NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 156

FREEWAY INCIDENT MANAGEMENT

TRANSPORTATION RESEARCH BOARD
National Research Council

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FREEWAY INCIDENT MANAGEMENT

DAVID H. ROPER
Roper and Associates
Santa Monica, Calif.

Topic Panel

CHARLES A. BAIN, *Tennessee Public Service Commission*
GLEN C. CARLSON, *Minnesota Department of Transportation*
ROBERT F. DALE, *New Jersey Turnpike Authority*
GREGORY L. GOODSON, *Arizona Department of Public Safety (ret.)*
RICHARD A. LILL, *American Trucking Associations (ret.)*
CHARLES McLEAN, *Illinois Department of Transportation*
JAMES ROBINSON, *Federal Highway Administration*
SAMUEL C. TIGNOR, *Federal Highway Administration*
DAVID K. WITHEFORD, *Transportation Research Board (ret.)*

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

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The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to traffic engineers, planners, and others interested in how highway agencies deal with freeway incidents. Information is provided on the procedures and processes that highway agencies use to respond to traffic congestion caused by incidents on freeways.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

Congestion on freeways frequently is caused by incidents such as stalled vehicles or accidents that reduce the capacity of the freeway below the level of demand. This report of the Transportation Research Board describes the procedures and processes used by states to respond to traffic congestion caused by incidents on freeways.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

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Special appreciation is expressed to David H. Roper, President, Roper and Associates, who was responsible for the collection of the data and the preparation of the report.

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David K. Witheford, Engineer of Traffic and Operations, Transportation Research Board (retired) assisted the NCHRP Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

FREEWAY INCIDENT MANAGEMENT

SUMMARY

Freeway congestion frequently results when lanes are closed by accidents or other incidents, reducing capacity below the level of demand. Recently, operating agencies have begun to deal with incident-related congestion in an organized, comprehensive manner.

When lanes are blocked, a series of events is set into motion: Volumes that can flow past the blocked lanes fall to a level below demand volumes, excess demand volumes are stored on the freeway, and a traffic backup forms. The congestion continues to extend until removal and cleanup take place and the lanes are reopened, queues of congested traffic are dissipated over time, and normal flows are restored. Every minute that a lane is blocked can add several minutes to the duration of congestion. Moreover, congestion causes stop-and-go operation, which causes even greater congestion.

The ideal system to deal with congestion caused by freeway incidents is one that blends several components, each of which can effectively solve a part of the problem, into an overall comprehensive incident management system that will deal with the problem in its entirety. The major components are surveillance and detection, response, and motorist information.

Methods of surveillance and detection vary from actual observations of an incident or of the congestion resulting from an incident, to sightings of an incident through the use of closed-circuit television, to detection through the use of computerized electronic surveillance and control systems. Sightings are often called in by motorists, by the highway patrol or other enforcement personnel, by construction and maintenance forces, by airborne or ground-based traffic-report units, or by a host of other forces in the field. This type of information relies to a great degree on someone being in the right place at the right time. Often the incident is detected only after considerable congestion has developed. Surveillance and control systems, using sensors placed along the roadway and computers to process traffic flow data, detect the effect of the incident (i.e., congestion) rather than detecting the incident itself. These systems do not rely on chance observations; instead, they monitor the entire freeway system continuously.

Regardless of the type of detection used and how information regarding the occurrence of incidents is gathered, one element is essential: a focal point where that information can be brought together to form an accurate picture of what is taking place on the freeway. That focal point may be something as simple as a room or designated area where the information is displayed with pins in a map mounted on a wall or as complex as electronic wall maps or graphics-display systems. Each system needs to be tailored in both size and scope to the problems with which it is intended to deal. Significant reductions in incident-related congestion, delay, and accidents can be achieved using fairly simple, low-cost systems with modest staffing requirements.

Once an incident has been detected and its nature is known, the benefits of incident management can only be achieved by taking the proper actions in response to the

situation. With many of today's incidents, a host of organizations will be involved in the resolution of the situation, each with a legitimate role and responsibility in that incident. The coordination of each agency's activities is critical to the success of the response effort. Arrangements between key agencies must be made in advance of incidents.

Motorists must make adjustments in travel patterns in response to the traffic management plan. To make these necessary changes—diverting around or away from the incident site, changing times of travel, switching travel modes, being alert for closed roadways and congestion—motorists need to receive information on traffic conditions and suggested alternatives to deal with the situation. Several methods of providing information to motorists effectively are being used in today's incident management systems. These include variable-message signing, highway advisory radio, commercial radio, citizen band radio, and print media.

A comprehensive incident management system for "planned" or repeat incidents (e.g., construction and maintenance activities) and special events (e.g., sporting events, fairs, and concerts) calls for virtually all of the measures needed for managing random incidents. One key difference in managing this type of incident is knowing the nature and extent of the incident beforehand. This provides the time needed to develop a precise plan to deal with the problem and to put the necessary pieces of that plan in place before the event.

The "ideal" incident management system combines various measures into a comprehensive system that will be effective in dealing with the problem. Such a system has several requirements:

- Incidents must be detected accurately and rapidly.
- The nature of incidents must be determined quickly.
- Information relative to incidents needs to be collected and passed on to various agencies.
- Roles and responsibilities of the various agencies must be developed, understood, and agreed upon.
- An appropriate coordinated response to the incident is necessary.
- Quick removal of both major and minor incidents needs to take place.
- Traffic management measures need to be applied for the duration of the incident.
- Information on traffic conditions and bypass routes needs to be provided to motorists.
- Traffic management plans for "planned incidents" need to be developed, implemented, and operated.

CHAPTER ONE

INTRODUCTION

Congestion has become a fact of life in urban areas across the country. No longer is it a problem associated only with the morning and evening commute; often, traffic conditions are no better at noon than at 8:00 a.m. or 6:00 p.m.

A look into the future offers little hope that things will get better. Nationally, travel has grown for several years at an annual rate of almost 5 percent, and it is expected to double in metropolitan areas by the turn of the century (*1*). The number of registered vehicles in the United States is rising at a rate that exceeds the growth of the population. The migration of jobs from the cities to the suburbs has brought with it immense growth in travel (*2*); and now instead of the traditional directional flows during peak periods, traffic jams occur simultaneously in both directions on many urban freeways and arterials.

On the supply side, the picture is not encouraging either. The number of miles of new highways being constructed each year is significantly lower than in past years. The cost of building or widening freeways and highways has increased dramatically over the years. Very few new freeways are being planned, and when improvements are made, additional lanes are filled almost as soon as they are opened to traffic. Thus, hopes of "building our way out" of today's congestion problems are dim.

There are two types of congestion on freeways: recurrent and incident-related. Each has distinct causes and potential solutions. Both occur when the volume of traffic wishing to use a facility (demand) exceeds the volume that the facility can accommodate (capacity); stated in another way, congestion will occur when the capacity/demand relationship is out of balance.

Recurrent congestion, which is typically associated with the commute period, occurs when volumes increase each morning and evening to the point at which roadways cannot handle the traffic demand. The basic cause of the problem is that demand has built to the point where it exceeds capacity. The congestion disappears as volumes drop after the peak period and eventually free-flowing conditions are restored.

Incident-related congestion frequently occurs as a result of a temporary lane closure. Congestion results because capacity has been reduced below the level of demand. After the incident is cleared and lanes are reopened to traffic, a period of time is required for the residual congestion to clear up and for normal traffic flows to be restored.

The incident-related congestion problem is prevalent, its effects potentially devastating, and the need for solutions critical. Wrecked vehicles and spilled loads must be removed more quickly, duration of lane closures must be reduced, the volumes of traffic attempting to squeeze past incident scenes must be decreased, and traffic management measures to accommodate traffic flows past maintenance and construction activities must be developed.

Even though congestion resulting from incidents is a substantial part of overall congestion, it is only in the recent past that operating agencies began to deal with incident-related congestion in an organized, comprehensive manner, and only a few did so. That picture is changing as the problem grows. Today, several organizations are engaged in at least some level of incident management.

This synthesis focuses on nonrecurrent (incident-related) congestion. The nature and magnitude of the problem is examined and a number of solutions are proposed. The synthesis also discusses current incident management programs, highlighting various measures being used in each program.

CHAPTER TWO

THE PROBLEM

THE SCOPE OF THE PROBLEM

Lane blockages and disruptions of traffic flows typically include: (a) major accidents that tie up several lanes or entire freeways for hours, (b) relatively minor accidents and stalled vehicles that block only one lane for short durations, (c) vehicles stopped on shoulders, (d) spilled loads, (e) construction and maintenance activities, and (f) special events that generate heavy traffic volumes.

Several years ago it was found that on 6 miles of freeway in Houston, between 6:00 a.m. and 8:30 a.m. at least one major incident occurred per week. Lanes were blocked an average of 13 times each week (*3*). In the Chicago area, in 1986, an average of 52 police accident reports were recorded daily on 135 miles of freeways (*4*). In Los Angeles, over a one-year period, incident management teams responded to more than 220 major incidents (*5*).

Most of these incidents cause major disruptions in traffic flow as lanes are blocked or severely restricted. Even when lanes are not physically blocked, motorists slowing to look at the problem (including those traveling in the opposite direction) create congestion. The previously mentioned Houston study reported that about 80 percent of the incidents reduced freeway capacity by at least 50 percent (*3*). Many closed the freeway entirely.

As freeways carry more and more traffic and operate at or near capacity, more accidents will occur. As increased maintenance and construction on aging freeway systems takes place, more lane closures will be necessary. Traffic generated by special events will make its way onto already overloaded freeways. These and other factors will combine to cause even greater traffic tie-ups and increased delays.

The number of trucks traveling on freeways is rising each year. As traffic volumes increase, these trucks have to travel in denser streams of traffic. There is little or no room to maneuver if these trucks need to avoid something on the road. The Michigan Department of Transportation reports that more than 13 percent of all accidents on freeways throughout the state involved trucks. In 1985, there were more than 12,000 truck accidents in California. That figure is growing at a rate of about 10 percent per year. This type of accident often blocks entire freeways and creates massive traffic tie-ups for many hours, as heavy vehicles and heavy loads are removed from the roadway. Delays averaging 2500 vehicle-hours for each accident have been noted in California. Accidents involving vehicles carrying hazardous materials often require similar full closures for extended periods as special cleanup operations take place. (A future synthesis—Topic 21-11—will cover highway agency procedures dealing with hazardous-materials incidents.)

Minor accidents and stalled vehicles stopped in traffic lanes are a significant part of the overall incident problem too. Each incident of this nature is normally resolved rather quickly and, taken individually, causes relatively little delay. However, the total delays resulting from this type of incident are substantial, because there are so many short-term mishaps in the traffic stream each day. In fact, these minor incidents cause a large part of the total delay attributable to incident-related congestion. In the Chicago area, where the Illinois Department of Transportation operates an emergency patrol on the freeways, about 108,000 assists were provided in 1985, up from about 70,000 in 1978 (*6, 7*). Most assistance responses involved vehicles that had not been involved in accidents but were merely disabled in some way. On one day in Chicago, during a snowstorm, 17 trucks jackknifed and caused serious congestion throughout the freeway system. The Minnesota Department of Transportation reports that, in the Minneapolis-St. Paul area, stalls represent almost 80 percent of the total incidents on freeways (*8*).

Incident-related congestion is a problem of huge proportions, resulting in millions of hours of delay to motorists. The California Department of Transportation (Caltrans) has estimated that more than 50 percent of all delays to motorists on the freeway system are the direct result of incidents. This amounts to more than 200,000 hours of delay each day, costing motorists more than $1 million. Although travel is increasing at about 5 percent each year, congestion in California is growing at an annual rate of 15 percent. By the year 2000, total delay from incidents is projected to reach more than ½ million vehicle-hours per day. It has been calculated that almost 300 million vehicle-hours of incident-related delay was incurred by U.S. motorists in 1984 (*9*). Thousands of secondary accidents, caused as unsuspecting motorists traveling at high speeds come upon pockets of congestion, add significantly to the total costs of incident-related congestion.

THE NATURE OF THE PROBLEM

When an incident takes place and lanes are blocked, a series of events is set into motion, as depicted in Figure 1. Volumes that can flow past the blocked lanes fall to a level below demand volumes, excess demand volumes are stored on the freeway, and a traffic backup forms. The congestion continues to extend upstream until removal and cleanup take place and the lanes are reopened, queues of congested traffic are dissipated over time, and normal flows are restored.

Of particular note is the recovery rate of the system (slope of the service volume line) relative to the arrival rate of vehicles (slope of the demand line), because these rates will determine

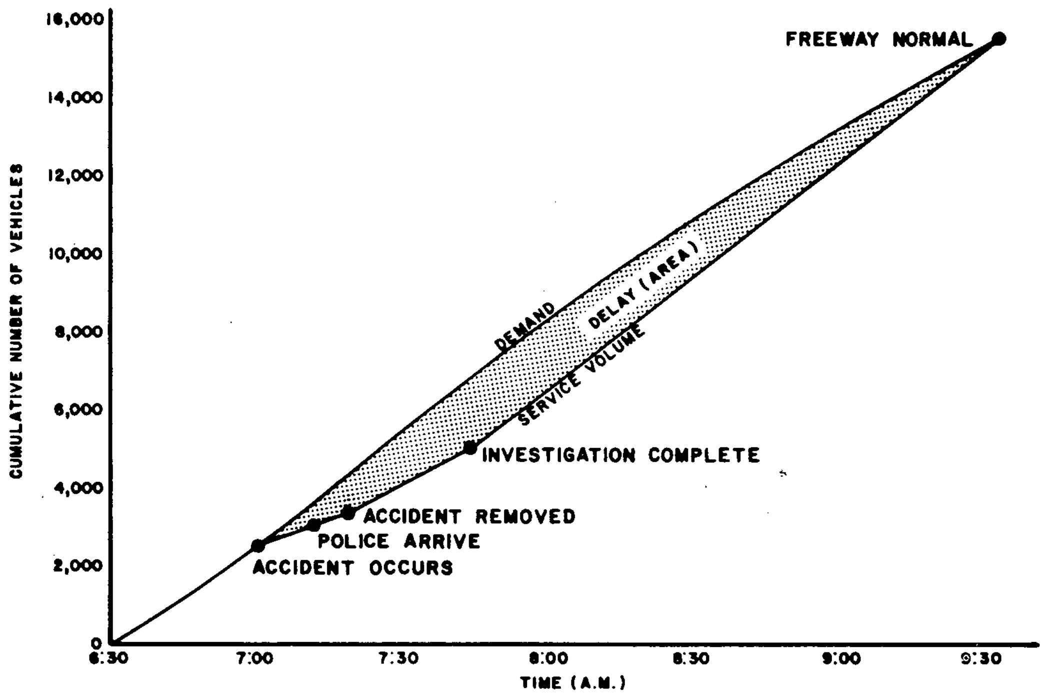


FIGURE 1 Effects of an incident on traffic flow (*11*).

the recovery time. On crowded freeways, recovery takes place slowly. Frequently, the recovery time will exceed the time of the actual lane blockage significantly. Full recovery will not take place until the capacity of the roadway is greater than the arrival rate of vehicles (the demand volume).

As shown in Figure 1, the shaded area represents the total amount of delay caused by an incident. As can be seen, any reduction in the incident duration can have a substantial effect on the recovery time and the delay associated with any particular incident.

The magnitude of delay can be calculated for each incident, if the volumes and times involved are known. Analytical procedures to estimate delays to traffic, and the reduction in delays brought about by the application of incident management measures, have been developed (*10*). Computer programs have been created that can quickly and easily compute delay, the total duration of influence of an incident, and the maximum queue conditions caused by freeway incidents. These provide the means to estimate the delay savings from using different incident management alternatives.

In a study of incidents on metropolitan freeways in Los Angeles, Caltrans determined that, under off-peak free-flow conditions, for each additional minute that a lane blockage was allowed to continue, 4 or 5 min were added to the duration of congestion (i.e., the time to restore free-flow conditions). Stated another way, for each minute that the time to clear blocked lanes is reduced, at least 4 or 5 min will be cut from the delays that each motorist will experience. Under peak-period traffic-flow conditions this factor is much greater. During the peak hour, a few minutes saved in opening lanes and restoring capacity can save hours in accumulated delay time. For example, Goolsby (*11*) found that a 2-min reduction in response time saved 411 vehicle-hours for a one-lane accident.

TABLE 1
EFFECT OF DIFFERING INCIDENT CONDITIONS ON TRAFFIC FLOW ON A THREE-LANE (ONE-DIRECTION) FREEWAY (*11*)

Condition	No. Blocked Lanes	Average Flow Rate (vph)	Volume Reduction (percent)
Normal	-	5,560	-
Stall	1	2,880	48
Non-Injury Accident	1	2,750	51
Accident	2	1,150	79
Accident On Shoulder	-	4,030	28

The effect of lane blockages on capacity and traffic flows is not linear. The blockage of one traffic lane will result in the loss of more capacity than is provided by that one lane. Studies conducted by Goolsby (*11*) established that a capacity reduction of about 50 percent occurred when one lane of a three-lane freeway section was blocked. He also noted a 79 percent loss of capacity with the closure of two of the three freeway lanes (Table 1). A 26 percent capacity reduction will occur even though an incident, such as a stalled vehicle or a law enforcement stop, is on the shoulder and is not blocking the lanes physically. This "gawking effect," as motorists slow to observe an incident, can cause a severe loss in capacity and create serious congestion even for those traveling on the side of the freeway opposite from the incident. Many hours of delay can be avoided by the quick removal of non-lane-blocking incidents from the sight of passing motorists.

Another significant cause of capacity loss is congestion itself. The stop-and-go operation brought on by congestion introduces inefficiencies and shock waves into the traffic stream. These, in turn, cause an erosion of capacity. A spiral of cause and effect is triggered, and congestion results in a loss of capacity that brings on even greater congestion.

A review of traffic flows on several freeways under varying conditions of congestion in California has revealed that the efficiency of freeways was reduced in some cases by as much as 50 percent as congestion set in, falling from a free-flow rate of 1800 to 2000 vehicles/hr/lane to, in the most extreme case, a flow of about 1000 vehicles/hour in each lane under stop-and-go operation. Traffic throughput losses in the 25 to 30 percent range were not uncommon.

The problem of incident-related congestion, and of delays and secondary accidents brought on by congestion, is complex. In some cases, the cause is a loss in capacity; in others, congestion occurs because of an increase in demand. Whatever the cause, the effect is the same: motorist delays, frustration, and reduced safety. Because of its varied nature, the development of overall solutions calls for a variety of measures to be drawn together into a comprehensive system aimed at avoiding the disruption of the capacity/demand balance or restoring the balance as quickly as possible. Those solutions must include measures that will both restore capacity and reduce demand during incidents.

CHAPTER THREE

SOLUTIONS

Systems to deal with the complex problem of incident-related freeway congestion are also necessarily complex. Certain techniques and procedures that are suitable for dealing with one aspect of the problem may not be effective in treating another aspect. The ideal system, then, is one that blends several components, each of which can effectively solve a part of the problem, into an overall comprehensive incident management system that will deal with the problem in its entirety.

As noted previously, the time taken to initiate and conduct various phases of incident management determines the duration of congestion resulting from an incident. Therefore, the system must include early detection, timely identification of the nature of the incident, rapid response, and quick removal of wreckage and debris. Throughout the duration of the incident, traffic management techniques must be applied and information provided to motorists in an attempt to minimize congestion and delays. Each phase will be employed in different ways and to varying degrees, depending upon the conditions at any particular incident.

SURVEILLANCE AND DETECTION

Methods of detection vary from actual observations of an incident or of the congestion resulting from an incident, to sightings of an incident through the use of closed-circuit television, to detection through the use of computerized electronic surveillance and control systems.

Incident sightings are often called in by motorists using freeway emergency call boxes, cellular phones, or citizen-band (CB) radios; by highway patrol or other enforcement personnel; by construction and maintenance forces; by airborne or ground-based traffic-report units; or by a host of other forces in the field. This information may be somewhat spotty in nature, relying to a great degree on being in the right place at the right time. Often the incident is detected only after precious time has been lost and a problem of considerable magnitude has developed.

A great deal of good, timely information about incidents and traffic conditions is available from a variety of sources. There is a need to organize these sources into a network, and to piece together information from each to form a comprehensive picture of what is occurring on the freeway system. In many cases, greatly improved incident detection can be achieved fairly easily and with only a modest commitment of resources by establishing a focal point for the collection and analysis of already available information. This step, along with the development of procedures and systems to get that information to appropriate agencies for response to the incident, can be the foundation of an effective incident management program.

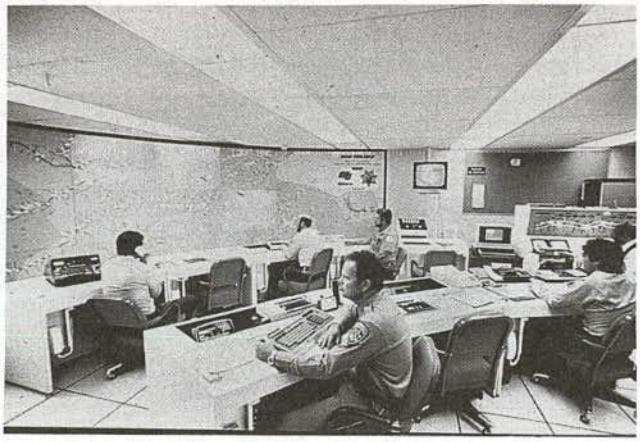
As an example, the Ontario Ministry of Transportation recently carried out an incident management project in conjunction with a major highway reconstruction project in the Toronto area (*12*). Detection of incidents was accomplished visually using observers positioned on towers placed along the freeway right-of-way. The observers, equipped with binoculars and radios, called any observed incidents in to a central location, and response activities were then initiated from the base station.

In contrast, surveillance and control systems, using sensors placed along the roadway and computers to process traffic flow data, detect the effect of the incident (i.e., congestion) rather than detecting the incident itself. These systems do not rely on chance observations; instead, they monitor the entire freeway system continuously. Under fairly heavy traffic conditions, these systems can detect the presence of congestion, with a relatively high degree of reliability, within a few minutes of the occurrence of an incident. When an unusual amount of congestion is detected, however, the nature of the incident remains unknown. In order for appropriate corrective actions to be taken, this type of detection system needs a companion system that can identify the nature of the incident.

The Traffic Operations Center

Regardless of the type of detection used and how information regarding the occurrence of incidents is gathered, one element is essential, a focal point where that information can be brought together to form an accurate picture of what is taking place on the freeway. That focal point may be something as simple as a room or designated area where the information is displayed by wall maps with pins representing incidents (an approach that has been used successfully in a number of installations) or as complex as the electronic wall maps or graphics systems that are being used today by several system operators (Figure 2). Each system needs to be tailored in both size and scope to the problems with which it is intended to deal. One point should be kept in mind: Significant reductions in incident-related congestion, delay, and accidents (and thus, benefits to the motoring public) can be achieved using fairly simple, low-cost systems with modest staffing requirements. There are many examples of these types of systems operating successfully today (see Appendix A).

The operations center needs to be equipped and staffed to analyze the information collected, to check other sources for supplemental information, to piece together as quickly as possible and as precisely as possible what is happening on the freeway, and to pass this information along to designated agencies so that an appropriate response can be made. Preparations must be made in advance—roles agreed on, procedures developed and put in



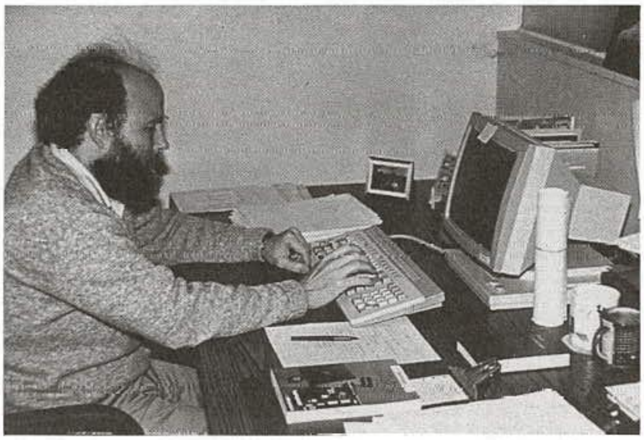


FIGURE 2 Traffic operations centers.

FIGURE 3 Closed-circuit television.

place, a sufficient number of trained staff assigned, and electronic devices and communications equipment installed. The level of development and staffing, and the costs of each of these, will vary with the complexity of each system and the degree to which incident management is to be carried out.

As mentioned, knowing the specific nature of the incident is critical in deciding the type of response that will be most effective in dealing with the problem. The situation may call for fire department response, rescue units, ambulances, heavy tow trucks, cranes, loaders, and trucks—or it may be a relatively minor accident or stall that can be cleared quickly with light-duty equipment.

Currently, the most common method of post-detection incident identification being used is visual observation. This is normally accomplished by dispatching an enforcement officer or highway maintenance unit to the scene. This often results in lengthy delays in initiating corrective action as ground units work their way through congestion for a firsthand look at the situation.

Closed-circuit television cameras spaced along the freeway are also being used effectively in some systems. Pictures of the freeway are transmitted to the traffic operations center, where the nature of incidents can quickly be determined.

Another approach to verifying an incident occurrence and identifying its nature is being tested by the Illinois Department of Transportation in Chicago, which has placed CB receivers at strategic locations along the freeway. These receivers can be activated remotely from the operations center. Upon detection of an incident, an appropriate unit can be turned on and monitored by listening to the CB radio transmissions by motorists in the area. In this way, the nature of an incident can be determined.

Just knowing about the occurrence and nature of an incident will do little to solve the problem unless some action is taken. Therefore, the center must have the capability of passing information on to those who can do something to correct the problem—the enforcement agency, emergency services units, response teams, and the motoring public through commercial radio stations, variable-message signs, or highway advisory radio. Equipment, staffing, and procedures to carry out these functions must be in place in the operations center if it is to be an effective element of an incident management system.

Closed-Circuit Television Cameras

When closed-circuit television is used it is necessary to have the cameras continually scanning the freeway and to have someone monitoring a bank of television screens in an operations center (Figure 3). Because of this need for continual monitoring, closed-circuit television has generally proved to be of somewhat limited effectiveness. Even with this drawback, television cameras do offer a means of monitoring freeways. They can be a fairly good way to cover particularly troublesome locations.

They have proved to be extremely useful when used as a means of identifying the nature of an incident, rather than as the primary detection device. In these situations, operations center personnel activate cameras after the incident has been detected, zoom in on the scene, and make decisions relative to the type of response needed. Appropriate units can then be dispatched to the site, again cutting time from the overall duration of an incident. They are also useful during inclement weather, when patrol vehicles or other detection techniques are less effective.

RESPONSE EFFORTS

A host of organizations, each with a different role and responsibility, may be necessary for the resolution of many situations.

FIGURE 4 Incident response team and a command post.

(In one incident in California, where a hazardous-material spill entered a stream near the incident site, more than 25 agencies were involved.) The coordination of the different agency activities is critical to the success of the response effort, but the essential element of an effective incident management system is advance planning between key agencies. Trying to coordinate activities of various agencies while an incident is occurring has led to situations in which the agency activities were actually counterproductive to the overall incident management. Thus, working relationships must be in place, a general approach to managing incidents must have been determined and be understood by the various parties, procedures must have been set, and communication links between the agencies must have been established. Post-incident critiques, in which the management of an incident is reviewed, are an effective means to refine the operation and improve working relationships between agencies. Conducting a practice exercise will reveal any weaknesses in the system and allow refinements to be made, thus improving operations during a real situation.

In the Los Angeles area, the California Highway Patrol and Caltrans are dispatching teams of traffic engineers to the scene of major incidents (Figure 4), at which they meet with enforcement officers and maintenance forces to establish a field command post to manage that particular incident. Personnel from other agencies—fire departments, ambulance and other emergency services organizations, tow truck operators, hazardous-material cleanup crews, local police forces, and others—join with team members at the command post to make coordinated decisions about how the removal and cleanup should be conducted and how traffic should be handled during the incident.

Once decisions have been made, individual team members carry out their particular activities in a manner consistent with the overall management plan. As removal of wreckage and cleanup of spills get under way, traffic management measures are also undertaken. Signs are placed to shift traffic to bypass routes, traffic is channeled through the incident scene or is diverted away from the area, motorists are advised of the situation, and congestion patterns are monitored and modifications to the plan made as conditions change throughout the duration of the incident.

The response team approach has been very successful in California. It gets the key players to the scene of a major incident in the shortest possible time; it sets up the management and control of the incident at the site, where decisions can best be made and implemented; and it establishes the means to bring about the essential coordination between the host of agencies and individuals who have a role in the successful management of a major incident. Using this measure, a savings in delay of about 500 vehicle-hours has been noted for each major incident. It is also estimated that one secondary accident is saved for every two incidents in which response teams have been used.

Coordination between Agencies

To date, one of the major impediments to the implementation of effective incident management programs has been a jurisdictional one, revolving around the questions of who is in charge at the scene of an incident and what the responsibilities are of each of the incident management team members. These problems arise because there is shared responsibility and authority and an overlapping of roles in protecting lives and property while normal conditions are restored.

Every day, a host of agencies make decisions associated with the management of incidents. These decisions are often made independently of those of others who are directly involved, resulting in a situation in which there may be conflicts between the actions of the responsible parties at the scene. In addition to enforcement agencies, the services of traffic engineering and maintenance organizations, emergency medical teams, fire departments, hazardous-material cleanup crews, and tow truck operators are frequently needed. Often, facilities and operations outside of the jurisdiction of those involved in the incident itself will be affected. For instance, when bypass routes must be set up on surface streets, a new set of agencies, each with its own responsibilities and authorities, is brought into the picture. The successful management of an incident will often depend, to a large degree, on the manner in which these agencies operate facilities. Including these others in the planning and operation of incident management plans is frequently a key element in the success or failure of the plan.

Invariably the question of who is in charge at the incident scene must be addressed. For the most part, the ultimate responsibility and authority for the management of any incident lies with the appropriate enforcement agency. In practice, it is only on rare occasions that this authority must be exercised. Instead, agencies are allowed to make decisions relative to their role in the situation as long as those decisions are consistent with the overall management plan.

The need, then, becomes not so much one of assigning authority as one of recognizing and working within the overlapping responsibilities and authorities that exist. Indeed, in every successful incident management program reviewed—large and small, complex and simple—there has been a recognition of these multi-jurisdictional responsibilities and authorities. In each case, the approach has been to develop a team effort with the necessary coordination and communication links to deal with the problem effectively.

With coordination procedures in place, an overall plan to deal with an incident can be developed jointly. Each agency can then continue to make its own decisions about its own operations but can make those decisions in coordination with others, within the framework of the overall plan. As conditions change and the

FIGURE 5 Service patrol.

FIGURE 6 Incident removal using heavy-duty tow trucks.

initial plan needs revisions, changes can be made in a coordinated way.

This arrangement calls for advance discussions and planning to establish general procedures for incident management, as well as securing in advance a commitment from the various agencies to cooperate. Working relationships need to be established before the incident occurs so that a smooth-running, coordinated operation can take place.

In the Los Angeles area, the use of incident management teams with an on-scene command post has provided the mechanism to bring about this essential jurisdictional coordination, while at the same time giving full recognition to the authority of the various parties. Each agency, working with others through the command post, is able to conduct its own activities consistent with the plan. The California Highway Patrol retains ultimate authority at the scene, but, operating in an atmosphere of cooperation and coordination, rarely needs to exercise that authority.

Service Patrols

As mentioned earlier, one of the key components of the incident problem is the large number of relatively minor accidents and stalls that take place each day on freeway systems. Each of these, taken alone, causes only a small amount of delay, but the total delay caused by these incidents is a large part of the overall delay problem.

Service patrols (Figure 5), which can provide assistance at this type of incident (some fuel, a tire change, a jump-start, or a push out of the roadway), can substantially cut the time of disruption to traffic flows. Lanes can usually be cleared and reopened in a matter of minutes, thereby minimizing traffic jams and cutting the delays resulting from this type of incident.

Service of this nature has been provided at many bridges and tunnels for several years, but its application on roadway sections has been somewhat limited. A similar approach has been used successfully on some of the turnpikes and toll roads in the eastern United States. In some instances, service units have been posted at central locations for dispatch to trouble spots. In others, units have patrolled a beat on the lookout for problems.

As might be expected, this service has proved to be highly popular with the motoring public. Its benefit, however, from a traffic management perspective, has been in the reduction of the time that the vehicles remain stopped in traffic lanes or along freeway shoulders, and the resultant reduction in congestion, delays, and secondary accidents.

During the mid-1970s, service patrols were operated in Los Angeles as part of a major traffic management research project (*13*). In this project, units were operated in both ways—posted awaiting dispatch when an incident was detected, and patrolling assigned beats looking for incidents, while at the same time being available for dispatch. Both methods of operation produced good results, considerably cutting the time to clear freeway lanes and to remove vehicles from shoulders. The use of roving service patrols was clearly the better of the two methods.

In Chicago, the Illinois Department of Transportation, has operated a similar service patrol (Minute Man) since 1961 (*6, 7, 14*). In this operation, service units patrol an assigned beat and are dispatched from their beats to incidents that have been detected during their patrols. Again, the benefits of service patrols were clearly evident as both response times and clearance times were significantly reduced.

It should be noted that a well-operated service patrol can be more than just a means of responding to and clearing incidents; it can also be an effective detection system in and of itself. Further, it becomes the means by which the nature of an incident is identified. For those incidents that are detected by service patrol personnel, service can be provided immediately and no time is lost in getting response units to the scene. The duration of the incident and the degree of congestion, and, thus, delay and secondary accidents, can be reduced significantly.

Tow Truck Services

A large number of accidents on freeways will require the services of tow trucks to clear wreckage and reopen blocked lanes (Figure 6). In the case of truck accidents, heavy-duty equipment and well-trained operators are frequently needed to right overturned vehicles or to remove heavy loads. All too often, lengthy delays are encountered in locating and getting heavy-duty wreckers to the scene. Frequently, the personnel and equipment dispatched to an incident are not capable of handling the problem, and additional time is spent in getting proper units to the site. Significant time in clearing incidents can be saved if providers of these special services are identified beforehand and standards for equipment, personnel, and general operating procedures are established in advance.

In order to speed clearance times, some agencies operate their own fleet of light-weight tow trucks, often combining the tow truck and service patrol operations into one (*6, 13, 14*). The Illinois Department of Transportation has a fleet of heavy-duty wreckers and trained personnel to provide this service in the Chicago area. Personnel and units dedicated to this duty are on round-the-clock standby to respond to major incidents. The service is credited with saving many hours of motorist delay and preventing secondary accidents each year on the freeway network in Chicago.

Off-Site Accident Investigation Locations

One method of reducing freeway congestion caused by rubbernecking at minor accidents is through the use of off-site accident investigation locations (*15*). These are signed areas off the freeway (and out of sight of freeway drivers) where damaged vehicles can be moved, motorists can exchange information, and police and motorists can complete accident reports. For minor property-damage accidents, motorists can move to these areas to wait for police. Experience in Houston showed a benefit-cost ratio of 28 during the first year of operation.

Alternative-Route Maps

With many incidents, it will be necessary to divert traffic off of the freeway onto surface streets or to other freeway routes to bypass the incident site. The selection of a good alternative route is critical to the success of any bypass plan. Such a route should be one that provides a reasonable detour and one that will not pass traffic through inappropriate sections of a community. Revisions of signal timing plans will often be required, traffic officers may be needed at key intersections, temporary parking restrictions may have to be put in place, and adequate vertical clearances and turning radii to accommodate trucks must be provided.

Under the pressures of an incident management situation, selecting an appropriate bypass route is difficult. Often, considerable time is taken in reaching decisions about where to detour traffic from the freeway, what surface streets to carry it on, and where to route it back onto the freeway. Many times, traffic has been diverted onto detours that simply could not handle it, and the result has been massive traffic jams and public outrage.

Preselecting alternative routes for various sections of freeway can speed the implementation of bypasses for freeway incidents. Although precise alternative routings cannot be determined for every conceivable incident at every possible location on a freeway system, the most desirable alternatives through areas along the freeways can be established. Routes that are not feasible or desirable can be eliminated from further consideration. Working together, the agencies having jurisdiction over the freeways and those controlling the surface streets can jointly determine what routes should be used under certain conditions. Plans can be prepared outlining requirements for signing, police traffic control, turn restrictions, parking prohibitions, etc. Assignment of responsibilities for implementation of the plan can also be made. Working relationships and interagency cooperation, so vital in the successful implementation and operation of the bypass routes, can be developed.

When a major incident takes place, decisions relative to alternative routes can be made much more quickly if these preliminary planning activities have already taken place. Preliminary plans can be modified and fine-tuned to meet any particular situation as it develops.

In Los Angeles, Caltrans, along with the California Highway Patrol and local agencies, has developed planned alternative-route maps for the entire freeway system (Appendix B). These have been used extensively in incident management team activities as response teams make joint decisions regarding how to handle traffic at major incidents.

A similar approach has been used successfully in Michigan on a 100-mile section of I-75 (*16*). Over the past several years, the freeway has been fully closed an average of once a month because of some type of incident. Under the lead of the Michigan State Police and the Michigan Department of Transportation, agencies have cooperatively developed alternative routes for the entire section of freeway, dividing it into implementable segments, depending upon the location of the incident. Procedures to divert traffic to the alternative route have been established and agreed on, signs have been prepared and stockpiled, and local agencies have been assigned roles.

Alternative-route mapping has also been developed by the Maryland Department of Transportation on I-495. Similar preselection of alternative routes is currently being developed by TRANSCOM for the New York metropolitan area and by the Michigan Department of Transportation in Detroit.

PROVIDING INFORMATION TO MOTORISTS

One of the most important participants in traffic management is the motorist, who must make adjustments in travel patterns in response to the traffic management plan. Without these changes, the effectiveness of the plan cannot fully be realized. To make these necessary changes—diverting around or away from the incident site, changing times of travel, switching travel modes, being alert for closed roadways and congestion—motorists need to receive information on traffic conditions and suggested alternatives to deal with the situation. They are also more likely to have a greater tolerance for any inconvenience or delay if they are kept informed of the situation and can plan ahead. Keeping motorists informed has the added benefit of improving safety, because motorists who are alerted to the existence of congested conditions can avoid secondary accidents.

If information is to be useful, though, it is essential that it be both accurate and timely. The credibility of the information being issued, as well as that of those providing the information, is crucial. Therefore, systems must be in place that collect accurate information relative to the incident, traffic conditions, and alternative routes on a real-time basis. This information must then be passed on to the public quickly and accurately.

Several methods of providing information to motorists effectively are being used in today's incident management systems. These methods are elaborated on in the following sections.

Signing

Variable-message signs (Figure 7), spaced along the freeway or on surface streets, are a particularly effective means of getting information to the motoring public. Truck-mounted or trailer-mounted variable-message signs (Figure 8) have also been used effectively in incident management. These signs can be located quickly and moved about as needed at a particular incident.

Several technologies are being used in variable-message sign systems—bulb matrix, rotating drum, disc, liquid crystal, and cloth panels (Figure 9)—each with varying degrees of effectiveness. An essential feature in each system is the capability to change messages quickly (in most cases by remote control) so

FIGURE 7 Variable-message sign.

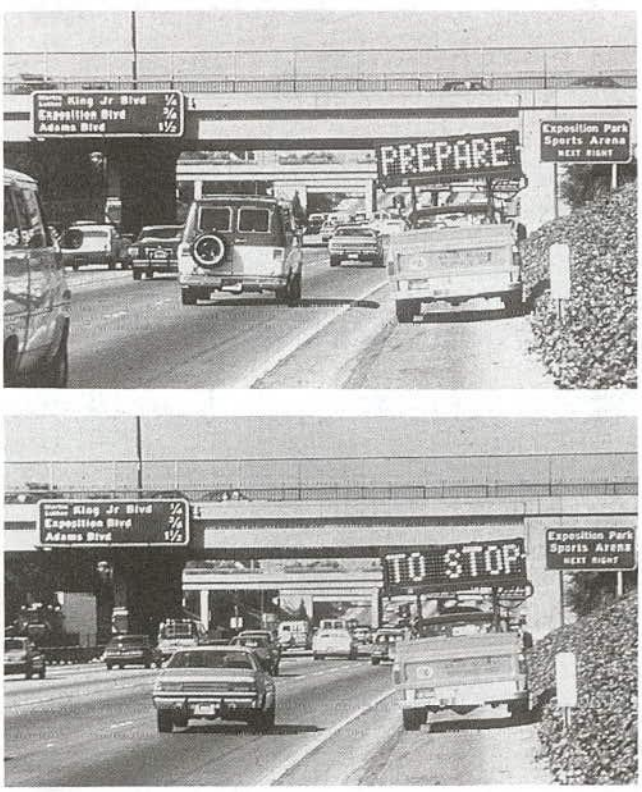


FIGURE 8 Bulb matrix variable-message sign, truck mounted.

FIGURE 9 Fabric variable-message sign, truck mounted.

that information can be provided to motorists in a timely manner.

Fixed-message signs have long been used to inform motorists of long-term situations, such as temporary road closures or restrictions for construction and maintenance work where conditions do not change appreciably, or in marking bypass routes around incident sites. They are also effective in giving the motoring public advance information regarding upcoming projects, so that adjustments in travel can be made.

Highway Advisory Radio

These systems are designed to broadcast, in a limited area, information on traffic conditions to motorists traveling in that area. One system uses low-powered transmitters, placed at intervals along the freeway or at key trouble spots, to broadcast a signal covering a 2-to-3-mile radius. Another system uses a cable buried along the freeway to send the signal. Motorists are informed by signs that information is being broadcast, and they are directed to tune their car radios to the proper frequency to receive the broadcast.

In the Chicago area, a test program is under way to broadcast freeway traffic information to motorists using a fully automated system. Traffic conditions are monitored on a continuous basis using a computerized detection system. When certain conditions are present, the system automatically activates a voice synthesizer and the information is broadcast to motorists over a highway advisory radio installation.

In California, truck-mounted highway advisory radio units (Figure 10) are being used in incident management by Caltrans. These mobile transmitters, which are generally located in the vicinity of an incident, are accompanied by signs informing the public that traffic information is being transmitted and instructing motorists to change their radio dials to pick it up. Highway advisory radio systems have also been used widely in other locations and in a variety of ways to broadcast traffic information to motorists. In general, this has been a very effective approach for communicating information to the traveling public.

Commercial Radio

One of the most effective means of providing traffic information to motorists is through the use of commercial radio stations.

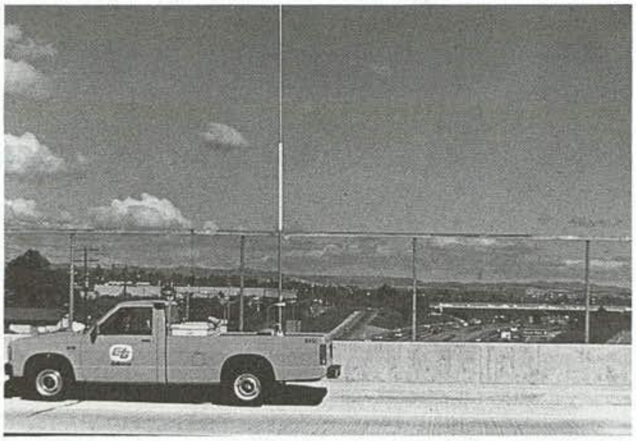


FIGURE 10 Highway advisory radio, truck mounted.

Many stations report on traffic conditions as part of their regular broadcasting format. Many have air- or ground-patrol units giving firsthand accounts of traffic conditions.

In several incident management systems, information about incidents and traffic conditions is being provided quickly—over the telephone, via teletype hookups, through electronic visual displays—to commercial radio stations for transmission to the motoring public. Making advance arrangements for the transmittal of information is essential for smooth transmission during an incident. The procedures and equipment for getting information to the stations needs to be in place, and broadcast-ready formats for the information have to be worked out. Providing timely, accurate information in a usable, understandable form is a key in getting the station operators to pass the information on to the public quickly and accurately.

It should be pointed out that commercial radio stations often broadcast traffic congestion reports to "sell" air time. On several occasions, one operating agency has noted that minor incidents were blown out of proportion in commercial radio traffic reports because there were no other newsworthy events occurring at the time. As a result, excessive rubbernecking delays were experienced that would not have occurred otherwise. As mentioned above, taking an active approach in providing information to the stations ensures timely and accurate information.

Print Media

Newspapers are an excellent means of providing traffic information to the public, particularly in those cases in which advance notice of traffic management plans for construction and maintenance activities, special events, and long-term incidents is being given. Another effective means of providing information in advance is through the use of brochures, pamphlets, flyers, etc., distributed to affected freeway users.

Citizen-Band Radios

Today, many vehicles are equipped with CB radios, and the number continues to grow. These CB-equipped vehicles provide one more means to pass on information to motorists. For example, this approach was used on a limited basis in the Chicago area during a period of particularly heavy rainfall and extensive flooding of the freeway system. State employees used CB radio in their trucks to warn motorists of flooding conditions.

MANAGING PLANNED INCIDENTS

A comprehensive incident management system for planned or repeat incidents (e.g., construction and maintenance activities) and special events (e.g., sporting events, fairs, and concerts) calls for virtually all of the measures needed to manage random incidents. One key difference in managing this type of incident is knowing the nature and extent of the incident beforehand. This provides the time needed to develop a precise plan to deal with the problem and to put the necessary pieces of that plan in place before the event. In some cases, there is the opportunity to control the time when the event will take place and thus minimize the traffic problems it will cause. There is time to identify and develop alternative routes; provide other modes of travel, if needed; and communicate the plan to the public. This extra time also allows the motoring public to adjust their travel patterns to deal with the condition most effectively. All of the measures that are effective for random incidents are also equally effective for planned incidents.

Construction Projects

The need to repair or replace many of today's aging freeways and bridges is critical. These facilities are carrying high traffic volumes and they must continue to handle traffic during reconstruction. There is a growing appreciation that an overall traffic management plan for construction projects, based on many of the concepts that are being used successfully in managing traffic at random incidents, is essential if major disruptions to traffic, and the ensuing public outcry, is to be avoided.

The topic of traffic management for construction projects was examined and discussed extensively at the National Conference on Corridor Traffic Management for Major Highway Reconstruction, held in Chicago in 1986. Identification of several key steps to be taken in the development, implementation, and operation of such a traffic management plan emerged from that conference and are set forth in the conference proceedings (*17*). (A videotape describing the issues and procedures developed at this conference is available from the Transportation Research Board.)

The development of the traffic management plan calls for the evaluation of the capacity/demand relationship for pre-project conditions as well as throughout the life of the project. If major traffic congestion and delays are to be avoided, steps must be taken to reduce demand and/or add capacity so that a reasonably close capacity/demand balance can be achieved.

A first step in this process is to develop the construction project, keeping in mind the need to continue to serve traffic. This requires designs and construction techniques that will minimize the impact on traffic flows. If possible, it is important to limit the hours of lane closures to off-peak periods, and provide incentives to contractors to shorten overall construction times.

Providing supplemental capacity during construction by establishing bypass routes is another step. This may necessitate construction on parallel routes to add capacity, changes in signal timing, the stationing of police officers to direct traffic, or the establishment of parking prohibitions. A full range of measures needs to be explored.

Demand in the freeway corridor can be reduced through more ride-sharing, increased use of transit, modification of working hours, and a complete rerouting of through traffic to other corridors. This type of measure usually requires a major public relations effort. Each technique and its potential for providing at least a partial solution should be evaluated. The selected measures need to be put in place early enough to allow the necessary shifts in demand to take place.

Similar to incident management for major accidents and spills on freeways, traffic management for construction projects also calls for a high degree of coordination between agencies in the development, implementation, and continuing operation of the traffic management plan. The success of the plan hinges on the ability and willingness of the various agencies to work together and to coordinate their activities.

Once the construction project is under way, the same incident management techniques used for random incidents can be used effectively on the sections of freeway under construction and on the surface streets being used as bypass routes. Adjustments to the plan can be made as needed to meet changing conditions as they develop.

Providing information to the public relative to traffic conditions expected as a result of construction activities, along with suggestions of how to avoid expected problems, is another effective step in managing traffic for major construction projects. If changes in the motorists' daily travel patterns will help the traffic situation, information about the need for changes and the options available must be provided to motorists. A program advertising the various ways to travel through the corridor is one way to do this. Motorists need to have this information well in advance in order to have sufficient time to modify their patterns. Experience around the United States has demonstrated the importance of public-information programs in these projects. The projects that have been most successful have included extensive public-information activities.

Maintenance Activities

Maintenance operations on freeways have an effect on traffic that is much like that experienced with many construction projects, although the effects are frequently to a lesser degree and for a much shorter time. Still, major traffic tie-ups often result from public-agency forces performing needed maintenance on freeways. Public resentment toward the agency creating the incident is often generated because of the delay problems that are created.

Management for this type of planned incident can employ the same approach as that used for construction projects—analyzing capacity loss (with the provision of supplemental capacity on bypass routes, if needed) and taking steps to divert traffic to alternative routes. Because these operations are generally short term, changing the demand level through flextime arrangements or modal split adjustments is not effective.

To minimize delay to the public, maintenance activities and lane closures should be scheduled, if possible, for periods when traffic volumes are lower. Closures for maintenance should be scheduled to avoid periods of heavy traffic that may be generated by other special events.

As with other planned incidents, methods to handle traffic can be developed beforehand, and the public can be given advance notice, before freeway traffic flows are affected by the operation. Again, steps to manage traffic actively during maintenance activities can be effective in minimizing traffic congestion, delays, and secondary accidents.

The California Department of Transportation has been successful in reducing congestion during maintenance operations through extensive application of traffic management measures. In one case in Los Angeles (*18*), a section of three-lane freeway serving more than 160,000 vehicles/day was closed during the midday hours so that necessary maintenance activities could be performed. A significant number of motorists moved to other routes voluntarily, and only a moderate amount of congestion and delay occurred.

Special Events

With special events, congestion problems arise as a result of a surge in demand (rather than a loss of capacity). Spectators move to and from an event, placing heavy traffic volumes on streets and freeways that often are already overloaded. The variety of traffic management measures previously discussed—developing as much supplemental capacity as possible; reducing demand through changing modes of travel, times of travel, and patterns of travel; communicating extensively with the traveling public, both those attending the event and those who are traveling to other destinations; and actively managing the traffic plan during the event—all can be effective in relieving congestion.

Parking management can also be a powerful tool in managing traffic demands and patterns at special events. Limited parking or expensively priced parking can provide added incentives for people attending the event to ride-share or to use transit (provided, of course, that adequate transit service is available). The location of parking lots and entrances and exits can establish arrival and departure routes. Reverse-lane patterns, temporary one-way streets, and restriction of certain turning movements can also be used to develop desired traffic patterns. The management of the rate at which traffic is allowed to exit parking lots onto surrounding surface streets and freeways can be used to control demand and to prevent the breakdown of traffic flows on these facilities.

There have been several instances in which the application of traffic management measures to handle high traffic volumes generated by special events has been highly effective. Steps taken to manage traffic during the 16 days of the 1984 Olympic Games in Los Angeles were extremely successful. A traffic crisis had been expected, but traffic operated under virtually free-flow conditions for most of the time (*19–22*). Other traffic management plans, less extensive and of shorter duration, have been operated for special events in many locations, with a good deal of success.

CHAPTER FOUR

CURRENT PRACTICE AND FUTURE TRENDS

Today, many agencies are engaged in at least some level of incident management activity. Several are making plans to implement new systems or to expand present operations. Much of present incident response is being carried out by law enforcement agencies and emergency services providers, because many transportation departments continue to take a somewhat passive role in incident management.

Agencies throughout North America were surveyed for this synthesis to inventory current incident management activities and ascertain what measures are being used. A tabulation of the survey response is presented in Appendix A.

There are two major systems in which comprehensive incident management is being provided:

- In the Chicago area, the Illinois Department of Transportation operates an extensive system that includes electronic surveillance and detection, a traffic systems center, a communications center that is operated 24 hr/day, emergency traffic patrols, heavy-duty tow trucks, variable-message signs, highway advisory radios, and systems to provide traffic reports to commercial radio stations and print media.
- In Los Angeles, Caltrans and the California Highway Patrol jointly operate a system covering several hundred miles of freeways. The system includes electronic surveillance and detection, a traffic operations center, television cameras, major incident response teams, variable-message signs, highway advisory radios, and a network of commercial radio stations and other media.

Less extensive systems are being operated in several other locations. Although these are less complex, each is, nevertheless, effective in reducing congestion and delays and in improving safety. Many of them are area wide in nature, whereas others deal with a particular location or corridor where incident-related problems are present. Some have been designed and operated for a single "incident" (i.e., a special event, a construction project) and have been discontinued following the event.

Several notable examples of these operations are listed below:

- The Washington State Department of Transportation operates a system covering several freeways in the Seattle area. Electronic surveillance and detection, an operations center, and closed-circuit television cameras are included, along with variable-message signs, highway advisory radios, and commercial radio stations to provide information to the public.
- The New Jersey Turnpike Authority monitors a portion of the turnpike with an electronic surveillance and detection system and an operations center. The entire system has service patrols or tow trucks that respond to incidents. Information is also provided to motorists along the entire length of the turnpike using variable-message signs and commercial radio stations.
- In Michigan, the Department of Transportation and the state police are engaged in a cooperative effort to manage incidents on about 100 miles of I-75. Alternative routes have been identified for various segments of the freeway, working arrangements developed, procedures adopted, communication systems set up, and signs stockpiled. The plan is being operated on a regular basis because, over the past several years, incidents have caused this stretch of freeway to be closed once per month.
- In the New York area, TRANSCOM is carrying out a program bringing together 16 transportation operating agencies to coordinate activities and implement incident management. An operations center is in place, interagency communications systems have been established, and procedures and working arrangements have been developed. An initial thrust has been to coordinate construction and/or maintenance operations on the facilities of the various agencies to minimize the overall impact of these activities on traffic. Management of other incidents and operation of facilities is being coordinated.
- In several metropolitan areas in Texas, operations centers have been established, service patrols are being operated, and coordination between various agencies in the operation of freeways and streets is taking place.
- Incident management techniques are being used on the Howard Franklin Bridge in Tampa, Florida. An electronic detection system provides data to a traffic operations center, alternative routes have been planned, closed-circuit television cameras are used, a service patrol is operated, and variable-message signs are activated to convey information to the motoring public. The San Francisco/Oakland Bay Bridge and the Lincoln Tunnel also have systems that speed detection and removal of incidents.

Several very effective incident management systems have been, or are being, operated to help relieve the traffic impacts brought on by major construction projects. In Toronto, a relatively low-cost system was used by the Ontario Ministry of Transportation and the provincial police during reconstruction of an 8-km segment of freeway. The primary detection system consisted of observers, equipped with radios and binoculars, stationed in towers placed at key locations along the highway. As incidents were detected, information was gathered at a base station located on the job site, the situation evaluated, and an appropriate response initiated. Police units, service patrol vehicles, contracted towing service, or other response services were dispatched to the incident scene to expedite removal of the problem and to restore normal operating conditions.

Other, more extensive traffic management systems are being operated as part of major construction projects. Reconstruction projects on the Dan Ryan Expressway in Chicago, the Southeast Expressway in Boston, the Ventura Freeway in Los Angeles, the Parkway East in Pittsburgh, and the I-394 Freeway in Minneapolis have all included significant traffic management programs that have been aimed at reducing demand on the freeway, developing bypass routes around or through construction sites, and achieving early detection and rapid removal of incident-related freeway blockages. Several other cities across the United States have implemented highly successful programs (*23*).

In every system that has been operating or continues to operate, significant benefits (i.e., reductions in congestion and delay, and increased safety) have been reported. Consistently, benefits to the public have exceeded costs, often by factors of two, three, or greater. In each, an improved public image of the agencies involved has been noted. The most successful operations contain a strong element of extensive coordination among the various organizations, both public and private, that play a role in the detection, response, and clearance of incidents. As each agency has gained experience in incident management, each has a growing appreciation of the benefits that can be realized with a comprehensive program. Many of the agencies involved in incident management continue to upgrade and to expand present systems.

CHAPTER FIVE

SOME CONCLUSIONS

Traffic problems are a growing problem today, not only in urban areas but also in suburban and rural areas. Congestion and the resulting delays and accidents are imposing enormous costs on society in terms of dollars, human suffering, and frustration. Many cities are being seriously affected by congestion on freeways and streets. All indicators point toward increased problems in the future as development continues to take place, traffic volumes build, and roadways become more clogged.

This problem, plus the slowdown in the construction of new highways, has placed greater emphasis on improving the operation of existing facilities. With this emphasis, there has come a broader understanding of congestion, the causes of congestion, and the effect of congestion on the operation of facilities.

The incident-related element of congestion is also receiving more attention as its nature, scope, and contribution to the overall congestion problem are more fully understood. As a result, a number of programs to deal with the problem of incident-related congestion have been developed and instituted. Agencies have reported significant benefits from these programs. Systems are being expanded and improved. As word of the successes has spread, the interest of other agencies in implementing such systems has heightened. New systems are being planned, designed, implemented, and operated in many locations.

Still, much more needs to be done. Traffic loads are increasing dramatically in every metropolitan area. Each day incidents are creating intolerable congestion, and the costs to the public of delays and secondary accidents continue to mount.

The problems are there, but so are the solutions. The techniques, systems, and procedures have been tested and used. They work and they are cost-effective.

Agencies with operating systems need to intensify their efforts to upgrade and expand those systems, broaden the application of proven techniques, and search for and test new approaches. Other agencies need to move to implement and operate new systems and join in the search for refinement of systems and techniques to deal with this major problem in the operation of freeway systems.

AN IDEAL INCIDENT MANAGEMENT SYSTEM

The problem of delays and secondary accidents brought about by incident-related congestion is multifaceted. Different incidents create imbalances in the capacity/demand relationship in different ways—some through a loss in capacity, others through an increase in demand, and still others by a combination of the two. Several measures may be effective in dealing with all types of incidents and their effects. Others may be useful only in dealing with one aspect of the problem. The overall solution, therefore, must be one that combines various measures into a comprehensive system that will be effective in dealing with the problem.

Several things need to happen if the system is to be effective:

- Incidents must be detected accurately and rapidly.
- The nature of incidents must be determined quickly.
- Information relative to incidents needs to be collected and passed on to various agencies.
- Roles and responsibilities of the various agencies must be developed, understood, and agreed on.
- There must be an appropriate coordinated response to the incident.
- Quick removal of both major and minor incidents needs to take place.
- Traffic management measures need to be applied all through the duration of the incident.
- Information on traffic conditions and bypass routes needs to be provided to motorists.
- Traffic management plans for "planned incidents" need to be developed, implemented, and operated.

The "ideal" incident management system, therefore, should include at least some of the measures given in Table 2.

TABLE 2
MEASURES FOR AN IDEAL INCIDENT MANAGEMENT SYSTEM

Need	Measures to Address the Need
Detecting and determining the nature of incidents.	Organize existing information sources into a comprehensive network for detection of incidents. Design, build, and maintain an electronic surveillance and detection system. Place closed-circuit television cameras along critical freeway links and at particularly troublesome locations. Use other systems and procedures to gather all available information regarding what is happening on the freeway system.
A focal point for processing data, collecting, and disseminating information.	Establish a traffic operations center, appropriately equipped and staffed. Use electronic displays, maps, or other means to visually depict freeway operating conditions. Develop communications systems to receive and dispense information.
Active management of major incidents to speed removal of incidents, and to manage traffic to minimize congestion throughout the duration of incidents.	Establish procedures and working relationships to bring about coordinated response efforts by various agencies. Form incident response teams. Use truck-mounted variable message signs and highway advisory radio systems. Design planned alternative routes.
Quick removal of incidents from traffic lanes.	Make use of service patrols that operate with vehicles capable of removing relatively lightweight vehicles from the freeway. Have heavy service patrol vehicles and/or tow trucks available that are equipped to remove stalled heavy vehicles from traffic lanes.
Quick removal of major incidents.	Establish tow truck services to provide needed services in a timely manner.
Provide traffic information to motorists.	Use variable message signs located at key locations throughout the freeway system. Use portable variable message signs that can be positioned and operated in conjunction with incident management. Establish a highway advisory radio system, either ground-mounted or portable. Develop a network of commercial radio stations to broadcast information and develop the means to quickly provide information to those radio stations. Create systems to provide information about long-term traffic conditions to print media.
Traffic management for construction, maintenance, and special events.	Institute the procedures and recruit the staff to develop traffic management plans for major activities. Organize an extensive public information effort for each major event. Apply incident management measures throughout the duration of each event.

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APPENDIX A

INCIDENT MANAGEMENT SYSTEMS IN NORTH AMERICA (1987-1988)

SYSTEM TYPE AND LOCATION	FIM PROGRAM		DETECTION & VERIFICATION							RESPONSE				MOTORIST INFO			
	Minor Emphasis	Major Emphasis	Operations Center	Service Patrol	Electronic Detection	Closed Circuit TV	C.B. Radio	Call Boxes	Other	Response Team	Wrecker Agreement	Agency Equipment	Other	Alternate Routes	Highway Advisory Radio	Media	Variable Message Signs
AREAWIDE SYSTEMS																	
Anaheim, CA	X	X	P			P				P				P	P	P	P
Baltimore		X	X											X			X
Chicago	X	X	X	X	X	X	X					X	X		X	X	X
Connecticut (State)	X	P	P	X	P	P							P				P
Detroit	X		X		X	X	X	X			X					X	X
Fairfax Co., VA	X	X	X						X		X			P		X	
Ft. Worth	X	P	P	X	P	P			P	X	X		P	P	P	X	P
Houston		P	P	X	P	P				X		X		P		X	P
Jacksonville, FL	X	X		X						X	X			X		X	
Los Angeles	X	X	X	P	X	X		X	X	X		X	X	X	X	X	X
Massachusetts Frwys	X	X	P				X	X		P			X	P			
Miami	X	X	P		P	P				X	X			X	P	X	P
Minneapolis/St. Paul	X	P	X	X	X	X	X	P		P	X				X	X	X
Norfolk Area, VA	P	P	P		P	P						X		P		X	P
Northern Virginia	X	X	X	X	X	X	X				X					X	X
Phoenix	P	P	P		P	P			P		X			P			P
San Antonio	P	P		X	P	P								P			P
San Diego	P	X	P	X	X			P		X		X			P	X	X
San Francisco	P	P	P	X	P	P		P		X		X			X	X	P
Seattle	P	P	X		X	X				P	P			P	X	X	X
Tampa Bay, FL	X	X	P		P	P				X	X			X	P	X	P
TRANSCOM - NY/NJ		X	X			P			X				X	P		X	P
Toronto	P		P		P	P										X	X
CORRIDOR SYSTEMS																	
Balt/Jones Falls			X		X			X									
Dallas/N. Cent Expy	X	P	P		P	P								P			P
El Paso, TX/I-10	X	P			P	P					X	X	X	X			X
Ft. Lauderdale/I-95	X	X															
Los Angeles/I-10	X	X	X	X	X	X	P	X	P	X	P	X	P	X	X	X	X
Maryland(West)/US-48		X								X				X			
Maryland/US-50	X	X		X			X			X		X				X	
Maryland/I-95/495	X	X		X						X		X		X			P
Michigan/I-75		X								X				X			
NJ Turnpike	X	X	X	X	X	P					X	X		X		X	X
NY/Long Island Expy	X	X	X		X	P	X			X	X	X		X		X	X
NY State Thruway	X	X	X	X		P	X			X	X	X		P	X	X	X
Orlando/I-4	X	X		X	X			X		X	X			X		X	
Rhode Island/I-95		X								X				X			X

X = In-place
P = Planned or Proposed

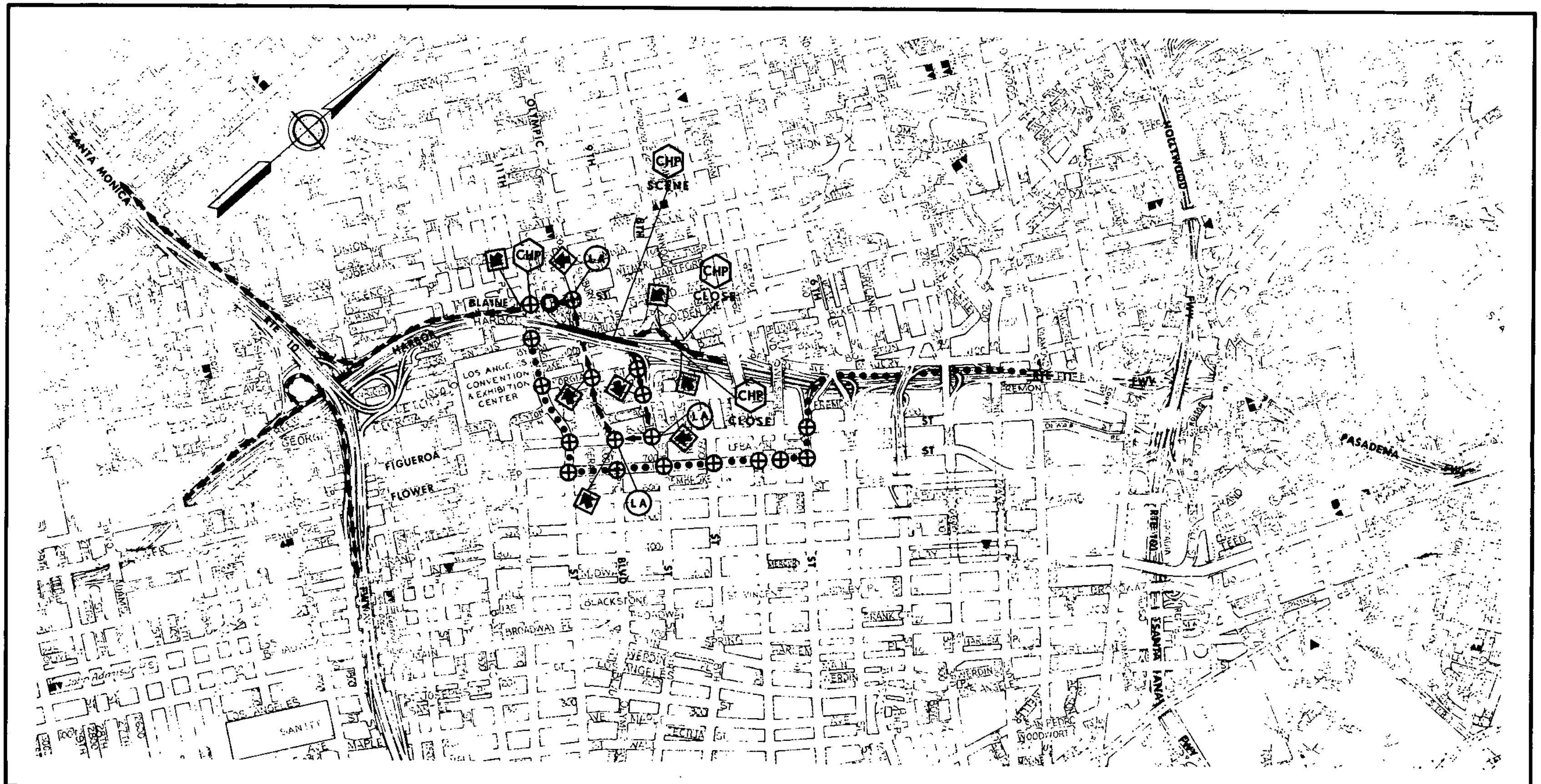
SYSTEM TYPE AND LOCATION	FIM PROGRAM		DETECTION & VERIFICATION							RESPONSE				MOTORIST INFO			
	Minor Emphasis	Major Emphasis	Operations Center	Service Patrol	Electronic Detection	Closed Circuit TV	C.B. Radio	Call Boxes	Other	Response Team	Wrecker Agreement	Agency Equipment	Other	Alternate Routes	Highway Advisory Radio	Media	Variable Message Signs
BRIDGES, TUNNELS, AND SPOT LOCATIONS																	
Baltimore Tunnels	X	X				X						X		X	X	X	X
Dewey Sq Tnl, Boston															X		
East St. Louis, IDOT	X			X			X	X				X			P	X	
Eliz. River Tunnels Norfolk/Ports. VA	X	X	P	X	P	P	X	X	X			X				X	P
Escambia Bay Brs (2) Florida I-10/US98	X	X	X					X		X	X						X
Franconia Notch/I-93 New Hampshire															X		X
Hampton Rd Br/I-64 and Tunnel, VA	X	X	X	X	X	X	X					X			X	X	X
Howard Franklin Br. Tampa, FL	X	X	X	X	X	X		X		X	X			X		X	X
James River Br/SR 17 Newport News, VA	X	X	X	X		X	X	X				X					
Lehigh Tunnel, PA PA Turnpike	X	X	X	X	X	X		X				X					X
Lewiston, ID/US-95		X			X												
Lincoln and Holland Tunnels, NY/NJ	X	X	X	X	X	X					X	X			P		X
Montana/I-90																	X
North Idaho/I-90			X			X											X
Oakland Bay Br (SF)	X	X	X	X	X	X		X		X		X				X	X
Sunshine Skyway Br. Florida	X	X	X			X		X		X	X			X		X	X
Tappen Zee Br., NY	X	X	X	X		P	X			X		X		X		X	X
Triborough Bridge & Tunnel Author., NY	X	X	X		P	X		X				X				X	X
Albany, NY				X													
Boston, MA				X													
Bridgeport, CT				X													
Hartford, CT				X													
New Haven, CT				X													
Stamford, CT				X													
Providence, RI				X													
Westchester Co, NY				X													

X = In-place
P = Planned or Proposed

SYSTEM TYPE AND LOCATION	FIM PROGRAM		DETECTION & VERIFICATION							RESPONSE				MOTORIST INFO			
	Minor Emphasis	Major Emphasis	Operations Center	Service Patrol	Electronic Detection	Closed Circuit TV	C.B. Radio	Call Boxes	Other	Response Team	Wrecker Agreement	Agency Equipment	Other	Alternate Routes	Highway Advisory Radio	Media	Variable Message Signs
CALL BOXES																	
CA/Los Angeles Co								X									
CA/Orange Co								X									
CA/Riverside Co								P									
CA/San Bernadino Co								P									
CA/San Diego Co								P									
CA/San Fran Bay Area								P									
CA/Ventura Co								X									
Connecticut/I-91								X									
DE/I-95, 295, & 495								X									
Florida Turnpike			X					X		X	X						
Florida Rural Interstates			X					X		X	X						
MA/I-93, 95, & 91								X									
Louisiana/I-10								X									
New York/I-87								X									

X = In-place
P = Planned or Proposed

APPENDIX B
ALTERNATE-ROUTE MAP



STAGES OF IMPLEMENTATION

NO. OF LANES CLOSED

	ESTIMATED DURATION	1	2	3	4	☒	☒
MID.	1 HOUR	—	—	I	IV		
TO	2 HOURS	—	I	II	IV		
0500	2-6 HOURS	II	III	III	IV		
	ESTIMATED DURATION	1	2	3	4	☒	☒
0500	1 HOUR	—	II	III	IV		
TO	2 HOURS	II	III	III	IV		
1900	2-6 HOURS	II	III	III	IV		
	ESTIMATED DURATION	1	2	3	4	☒	☒
1900	1 HOUR	—	II	III	IV		
TO	2 HOURS	—	II	III	IV		
MID.	2-6 HOURS	I	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.	213 620-3270
LOS ANGELES TRAFFIC DEPT.	213
LOS ANGELES POLICE DEPT.	213 485-3223
LOS ANGELES FIRE DEPT.	213 485-6185

LEGEND

Symbol	Meaning
▬▬	LIMITS OF CLOSURE
→→→	PRIMARY ALTERNATE ROUTE
•••••	SECONDARY ALTERNATE ROUTE
⊕	SIGNALIZED INTERSECTION
◘	STOP SIGN INTERSECTION
◆	SIGNING
CHP	CALIFORNIA HIGHWAY PATROL
LA	LOS ANGELES POLICE DEPT.
▲	FIRE STATION

LIMITS OF CLOSURE

BETWEEN 8TH ST ON-RAMP AND OLYMPIC BLVD. OFF-RAMP

ALTERNATE ROUTES

PRIMARY:
OFF TO E/B 9TH ST TO S/B FIGUEROA ST TO W/B OLYMPIC BLVD TO S/B BLAINE ST TO ON-RAMP

SECONDARY:
OFF TO COLLECTOR RD TO E/B 6TH ST TO S/B FLOWER ST TO W/B 11TH ST TO ON-RAMP

SPECIAL NOTES:

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

OTHER- 1. THIS SECTION ALSO INCLUDES AN ADDITIONAL UNSTRIPED AUXILIARY LANE

ALTERNATE ROUTES

HARBOR FREEWAY
ROUTE 11
SOUTHBOUND

DATE REVISED ___ ___

LA-11-S 22.3

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