MODULE 8. INCIDENT MANAGEMENT

TABLE OF CONTENTS

MODULE 8. INCIDENT MANAGEMENT

Figure 8-1. Example of an Incident Response Site.

8.1 INTRODUCTION

BACKGROUND

Congestion occurs when the amount of traffic wishing to use a facility (demand) exceeds the traffic-carrying capabilities of the facility (capacity). There are two types of congestion: recurring and nonrecurring. Recurring congestion occurs when normal demand exceeds the physical capacity of the freeway. This type of congestion typically occurs during high volume periods (such as the a.m. and p.m. peak periods) and is predictable in terms of its location, duration, time, and effect. Through experience, most motorists have learned to deal with the effects of recurring congestion by planning for it in their daily routines.

Nonrecurring congestion, on the other hand, is a result of either 1) a temporary reduction in capacity of the freeway (such as an accident or a work zone lane closure) or 2) a temporary excess of demand (caused by a special event or other similar activity). Generally, the activities that cause nonrecurring congestion can be either unpredictable (as in a stalled vehicle) or planned (such as a construction activity). The primary factor distinguishing nonrecurring and recurring congestion is that nonrecurring congestion is unexpected by motorists. As a result, nonrecurring congestion can be a considerable safety hazard and cause excessive delays to uninformed motorists.

Most of the activities that cause nonrecurring congestion can be classified as incidents. Incidents are responsible for a significant proportion of the delays and costs to the motoring public. For example, Caltrans estimates that over 50 percent of all delays experienced by motorists on their freeway system are caused by incidents. [(1)] In Texas, freeway incidents in 1990 were the source of over 440,000 hours of delay, costing the motoring public approximately $2.2 billion. [(2)] By 2005, the impacts of incidents in terms of hours of delay, wasted fuel consumption, and excess road user costs are expected to increase 5 fold over levels experienced just 10 years ago. [(3)]

One method for combating nonrecurrent congestion problems is to implement an incident management program or component of a freeway management system. Incident management refers to a coordinated and planned approach for restoring traffic to its normal operations as quickly as possible after an incident has occurred. It involves a *systematic* use of human and mechanical processes for the following purposes:

- Detecting and verifying the incident.
- Assessing its magnitude and identifying what is needed to restore the facility to normal operation.
- Providing the appropriate response in the form of control, information, and aid.

MODULE OBJECTIVES

The goal of this module is to provide guidance on how to develop or enhance incident management as part of a freeway management system. The specific objectives are as follows:

- To illustrate the decision-making process associated with developing improved incident management capabilities as part of a freeway management system.
- To describe and provide current summary data on the various techniques and devices available to facilitate freeway incident detection, verification, response, clearance, and traffic management.
- To identify and discuss unique issues and lessons learned pertaining to the planning, design, operation, and maintenance of an incident management component of a freeway management system.

MODULE SCOPE

This module is intended to be an overview of the incident management development process. The reader should note that a number of other documents dealing with incident management are available, and should be reviewed for additional information (See references 4,5,6,7.) The focus of this module is to present the decision-making process to assist in identifying, selecting, and implementing an integrated package of incident management actions that are most appropriate for the region of interest.

8.2 DECISION PROCESS

Incident management is a coordinated and planned approach for responding to incidents when they occur on the freeway systems. It involves the systematic use of human and mechanical processes for detecting, responding to, and clearing incidents. In this section, the systems engineering process that serves as the common thread throughout this handbook is applied to the development of this incident management module. It is important to note that incident management is a separate metropolitan component of an integrated regional transportation system. It is very often implemented with freeway management systems.

IDENTIFY NEEDS

Before an incident management component can be properly designed, it is important to have an understanding of the characteristics and impacts of incidents on freeway traffic in the region. Non-recurrent congestion is caused by one of three events:

- Roadway incidents (crashes, stalls, spilled truck loads, work zones, etc.).
- Special events.
- Regional transportation emergencies (flooding, hurricanes, chemical plant emergencies, etc.).

All of these events can reduce the amount of roadway space available to carry traffic. Furthermore, the last two categories can also increase traffic demands on a roadway segment, causing additional congestion.

To date, data regarding the frequency of incidents remains somewhat limited. Table 8-1 presents a summary of some of the different freeway incident frequencies that have been reported, and the units of measure utilized to describe these frequencies.

Rates of between 12 and 125 incidents per million-vehicle-kilometers (MVK) have been reported in the literature over several years.(1,7) Other studies have reported freeway incident frequencies as a daily or hourly rate per lane-kilometer.(8) Generally, these rates represent all reported incidents, from very minor vehicle stalls lasting only a few moments to major incidents involving hazardous materials or fatalities that take several hours to clear. Rates of more severe incidents that typically involve multiple agency response are significantly lower. For example, data from Houston indicated that a major lane-blocking freeway incident lasting more than 45 minutes occurred once every 137 MVK, or a rate of 0.73 per 100 MVK.(9) Undoubtedly, use of local data is the preferable method of assessing the severity of the incident problem at a location or in a given region.

Table 8-1. Summary of Reported Freeway Incident Rates.

Unit of Measure	Value
Incidents per million-vehicle-kilometers (1)	12-125
Incidents per million-vehicle-kilometers(7)	65
Lane-blocking incidents per hour per lane-kilometer(8)	0.006-0.023
Lane-blocking incidents lasting more than 45 minutes per 100 million-vehicle-kilometers(9)	0.68

Incident severity is also described in terms of its capacity-reducing effect on the roadway. Generally speaking, an unplanned incident or work zone activity will reduce freeway capacity by an amount greater than the reduction in roadway space due to that incident. For example, an incident that blocks one lane of a three-lane freeway section reduces available roadway space by 33 percent, yet reduces the capacity of the freeway by about 50 percent.(1) This additional capacity loss is due to the turbulence caused in the traffic stream as drivers attempt to move from the closed lanes into open lanes, and from driver "rubbernecking."

Table 8-2 summarizes the effect of stalls and accidents on freeway capacity.(1) Data regarding roadway capacities for work zone lane closures are shown in table 8-3.(11) Note the similarity in the estimated percentage reductions in capacity for one and two-lane blockages on freeway sections with three travel lanes per direction.

Generally speaking, frequencies of special events and major transportation emergencies are much smaller than those referred to above. However, when they occur, they can have a severe impact upon mobility and traffic conditions in an entire region. Fortunately, they are usually confined to a specific location and future time period, so that more preparation time can be spent analyzing and implementing various alternatives to help combat any adverse impacts expected.

It is important not only to attempt to quantify the overall magnitude of the incident problem that must be addressed, but also to identify in as much detail as possible the types of incidents that are a problem and the magnitude of their impacts. The degree to which specific problem areas can be identified in this step of the process determines how effectively possible mitigation alternatives are identified and implemented.

Table 8-2. Typical Capacity Reductions During Incident Conditions.(1)

Type of Incident	Normal Number of Lanes	Number Lanes Blocked	Capacity Reduction (%)
Accident on shoulder	3	0	26
Vehicle stall	3	1	48
Non-injury accident	3	1	50
Accident	3	2	79

Table 8-3. Typical Capacities During Work Zone Activities.[(Adapted from 11)]

Normal Number of Lanes	Number of Lanes Closed	Average Capacity (vph)	Reduction in Roadway Space (%)	Capacity Reduction (%)[a]
2	1	1340	50	63
3	1	2980	33	45
3	2	1170	67	81
4	1	4560	25	37
4	2	2960	50	59
5	3	2740	60	70

[a] Percent reduction based on an assumed normal vehicle capacity of 1800 vehicles/hour/lane
vph = vehicles per hour

As a final note, it is important to limit problem identification at this point in the process to the symptoms that need to be addressed, and not try to attach responsibility (or blame) for that symptom to an individual or organization. Part of the difficulty in establishing effective incident management programs is developing the lines of communication, cooperation, and trust within and between the various agencies that need to be involved. These cannot be established effectively in an environment where affected parties are pointing fingers at each other.

IDENTIFY INCIDENT MANAGEMENT PARTNERS

A key to effective freeway incident management lies in the ability of multiple agency partners to coordinate and cooperate before, during, and after an incident. Generally speaking, some or all of the following agencies will have a vested interest in improving freeway incident management capabilities and procedures within a region:[(12)]

- Elected officials.
- State and city/county DOTs.
  - traffic operations.
  - traffic management.
  - maintenance.
  - public relations.
- Transit operators.
- State, city/county, and transit law enforcement agencies.
- Fire and emergency medical services.
- Hazardous materials (Hazmat) contractors.
- Other emergency agencies (office of emergency management, etc.).
- Environmental protection agencies.

- Towing services.
- Corporate service patrol providers.
- Regional authorities (metropolitan planning organizations, council of governments, etc.).
- Media representatives.
- Special event promoters.

Depending on the number of agencies potentially involved in the incident management process, it may be advantageous and necessary to establish smaller subgroups of partners who must interact and cooperate for specific types of incidents.[13] For example, fire and emergency medical services, environmental protection agencies, and offices of emergency management typically have little involvement in the minor accidents and stalls that are of concern to police, DOTs, transit agencies, towing services, etc. Of course, partners such as police and State DOTs will be involved in nearly all subgroups.

BUILD CONSENSUS AMONG PARTNERS

One of the most critical activities that must occur early on in the incident management development process is consensus building among the partners. A consensus is needed on both the importance of optimizing the incident management process and the importance of adopting a "team" approach to addressing the need for coordinated incident management in a region.

Consensus-building does not just "happen." It must be fostered and developed over time. One way to facilitate consensus-building is for each partner to develop a true understanding of the goals, responsibilities, and capabilities that the other partners have within the incident management process.[9] Also, a critical review should be made not only of what the roles and responsibilities of each partner currently are, but also of what they could be (or what the partner wants them to be).[5] Finally, legal ramifications pertaining to each partner's involvement in incident management must be assessed. Formal agreements of understanding and cooperation may need to be written and signed by upper management of each partner to further promote a unified team approach.

Traffic management teams (TMTs), established in numerous regions nationwide, serve as an excellent beginning of a cooperative environment in which to improve incident management. Basic guidelines for successful TMTs are shown below:[1]

- Regular meetings (monthly or bimonthly).
- Attendance by the same personnel at each meeting.
- Attendance by personnel with authority to commit the partner's resources.
- Informal interaction.
- Preparation of agenda for each meeting.
- Focus on reaching verbal consensus on issues being discussed.

It is important that the organization responsible for organizing and running the TMT meeting make an active, consistent effort to identify agenda items and tasks to be undertaken by the team. This is essential to keeping other partners interested and involved. The Palm Beach and Broward TMTs in Florida have hired a consultant to run their meetings. The consultant is seen as having a more organizationally neutral viewpoint on agenda items, and has more time to keep the various partners interested and involved.

ESTABLISH INCIDENT MANAGEMENT GOALS AND OBJECTIVES

Once a consensus to cooperate and coordinate incident management activities has been reached among the various partners, the goals and objectives that the partners wish to accomplish relative to improved incident management must be defined. As stated in **Module 2**, goals are broad statements about the intent of the system or one of its components, whereas objectives are specific statements about what the system or component of that system will attempt to accomplish. A given goal may have more than one specified objective. Furthermore, the emphasis at this point in the process is on identifying what the subsystem or component will accomplish, not what technology will be employed. Table 8-4 presents examples of some possible goals and objectives relative to incident management.

ESTABLISH PERFORMANCE CRITERIA

Performance criteria are used to determine whether the objectives established in the previous step are being achieved. For incident management, these criteria can be both quantitative and/or qualitative. Examples of some types of performance criteria for incident management are shown in table 8-5.

Table 8-4. Examples of Goals and Objectives of Incident Management.

Category	Examples
Incident management goals	• Reduce the impact of incidents upon peak-period traffic • Reduce the potential for injury to motorists stranded by disabled vehicles • Reduce the freeway congestion that develops at exits to a regular special event
Incident management objectives	• Detect all lane-blocking peak-period incidents within 2 minutes of occurrence • Provide first response to an incident within 5 minutes of occurrence • Reduce the time to clear an incident by 15 minutes • Reduce freeway traffic volume approaching a peak period lane-blocking incident by 10 percent • Detect 75 percent of all disabled vehicles within 20 minutes after they have stopped on the shoulder • Divert 25 percent of traffic that normally uses a given ramp to access a special event facility to other exits

Table 8-5. Examples of Incident Management Performance Criteria.

Objective	Examples of Performance Criteria
Detect all major incidents within 2 minutes of occurrence	• Average detection time • Percent of incidents detected within 2 minutes of occurrence
Provide first response to an incident within 5 minutes of verification	• Average response time • Percent of incidents responded to within 5 minutes of verification
Reduce the time to clear an incident from the freeway by 15 minutes	• Change in average clearance time due to improvements in incident management procedures

DEFINE FUNCTIONAL REQUIREMENTS

Once the goals and objectives for incident management have been identified, the functions (specific features or activities) that are required to achieve the objectives need to be defined. As with the objectives, the functions should be described independent of the technologies that could be used to accomplish the objectives (focusing on what should be done, not how it should be done).[14] Often, these functional requirements can be outlined in a hierarchial order. Figure 8-2 provides an example of possible functional requirements for the incident management component of a freeway management system. Note that each of the functional elements defines an action that is to be performed, and is independent of the technology that could be used to accomplish that action.

DEFINE FUNCTIONAL RELATIONSHIPS, DATA REQUIREMENTS, AND INFORMATION FLOWS

The purpose of defining the functional relationships, information flows, and data requirements is to establish an understanding of how the various incident management functions that are to be accomplished will be integrated with each other and among the other components in the freeway management system. Much of these relationships, flows, and requirements have been prepared through the National Architecture development effort for ITS. The National ITS Architecture for incident management can be adapted to incorporate local issues, concerns, and capabilities.

Within this step in the decision process, local and regional details that further define when and how incident management functions will be accomplished are established. For example, it may be necessary to subdivide the freeway or corridor into smaller segments because of jurisdictional differences, and adjust the design of the system slightly for each segment, depending on the partners involved, chain-of-command for contacting each partner, etc. Special legislation may need to be established to allow certain incident management tasks (such as service patrol operations) to be privatized.[5] These and other institutional issues identified during problem

Identify incident
- Identify incident location
- Identify incident characteristics (vehicle types, injuries, etc.)
- Identify incident impacts upon traffic flow

Formulate response actions
- Identify necessary emergency vehicle response
- Select incident information for dissemination to travelers
  - Notify transit riders at a park-and-ride lot that their bus may be delayed
  - Notify traffic information services of incident location
- Identify traffic control strategies
  - Increase green time on parallel arterial nearest to the freeway
  - Initiate ramp metering upstream of the incident

Initiate and monitor response
- Initiate coordinated response by the appropriate agencies
  - Implement emergency vehicle response
  - Provide incident information to travelers
  - Implement traffic control strategies
- Monitor response
  - Arrival of emergency vehicles
  - Implementation of traffic control
  - Clearance of incident
  - Clearance of congestion

Figure 8-2. Examples of Incident Management Functions.

identification and goal/objective definition are resolved during this step of the process.

IDENTIFY AND SCREEN TECHNOLOGY

After the various institutional issues relative to incident management have been addressed, the decision process then reaches the point where it is necessary to identify and screen technologies available to achieve the functional requirements and incident management architecture defined for the freeway management system. A review of the various techniques available to facilitate incident management is provided later in this module. This section provides a review of the major issues pertaining to each of the basic phases of incident management (detection and verification, response, and clearance) as they relate to freeway management systems.

Incident Detection and Verification

Incident detection and verification requires the following:[(1)]

- A means of sensing that an incident has occurred.
- A means of verifying the incident's existence and location.
- A focal point for the fusion of data from multiple detection sources.
- Communications links between detectors and receivers of incident data.

- A means of displaying and recording incident information.

Many different technologies exist which can be used for incident detection and verification. Incident detection in many locations involves a combination of several different detection technologies, and appears to work quite well. Overall, detection and verification technology screening requires a consideration of the following issues:

- Detection speed.
- Accuracy.
- Costs.
- Maintainability.
- Personnel requirements.
- Usefulness of data for other freeway management purposes.
- Speed with which the technology can be implemented and benefits begin accruing.

It is the responsibility of the various partners involved in incident management to decide upon the relative importance of each of these items. The last bulleted item is particularly relevant to all phases (detection, verification, response, and clearance) of incident management. Several agencies have strongly recommended initially implementing low-cost technologies that can provide immediate and demonstrable benefits to the general public, and then building upon those successes to further enhance and improve incident management capabilities in an incremental fashion.[5,12] For instance, cellular phone calls from motorists and CB radio reports from truck drivers have become very important components of incident management efforts in many metropolitan areas, and are often the fastest means available for detecting incidents.[15] Methods of incorporating these detection sources into incident management efforts early on can yield significant benefits almost immediately.

Details of various incident detection and verification technologies are addressed in the Techniques section later in this module, and also in **Module 3**.

Incident Response and Clearance

Technology screening relative to incident response and clearance will depend on the specific types of problems identified initially in the process. Certain types of problems, such as lengthy clearance delays for large truck incidents, can be reduced by making sure that specialized response equipment (heavy-duty wreckers, inflatable air bag systems to upright overturned trucks, etc.) are available from private-sector services. However, specialized hardware or software to assist in incident response and clearance is only one part of the overall technology screening process. Other focus areas to be screened include:

- Minor geometric modifications to enhance response and clearance capabilities (i.e., installing or moving median barrier gates, constructing staging areas for incident management, etc.).
- Institutional arrangements to facilitate cooperation and coordination of incident response and clearance activities among the partners.
- Legislation supporting vehicle removal policies or other clearance activities.

As with incident detection and verification, the screening process for incident response and clearance should include consideration of the following issues:

- Costs.
- Maintainability.
- Personnel requirements.
- How quickly the technology can be implemented and benefits begin accruing.

Also, it is important to recognize that the technology screening process for incident management cannot occur in isolation from other ongoing or planned freeway management system activities. Implementation actions related to ramp control, information dissemination, HOV treatments, and lane use control all affect and tie into incident management efforts and initiatives as well.

Additional details regarding incident response and clearance are discussed later in the Techniques section of this module.

DEVELOP PLANS

This step in the decision process involves the development of a plan to implement the technologies that have been determined to best meet the goals and objectives of incident management and that are the most feasible for the unique geographic, environmental, and institutional characteristics of the region. As discussed in detail in **Module 2**, this plan documents the following features of the incident management system:[16]

- Needed legislation.
- System design (architecture, technologies utilized, etc.).
- Procurement methods.
- Construction management procedures (if construction is involved).
- Start-up plan.
- Operations and maintenance plan.
- Institutional arrangements.
- Required personnel and budget resources.

In conjunction with the implementation plan (or possibly as a separate development effort), an incident response plan can also be an important activity to facilitate improved incident management within the region. This plan is a detailed document which specifies the following:

- Key partner roles.
- Communication links.
- Detailed traffic management procedures.
- Resources (and their locations).
- Logistics.

Table 8-6 summarizes the information provided for each of the items listed above. Commonly, a detailed response plan recognizes that traffic demands vary over time and location within the region, and so the management procedures required to effectively accommodate an incident will depend upon where and when it occurs as well as its severity. Consequently, some agencies have found it convenient to develop varying levels of incident management implementation. These levels may range from minor on-site management activities during low-volume conditions to a full-scale integrated major response effort involving

Table 8-6. Information in an Incident Response Plan. [1]

Section	Function
Participating Agencies	• Lists all participating partners and telephone numbers of the incident management coordinator for each • Lists other agencies that may participate (i.e., resource locations)
Summary	• Describes major plan elements
Levels of Implementation	• Describes the series or levels of incident management intensity and conditions under which each level is to be invoked
Traffic Management	• Describes communications procedures for each roadway section, agencies to be informed, diversionary routes, traffic control locations, local and regional signing
Resources and Responsibilities	• Lists each partner, contact numbers, key personnel, responsibilities, and other pertinent information
Media Contacts	• Lists each media contact, contact numbers, key personnel, responsibilities, and other pertinent information
Team Coordinators	• Lists all involved partner coordinators and telephone numbers

diversion strategies, information dissemination efforts, and other techniques.[1]

IDENTIFY FUNDING SOURCES

Because incident management is the coordination of multiple entities and techniques to achieve an overall goal (reduced disruptions to travel due to incidents), many different funding sources can play a part in the development and operation of an incident management subsystem. Typically, infrastructure-based investments (automated surveillance, roadway information dissemination tools, traffic signal timing improvements, accident investigation sites) have typically come from the public agencies (State, local) that have direct jurisdiction over the facilities on which they are located.

Initially, courtesy service patrols were funded primarily by DOTs, with the agency benefiting both from positive public relations and from the improvements in traffic operations.[12] In recent years, though, several regions have successfully implemented patrols in which different funding mechanisms have been used.[17] These mechanisms include the following:

- Additional gasoline taxes.
- Additional sales taxes.
- Department of motor vehicle fees.
- Federal construction funds.
- Bridge or highway tolls.
- Congestion Management and Air Quality (CMAQ) funds (for start-up and initial operating costs).
- National Highway System funds.

- Surface Transportation Program funds.
- Private funds.

IMPLEMENT

Experiences from several past incident management implementation efforts indicate that partners should utilize a building-block approach, initiating low-cost components first to demonstrate to the public and to elected officials the benefits of incident management activities.(12) It is then easier to "sell" other components (such as electronic surveillance) that are more capital intensive.

In general, the initiation of service patrols should be one of the first incident management activities that partners consider for their region. Benefit-cost ratios between 2.3:1 and 36:1 have been reported.(17) Again, partners should start small, and gradually build upon this service as they learn more about its operation and develop public and elected official support for it over time.(12)

EVALUATE

Evaluation is a critical component of the incident management decision process. Evaluation helps to define the benefits of incident management in order to maintain and improve funding levels. Also, evaluation is necessary to assess the extent to which the goals and objectives established for incident management are being met. Finally, evaluation is important in identifying new, unforseen difficulties that arise in the incident management process, as well as in identifying possible solutions for dealing with those difficulties.

Methods of evaluation of an incident management program include the following:(18, 19)

- Quantifying the impact upon traffic flow (delays, fuel consumption, emissions, secondary accidents, etc.).
- Critiquing the program through periodic traffic management team reviews or special debriefings held after major incidents.
- Staging mock drills or exercises of a major incident as a training activity and process review.
- Holding post-incident debriefings to review effectiveness of incident management activities and identify areas of improvement.

8.3 TECHNIQUES AND TECHNOLOGIES

INCIDENT DETECTION AND VERIFICATION

Rapid detection is a critical element in the incident management process. The sooner an incident can be detected, the quicker a response to clear the incident can be initiated. Technologies available for detecting incidents range from low-cost non-automated methods to sophisticated automated surveillance techniques requiring extensive public agency investments. It should be noted that emerging Intelligent Transportation Systems (ITS) technologies offer promise for dramatically improving detection capabilities and reliability. The various technologies used by transportation agencies to detect incidents are discussed in the following sections.

Non-Automated Detection Techniques

Whereas most thoughts of incident detection for a freeway management system focus on the various automated technologies that are available, experience suggests that non-automated detection methods serve a valuable and often primary role in incident detection efforts in many instances. These methods typically utilize motorist call-in technology or manual surveillance methods to achieve incident detection. Non-automated detection methods include the following:

- Cellular telephone calls to 911 or incident reporting hotline.
- Dedicated freeway service patrols.
- Peak-period motorcycle patrols.
- Citizen-band radio monitoring.
- Motorist call boxes.
- Aircraft patrols.
- Fixed observers/volunteers.
- Closed-circuit television.
- Fleet operators (taxis, transit, delivery drivers).

Table 8-7 summarizes the advantages and disadvantages of each of these non-automated detection technologies. It should be noted that the growth of cellular telephone popularity has resulted in that becoming the most important detection technology in most metropolitan areas.[(15)]

Freeway service patrols are able to begin incident response and clearance activities immediately, which increases their attractiveness from an overall incident management perspective. They are also a valuable public relations tool for the sponsoring agency. [(12)] Conversely, the use of fixed observers is most applicable to short-term needs (during special events, major freeway construction activities, etc.).

Closed-circuit television can serve as a manual means of incident detection by having system operators continually watch the monitors. However, this technology is more commonly used as a verification tool for incidents detected via cellular telephone reports or automated detection algorithms (discussed in the next section).

Automated Surveillance Techniques

Technologies

Most freeway management systems include some form of automated surveillance which can be used to detect freeway incidents. Types of automated surveillance are listed below:

- Inductive loop.
- Magnetometer.
- Microwave/radar.
- Laser.
- Infrared.
- Ultrasonic.
- Acoustic.
- Machine vision.
- Vehicle probes (automatic vehicle identification, automatic vehicle location).

Module 3 presents additional details about these detectors. The first two technologies, inductive loops and magnetometers, are placed within the pavement. The others are non-intrusive surveillance technologies,

Table 8-7. Comparison of Non-Automated Incident Detection Technologies.[1, 5]

Technology	Definition	Advantages	Disadvantages
Cellular telephone calls to 911 or incident reporting hotline	Motorists use their cellular phones or call from a roadside telephone to report incident.	Often fastest detection method available.	Dependent upon motorist input. Verification needed. May need additional staff to handle calls.
Freeway service patrols	Special vehicles circulate to provide breakdown assistance.	Serves detection, verification, and response functions.	Congestion reduces circulation frequency. Labor-intensive.
Peak-period motorcycle patrols	Motorcycle police officers patrol freeway segments.	Serves detection and verification functions. Already in place as part of regular police functions. Can travel through stopped traffic to get to incident.	Congestion reduces circulation frequency. Labor-intensive.
Citizen-band radio monitoring	Can establish a special frequency for incident reporting.	Inexpensive. Generally can be monitored by existing staff.	Detection dependent upon number of trucks/CB owners on facility. CB owners may need to be trained to use.
Motorist call boxes	Devices located on side of road which motorists can use to notify authorities.	Incident reporting can occur 24 hours/day. Citizen acceptance is high.	Start up costs are high. Requires motorists to walk to activate. Potential for vandalism. May require additional staff to handle calls.

Manual TABLE OF CONTENTS

Module 8. TABLE OF CONTENTS

Table 8-7. Comparison of Non-Automated Incident Detection Technologies.[1,5] (Cont'd.).

Technology	Definition	Advantages	Disadvantages
Aircraft patrols	Use of airplanes or helicopters to locate incidents.	Can be used to detect and verify incidents. Can cover a wide region, and see things from a larger perspective (easier to assess impacts of incident).	Costly, significant delays may occur between passes over a given segment. May not be useable during severe weather, fog, etc. Some areas may have airspace restrictions.
Fixed observers/volunteers	Observers are positioned on towers or buildings to watch traffic and report incidents.	Flexible. Useful as an interim measure such as for special events or during roadway construction.	Labor-intensive. Not practical during severe weather conditions.
Fleet operators (taxis, transit, delivery drivers)	Drivers call in incidents they encounter during their normal travels.	Large number of observers can be recruited. Little or no cost to public agency.	Accuracy, reliability cannot be controlled. Limited by fleet size.
Closed-circuit television (CCTV)	Cameras located in traffic management center are continuously monitored by system operators.	Provides detection and verification functions together.	Can cause operator boredom problems. Effectiveness dependent upon camera placement.

located above the travel lanes or off to the side. The first eight technologies typically measure speed, volume, and/or occupancy. Conversely, vehicle probe detection systems monitor vehicle position and elapsed travel time.

Although not listed as an automated detection technology, closed-circuit television is commonly used with automated detection systems to verify that an incident is truly present at a location and to begin evaluating and anticipating appropriate response measures.

Detection Algorithms

The effectiveness of automatic detection technologies depends in part on the type of algorithm used to analyze the detector data. Three parameters are generally used to monitor the performance of an incident detection algorithm: detection rate, detection time, and false alarm rate.[20] Detection rate is defined as the percentage of the total number of capacity-reducing incidents that are detected by the computer algorithm. Detection time is defined as the time between when an incident occurs and when it is detected by the algorithm. The false alarm rate is generally used to provide an indication of how many times the algorithm incorrectly indicates that an incident condition exists when, in fact, no incident is present.

As shown in figure 8-3, there is a general relationship that exists between detection rate, false alarm rate, and detection time. With most incident detection algorithms, the false alarm rate increases as the detection rate increases. Also, the false alarm rate increases as the detection time decreases. This is because as the sensitivity of the algorithm is adjusted to detect less severe incidents more quickly, minor fluctuations in traffic can trigger the algorithm to signal that an incident is present, when in fact no incident exists on the freeway.

Agencies must decide for themselves what is an acceptable balance between detection sensitivity and false alarm rate for their detection system. False alarms can be tolerated in order to achieve a higher detection sensitivity, so long as they are not too frequent and liable to be ignored by the system operator. Evaluation of false alarm rates should generally be based on the their frequency over a given time period (i.e., hourly or peak period). An algorithm may be reported as having a very small false alarm rate percentagewise (based on the total number of detection "checks" it performs), but yield a fairly high number of false alarms because the total number of such "checks" made during a given time period is so high.

The four general categories of incident detection algorithms that rely on volume, speed, and or occupancy data include the following:[21]

- Comparative.
- Statistical.
- Time-series/smoothing.
- Modeling.

Comparative (or pattern recognition) algorithms compare traffic parameters at a single detector station or between two detector stations against thresholds that define when incident conditions are likely. Statistical algorithms use statistical techniques to determine whether observed detector data differ statistically from historical or defined conditions. Time series and smoothing algorithms compare short-term predictions of traffic conditions to measured traffic conditions. Modeling algorithms use standard traffic flow theory

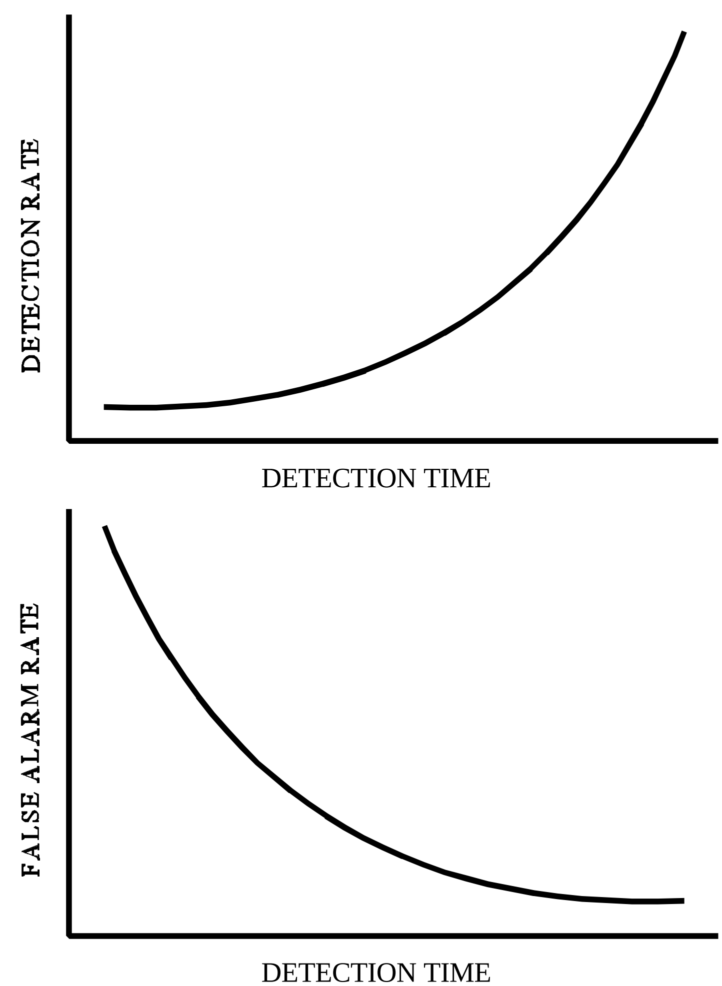


Figure 8-3. Relationship between Detection Rate, False Alarm Rate and Detection Time.[20]

to model expected traffic conditions on the basis of current traffic measurements. Table 8-8 lists the algorithms available in each category.

A recent review of the algorithms indicated that two of the Modified California Algorithms (#7 and #8) and the McMaster Algorithm rated the highest on the basis of reported performance, operational experiences, and model complexity. When calibrated properly, these algorithms can be expected to achieve detect 70 to 85 percent of all incidents, while incorrectly triggering a false detection alarm about 1 percent of the time or less.[22] Conceptually, these algorithms were also judged to be easy to understand and implement from an operator's perspective.

Detectors that monitor traffic parameters other than volume, speed, and occupancy (i.e., travel times, individual vehicle movements, queue lengths, etc.) have only recently been introduced. Consequently, only limited experimental data is available on the feasibility of these technologies for detecting incidents.[23, 24] More work in this area will be needed before AVI/AVL or

Table 8-8. List of Available Incident Detection Algorithms.[22]

Algorithm Type	Algorithms	
Comparative	California All Purpose Algorithm Pattern Recognition (PATREG)	Modified California (10 different algorithms)
Statistical	Standard Normal Deviate (SND)	Bayesian
Smoothing/Filtering	Exponential Smoothing	Low-Pass Filtering
Traffic Model	Dynamic Model	McMaster

other non-traditional technologies will be viable for incident detection purposes.

INCIDENT RESPONSE AND CLEARANCE

Response is defined as the activation, coordination, and management of appropriate personnel, equipment, communication links, and information media as soon as there is reasonable certainty that an incident is present. Steps in the response process include:

- Verifying the existence and location of the incident.
- Assessing the incident to determine the type of response needed to clear it.
- Initiating the appropriate response.
- Removing the incident.

A quick and timely response by the necessary resources to clear the incident can significantly reduce its duration. The following sections provide a summary of the technologies available to facilitate incident response and clearance, and thereby reduce its total duration and impact upon travel in the region. Each category is discussed in terms of equipment, management strategies, and operations involved.

On-Site Response Techniques

One of the most critical facets of incident response is the utilization of equipment and management strategies on-site. The effectiveness of incident response is a function of both the use of appropriate techniques for the situation and how well these techniques are managed by the personnel present. A well managed response that utilizes minimal available resources can still operate more effectively than a poorly managed response that has all of the latest and greatest equipment. In the following sections, equipment and management strategies/operations relative to on-site incident response are summarized.

Equipment

Several types of equipment are available to help with on-site response. These range from items that improve the management of resources, to special-use equipment items that help reduce the response and clearance times of certain types of incidents. Some of the more effective items are discussed below.

Identification Arm Bands and Vests. These can be used to quickly differentiate respondents from members of the public or media who may also be at the incident site. Specially-designated colors and/or patterns can be provided for each of the agencies. This can reduce confusion, and help in controlling who is allowed within the incident site.(5)

Incident Response and Hazardous Materials Manuals. Having adequate documentation detailing how to handle an incident situation can significantly reduce response times. Generally, a transportation agency needs to develop two types of manuals: a response manual and a hazardous materials manual.

- *Response Manual* - The response manual outlines how to respond to specific incident situations and who should be contacted.(6) It should list all of the resources available for responding to an incident regionwide, including both public agency and private sector sources. This list should include the locations and possible operators of large tow trucks, special incident handling equipment, and equipment suitable for handling hazardous materials.

  A key to the effectiveness of these lists is a commitment to keeping them current, updating them as personnel and other resources change within the region. Agencies may wish to consider keeping the manual on-line in a computer database to help keep it current. The manual may also include other important information such as maps, diagrams of selected interchanges, milepost identifiers, utility locations, and sensitive or hazardous off-freeway facilities. It should be organized to facilitate immediate access to specific information or telephone numbers. The type of information generally included in a response manual is shown in table 8-9.

- *Hazardous Material Manual* - Although the primary rule for responding to hazardous materials spills is "leave it to the expert," it is necessary to provide those agencies who are likely to respond first to an incident scene with some basic guidelines for when they suspect that hazardous materials may be involved.(6) These guidelines should be provided in the form of a reference manual. Two hazardous materials manuals are generally developed: one for use by field personnel (e.g., police and DOT personnel) on the scene, and one for use by response dispatchers. The field manual should include guidelines on identifying types of hazardous materials and how to stabilize them at the incident scene. In addition to describing who should be contacted in case of a hazardous materials spill, the dispatcher's manual should also include more detailed information that can be used to consult and advise the field personnel as to any situation that may occur before a hazardous materials response team arrives on the scene. Table 8-10 shows potential subject matter to be included in a hazardous materials manual.

Total Stations Surveying Equipment. This equipment utilizes infrared surveying technology to measure distances critical to an accident investigation. This technique is currently being used by law enforcement personnel in several States as an aid in investigating major accidents.(25, 26)

Table 8-9. Example of Resource Material Included in Response Manual. [6]

Police State City Park Tollway County (including sheriffs) Military	**Fire/Rescue** State City Airport County Industrial Military
News Media Radio stations Newspapers Television stations Traffic reporting services (Metro, Shadow, Smartroutes, etc.)	**Local and State Agencies** Health Pollution control Agriculture Air control
Highway Department Engineering Maintenance Cleanup Traffic Management Center Tollway or turnpike authority Traffic Management Team	**Emergency Medical Services** Coroner Red Cross Funeral homes Helicopters Special medical vehicles Ambulance Hospital emergency rooms Rescue squads-extrication
Special Vehicle and Equipment Cranes Oversize wreckers Tanker trucks Trucking companies Local transit service Livestock trailers Earthmoving equipment	**Towing and Road Service** Auto clubs Franchised tow truck operators Private-gas stations, garages, junkyards Public-police, hwy authority, service patrol
Special Hazard Teams Chemical Electrical Mechanical Biological Radioactive Ordinance disposal	**Utilities** Telephone Electric Gas Water Sewer Cable
Federal Agencies Department of Energy Energy Resources Development Administration Federal Aviation Administration Department of Defense U.S. Public Health Service Defense Civil Preparedness Agency Office of Emergency Transportation Environment Protection Agency Department of Agriculture Postal Service Federal Emergency Management Agency	**Other** National Guard and Reserve Accident investigation teams Vehicle rental companies Institutions Humane society Game warden Military personnel Railroads Weather bureau Pipeline companies Water authorities Scuba divers Transportation services

Table 8-10. Example of Material to Be Included in a Hazardous Materials Manual.[6]

● **INTRODUCTION** ● **RESPONSE AT SITE** ○ **Information to be gathered** ○ **Specifics of spill** - Liquid/gaseous - Description of leak ■ Rate of flow/quantity spilled ■ Odor ■ Color ■ Density - Type of container ■ Box, box trailer ■ Tanker type - Precise labels from truck ■ UN numbers ■ Company name ○ **Drainage systems in area** - Ditches - Bodies of water ○ **Weather conditions** ○ **Traffic flow** - Number of lanes open/blocked ○ **Communications** - Communications with central command post ■ Fire ■ Other police ■ Ambulance ■ Environmental protection ■ Other ○ **Securing the scene** - Establish field command post - Cordon off area ■ Green zone ■ Yellow zone ■ Hot zone - Types of vehicles to position in each zone - Implement traffic diversion plans	● **RESPONSE AT CENTRAL COMMAND POST** ○ **Query field personnel to obtain all relevant information on spill** ○ **Notify other agencies** - Environmental Protection Agency - Local Boards of Health ○ **Notify local contractors if required for clean-up** ○ **Notify personnel on scene as to protection required** ○ **Notify media** ○ **Utilize available literature and guides** - US DOT Guidebook Chemtrec Center, Washington, D.C. ○ **Notify shippers** ● **APPENDICES** ○ Drills and Training ○ State Regional Coordinators ○ County Offices - Boards of Health ○ Traffic Control Guidelines ○ Blank Forms for Environmental Protection Agencies ○ Radiation Accidents ○ References to Laws and Regulations ○ List of References

The equipment is used to quickly obtain measurements needed to reconstruct the accident, and can significantly reduce the time required to collect the necessary data to reconstruct the accident. It also allows more accident-related information to be collected with greater accuracy. A supporting computer system is required to achieve the maximum benefits. In addition, training and continued use is required to ensure that the officers are using the equipment properly. For example, the Maryland State Police have three "crash" teams which operate total stations equipment and are proficient in its use. They are on call 24 hours a day and report to an incident within 30 minutes.

Inflatable Air Bag Systems. These can be used to right overturned heavy vehicles.[5] The system consists of several heavy rubber inflatable cylinders of various heights. These bags are placed under the overturned vehicle at strategic locations, and inflated to right the vehicle. This system can be used in almost any location to right an overturned vehicle. Wreckers are still required to assist in the process, and, depending upon the size and shape of the vehicle, some vehicles can puncture the bags. Most large-scale towing and recovery specialists in large metropolitan areas have this type of equipment available. Appropriate contracts may need to be established between public agencies and these specialists to ensure that the equipment is available for use in an incident.

This type of system is ideal for righting vehicles with fragile loads or tankers where other means of righting the vehicle may rupture or damage the cargo. It is also ideal for working in constrained areas, such as tunnels, bridges, and overpasses, where larger towing or response vehicles may have difficulty maneuvering. Figure 8-4 illustrates the use of an air bag system.

Equipment Storage Sites. These sites are key locations, normally suffering from high incident rates, where incident response equipment is stored (particularly traffic control devices). To be effective, they need to be easily accessible and used by all response agencies. Also, agreements must be established as to who will stock and maintain the equipment and materials contained at the storage sites.[5]

Tow Truck/Removal Crane Contracts. These contracts can achieve minimum response times in specific sections of freeway. Tow trucks can be summoned to an incident location either by using a rotation list (in which each wrecker service in a specific section of freeway is called in order) or by securing a bid contract for service for a specific section of freeway. The use of tow truck contracts or agreements may require local agencies to adopt ordinances that ensure that existing wrecker services are not adversely affected. It is also essential to have a local ordinance providing the police with the authority to establish wrecker contracts, to lay the ground rules for using such contracts, and to determine penalties for non-compliance by wreckers with the ordinance. Some requirements that are commonly used in wrecker contracts include the following:[1]

- Minimums on equipment, storage space, insurance, and licensing.
- Specifications calling for the availability of heavy duty towing and recovery equipment.
- Twenty-four hour availability of wrecker service.
- Specified minimum response times (30 minutes is commonly used).

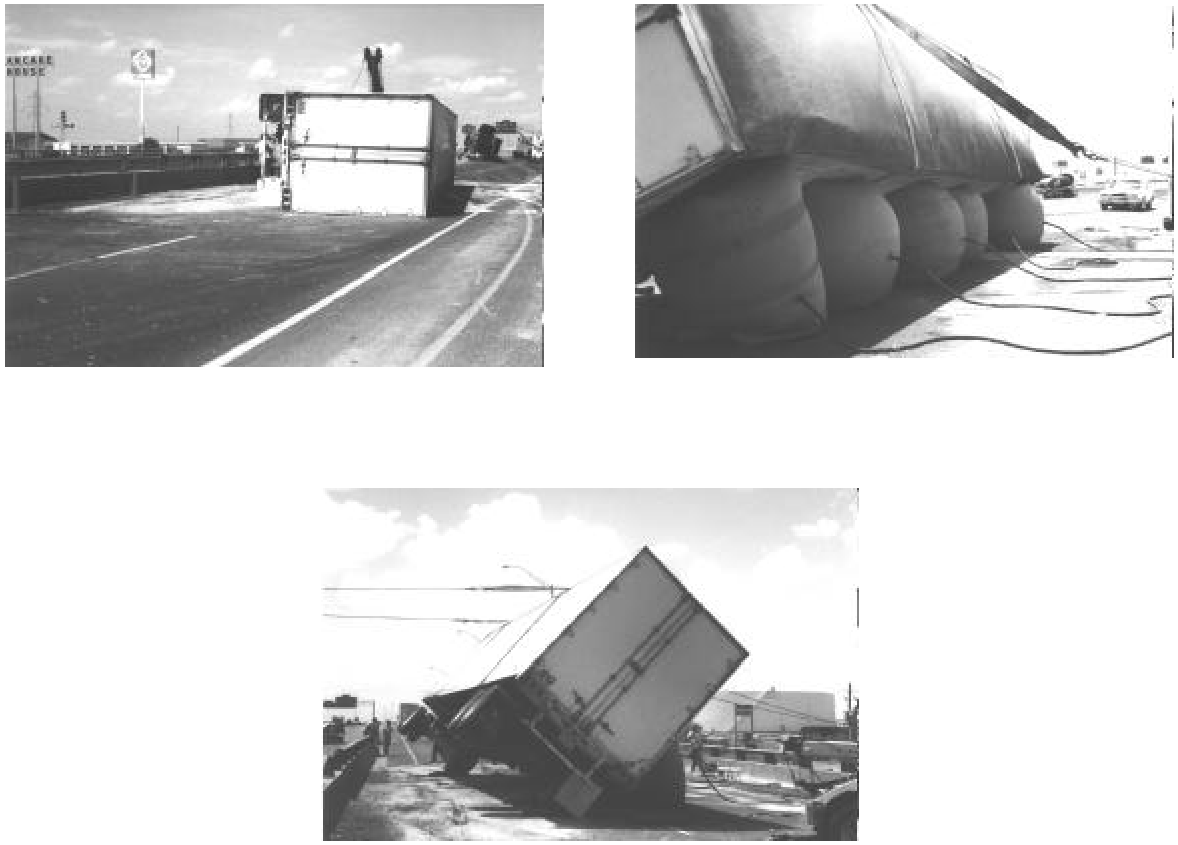


Figure 8-4. Air Bag Use to Overturn Tractor Trailer.

Management Strategies/Operations

In addition to special equipment to facilitate on-site response, a number of management strategies can be developed and invoked, as necessary, to assist in the response process, as summarized in the following sections.

Emergency Response Vehicle Parking Coordination. This coordination may be enacted to help facilitate an "order" as to the number of response vehicles parked in travel lanes at an incident site and how other response vehicles will be parked on the shoulder or similar off-roadway location in the most efficient manner possible. This "order" may differ depending on the type of incident.[5] However, the overall goal is to minimize the amount of maneuvering required by the different response vehicles, to ensure that no more space is taken up by the incident scene than is necessary, and that lanes can be reopened with minimal movement of response vehicles or disruption of incident clearance activities.

On-Site Traffic Control. This control is required to facilitate the orderly movement of traffic past the incident site or off of the freeway (in the case of a total freeway closure).[27] Channelization of traffic can be accomplished with flares or cones, depending on the anticipated duration of the incident. If the incident is anticipated to last several hours or days, a more elaborate traffic control plan, similar in content to a work zone lane closure set-up, should be employed. Figures 8-5 and 8-6 illustrate typical set-ups for traffic flow past an incident site and diverted completely from the freeway, respectively.

Incident Response Teams. These teams are often needed to clear major incidents. By assembling a major incident response team prior to an actual incident, a faster and more coordinated response can be provided.[1] Most major incident response teams are composed of individuals from law enforcement, traffic engineering, maintenance, and fire and emergency services. These individuals should be of sufficient rank to make decisions about committing the resources of their agencies without further approval from their superiors.

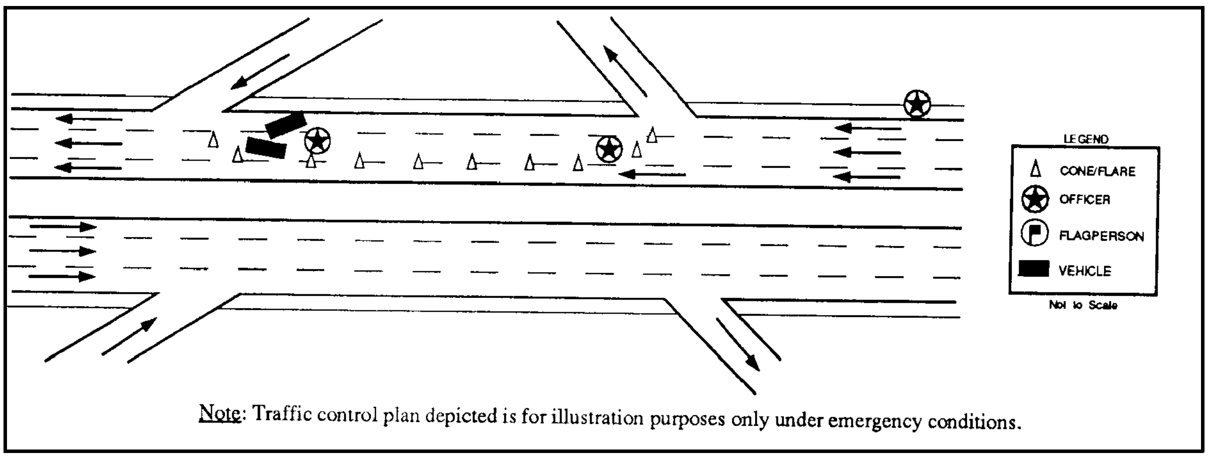


Figure 8-5. Typical Set-up for Traffic Flow Past a Freeway Incident. [27]

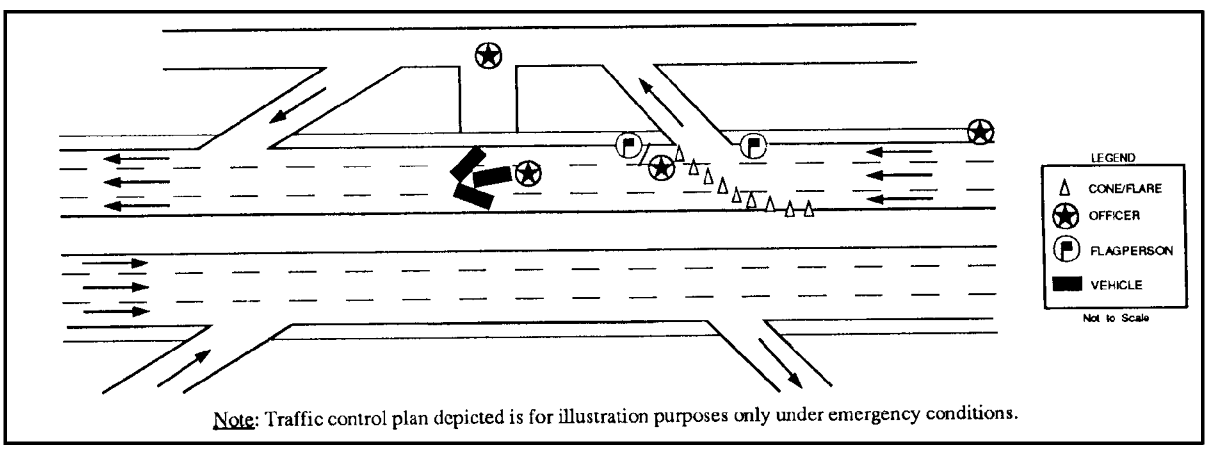


Figure 8-6. Example of a Typical Total Freeway Closure at an Incident. [27]

At a major incident, the team is responsible for assessing the situation and coordinating the implementation of a prepared response within each member's own agency. The team can also make on-site adjustments to the plan to conform to the specifics of the situation. Examples of the types of decisions that will be required by team members include:[1]

- Where traffic will be diverted.
- How and when the wreckage will be cleared.
- How and when repairs to the roadway will be made.
- When the roadway can be partially reopened.

The most important aspect of a major incident response team is that the same individuals report to the incident scene each time, and are familiar with the personnel, authority, and resources of each of the responding agencies. The major function of the team is to handle all logistical problems in support of the incident commander, and to smoothly transfer control of the scene from one agency to another as the incident progresses. Also, the team can be the single source for information to the media, so that consistent information is given out. One means of effecting ongoing improvement in incident response team operations is to hold post-incident debriefings to evaluate procedures and identify areas of improvement.

Vehicle Removal Laws. These laws are legislative or administrative policies that promote the fast removal of disabled, abandoned, or damaged vehicles that constitute a hazard to other motorists. Local laws or ordinances can be enacted that require motorists to move their vehicles (if driveable) off the freeway immediately after an incident. These laws can also define the maximum time limit for leaving a vehicle unattended in the right-of-way, and can establish procedures for removing vehicles by local authorities with push bumpers or tow trucks. To be effective, the enactment of these laws must be followed up with an extensive publicity campaign informing motorists of what to do in case of an incident. Local agencies must also translate the new laws or policies into effective operating procedures and must provide a mechanism for enforcing the new law.

Techniques to Improve Emergency Vehicle Access and Traffic Flow

The next category of techniques to be discussed are those related to improving vehicle access to, from, and around an incident. Whereas the controlled-access and barrier-protected designs of freeways promote the highest degree of safety possible, they are problematic when it comes to trying to get emergency vehicles to an incident site when traffic has queued behind the incident. Equipment and management strategies relative to vehicle access are discussed below.

Equipment

Barrier Openings. These openings can be designed into freeway sections with inadequate access for emergency vehicles, thereby reducing the time it takes for those vehicles to reach an incident location. However, adequate crash cushion protection must be provided for the exposed end of the barriers. Also, an improperly designed opening can be a temptation to freeway motorists to use as a turn-around if they miss an intended exit.

Barrier Gates. These gates have been used in some jurisdictions to combat unauthorized vehicle use. The gates are kept closed and locked until access is needed by an authorized vehicle. One of the major concerns with previous gate assemblies, however, has been with their crash worthiness. Houston has recently installed new remote-controlled barrier gate systems that the developers claim will meet NCHRP Report 350 standards for longitudinal barrier crash worthiness.[28] Figure 8-7 shows this barrier gate.

Emergency Ramps. As agencies reconstruct their aging freeways, entrance and exit ramps are often removed or relocated to improve freeway operations. Unfortunately, this can also reduce the ability of emergency vehicles to reach an incident scene. In some instances, emergency ramps are employed to maintain emergency freeway access. These ramps are closed to regular traffic, but can be utilized by authorized vehicles through a manual or electronic gate system.

Management Strategies/Operations

Police Escorts and Wrong-Way Entrance of Non-Emergency Response Vehicles. This strategy can yield significant incident response benefits. Since both towing services and most DOT equipment utilize yellow flashing lights, it is difficult for them to reach an incident scene. Providing for police escorts of these vehicles, or allowing them to enter the freeway in the wrong direction (i.e., from downstream of the incident) can reduce access times of these

Figure 8-7. Example of Crash Worthy Barrier Gate.

vehicles. Of course, this strategy must be planned beforehand and implemented through ongoing training efforts.

Shoulder Utilization. This management technique has been successfully used to increase traffic flow capacity around an incident site. This is normally implemented best by uniformed officers positioned upstream of the incident site. For this technique to be effective, a minimum of 3 m of clearance is needed from the outer edge of the paved shoulder to the incident or any emergency vehicles that are needed at the response scene. Figure 8-8 illustrates the set-up of a shoulder utilization technique at an incident site.[28]

Contraflow Diversion. This technique can sometimes be used at an incident site that will close the entire freeway for several hours. This involves getting traffic across the roadway median (or across the concrete barrier via a barrier opening or gate as described earlier), utilizing a travel lane from the opposing traffic direction to bypass the incident, and returning the traffic back to its original side of the freeway. It also requires close coordination between law enforcement and transportation personnel, and is generally warranted for only the most severe, special cases. Figure 8-9 illustrates a contraflow diversion set-up at a freeway incident site.

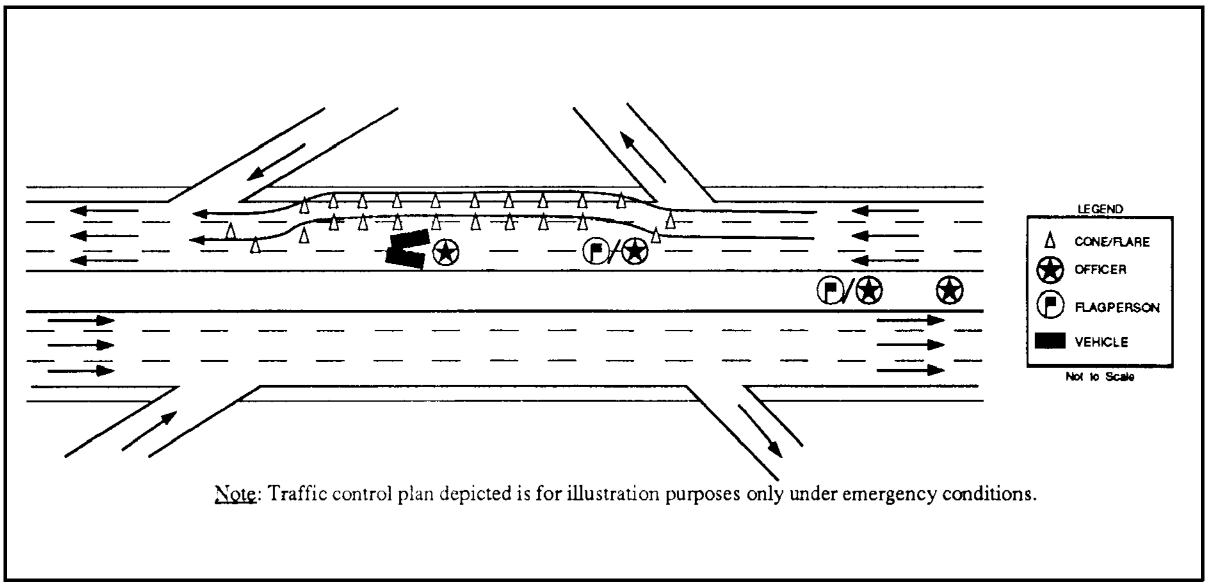


Figure 8-8. Example Set-Up for Shoulder Utilization at a Freeway Incident Site. [27]

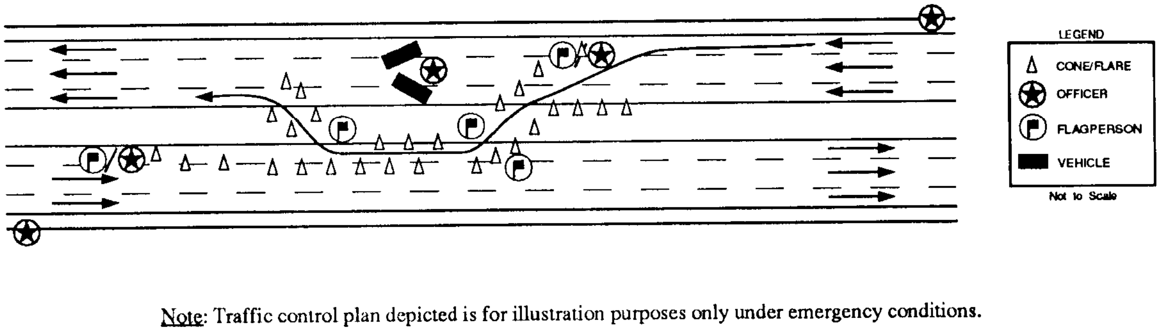


Figure 8-9. Example of a Contraflow Diversion Set-Up at a Freeway Incident. [27]

Accident Investigation Sites

Accident investigation sites are special designated and signed areas off the freeway or roadway where drivers of damaged vehicles can exchange information, and police and motorists can complete necessary accident report forms. These sites can also serve as an incident relocation point by agency-operated clearance equipment and as a media assembly location. In order to reduce rubbernecking, accident investigation sites are generally located so that motorists involved in an accident, the investigating police officer, and the tow truck operators are out of view from the freeway. The benefits of an accident investigation site include reduced motorist delays, reduced vehicle operating costs, reduced secondary accidents, reduced pedestrian exposure, and more efficient use of a public agency's personnel. Unfortunately, such sites have not been well received by the public or law enforcement in some instances, due to security concerns, poor access, or a general lack of awareness about their existence and location.

Equipment

Typical locations of accident investigation sites include under a freeway overpass, on a side street or parallel frontage road, or in a shopping center parking lot out of view of the freeway. An accident investigation site should have space for parking a minimum of five vehicles. This equates to a minimum size of 92 square m. Also, there should be a minimum of 31 m, longitudinally, to pull into and out of curb parking accident investigation sites.[29] Figure 8-10 illustrates examples of accident investigation site design.

Management Strategies/Operations

The criteria for locating an accident investigation site includes the following: [29]

- Easy access to and from the freeway.
- Sufficient overhead lighting and other provisions to ensure personal safety.

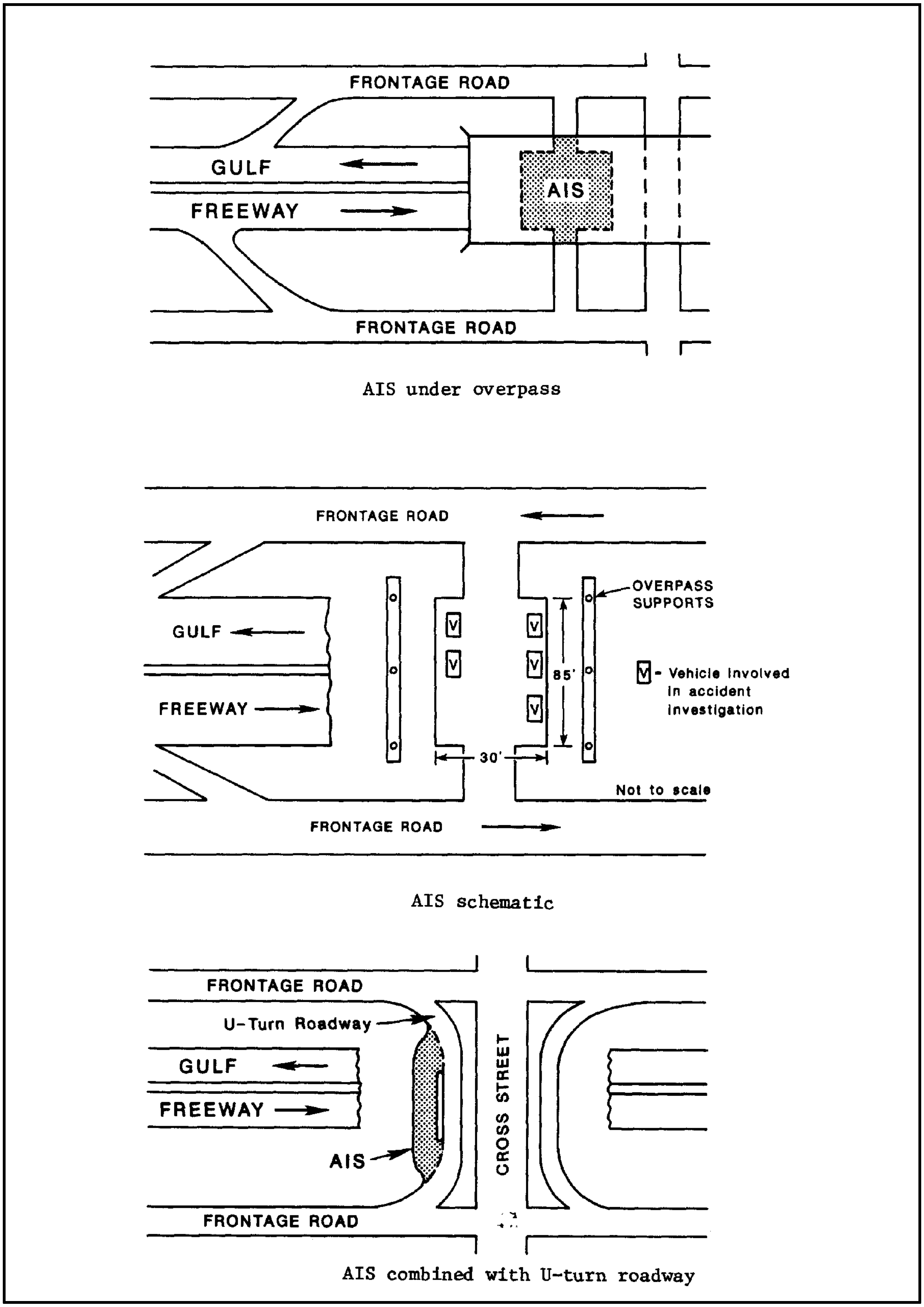


Figure 8-10. Examples of Accident Investigation Site Locations.[29]

- Concealed from the freeway.
- Well delineated and signed.
- Located near a high accident location.
- Little or no construction required.
- Access to a public telephone.

Also, the provision of accident investigation sites must be supported by proper vehicle removal legislation and by law enforcement personnel in order to be effective.

Freeway Service Patrols

Freeway service patrols are a major tool for combating the effects of incidents in metropolitan areas. The primary objectives of service patrols are to locate incidents, reduce the risks to motorists and patrol personnel around the incident, and reduce incident duration so that full capacity can be restored to the freeway as quickly as possible.

Equipment

Typical service patrols rely on light-duty trucks or vans, equipped with a wide assortment of supplies that could be needed to assist a stranded motorist. Some agencies, such as the Illinois DOT in Chicago, use medium-duty wreckers in their service patrol fleet to allow them to quickly relocate automobiles ans small trucks from the freeway lanes. Some of the more common supplies include the following:

- Gasoline.
- Water.
- Tools for minor automotive repair.
- Jumper cables.
- Flares.
- First-aid kit.
- Warning lights.
- Push bumpers.

Access to more extensive and specialized equipment may need to be worked out through private-sector agreements or by other methods. This equipment includes such things as heavy-duty tow trucks, removal cranes, sand spreaders, and rescue and extricator trucks. For large incident management operation in a major metropolitan area, this equipment will need to be accessible 24 hours per day, 7 days per week. [30]

Management Strategies/Operations

Freeway service patrols can be operated from stationary points to deal with spot locations (i.e., bridges, tunnels, construction zones, etc.), dispatched on a call-in basis, or circulated throughout a coverage area (the preferred method for dealing with larger freeway sections).[12] They can be organized and funded by several different organizations:[17]

- Enforcement agencies.
- Transportation agencies.
- Private organizations.
- Multijurisdictional cooperative arrangements.
- Private sector contracts with public agencies.

Electronic Traffic Management and Control Techniques

Equipment

The various traffic management and control components of a freeway management system are intended to assist in incident management activities. These components help to warn motorists approaching the incident about downstream traffic conditions, advise about reduced advisory speeds, reduce approaching traffic demands, and adjust control settings on other roadways that are accommodating increased traffic volumes due to diversion from the freeway. The management and control components that can be used for this purpose include ramp metering and information dissemination.

Ramp Metering. Ramp metering can be implemented upstream of incidents to reduce traffic demands entering the freeway. This technique requires metering of all entrance ramps along a section of freeway (since incident locations vary) and real-time control of these ramp meters.[31] Ramp metering typically operates during peak traffic periods, and may be adjusted slightly if an incident occurs during these periods. However, implementation of ramp metering explicitly for incident management during off-peak periods (when ramp metering is not normally operating) is less common. Additional information regarding ramp metering can be found in **Module 5**.

Information Dissemination Components. These components are typically activated to warn motorists upstream of an incident which travel lanes are closed and to encourage motorists to leave the freeway early or not enter the freeway at all. Notification can occur via any of the different information dissemination technologies (discussed in **Module 7**) present within the region, but must be coordinated and managed so that the information remains current (particularly with respect to location, expected duration, and its impact upon traffic conditions).

Management Strategies/Operations

Although the exact location, severity, and other characteristics of any given incident cannot be predicted in advance, some level of planning is appropriate for the management and operation of both ramp metering and motorist information subsystems for incident response. Table 8-11 summarizes some advance planning steps to facilitate the use of certain information dissemination technologies for incident response.

Alternative Route Diversion Techniques

Alternative route planning is a systematic process that involves examining where and how much traffic should be diverted whenever an incident or other blockage occurs on any section of freeway at any time of the day. In effect, alternative route contingency plans are developed for various levels of freeway incidents anywhere in the system.[12] Coordination and cooperation with local agencies during alternative route plan development is essential for these routes to be safely and effectively implemented when needed.

Alternative route planning involves determining not only where and how much traffic should be diverted, but also when diverting traffic would produce positive benefits. Since diverting traffic to alternate routes is often politically sensitive, how long a freeway is to remain closed before an official detour route is established is often a policy decision. For example, some areas

Table 8-11. Advance Information Dissemination Planning for Incident Response. (Adapted from 1)

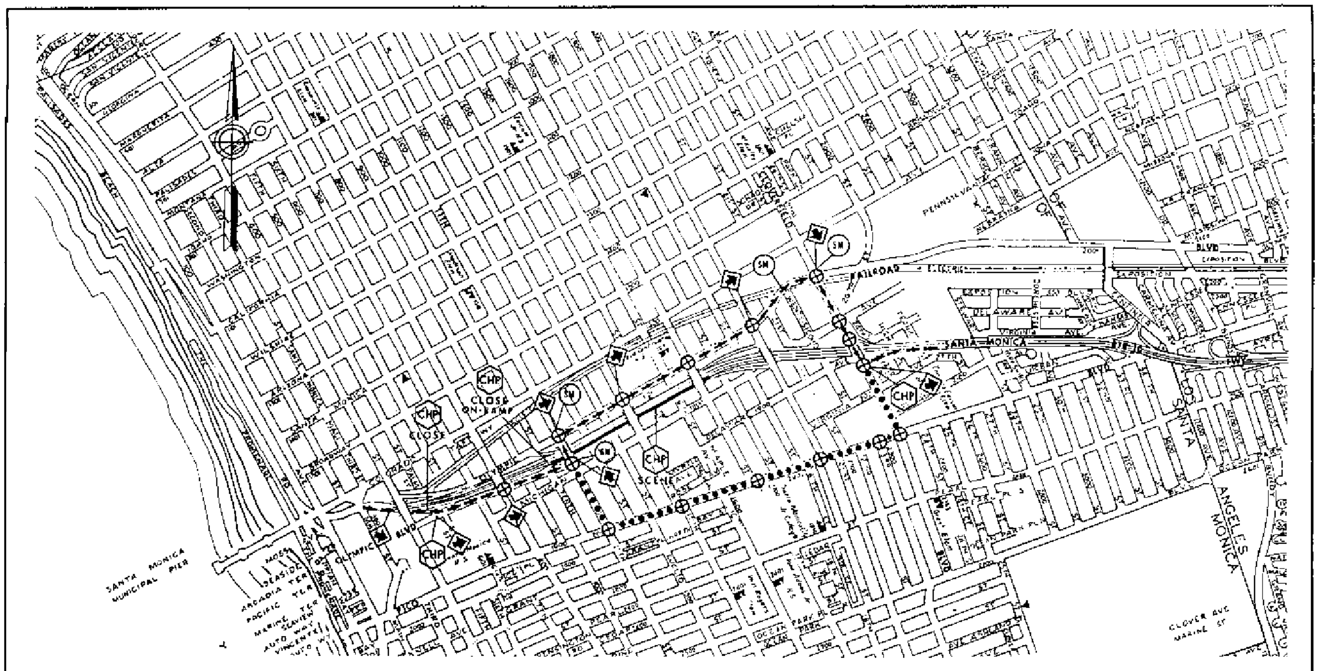
Technique	Planning Required
Variable Message Signs	• If messages are not computer selected, establish responsibilities for message selection and display. • Establish criteria for message selection/display. • If portable, establish dispatch procedures.
Highway Advisory Radio	• If messages are not computer selected, establish responsibilities for message composition and recording. • Establish criteria for message selection/activation. • If portable, establish dispatch procedures.
Private-Sector Information Service Providers (ISPs)	• Information transfer protocols and agreements need to be established between ISPs and agencies providing data.
Commercial Radio/Television	• Set up means for transfers of information to radio/television stations. • Meet with station managers to establish guidelines for reporting frequency. • If information not transmitted by computer, set up procedures and responsibilities for message transmissions.
Print Media	• Define formats for press releases. • Set up procedures and responsibilities for issuing press releases.
Telephone Hotlines	• Set up procedures and responsibilities for message updating and recording.

divert traffic only when an incident is likely to last more than one hour.

Equipment

The information needed on any alternative route plan may differ from jurisdiction to jurisdiction. Most commonly included are specifications about the equipment and manpower that will be needed to implement the specific plan, such as police officer control locations, barricades, signing, etc.[12]

Initially, alternative route plans were prepared on hardcopy printouts that were distributed to law enforcement personnel and to the incident response team. An example of an alternative route plan is provided in figure 8-11. Recently, however, these plans have began to be converted to computerized format on Geographic Information System (GIS) or other platforms to assist in organization and retrieval. Methodologies are also being developed to computerize



STAGES OF IMPLEMENTATION

NO. OF LANES CLOSED

	ESTIMATED DURATION	1	2	3			
MID	1 HOUR	—	I	IV			
TO	2 HOURS	I	II	IV			
0500	2-6 HOURS	III	III	IV			

	ESTIMATED DURATION	1	2	3			
0500	1 HOUR	II	III	IV			
TO	2 HOURS	III	III	IV			
1900	2-6 HOURS	III	III	IV			

	ESTIMATED DURATION	1	2	3			
1900	1 HOUR	II	III	IV			
TO	2 HOURS	II	III	IV			
MID	2-6 HOURS	II	III	IV			

I FIELD CHECK ALTERNATE ROUTES
II ALTERNATE ROUTE TRAFFIC ADVISORIES
III OFFICER & SIGN DEPLOYMENT (VOLUNTARY DIVERSION)
IV EMPLOY ALTERNATE ROUTE (MANDATORY DIVERSION)
V CLOSE FREEWAY CONNECTORS
VI BARRICADE ON-RAMP & CONNECTOR CLOSURES

NOTE: ROMAN NUMERALS ARE STAGES OF IMPLEMENTATION UP TO AND INCLUDING THE STAGE SHOWN.

PERSONS TO NOTIFY

AGENCY	TEL. NO.
CALIFORNIA HIGHWAY PATROL	213 620-3456
DEPT. OF TRANS. MAINT. COMM	213 620-3370
SANTA MONICA POLICE DEPT	213 395-9931

LEGEND

- LIMITS OF CLOSURE
- PRIMARY ALTERNATE ROUTE
- SECONDARY ALTERNATE ROUTE
- SIGNALIZED INTERSECTION
- STOP SIGN INTERSECTION
- SIGNING
- CHP CALIFORNIA HIGHWAY PATROL
- SM SANTA MONICA POLICE DEPT
- FIRE STATION

LIMITS OF CLOSURE

BETWEEN LINCOLN BLVD ON-RAMP AND 20TH ST OFF-RAMP

ALTERNATE ROUTES

PRIMARY:
LINCOLN BLVD OFF-RAMP TO E/B OLYMPIC BLVD TO N/B 11TH ST TO E/B OLYMPIC BLVD TO S/B CLOVERFIELD BLVD TO ON-RAMP

SECONDARY:
LINCOLN BLVD OFF-RAMP TO E/B OLYMPIC BLVD TO S/B 11TH ST TO E/B PICO BLVD TO N/B CLOVERFIELD BLVD TO ON-RAMP

SPECIAL NOTES:

OTHER - CLOVERFIELD BLVD ONE LANE

YES NO
☐ ☐ MEDIAN SHOULDER OK FOR TRAFFIC
☐ ☐ OUTSIDE " " " "
(MAJOR PORTION OF CLOSURE AREA, FIELD CHECK AT INCIDENT AREA)

ALTERNATE ROUTES

SANTA MONICA FREEWAY
ROUTE 10
EASTBOUND

DATE REVISED 10/75

LA-10-E24

Figure 8-11. Alternative Route Plan.[12]

Manual TABLE OF CONTENTS

Module 8. TABLE OF CONTENTS

some of the decision-making processes involved in alternative route selection. [32]

Management Strategies/Operations

Planning of alternative routes must be done by a team consisting of State and local transportation and enforcement agencies, as a minimum.[12] Not all arterials near a freeway may be desirable alternative routes. Features that make an arterial undesirable as an alternative route include the following:

- Schools.
- Hospitals.
- "Sensitive" neighborhoods.

Work Zone and Special Event Traffic Management

Work zones and special events constitute a special type of incident in that the location and duration are usually known in advance. This allows agencies to analyze beforehand the potential impacts of a work zone or special event, and if necessary, to develop a customized package of transportation system improvements to mitigate those impacts.

Equipment

General guidelines for traffic control are provided in the *Manual on Uniform Traffic Control Devices*.[33] In addition, various state and local agencies adopt their own version of these guidelines. These guidelines cover appropriate advance signing, barricades, channelizing devices (where lanes are to be closed) and other approved devices. Many of these devices are appropriate for site control at and near special events as well.

Management Strategies/Operations

The *MUTCD* also provides guidance on appropriate management strategies for various types of work zone lane closures, indicating such things as minimum cone taper lengths, locations of advance signing, and proper layout of channelization devices. These guidelines are dependent upon the duration of the scheduled work activity, the time of day, the roadway type, and the operating conditions.[32]

Major freeway reconstruction activities and special events place tremendous demands upon the freeway and surrounding surface street system to accommodate unusual traffic patterns. The planning horizon available for these types of activities allows for a number of demand management strategies to be implemented within the freeway corridor, if appropriate. Table 8-12 summarizes some of the impact mitigation strategies that have been implemented at a sample of major reconstruction projects and special events nationwide.[12]

8.4 LESSONS LEARNED

WATER ACCESS

Not all incident response and management activities must involve a high degree of technical complexity in order to provide a significant benefit to the public and to incident response agencies. Often, simple low-tech solutions can offer substantial benefits to a response agency or to the public.

In San Antonio, for example, officials have commented about problems encountered when trying to combat vehicle fires on elevated freeway sections. Simple standpipe assemblies that provide a fire department with access to a fire hydrant from an

Table 8-12. Traffic Management Actions During Major Freeway Construction and Special Events. [12]

Types of Actions	Actions Implemented
Actions to Improve Alternative Routes	Traffic signal timing adjustments Traffic signal equipment improvements Left-turn restrictions at critical locations Parking restrictions Police control of critical intersections Reversible lanes Implementation of alternating, one-way pairs Intersection widening and channelization Resurfacing and other pavement repairs Signing and lighting improvements Use of real-time information systems to encourage diversion Constructing temporary pedestrian overpasses at vehicle/pedestrian conflict points
Actions to Improve HOV and Transit Utilization	New or expanded commuter rail service Expanded rapid transit service New or expanded bus service Implementation of HOV only ramps and lanes New or expanded park-and-ride lots New or expanded ridesharing programs Eliminating or moving single occupant vehicle parking locations Increasing parking fees for single occupant vehicles
Actions to Improve Public Understanding, Cooperation, and Acceptance	Traditional P-R tools (press conferences, new releases) Special publications Toll-free hotlines Highway advisory radio systems Special freeway signing Employment of an ombudsman Rescheduling event start and end times to avoid peak periods Developing agreements with trucking agencies to avoid peak period deliveries

elevated freeway section can greatly facilitate their response capabilities. In other jurisdictions nationwide, the DOTs and fire departments have worked together to mark the location of hydrants, and to provide access doors through noise barrier walls to connect to hydrants on the other side.

SERVICE PATROL CHARGES FOR ASSISTANCE

A question often arises relative to courtesy patrol operations about whether or not to charge motorists for "service supplies" (typically gasoline) that are provided. For years, Chicago requested that motorists pay for gasoline provided by its Emergency Traffic Patrol; however, auditors recently found it more cost effective for them to give the fuel away than to try and recoup these expenses.[30] Likewise, a recent analysis of the Los Angeles service patrol system concluded that charging motorists for gasoline by that agency would cost more to administrate than would be recouped through revenues.[17] The differences in these two operational philosophies could be due to the different administrative structures utilized by each for managing service patrol operations (see the Examples section at the end of this module for a description of various service patrol operations).

TRAINING

A component of incident management that is sometimes overlooked is the need for proper training and retraining. This is particularly important for dealing with larger-scale incidents that involve multiple agencies. Because these types of incidents may occur very infrequently (hopefully), it is difficult to test out the processes and procedures that have been developed for these situations beforehand. In addition to working out the "kinks" of coordination, training also helps to demonstrate to incident response personnel the need for, and benefits of, some of the procedures and protocols that have been established. Methods of training for such large events include the following: [19]

- Workshops.
- Conferences.
- Instructional videos.
- Mock disaster exercises.
- Post-incident debriefings.

It appears that the liability an agency bears for failing to properly train its personnel to react to normal day-to-day situations is slowly being extended in the courts to cases involving more dynamic emergency situations.[34] In the future, if it can be proven that adequate training to handle emergency situations could have prevented injuries or damages, an agency may be forced to assume at least some liability for failing to provide that training.

Interagency training is also important. Fire departments, for instance, can provide training for police and DOT personnel in hazardous materials identification and response.

8.5 EXAMPLES OF FREEWAY SERVICE PATROLS

CHICAGO EMERGENCY TRAFFIC PATROL

The Chicago Emergency Traffic Patrol (ETP), also known as the "Minutemen" patrol, began operations in 1961 as an Illinois DOT effort. This program is an example of a completely State-DOT-operated project. The ETP consists of 58 drivers, 35 patrol vehicles, 11 light-duty four-wheel drive vehicles, three heavy-duty tow rigs, a crash crane, a tractor-retriever, a sand spreader, heavy rescue and extricator truck, and a hazmat response trailer.[17]

The ETP patrols 125 centerline kilometers of freeway 24 hours per day, 365 days per year.

Annually, the patrol assists at over 100,000 incidents.[30] The patrol drivers are trained to handle most incidents. They also provide fuel, water, and minor repairs, and can tow or push vehicles to the shoulder or frontage road.

Overall, the Chicago freeway management system (including the ETP and other incident management activities) have been estimated to provide a benefit-cost ratio of 17:1.[30] The ETP alone is estimated to provide an annual 9.5 million hour reduction in delay, for a $95 million delay savings per year.[35] The ETP costs approximately $5.5 million to operate annually, equivalent to about $55 per assist. Funding for the ETP comes from State taxes on motor fuel. Additional funding is being sought to equip ETP vehicles with automatic vehicle locating (AVL) systems.

MINNEAPOLIS HIGHWAY HELPER PROGRAM

The Minnesota Highway Helper program began in December 1987. The program initiated out of the Minnesota Department of Transportation's District Maintenance office, and was operated only during peak periods. In March 1993, the traffic management center in Minneapolis took over management of the program and increased operations to daytime off-peak hours as well.[17]

As of 1994, the Highway Helper program patrolled 109 centerline kilometers (68 centerline miles) of freeway. Seven pick-up trucks logged approximately 125,000 kilometers (78,000 miles) during the year, assisting 13,000 motorists.[17] According to program logbooks, about 34 percent of stranded motorists were assisted within 5 minutes of disablement. Meanwhile, 26 percent of motorists were assisted within 5 to 10 minutes of disablement, and 20 percent were assisted within 10 to 20 minutes.[17]

Annual operating costs for the program are approximately $550,000.[17] A 1994 evaluation of the program yielded a benefit/cost ratio of 2.3 to 1.[37]

LOS ANGELES FREEWAY SERVICE PATROL

Los Angeles is home to the largest freeway service patrol in the U.S. The patrol was initiated in 1991, and consists of 144 tow trucks patrolling 610 centerline kilometers of freeway. The Los Angeles program contracts out the actual patrol activities to private wrecker services. Currently, 20 different towing companies are participating in the program.[17] The program is funded and administered through a cooperative effort between the following agencies:

- California Department of Transportation (jointly responsible for the overall supervision of the program).
- California Highway Patrol (jointly responsible for overall supervision and for dispatching patrols).
- Metropolitan Transit Authority (responsible for the contractual arrangements with the private towing companies).

Patrol routes and vehicle frequency were designed so that a patrol vehicle passes each point on the route every 15 minutes, which was recently verified by an evaluation of average response times.[17] Also, patrol vehicles are outfitted with automatic vehicle locating (AVL) systems that allow dispatchers to know the exact location of patrol vehicles and whether or not the unit is available to respond to a call.

On average, the Los Angeles service patrol program assists at over 750 incidents per day, equaling almost 250,000 assists per year. Funding for the Los Angeles service patrol program comes from state funds and a 0.5 percent local sales tax. Costs of the program are estimated to be between $15 million and $20 million, yielding a per assist cost of approximately $80.(35)

HOUSTON MOTORIST ASSISTANCE PATROL

The service patrol in the Houston region is known as the Motorist Assistance Patrol (MAP). This program began operations in its current form in 1989, and is an example of a cooperative venture between several public agencies and private-sector companies. Partners in the Houston MAP include the following:(36)

- Texas Department of Transportation (supervising dispatch and operations, providing space and personnel in the interim control center, partially supporting MAP personnel salaries, supporting necessary equipment purchases).
- Metropolitan Transit Authority (supervising operations, partially supporting MAP personnel salaries, supporting necessary equipment purchases).
- Harris County Sheriff's Department (providing deputies to operate the MAP vans, maintaining and operating the MAP vans).
- Houston Automobile Dealers Association (providing MAP vans).
- Houston Cellular (providing cellular phones, air time, and a toll-free number for motorists [CALLMAP]).

The program operates between 6 a.m. and 10 p.m. weekdays, patrolling 240 centerline kilometers of freeway. In 1993, Houston MAP assisted at over 25,000 incidents.(36) It is estimated that the MAP program saves 2,376,000 hours of delay on Houston freeways annually. The current funding for Houston MAP is $1.4 million per year, yielding a per assist cost of about $56.(17)

SAMARITANIA, INC.

The Samaritan program, operated by Samaritania, Inc., is an example of a privately financed service patrol. Samaritania, Inc., based in Franklin, Massachusetts, has established service patrols in the following locations:(12, 17)

- Albany.
- Boston.
- Cincinnati.
- Hartford.
- Indianapolis.
- Philadelphia.
- Providence.
- Washington, DC
- White Plains.
- Worchester.

Samaritania, Inc. seeks out large metropolitan areas, typically with populations greater than 100,000, that have significant incident traffic problems on area freeways. Potential corporate sponsors with annual receipts of over $200 million are contacted about sponsoring a service patrol. Samaritania, Inc. demonstrates the marketing and public relations benefits of such sponsorship. Once a sponsor is obtained, their logo is prominently displayed on the side of the service patrol van.

Local personnel in each area operate the patrols, and are trained in basic emergency medical procedures, traffic pattern analysis and reporting, and emergency vehicle repairs. If the motorist needs more assistance than the patrol driver can provide, the patrol driver will contact the appropriate organizations for the motorist.

Samaritania reports that 75 to 90 percent of all disabled vehicles encountered on patrol are returned to the freeway at no cost to the motorist.[17] Some of the patrols also provide traffic information to local radio and television stations for dissemination to motorists.

8.6 REFERENCES

1. Reiss, R.A., and Dunn, W.M. *Freeway Incident Management Handbook*. Report No. FHWA-SA-91-056. FHWA, U.S. Department of Transportation, Washington, DC, July 1991.

2. Schrank, D.L.,Turner, S.M., and Lomax, T.J. *Estimates of Urban Roadway Congestion -- 1990.* Report FHWA/TX-90/1131-5. Texas Transportation Institute, College Station, TX, March 1993.

3. Robinson, J. What's New in Freeway Incident Detection and Response. *Technical Papers from ITE Specialty Conferences 1990, 1989, and 1988.* Institute of Transportation Engineers, Washington, DC, pp 244-257.

4. Roper, D.H. *Freeway Incident Management*. NCHRP Synthesis of Highway Practice No. 156. TRB, National Research Council, Washington, DC, December 1990.

5. Mannering, F., Hallenbeck, M., and Koehne, J. *Framework For Developing Incident Management Systems*. Report No. WA-RD 224.1 Washington State Transportation Center, University of Washington, Seattle, WA, August 1991.

6. Sumner, R. et al. *Freeway Management Handbook.* Report No. FHWA-SA-88-026. FHWA, U.S. Department of Transportation, Washington, DC, May 1983.

7. Skabardonis, A., Petty, K., Noeimi, H., Rydzewski, D., and Varaiya, P.P. I-880 Field Experiment: Data-Base Development and Incident Delay Estimation Procedures. In *Transportation Research Record 1554.* TRB, National Research Council, Washington, DC, 1996, pp 204-212.

8. Goolsby, M.E. Influence of Incidents on Freeway Quality of Service. In *Highway Research Record 349*. TRB, National Research Council, Washington, DC, 1971, pp 41-46.

9. Ogden, M.A., Mounce, J.M., Middleton, D.R., and Ullman, G.L. *Traffic Management in Response to Major Freeway Incidents, Volume I.* Report No. FHWA/TX-94/1345-2F. Texas Transportation Institute, College Station, TX, August 1994.

10. Gordon, R.L., Reiss, R.A., Haenel, H., Case, E.R., French, R.L., Mohaddes, A,. and Wolcott, R. *Traffic Control Systems Handbook*. Report No. FHWA-SA-95-032. FHWA, U.S. Department of Transportation, Washington, DC, February 1996.

11. *Highway Capacity Manual*. Special Report 209 (3rd Edition). TRB, National Research Council, Washington, DC, 1994.

12. Dudek, C.L. and Ullman, G.L. *Freeway Corridor Management*. NCHRP Synthesis of Highway Practice No. 177. TRB, National Research Council, Washington, DC, March 1992.

13. Cyra, S.J. and Stilp, K.A. *Developing the Southeastern Wisconsin Incident Management Program: An Application of the ITS Planning Process*. Presented at the 3rd ITS World Congress, Orlando, FL, October 1996.

14. *Building the ITI: Putting the National Architecture into Action*. Report No. FHWA-JPO-96-011. FHWA, U.S. Department of Transportation, Washington, DC, April 1996.

15. McLean, C.H. Cellular Phones -- A Key Traffic Management Component. *Compendium of Technical Papers*, Institute of Transportation Engineers, Washington, DC, 1991.

16. Implementation Plan Guidance (23 CFR 655.409). Federal-Aid Policy Guide, FHWA, U.S. Department of Transportation, Washington, DC, December 7, 1994, Transmittal 12.

17. Fenno, D., Ogden, M., Morris, M., Thompson, B., and Benz, R. Guidelines for Establishing Freeway Service Patrols. *Compendium of Technical Papers*, 66th Annual Meeting of the Institute of Transportation Engineers, Minneapolis, MN, September 1996, pp 54-61.

18. Petty, K.F., A. Skabardonis, and P.P. Varaiya. Methodology for Estimating the Impacts of Incident Management Measures. Presented at the 3rd ITS World Congress, Orlando, FL, October 1996.

19. Ullman, G.L. and Trout, N.D. Traffic Management for Major Emergencies. *Compendium of Technical Papers*, Institute of Transportation Engineers, Washington, DC, 1994, pp 293-297.

20. Wilshire, R., Black, R., Grochoske, R. and Higginbotham, J. Traffic Control Systems Handbook. Report No. FHWA-IP-85-11. FHWA, U.S. Department of Transportation, Washington, DC, April 1985.

21. Payne, H.J., Helfenbein, E.D., and Knobel, H.C. Development and Testing of Incident Detection Algorithms, Volume 2: Research Methodology and Detailed Results. Report No. FHWA-RD-76-20. FHWA, U.S. Department of Transportation, Washington, DC, April 1976.

22. Balke, K.N. An Evaluation of Existing Incident Detection Algorithms. Report No. FHWA/TX-93/1232-20. Texas Transportation Institute, College Station, TX, November 1993.

23. Balke, K.N., G.L. Ullman, W.R. McCasland, C.E. Mountain, and C.L. Dudek. *Benefits of Real-Time Travel Information In Houston, Texas*. Report No. SWUTC/95/60010-1. Southwest Region University Transportation Center, Texas Transportation Institute, College Station, TX, January 1995.

24. Parkany, E. and Bernstein, D. Design of Incident Detection Algorithms Using Vehicle-to-Roadside Communication Sensors. In *Transportation Research Record 1494*. TRB, National Research Council, Washington, DC, 1995, pp 67-74.

25. Jacobson, L.N., Legg, B., and O'Brien, A.J. Incident Management Using Total Stations. In *Transportation Research Record 1376*. TRB, National Research Council, Washington, DC, 1992, pp 64-70.

26. Agent, K.R., Deacon, J.A., Pigman, J.G., and Stamatiadis, N. Evaluation of Advanced Surveying Technology for Accident Investigation. In *Transportation Research Record 1485*. TRB, National Research Council, Washington, DC, 1995, pp.124-133.

27. Mounce, J.M., Stokes, R.W., Brackett, R.Q., and McCasland, W.R. *Guidelines for Utilization of Police Officers in Traffic Control and Enforcement on Urban Freeways*. Report No. FHWA/TX-86/75+410-7F. Texas Transportation Institute, College Station, TX, September 1986.

28. Promotional literature for BarrierGate™ system. Energy Absorption Systems, Inc., Chicago, IL. 1993.

29. Dudek, C.L., McCasland, W.R., and Burns, E.N. *Promotional Issues Related to Off-Site Accident Investigation*. Report No. FHWA/RD-87/036. FHWA, U.S. Department of Transportation, Washington, DC, July 1987.

30. McDermott, J.M., Mclean,C.H., and Smith, A.T. Three Decades of Progress: Freeway Traffic Management in Illinois. *ITE Journal*, Vol. 62, No. 3, March 1992, pp 27-31.

31. Ritchie, S.G., and Prosser, N.A. Real-Time Expert System Approach to Freeway Incident Management. In *Transportation Research Record 1320*. TRB, National Research Council, Washington, DC, 1991, pp 7-16.

32. Albert, S., Siegfried, R., and Levine, S. Application of Geographic Information Systems to Houston Freeway Incident Management Program. *Compendium of Technical Papers*, Institute of Transportation Engineers, Washington, DC, 1990, pp 131-132.

33. Part VI, Standards and Guides for Traffic Controls for Street and Highway Construction, Maintenance, Utility, and Incident Management Operations. *Manual on Uniform Traffic Control Devices*. FHWA, U.S. Department of Transportation, Washington, DC, September 1993.

34. Knight, B.L. General Liability Issues for Local Government in Hurricanes. Presented at the National Hurricane Conference, Houston, TX, April 1990.

35. Nowlin, R.E. Institutional Concerns Regarding the Implementation of State Managed Service Patrols. In *Graduate Student Papers on Advanced Surface Transportation Systems*. Report No. SWUTC/94/72194-2. Southwest Region University Transportation Center, Texas Transportation Institute, College Station, TX, August 1994.

36. Wohlschlaeger, S.D. and K.N. Balke. Incident Response and Clearance in the State of Texas: Case Studies of Four Motorist Assistance Patrols. Report No. FHWA/TX-92/1232-15. Texas Transportation Institute, College Station, TX, November 1992.

37. *Highway Helper Summary Report, Twin Cities Metro Area.* Report No. TMC 07450-0394. Minnesota Department of Transportation, Minneapolis, MN. March 1994.