection, Verification, and Traffic Management: ITS Field Operational Test Cross-Cutting Study* (Washington, DC: U.S. DOT, September 1998), EDL No. 6328.

U.S. DOT, *Minnesota Smart Work Zone Case Study* (Washington, DC: U.S. DOT, June 1998).

U.S. DOT press release, *U.S. Transportation Secretary Slater Announces Public-Private Partnership to Improve Emergency Response and Save Lives* (Washington, DC: U.S. DOT, July 19, 2000).

U.S. DOT, *Regional Traffic Incident Management Programs Implementation Guide* draft (Washington, DC: U.S. DOT, 2000), EDL No. 13149

U.S. DOT, *Transportation Management Center Concepts of Operation – A Cross Cutting Study* (Washington, DC: U.S. DOT, October 1999), EDL No. 10923.

U.S. DOT, *Transportation Management Center Concepts of Operation Implementation Guide* (Washington, DC: U.S. DOT, December 1999), EDL No. 11494.