TRANSPORTATION RESEARCH

# CIRCULAR

Number 344, January 1989



# Traffic Management for Freeway Emergencies and Special Events

TRANSPORTATION RESEARCH BOARD / NATIONAL RESEARCH COUNCIL

TRANSPORTATION
RESEARCH
CIRCULAR

Number 344, January 1989
ISSN 0097-8515

# TRAFFIC MANAGEMENT FOR FREEWAY EMERGENCIES AND SPECIAL EVENTS



James I. Taylor
Chairman, Group 3 Council

Conference Planning Co-Chairmen
O.K. Dart, Jr.
W.M. Dunn, Jr.
S.C. Tignor
T.C. Werner

TRB Staff
David K. Withefórd

mode

1 highway transportation

subject areas

40 Maintenance and Equipment
51 Transportation Safety
54 Operations and Traffic Control

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

## CONTENTS



## FOREWORD

Because of the interest expressed by attendees at three earlier one-day conferences on the subject, three Transportation Research Board committees jointly developed and sponsored the conference on January 10, 1988 that is reported in this circular.

The Committees on Freeway Operations, Travelers' Services and Traffic Law Enforcement established a subcommittee composed of Olin K. Dart, Jr., Walter M. Dunn, Jr., Samuel C. Tignor, and Thomas C. Werner to plan and conduct this fourth Conference on Traffic Management and Planning for Freeway Emergencies and Special Events. The objective was to create an understanding of the planning and actions that can be undertaken to reduce the impacts of congestion due to freeway incidents and special events. Emphasis thus continued to be placed on discussions about non-recurrent congestion resulting from incidents and the control of incidents and traffic generated by special events.

The program, a copy of which is listed in the Appendix, included technical presentations, discussions of case studies and a group workshop analysis session. Some presentations essentially the same as the preceding years program were published in Transportation Research Circular 326, (December 1987). They are not repeated here. The presentations contained here do convey the nature of the conference and should be of interest to highway administrators, traffic engineers, law enforcement and emergency services personnel who are in positions to influence program priorities.

# THE URBAN FREEWAY CONGESTION PROBLEM

Jeffrey A. Lindley
Federal Highway Administration

Urban traffic congestion is not a new problem. Virtually from the introduction of automobiles into the transportation system, there have been congestion problems. But in recent years the congestion problem has become much more serious and truly national in scope. In fact, the residents of several cities, including Phoenix, Atlanta, Houston, San Francisco, and Washington have all identified traffic congestion as their most serious regional problem (1). As citizen concern has grown, the news media, which once covered congestion-related stories only rarely and on back pages, now cover traffic congestion much more frequently and as front page news.

As an example of how traffic congestion can affect individuals, consider the example of a 20 year-old worker in an urban area who has a 40 minute commute each way to work. An average of ten of these forty minutes are spent being delayed due to congestion. In the course of a working lifetime (to age 65), assuming conditions do not worsen, this worker will be delayed by a total of nearly 4,000 hours, or about two working years.

Congestion on urban freeways causes particularly serious problems, because of the freeway's role as the backbone of the urban transportation network. Freeways account for less than three percent of the roadway milage in urban areas, yet accommodate over 30 percent of the total vehicle-miles of travel (2). Severe congestion on an urban freeway will typically spill onto adjacent arterials and local streets and further aggravate the overall congestion problem.

There are two basic types of freeway congestion. The first is recurring congestion, which occurs in the same locations on a daily basis. Recurring congestion is normally caused by the combination of heavy traffic demand and some sort of bottleneck. This may be a lane drop, particularly heavy traffic flow at an on or off-ramp, a steep grade, a weaving section, or a roadway segment with a particularly narrow cross section, such as a bridge.

The second type of freeway congestion is nonrecurring congestion, which is caused by random, but not infrequent events, such as disabled vehicles, accidents and adverse weather. Congestion due to planned events, such as a large sporting event or maintenance and construction work is also considered to be nonrecurring congestion. However, since these events are planned, their impact on freeway congestion can be calculated in advance and appropriately mitigated. Delays due to nonrecurring congestion can be very minor, such as those caused by a disabled vehicle on the shoulder, or quite major, such as those caused by a an accident which blocks all available freeway lanes.

In order to quantify the magnitude of the urban freeway congestion problem on a national scale, the Federal Highway Administration (FHWA) sponsored a study in 1986 (3) to analyze the problem based on highway performance data submitted to FHWA by the States. The methodology used in this study was based largely on the freeway capacity and level of service procedures contained in Chapter 3 of the 1985 Highway Capacity Manual (4). Estimates were made for delay due to recurring congestion, delay due to nonrecurring congestion, excess fuel consumption, and excess user costs, based on assumed values of user travel time and wasted fuel. Estimates were made for both 1984 and 2005 assuming no improvements to the urban freeway system.

The results of this study are shown in Table 1. It was found that urban freeway congestion led to over 1.2 billion vehicle hours of delay, over 1.3 billion gallons of wasted fuel and over 9 billion dollars in excess user costs in 1984 alone. Over 60 percent of the wasted delay, wasted fuel and excess user costs were due to nonrecurring congestion caused by incidents. These figures were recently updated for 1985 and ita was found that there had been a nearly 30 percent increase in delay between 1984 and 1985 (5).

As astounding as the figures for 1984 and 1985 are, the results of the study for 2005 are positively alarming. Delay, wasted fuel and excess user costs will all increase more than fivefold unless substantial improvements to the urban freeway system are made. Over 70 percent of improvements to the urban freeway system are made. Over 70 percent of all delay will be due to nonrecurring congestion caused by incidents.

There are two basic types of strategies for addressing urban freeway congestion problems: adding capacity and reducing demand. The most direct way to add capacity to the freeway is to add lanes. Unfortunately, this type of improvement is also very expensive, highly disruptive to traffic already on the freeway, and in many areas, infeasible due to right-of-way, terrain, or political constraints. Capacity can also be added to the freeway by implementing low-cost measures, such as narrowing existing lanes to gain an additional lane, allowing travel on the shoulder during peak periods, lengthening acceleration and deceleration lanes, widening on and off ramps, or closing selected ramps during peak periods. These types of projects have been successfully implemented in many locations throughout the country.

The traffic carrying capability of a freeway can also be improved by managing the traffic with a computerized surveillance and control system. These systems generally consist of four major components:

1) A surveillance system to monitor the flow of traffic on the freeway and identify problems. This is generally done using electronic loop detectors, closed circuit television or both.

2) Control of the flow of traffic entering the freeway using signals at entrance ramps. The purpose of these signals is to "meter" the rate of traffic entering the freeway at a rate that can be absorbed.

3) An incident management program to quickly and effectively respond to, manage the impacts of, and clear both major and minor incidents. Such a program requires a significant commitment of both personnel and equipment to be effective.

4) An effective information system to keep motorists informed about traffic delays and appropriate alternate routes. This is currently done using changeable message signs, commercial radio traffic reports, or highway advisory radio; however, in-vehicle route guidance systems show a great deal of promise for performing this function in the future.

The second type of strategy to reduce congestion on urban freeways is to reduce traffic demand during peak periods by shifting demand into higher occupancy vehicles or by shifting demand outside the peak period. This can be done in a variety of ways, including ridesharing, widespread use of staggered work hours and flextime, priority treatment for high occupancy vehicles, or charging tolls to motorists who drive alone or during the peak period.

This specialty conference concentrates on mitigating the impacts of nonrecurring congestion, typically the cause of more than half the delay on the urban freeway system. Both strategies that increase freeway capacity and those that reduce demand can be used to reduce the impacts of nonrecurring congestion. Strategies which increase capacity do not directly reduce the overall incident rate, but can reduce the number of minor secondary accidents which tend to occur under congested conditions. These strategies also provide additional capacity when an incident occurs, which reduces the time required for traffic flow to return to normal after the incident is cleared. Strategies which reduce demand have more direct impact on the overall incident rate, since this rate is closely correlated to the number of vehicle-miles of travel on the freeway. If total vehicle-miles of travel are reduced =, the incident rate will typically be reduced as well.

The primary goal of an incident management program is to minimize the impacts of incidents on traffic flow. This is generally accomplished in two ways:

- reducing the duration of the incident
- efficiently managing traffic during the incident

These two goals can, in turn, generally be achieved by:

- reducing the time needed to detect that an incident has occurred
- reducing the time for response personnel and equipment to arrive at the scene
- exercising proper on-scene management of personnel and traffic
- reducing the time needed for the incident to be cleared from the roadway
- providing timely and accurate information to the public

Table 2 lists some ways that these goals can be achieved in an overall incident management program. Some of these actions are effective for all types of incidents, some apply only to "routine" minor incidents, while others are clearly intended to address the problems associated with major incidents. The strategies selected by an agency for a particular freeway will depend on the specific incident problem and the resources available. It should be noted while major incidents such as multi-lane accidents or hazardous material spills cause large amounts of minor accidents and vehicle disablements are far more common and can easily cause as much traffic congestion as a major incident if not properly managed.

An important item to note from Table 2 is that freeway incident management is truly a multidisciplinary activity. All of the key players, such as those from the highway agency (both traffic and maintenance), police agencies, and fire/rescue agencies, as well as other involved agencies, must be committed to making the incident management program work. Without the involvement and commitment of all necessary parties, the incident management program will never be truly successful.

Urban freeway congestion is general and nonrecurring incident congestion in particular are serious and growing problems. Incidents on urban freeways cannot be prevented entirely; however, proven existing techniques to address the nonrecurring congestion problem can minimize the delay caused by incidents. A systematic and vigorous application of these techniques is required if our current urban freeway congestion problem is not to grow to an intolerable level.

**Table 1. Urban Freeway Congestion Statistics**

| | 1984 | 2005 |
|---|---|---|
| Freeway Miles | 15,335 | 15,335 |
| Vehicle-Miles of Travel (millions) | 276,635 | 410,987 |
| Recurring Delay (million vehicle-hours) | 485.0 | 2,048.6 |
| Delay Due to Incidents (million vehicle-hours) | 776.8 | 4,857.5 |
| Total Delay (million vehicle-hours) | 1,251.8 | 6,906.1 |
| Total Wasted Fuel (million gallons) | 1,377.5 | 7,317.1 |
| Total Excess User Cost (billion dollars) | 9.2 | 50.0 |

Source: Reference 3

# Table 2. Candidate Incident Management Techniques

## TECHNIQUES FOR REDUCING DETECTION TIME

- Elcctronic loop detection
- Closed circuit television
- Call boxes
- Service patrols
- CB radio monitoring
- Increased police patrol frequency
- Stationing fixed observers at strategic locations
- Use of cellular telephones through 911 or designated "hot line"
- Ties with transit and taxi companies
- Aerial surveillance

## TECHNIQUES FOR REDUCING RESPONSE TIME

- Cooperative agreements between responding agencies
- Equipment and materials located in strategic locations
- Development of key personnel resource list
- Tow trucks and other response vehicles stationed at high incident rate locations
- Peak period motorcycle patrols
- Development of freeway management team manual
- Improved interagency radio communication

## EFFECTIVE ON-SCENE MANAGEMENT TECHNIQUES

- Advance alternate route planning
- Implementation of flashing lights policy
- Command posts and established procedures
- Development of hazardous materials manual
- Proper traffic control techniques at incident scene
- Proper parking of response vehicles at incident scene

## TECHNIQUES FOR REDUCING CLEARANCE TIME

- Equipping response vehicles with appropriate materials and equipment
- Equipping response vehicles with push bumpers and establishing clear procedures for their use
- Off-freeway accident investigation sites
- Clearly identifying locations of fire hydrants accessible from the freeway
- Training for all response personnel on handling of various types of incidents

## EFFECTIVE MOTORIST INFORMATION

- Media agreements
- Variable message signs
- Highway advisory radio

**References**

1. Rothenberg, M. J., "Urban Congestion in the United States: What Does the Future Hold?", Urban Traffic Congestion: What Does the Future Hold, Institute of Traffic Engineers, Publication No. IR-040, 1986.

2. Selected Highway Statistics and Charts 1986, U. S. Department of Transportation, Federal Highway Administration, Report No. FHWA-PL-88-003, October 1987.

3. Lindley, J. A., Quantification of Urban Freeway Congestion and Analysis of Remedial Measures, U. S. Department of Transportation, Federal Highway Administration, Report No. FHWA/RD-87/052, October 1986.

4. Highway Capacity Manual, Transportation Research Board, Special Report 209, 1985.

5. Urban and Suburban Highway Congestion, U. S. Department of Transportation, Federal Highway Administration, 1987.

# THE NEED FOR INTER-AGENCY COOPERATION DURING INTERSTATE HIGHWAY MOVEMENT OF OVERSIZE LOADS AND DIVERSION OF TRUCKS AROUND METROPOLITAN AREAS

Colonel Jack Walsh
Ohio State Highway Patrol

Many situations and events result in freeway emergencies. They include events caused by man as well as those resulting from the forces of nature. Ideally, the best way to handle freeway emergencies is to prevent them from ever happening. This, of course, is not possible. But through Enforcement, Engineering, and Education ... the 3 E's ... we accomplish a great deal.

Effective traffic safety management demands a fluid working relationship between traffic engineers and law enforcers throughout all levels of the command structure. In a continuing effort tó promote cooperative communications, I've agreed to cohost, along with the Ohio Department of Transportation, a Safety Conference for State Highway Engineers and Law Enforcement Officials this Spring (May 1-3) in Columbus, Ohio. The conference concept promotes cooperation and coordination between the two disciplines. About 15 states from the Midwest have been invited. The future of traffic safety management rests largely on the shoulders of engineers and enforcement officials. To be successful we must coordinate our work at all stages.

When we speak of freeway emergencies, images of fires, accidents and traffic congestion readily come to mind. These events can be as diverse and varied as a landslide or a traffic accident; a flood or a football game; a bridge collapse or a construction zone. Some of these situations are the results of planned events, such as construction zones and sporting events, while others are not, such as the forces of Mother Nature. Let us examine the management of a not so traditional freeway emergency; one which had no pre-planning and no inter-agency communication before the event occurred.

## IS-75 Truck Ban - Kentucky

On Tuesday, July 8, 1986, the governor of the Commonwealth of Kentucky issued an executive order prohibiting northbound commercial truck traffic travelling through the Greater Cincinnati metropolitan area from using a 6-mile stretch of Kentucky Interstates 71 and 75 just south of the Ohio River. All affected tractor-trailers were rerouted onto Interstate 275, bypassing the City of Cincinnati. This order occurred a week after a fatal crash involving a commercial vehicle in an area known as Death Hill.

I wish to point out that I am not here to criticize the Kentucky governor's unilateral action. I will let history determine if the timing of the executive order was correct. There are times when circumstances dictate that swift and decisive action is necessary to alleviate a problem -- or -- to focus attention on a prolonged hazardous situation.

Let us direct our attention, however, to the effect of this event and the proper management of this freeway emergency. Ohio officials, including the Highway Patrol, were not informed of the truck ban until the day it took effect, the same day that detour signs were erected in Kentucky. As a result, we took several immediate steps to counter what resulted in a 300% increase in truck traffic on IS-275.

1. Patrol hours in the affected area were doubled.

2. Our portable truck scales team was assigned to the area on a regular basis.

3. Air speed enforcement was increased.

4. Statistics and results of our efforts were provided to the media. A newspaper reporter was permitted to accompany one of our troopers on patrol.

5. Weekly activity reports were initiated.

While we were increasing our visibility and impact on the interstate, citizens and local officials were also reacting to the diversion of truck traffic. IS-275 is an 84 mile interstate circling the City of Cincinnati, and travels through three states and numerous municipalities. While Cincinnati and other centrally located cities were supportive of the truck ban, the suburban communities raised a hue and cry that the detouring of trucks would endanger their communities. They argued that speeding would increase as drivers attempted to make up for lost time; and that traffic accidents would increase, especially those involving hazardous materials, endangering their communities. This pressure was directed not only at the Governor of Kentucky, but also the State of Ohio.

This pitting of the inner city interests against the suburban community concerns made the truck ban a very controversial issue. Of paramount interest was the increase in hazardous materials moving through the suburban communities. Small suburban communities and rural fire departments felt they couldn't handle a significant freeway emergency because they were not adequately trained or equipped to deal with a hazardous materials incident. They argued that advance notice could have permitted pre-planning for truck traffic diversion through their community. City officials would have had an opportunity to reallocate their resources. Having time to train and equip their emergency response forces could have alleviated some of their concerns.

The Ohio Department of Transportation had construction projects in progress on IS-275 which affected the flow of traffic. As a result of the truck ban on IS-75 and IS-71, ODOT planners had to reexamine their construction and highway maintenance plans.

Since the diversion of trucks began, there have been public hearings, task forces established and in-depth studies initiated by agencies at the local, state and federal levels. The Highway Patrol has actively participated in many of these studies and meetings. We feel that overall successful management of this situation has depended upon:

1. Inter-agency cooperation and communication.

2. Knowing other decision makers on a one-on-one basis.

3. Understanding other agencies' needs, philosophies, and objectives.

4. Communicating the Highway Patrol's commitment to provide the resources necessary to ensure safety on the highways.

Given the opportunity to conduct some planning and evaluating of our resources, we initiated certain strategies:

1. We scheduled a four man tactical squad to work 12 hour enforcement shifts Monday - Friday.

2. We increased our airspeed checks to at least one per day. We also supplemented our painted airspeed lines with use of our aircraft VASCAR units. One aircraft can utilize troopers located in multiple zones, thus impacting more traffic.

3. We involved deputy sheriffs as ground units in our airspeed enforcement. This extends the effectiveness of our aircraft. And it promotes inter-agency cooperation between law enforcement agencies to impact a problem that could be perceived as solely a Highway Patrol responsibility.

4. We have cooperated with the PUCO Enforcement Division to schedule their inspectors with our portable scales team to work together at a closed rest area along IS-275.

5. We initiated contact with the State Fire Marshal's Hazardous Material Response Teams, to provide training for local agencies. The State Fire Marshal has located Emergency Response Units strategically at several of our posts throughout the state. One is located off IS-71 just north of IS-275.

Currently we are awaiting a Federal Highway Administration decision on the continued diversion of truck traffic until highway reconstruction of the affected area is completed. This decision is due next month.

This example of a not-so-traditional freeway emergency underscores the need for pre-planning. Traffic management is a system involving many disciplines from both the public and private sectors. The actions of one government agency, large or small, can have far-ranging implications for other states, regions, or municipalities. No longer can each political subdivision manage its own traffic problems internally without influencing its neighbor's traffic patterns.

In Columbus, Ohio a city ordinance has resulted in the diversion of all thru hazardous loads around Columbus on IS-270. Lack of inter-agency cooperation and communication contributed to the delay in implementation of this ordinance until a semi carrying liquid hydrogen overturned at the IS-70 / IS-71 interchange near downtown Columbus. This freeway emergency, which paralyzed traffic for many hours, sparked much activity and media attention. This resulted in the cutting of red tape and the posting of interstate signs diverting hazardous materials onto IS-270 around Columbus.

We in the Patrol believe strongly in the "systems" approach to problem solving; and see clearly that to achieve our traffic safety objectives requires close inter-agency communication and coordination.

**Oversize Movements - Mansfield**

Now let's turn to an example of what I feel is excellent pre-planning of an unusual event.

In 1985 the Ohio Department of Transportation advised us of an upcoming series of movements of oversized machinery. These so-called "Superloads" would depart from the Port of Cleveland for a General Motors stamping plant near Mansfield, Ohio, and were segments of computer-operated, high-speed stamping presses which were up to 14 feet high and 140 feet long. They weighed between 200,000 and 600,000 pounds and some approached 25 feet in width, more than the width of the two lanes of interstate highway over which they would travel. These huge presses had traveled across the Pacific Ocean from Japan, through the Panama Canal, and up the Atlantic Coast before reaching the Port of Cleveland by way of the St. Lawrence Seaway. Before the first press was unloaded, a planning session was scheduled. Attending the meeting were the Department of Transportation, the Highway Patrol, the City of Cleveland, the contracted trucking company, and the engineering firm that was to install the presses at the GM facility.

The objective of the planning session was to coordinate the safe movement of the machinery with a minimum of inconvenience to the motorists who use busy Interstate 71 and Cleveland city streets.

During the planning sessions, a system of inter-agency communications and emergency procedures were developed. Of particular importance to us was a pre-move public information program to provide advance notification of the move to the hundreds of thousands of motorists who daily use the interstate system to commute to and from Cleveland. Motorists' attitude and knowledge of the reason for the congestion was extremely important to the safe management of affected traffic.

Just before the first shipment moved out from the Ninth Street pier, the Director of Highway Safety conducted a news conference in Cleveland. The public was informed of the impending move and the precautions that were being taken for their safety. The first shipment began shortly after the morning rush hour. Subsequent shipments were scheduled during both the day and night. The hauling vehicle was as long as four semitrailers coupled together. To the rear were several smaller trucks carrying lighted, programmable signs. These signs were positioned at intervals to warn approaching motorists of the slow moving vehicles ahead. Initially, Cleveland Police escorted the convoy through their city. Off-duty troopers were then employed to escort the convoy the remaining distance to Mansfield. The State of Ohio was reimbursed for the use of the patrol cars, and off-duty troopers were paid directly by the trucking company.

It took about 12 hours for the convoy to make the 98 mile trip. Contributing to the expected traffic congestion was a provision in the special hauling permit to reduce speed to five miles per hour upon crossing any bridge. There are over 45 bridges to cross and each load was required to come to a complete stop before starting across each bridge. Except when crossing bridges, one lane of traffic was permitted to pass the convoy by using the berm. There were several stops scheduled along the route to allow any traffic buildup to clear. These stops were usually made at an interchange exit ramp to give traffic the widest pavement available to pass. This practice also reduced the possibility of interchange congestion. Once traffic cleared, the load resumed its slow journey to Mansfield.

Communication between the trucking company, the Highway Patrol, and the Department of Transportation was maintained with CB radios. The radio proved to be especially effective when it was necessary to restrict traffic as the convoy inched its way over the numerous bridges. Incidentally, citizen band radio traffic was especially complimentary about the manner in which the movements were made. There was none of the usual criticism that results from freeway congestion.

Since the convoy would be on the highway for almost 12 hours, it was important to keep motorists aware of their location. Periodically, we would notify local radio and television stations of the progress so they could provide their audiences with the most current and accurate traffic reports. These progress reports were particularly well received both by the media and local motorists. And curious spectators did not create a serious traffic problem.

After the first oversize movement was completed, the participating agencies met to critique their performance. Recommendations were made to improve operations. It has been difficult to identify any significant shortcomings in the oversized shipment plan. Motorists were delayed no more than 10 - 20 minutes. Subsequent moves were just as safely completed. No traffic accidents resulted from any of these shipments.

From October 1985 through July 1987 there were 113 loads transported in this manner, the largest of which was 286 tons (572,850 pounds). Almost 10,000 tons (19,490,000 pounds) made the 98 mile trip without a major incident. The only incident was a flat tire on the very first load.

Ohio has experienced a dramatic increase in these so-called "Superloads" traveling into and through our state. During 1986 there were 156 superload permits issued. That increased 84% in 1987 to 287 permits. This underscores the increasing need for inter-agency communication and cooperation.

**Summary**

As traffic safety professionals, we are expected to perform our responsibilities in a safe, efficient and effective manner. Pre-event planning helps us maximize our inter-agency cooperation and task performance. The Ohio State Highway Patrol is a strong believer in the "systems" approach to problem solving, especially when field operations and traffic safety are involved. To achieve true success in the management of a freeway emergency, decision makers from the involved agencies must get to know each other one- on-one. That way, they can better understand each others' problems and capabilities. Only then can they fine tune their relationships, and chart parallel courses to achieve an objective. Waiting until an emergency occurs is too late to begin communicating with other emergency response personnel and to coordinate your response plans with theirs.

# REAL TIME TRAFFIC CONTROL OF URBAN FREEWAY WORK ZONE OPERATIONS

Steven Z. Levine
Texas State Department of Highways and Public Transportation

## Introduction

Between 1979 and 1981, the need for repair work on Houston area freeways (particularly those over twenty years old or carrying traffic volumes near or over 200,000 vehicles per day) increased markedly. Complaints from the traveling public about traffic congestion caused by such work led to one legislative suggestion (not passed) that all freeway work in the Houston area be limited to night operations. Although no legislation was passed, a result of the above sentiment was that work zone operations were generally restricted to night-time hours and weekends. It is during these time periods that speeds are high and the chances for errant behavior increase. Unfortunately, these concerns became fact at an alarming frequency. In 1980 and 1981, 12 highway workers were killed and 34 injured while working on Houston's freeways. Most of these casualties were caused by drunk drivers and speeding motorists.

## The Problem

With almost 600 miles of State-maintained roads in Harris County alone, and work predominantly restricted to weekends, the rate of maintenance activity had fallen far behind the needed rate. This situation became increasingly critical in light of funding limitations and extensive red-tape facing the initiation of major roadway rehabilitation efforts. Consequently, in the spring of 1982, the District Office of the State decided that a means for performing maintenance operations on even the highest volume roadways during previously restricted hours must be found. The objectives of this strategy were threefold:

1. Allow time for the needed remedial maintenance to be performed

2. Insure worker safety

3. Prevent intolerable delay to the traveling public

## Deployment of Special Traffic Handling Crew

Several research studies have been conducted (2, 3, 4) on "traffic management type" capacity improvements for work zone operations. These have included the temporary use of shoulders as a travel lane, modifying intersection signal timing, encouraging traffic to divert to alternate routes and closing entrance ramps within the work zone area. Some of these measures have been successfully implemented on major rehabilitation efforts such as on the Edens Expressway in Chicago and the Gulf Freeway in Houston. However, these techniques have been used only on a limited basis for short-term operations. Some earlier efforts to apply such techniques to maintenance work in the Houston area showed promise.

Accordingly, it was decided that a specially trained crew should be formed and specifically assigned the task of handling traffic during maintenance operations on high-volume roadways, thereby increasing the hours available for maintenance activity. The crew would have the authority and capability of implementing proven work-zone traffic management techniques, in a manner consistent with the "Manual of Uniform Traffic Control Devices". A major advantage of the special crew would be its ability to actively manage traffic during the maintenance operation.

Prior to this, a traffic control plan would be prepared based upon historical traffic volumes and flow-rates through a proposed work zone. The traffic data would indicate the number of lanes needed to minimize motorist delay -- or, if the work zone resulted in inadequate capacity, to handle anticipated flow-rates around the work area. Then, for example, shoulder signing would be deployed at the outset of the operation and remain until the operation was complete. This would occur despite changing traffic patterns.

With the special crew, the traffic control plan would be changed to react to changing traffic conditions. For example, one of the objectives is to insure worker safety. Excessive speed adjacent to the work zone is a contributing factor to accidents. The use of the shoulder to provide additional capacity at work sites may actually contribute to speeds higher than desirable during "lulls" in traffic. The crew would react to this situation and "turn off" the shoulder-use signing, thus lowering speeds. This method of handling traffic has been termed "Active Traffic Management".

The District Office decided that the special crew concept should be tried on an experimental basis. An urban freeway in Houston carrying 175,000 to 200,000 vehicles per day was badly in need of pavement repair and rehabilitation but a major contract could not be let for several months. Some of the needed repairs were critical, but high traffic volumes precluded use of normal techniques used by maintenance personnel. Interim repair was needed and this site provided the first test for the special traffic handling crew.

A group of individuals who were not usually involved in field activities, but who were experienced in traffic management techniques, were asked to handle traffic while the "interim maintenance" was performed. Workload analysis indicated that working Monday through Thursday during daytime off-peak for two consecutive weeks and one weekend would provide enough time to make the interim repairs. This schedule required three road-work crews to be available to work simultaneously. A job of this magnitude would have required at least 2 months if work was restricted to Sunday mornings. If motorist delay could be kept to an acceptable level of under 20 minutes (5) then the project would be successful.

Specifically, the crew was responsible for the following:

1. Prepare a daily report on the scheduled hours and areas of work zone activity and with the Department Public Affairs Section coordinate the dissemination of the information to the public through press releases and radio broadcasts on a daily basis.

2. Coordinate change in signal timings for traffic signals.

3. On parallel frontage roads along the project, since the signals are operated by the City of Houston, coordinate activities with the City's Traffic and Transportation Department to obtain their help in modifying affected intersection signal timings.

4. Arrange for the use of Selective Traffic Enforcement Program officers for the project.

5. Actively manage traffic by using the shoulder as a travel lane; closing entrance ramps as required, and utilizing other "active" traffic management techniques.

The project was successful. On the one day that a long queue developed, it was quickly dissipated when members of the special crew adjusted work-site traffic control. The "ultimate" measure of success applied to this project -- not one phone call of complaint was received from the public!

**Managing Traffic During Special Sequences in Long Term Contstuction Projects**

During certain construction sequences in long term freeway rehabilitation and widening projects, it has been necessary to close the freeway in one direction for 12 to 36 hours. At the committed annual funding level of $1.2 billion for construction work in Houston, this type of activity is becoming more frequent. Work tasks primarily consist of the placement of concrete median barrier, striping placement, removal and pavement repair. By closing the freeway, the work could be performed without endangering the workers.

The weekends are targeted for this type of control, since traffic volumes are less than weekdays. However, the volumes are high enough to require the use of active traffic management.

A demonstration of this concept was conducted on IH-45 (Gulf Freeway). In order to place a concrete median barrier and restripe a section of this freeway, a freeway closure of 36 hours was needed. This was scheduled for a weekend when an ADT of 75,000 was expected.

Traffic was detoured from the freeway onto the parallel frontage road with a roadway width of three lanes. The exit ramp was temporarily modified to 2 lanes of capacity. Traffic proceeded through 2 signalized intersections before being allowed to reenter the freeway. The signal timings at these intersections were modified by the City of Houston Traffic and Transportation Department. Traffic operations at the intersections were monitored by the City of Houston Police Department. The entrance ramp used to reenter the freeway was one lane wide and could not be modified. Consequently, traffic cones and active control by police officers directed traffic in the middle and right lanes of the frontage road to the next downstream entrance ramp.

Alternative routes were available and extensive public information program was executed to increase diversion. Static changeable message signs were placed 7 days in advance of the freeway closure to identify these alternate routes. On the day of the closure, the traffic diversion strategy was supplemented with electronic changeable message signs to increase diversion. In addition, a right lane closure of IH-45 (Gulf Freeway) Northbound was implemented at the IH-610 interchange. This lane closure was 3 miles upstream of the freeway closure setup, but presented an impression of work zone activity in the immediate area and resulted in increased diversion to IH-610.

It was estimated that over 50 percent of the traveling public avoided this section on the day of the closure. Delays to the traveling public never exceeded 10 minutes, which was an acceptable level.

With a much expanded work area available, the contractor was able to increase his equipment and man-power for this operation. As a result of this increased effort and the active traffic management strategies utilized, this work was accomplished in 12 hours; far less than the original 36 hour estimate. The final measure of success was again the total acceptance of the operation by the public - no complaints were received.

A second application of active traffic management to a construction sequence operation took place on IH-10 (Katy Freeway). The ADT in this section was over 100,000. The principal difference between this operation and the one on the Gulf Freeway was the lack of a good alternative freeway route. The operation started at 6:00 a.m. on Saturday and extended to midnight on Sunday. An extensive public information program was implemented. In addition, active traffic management was used in a similar fashion to the other projects. Therefore, work was accomplished without incurring an intolerable delay to the motorists.

## Conclusions

Several conclusions can be drawn from the use of active traffic management in Houston. They are:

1. Advance public information of impending work zone activity can minimize public complaints and unsafe traffic operations.

2. The active presence of law enforcement officers in urban highway work zones can minimize erratic and unsafe driving.

3. Carefully planned "active traffic management techniques" can allow work zone activity to be done on high volume urban highways during daylight hours without severely inconveniencing the traveling public while protecting workers from errant motorists.

4. Cooperation with law enforcement agencies and other affected governmental agencies is a necessary part of the "active management strategies".

## Future Applications of Active Traffic Managemtnt in Work Zones

In most instances, the number of travel lanes on urban highways cannot be reduced during peak periods for construction activities. This policy means that narrow lane widths (10 to 11 feet) and the use of the inside and outside shoulders for travel are needed. This traffic management technique is being used for projects on the IH-45 (North Freeway), the IH-45 (Gulf Freeway) and US

290 (Northwest Freeway). While this method has been successful in minimizing the delay to peak period motorists (7), it does not provide a refuge area for stalled motorists. To minimize the impact of such incidents, temporary shoulders have been constructed where possible. However, the need to reduce the time required to clear such incidents is very important. In Houston, approximately 50% of stalled vehicles can be attributed to flat tires, "dead" batteries and other problems that can be expeditiously handled by courtesy patrols or wrecker companies (8). The benefit/cost ratio of a privately funded courtesy patrol operation that utilizes Harris County Sheriff deputies is approximately 10 to 1 (8). Based upon the demonstrated effectiveness of such a program, provisions in the proposed plans for the reconstruction of freeways include a dedicated courtesy patrol. This type of program has been used in reconstruction projects in Pittsburgh, Chicago and Boston. In addition, methods for providing real time information to motorists of impending delays due to incidents are being studied. In addition to the already proven traffic management techniques (changeable message signs, static messages), the placement of computer terminals at major traffic generators along the corridor is being considered. These terminals would be linked to traffic service organizations and the State Highway Department. They would display real-time information on freeway conditions to motorists.

**References**


1. Hauer, E., Ahlin, F. J. and Bowser, J. S.
Speed Enforcement and Speed Choice. Transport Canada ISBN 0-7727-7006-9. 1981

2. Richards, Stephen H., and Dudek, Conrad L.
Special Traffic Management Requirements for Maintenance Work Zones on Urban Freeways. Texas Transportation Institute. FHWA/TX-82/1+228-8. 1982

3. Dudek, Conrad and Richards, Stephen H.
Traffic Capacity Through Work Zones on Urban Freeways. Texas Transportation Institute. FHWA/TX-81/28+228-6. 1981

4. Dudek, C. L.. Richards, S. H. and Faulkner, M. J.
Traffic Management During Urban Freeway Maintenance Operations. Texas Transportation Institute. FHWA/TX-82/2+228-10F. 1982

5. Huchingson, R. Dale, Whaley, John R. and Huddleston, Nada D.
Delay Messages and Delay Tolerance At Houston Work Zones. Texas Transportation Institute. 1983

6. Levine, Steven Z. and Kabat, Richard J.
Planning and Operation of Urban Highway Work Zones. Presented at the Annual Transportation Research Board Conference. 1984.

7. Borchardt, B. Darrell,
I-45 North Freeway Corridor Traffic Analysis. Texas Transportation Institute. 1986

8. Albert, Stephen
Utilization of Motorists Assistance Program for Incident Response During Southwest Freeway Reconstruction. Texas Transportation Institute. 1987

# TRAFFIC MANAGEMENT TEAMS IN FLORIDA

Gary C. Price, P.E.
Kunde, Sprecher, Yaskin & Associates, Inc.

In the early 1970's, the need for a multi-disciplinary team approach was recognized by the Florida Department of Transportation in the development of a freeway surveillance and control project on the I-275 corridor encompassing the 3-mile Howard Frankland Bridge across Tampa Bay. This need led to the establishment of the State's first traffic management team, which played a vital role in the design and continuing updates to this project installed in the late 1970's. The successes that were achieved through the use of this team led to the establishment and continuing involvement of traffic management teams in all major urban areas in Florida. The purpose of this paper is to present the purpose and objectives, organization, and functions of these teams in Florida.

Presently there are five active freeway management teams in Florida. The original team in the Tampa Bay area has been expanded to address more than its initial segment of I-275 and now concerns itself with all freeways in the Hillsborough and Pinellas County area surrounding Tampa Bay. Teams were established in the Jacksonville and Orlando areas in 1986. In 1987 Dade County and Broward County teams became fully functional. Each of these teams meet on a regular monthly schedule and address items of interest to all participants in the team. The primary purpose and objective of these monthly meetings are as follows:

- Increase awareness and personal relationships among all parties involved in responses to freeway incidents.
- Advise other participants on the concerns and interests from their area of expertise and prospective.
- Coordinate their activities with those of other areas of expertise to provide the most effective and efficient approach to servicing freeway incidents.
- Assist in the development in the overall plan for coordination of team activities and response to incidents.
- Assist and support other team members in obtaining support and resources required for their area of expertise in the overall coordinated effort.
- Critique past efforts of the team in responding to major freeway incidents and development modifications and revisions to the overall coordinated effort.
- Review and advise the Department of Transportation on the maintenance of traffic plans associated with major freeway reconstruction activities.

To accomplish these objectives, Florida's Traffic Management Teams have evolved from teams composed of limited areas of expertise to ones with diversity and a wide variety of expertise. Some of Florida's teams have as many as thirty participants. The majority of these participants, however, do not attend monthly meetings on a regular basis but respond when required to the team's needs in specific areas. The nucleus of these traffic management teams consists of the following:

- Traffic Engineering at the City, County and State levels
- Police enforcement at the City, County and State levels
- Highway maintenance at the State level
- Emergency medical and Fire rescue.
- News Media.
- Special interests groups such as American Automobile Association.

Other supporting participants in Florida's Traffic Management Teams are as follows:

- Environmental protection agencies
- Local Emergency Preparedness organizations
- Wrecker services
- FDOT Weight Enforcement
- Local Military groups
- Metropolitan Planning Organizations.

Traffic Management Teams in Florida have been meeting regularly and have had many team successes in implementing recommendations and changes to the way freeway incidents are responded to in their area. These successes have succeeded in building the "esprit de corps" required for continued enthusiasm and aggressive activities by these teams. Below is a listing of Early Team Products from Traffic Management Teams in Florida. Some of these products currently exist only in one location, but through the sharing of efforts by all teams, each takes advantage of the successes of others and blends these successes into products for its own team. This sharing and communication among the teams in Florida is a vital element in the continuing promotion and success of this effort.

Two of the current teams in Florida are expected to split into four teams covering more specific areas of Florida's interstates. At least one more team is anticipated in the near future for the Palm Beach area. These new teams will increase the total number of Traffic Management teams in Florida to eight by the end of 1988. Continued successes by these teams and persistence by the members in selling, to management and the public, this approach to congestion relief on Florida's freeways will ensure the continuation and growth of this activity in Florida.

## EARLY TEAM "PRODUCTS"

1. Alternate route maps (first generation)

2. Modification of pickup truck with hinged sign frame for incident management

3. Two service patrol wreckers now in operation weekdays (six hours) on bridge. FDOT equipment and drivers are being used but will be replaced by contract services.

4. Two additional service patrol vehicles (non-wreckers) to begin service soon on another bridge.

5. Emergency locator markers will be installed on a test section of I-95 in Miami for purposes of more accurate reporting of incident sites by one on-site agency to another responding agency. These will be small signs on existing sign and lighting poles. Also to be tried will be painted info (route number, roadway direction, and milepost to one tenth) on median barrier.

6. Plans being formulated to get "fire-fighting" water to top of multi-level interchange: possible pipe only, through which water will be pumped during times of need only.

7. Provisions being made in noise barrier walls for running fire hose from neighborhood fire plugs to an incident site on the freeway (fire fighting, flushing, and washing).

8. Special signs or markers along the edgeline and/or freeway fence showing closest neighborhood fire plug.

9. Assisted (by letter of endorsement) local sheriff's securing budget for additional helicopter aircraft.

10. Preliminary locations for off-freeway accident investigation sites.

11. Median signs installed to strengthen motorists' knowledge of state statutes, "Accident Vehicles Must be Moved from Traffic Lanes".

12. Improved statewide standard sign being developed (by Orlando Team) concerning item 11, "Move Accident Vehicles from Travel Lanes".

13. An "olympian" sized planned event in Miami was successfully orchestrated by numerous federal, state, local and Vatican agencies who developed a plan for a two-day visit by Pope John Paul and President Reagan in September,

1987. The team chairman played a major role via a special traffic management plan.

14. Special traffic redirection provisions by special U-turns beneath the I-275, Howard Frankland Bridge, were developed by the team for times of total or one-direction bridge closure during hours of major incidents. Since the 8 to 9 foot clearance will only clear an estimated 85 to 90 of the vehicles, we will install "overheight" detector to separate the "goes" from the "no-goes"!

15. Agenda included an F.C.C. engineer to explain more about emergency communications -- an acknowledged weak link in freeway management at the FDOT, FHP, and local agencies, both from inadequate, antiquated equipment and need for special equipment (and possible frequencies) for direct inter-agency communication during a major incident.

16. Interest developed for both portable, changeable message (matrix) signs for mainline communication with drivers about incidents ahead and for diversion route signs (usually, roll-up, reflective, with velcro message changeability). One FDOT District (Tampa) is ready to requisition the later.

# THE 1986 U.S. OPEN GOLF TOURNAMENT

Walter M. Dunn, Jr.
Dunn Engineering Associates

## Introduction

The handling of a special event, such as a golf tournament, a fair, or a concert, requires the same attention from a traffic standpoint as the occurrence of an incident created by an accident or a maintenance/construction activity. Proven traffic management techniques should be applied from the earliest planning stages through the actual event so that traffic congestion associated with the staging of these special events can be significantly reduced.

The 1986 U.S. Open Golf Tournament that was held at the Shinnecock Hills Golf Club on the South Fork of Long Island, New York during the week of June 9 - 15, 1986, gave dramatic proof that the application of traffic management techniques for a special event does work.

As shown in Figure 1, the 1986 U.S. Open was held approximately 90 miles east of Manhattan at the Shinnecock Hills Golf Club in Shinnecock Hills, Town of Southampton, New York. As shown in Figure 2, the Shinnecock Hills Golf Club is located on the north side of the major east/west highway, Suffolk County Road 39, which is approximately 2 miles east of the terminus of the limited access facility of State Route 27. Its major entrance is aligned with the north/south roadway of Tuckahoe Road which extends southerly to connect to the other major east/west arterial roadway, Suffolk County Road 80, which is also known as State Route 27A or Montauk Highway. The Montauk Branch of the Long Island Railroad runs parallel to and 100 feet south of County Road 39 in the vicinity of the site. Furthermore, the Southampton Campus of the Long Island University borders the south side of the railroad tracks and extends southerly to Montauk Highway.

The Shinnecock Hills Golf Club is one of the most prestigious golf courses in the United States. With many sand traps and adjacent rough areas, the Shinnecock Hills Golf Club presented a challenge to the best professional golfers. Also, the 1986 U.S. Open proved to be a challenge to the professional traffic engineering community of Long Island that was met head-on. Indeed, one of the biggest stories of the U.S. Open was the anticipation of traffic delays and horrendous traffic jams that never occurred. The approach and the successful traffic management techniques that were applied are described in the following sections of this paper.

## Major Concerns

There were three major concerns that faced the U.S. Golf Association and the responsible jurisdictions within which the 1986 U.S. Golf Open was to be played.

The first major concern related to the event's coincidence with June recreational summer activities, which was expected to create major problems in terms of overall traffic and available lodgings. During the summertime the population of the South Fork of Long Island quadruples with the influx of weekenders and tourists headed to the beaches, boating and recreational-oriented activities. It was predicted that housing for the players, the media, and the visitors to the event would be scarce with anticipated costs of approximately $5,000 - $15,000 per week for the rental of a summer home during the tournament.

The second major concern was the presence of only two crossings over the Shinnecock Canal:

1. State Route 27, a limited access facility, consists of two lanes in each direction as it crosses the canal but, approximately two miles east of the canal becomes a rural undivided roadway with one lane in each direction known as County Road 39.

2. County Road 80, Montauk Highway, is an east/west arterial highway facility parallel to and located south of Route 27 (County Road 39). Also known as Route 27A, this roadway consists of two lanes in each direction as it crosses over the Shinnecock Canal; however, it consists of one lane in each direction on both sides of the canal.

Third, the presence of Route 27 (County Road 39) as the only major east/west roadway passing the site limited the overall roadway capacity available to accommodate the anticipated flow of traffic to the golf tournament.

Based upon these three major concerns, predictions of horrendous traffic problems and extreme difficulties in reaching the event were anticipated. Writers for several golf magazines viewed the journey to and from the 1986 U.S. Open as "The Impossible Dream". A variety of solutions was suggested including transportation by helicopters, yachts, balloons and large ships.

Many in the community adopted the philosophy that traffic congestion was going to occur with intolerable traffic delays. Some believed that the predictions would actually keep people away from the 1986 U.S. Open.

**Work Efforts**

At the suggestion of the State, the Suffolk County and the Southampton Town governments, the United States Golf Association engaged Dunn Engineering P.C. as the traffic consultant for the 1986 U.S. Open. There were five major aspects that were undertaken as part of our work efforts.

First, a Feasibility Study was prepared to determine the overall impact of the proposed event on the surrounding street and highway network.

Next a Traffic Management Plan was developed to assure that the existing roadway network could accommodate the composite traffic flows that would occur.

Third, design plans were prepared to indicate the traffic operations and roadway signing that would be required for the successful implementation of the traffic management plan. These plans were reviewed and approved for implementation by the New York State Department of Transportation and the

Suffolk County Department of Public Works.

Fourth, in order to assure the proper location and installation of the elements in accordance with the design plans, the supervision and layout of the system construction were carefully undertaken.

Last, the traffic management of the event was aimed at assuring that the initial plan could be modified if necessary to accommodate the real-time traffic conditions. Coordination with the involved agencies and adjustments to the Traffic Management Plan were essential to achieve the objective of successful traffic flow.

**Feasibility Study**

The major steps of the Feasibility Study are similar to those efforts normally included in the preparation of a Traffic Impact Study for a proposed development. Knowledge of existing traffic volumes was obtained from historical records compiled by the Suffolk County Department of Public Works and the New York State Department of Transportation. Personal knowledge of the roadway network and the summer traffic conditions was essential to understanding the traffic flow conditions. One of the major difficulties occurred in determining the anticipated traffic to be generated by the U.S. Open Golf Tournament. Discussions with U.S.G.A. officials resulted in forecasts of anticipated attendance on a day by day basis for both the preliminary and final rounds of the tournament.

Difficulty was encountered also in estimating the modal split between automobiles, the Long Island Railroad, the Hampton Jitney Bus service and the Montauk Bus service. Several scenarios were prepared with varied percentages of modal split.

In conducting the Directional Distribution Analysis, consideration was given to the likelihood of attendees staying at available lodging in the Southampton area for the entire week. Again, several scenarios were examined which varied the Directional Distribution to assure that the traffic could be accommodated. The anticipated traffic generated by the event was then assigned to the surrounding street and highway network based upon the previously conducted Trip Generation Analysis, Modal Split estimates, and the Directional Distribution Analysis.

The composite traffic volumes that would result once the site-generated traffic from the U.S. Open was added to the existing traffic volumes were examined with respect to the existing capacity of the roadway network. Adjustments in the traffic assignment were made to assure that the traffic distribution plan would work.

These steps in the Feasibility Study revealed that additional roadway capacity would be necessary to accommodate the peak traffic flow conditions. Furthermore, to reduce the overall impact, it was recognized that a carefully designed parking management plan would have to be developed in order to distribute the traffic destined to the parking areas on the appropriate roadways. The Parking Management Plan also recognized the need to provide a shuttle bus service to transport the event goers between the parking fields and the tournament site.

**Traffic Management Plan**

As previously noted, in order to minimize the impact on the existing roadway network, a parking management plan carefully located the available parking facilities in order to a) distribute the flow of traffic efficiently, b) minimize the superimposing of traffic flow all on one roadway section, and c) separate the pedestrian, automobile, and shuttle bus traffic as best as possible. Figure 3 indicates the locations of the four major parking areas established for the public parking. Parking Lots A and B, located on the site of the Southampton College, were closest to the actual event from a distance standpoint. Parking Lot A was assigned for preferred parkers, while Parking Lot B was assigned to season ticket holders. In addition, the major parking facility (Parking Lot D) was located on the Shinnecock Indian Reservation. This lot was assigned to season ticket holders and daily ticket holders. Parking Lot C was established for the U.S. Open staff and volunteers.

People parking in Parking Lots A and B were directed to walk to the site. In order to avoid pedestrian/vehicular conflicts with an at-grade crossing of C.R. 39, which separates Parking Lots A and B from the golf course, the Suffolk County Department of Public Works erected a temporary pedestrian overpass over C.R. 39 to link these two locations. The pedestrian overpass was essential in order to keep traffic moving on the adjacent roadways.

A shuttle bus operation was extablished to transport people from Parking Lots C & D.

Passengers on the Long Island Railroad utilized the Southampton College station and walked directly across the pedestrian overpass into the tournament site. A separate bus unloading and loading area for press and corporate buses was established along the northerly section of Parking Lot A, with riders using the pedestrian overpass to enter the golf course. Other public bus transportation operations were directed to the rear of the golf course, where a separate unloading and loading area was established so the mass transportation and shuttle bus operations were separated from the major automobile traffic.

In designing the access locations for the parking facilities, the entrance and exits were located as far as possible away from the major intersections so that the vehicles could exit immediately from the roadways without disrupting the flow of traffic on the roadways. In this manner, backups and delays on the roadways were avoided.

Other key elements of the Traffic Management Plan are described in the following sections.

## Route Marking/Destination Signing

In order to guide and direct motorists to the desired roadways in accordance with the traffic management plan, it was determined that it would be best to provide a comprehensive series of route marker and destination signs. A signing system was designed that incorporated the use of letters and color coded letter symbol signs similar to route marker or trail blazer signs. Introductory signs were located as far as 20 miles away on the Long Island Expressway to advise motorists which exit to use to reach the Southampton area. On these signs, motorists were introduced to the U.S. Open trail blazer sign that they would follow, along with a subsequent route marker sign with the parking lot letter destinations. In conjunction with the signing system that was implemented in the field, directions were distributed to motorists as part of the ticket dissemination. Again, these directions and the field signing system were based on assigning vehicles to roadways to assure distribution in accordance with the overall traffic management plan. Figure 4 indicates some of the sign texts that were designed for the sign system. The letters on the route marker assemblies correspond to the parking lot designations assigned as part of the parking and traffic management plan previously shown on Figure 3.

The only signs that were unique to the golf tournament were a) those signs directing players to a specific entrance and b) the "Will Call" sign that advised motorists of the trailer location where they could pick up tickets left for them by someone already on the golf course. The design and placement of the signs were in accordance with the requirements of the New York State Manual of Uniform Traffic Control Devices.

## Three Lane Operation For Peak Traffic Flows

The Feasibility Study determined that there was insufficient available capacity on the roadway network to accommodate the addition of traffic from the U.S. Open. As a result, a reversible three lane operation was established on two roadways by utilizing a portion of the shoulder areas to provide three travel lanes. A reversible center lane was set up so that morning traffic headed eastbound to the golf tournament would utilize two traffic lanes while westbound traffic would utilize one travel lane. Traffic cones and signing were used to guide motorists through the three lane sections. Field maintenance crews of the Suffolk County Department of Public Works set the cones and changed the signing for the three lane operation. During the afternoon, the operation converted to provide two westbound travel lanes and one eastbound travel lane.

The two sections of roadway with the reversible three lane operation were:

1) C.R. 39 from the terminus of the two lanes in each direction, divided limited access section of N.Y.S. Route 27 easterly to approximately 1,000 feet east of the golf course entrance/Tuckahoe Road, for a total distance of approximately 2 miles.

2) N.Y.S. Route 27A (C.R. 80) between Tuckahoe Road on the west and the westerly entrance to the parking lots on the Shinnecock Indian Reservation.

The establishment of the three lane reversible operation provided the additional capacity needed to accommodate the traffic generated by the U.S. Open. No traffic safety problems occurred within the three lane roadway sections. In fact, the only problem that occurred within the three lane section was the high travel speeds that were occurring. Although the section was signed with a 30 mph speed limit, traffic was flowing so smoothly that vehicles often exceeded the speed limit. As a result, motorcycle police officers were assigned into the traffic stream in order to slow down the traffic to comply with the 30 mph speed limit.

## Highway Advisory Radio

Highway Advisory Radio has been used successfully to provide information to motorists on traffic conditions relating to incidents and maintenance/construction activities. Two forms of Highway Advisory Radio were examined for use in providing information on traffic conditions to motorists during the operation of the U.S. Open. The cable radiator approach was eliminated from consideration as a) it required an extensive amount of cable to be laid temporarily alongside the roadway in order to radiate the message and b) it was the most expensive alternative. The selection of the monopole antenna alternative for the Highway Advisory Radio installation yielded a lower cost and an easier installation with a greater broadcast range.

A monopole antenna was installed on the top of a telephone pole on the site of the Shinnecock Hills Golf Club, adjacent to the Command Control Center. The power supply and the transmission equipment were located in a temporary electrical building outside the Command Center. The voice recording deck unit was located in the command center. Four messages were prepared to provide information to motorists on the status of the three lane operation for both directions of travel on C.R. 39 and Montauk Highway. Furthermore, one message location was left available to record any possible message that might be required. In particular, it was felt that up-to-date information on 1) any accident that might occur or 2) any diversion information necessary to divert traffic from one roadway to another, could utilize this message band. However, no situation occurred that required the use of any additional messages beyond the four messages recorded in advance. Table 1 contains the messages that were disseminated to the motorists.

Information on the A.M. radio frequency that motorists should turn to and the beginning of the broadcast area was provided via fixed signs along the major roadways.

## Establishment of Command Center

A command center was established on the site of the golf club. Chief Conrad Teller of the Southampton Town Police was in charge of the overall police operation, while the Suffolk County Police Department, the New York State Police and the Suffolk County Sheriff's Department provided assistance and reported to him.

The United States Golf Association closely coordinated its activities with the police command center to assure efficient operations on the external roadway network and the internal roadway network. The shuttle bus operations, the parking lot operations, the corporate bus operations, the maintenance and operations of the reversible traffic flow lanes by the Suffolk County Department of Public Works, and the aerial surveillance were coordinated by the traffic engineering consultant. The traffic engineering consultant worked very closely with the police command center to assure the efficient traffic operations during the special event.

**Left Turn Restrictions**

In order to achieve the objective of keeping traffic moving on the external roadway network, left turn lane restrictions were established at key locations. For instance, prohibitions of both eastbound to northbound and westbound to southbound left turns were established on C.R. 39 in the vicinity of the entrance to the Shinnecock Hills Golf Club/Tuckahoe Road. Eastbound to northbound left turns were also restricted on Montauk Highway at Tuckahoe Road. As part of the left turn restrictions, a routing plan was designed so that motorists could use an alternative roadway to reach their intended destination.

**Radio Communications**

Two different radio communications were established. Utilizing the Suffolk County Department of Public Works radio network, coordination was established between the police command center, the traffic engineering consultant, and the Suffolk County Department of Public Works' field crews. Another radio communications network was arranged between the traffic engineering consultant, the police command center, the parking crews, and the U.S.G.A. internal tournament staff. These two systems permitted continual coordination among the key members required to operate the external roadway network as well as the internal operations of the U.S. Open.

In addition, the use of the Suffolk County Department of Public Works radio network permitted changes in the roadway network to be accomplished in a short period of time. This radio network was also utilized to establish a traffic flow control system through the use of a manual coordination movement system. This effort was utilized to keep traffic moving during the peak entering and exiting periods to and from the parking lots. The use of this radio communications is further described later in this paper under the parking lot metering system.

**Aerial Surveillance**

The New York State Police helicopter was used by the traffic engineering consultant to obtain an overview of traffic during the peak morning and afternoon periods of travel to and from the U.S. Open. This aerial surveillance provided the capability of modifying the traffic assignments through traffic diversion at those locations where any bottlenecks or traffic congestion occurred. Based on the initial traffic management plan , the aerial surveillance primarily served to confirm that the roadway system was operating effectively.

**Exclusive Bus Roadway**

The United States Golf Association had indicated that difficulties in several past golf tournaments occured where shuttle buses had been caught in the traffic congestion along with automobiles. As a result, the shuttle bus operation between Parking Lot D on the Shinnecock Indian Reservation and the golf course utilized an exclusive bus roadway that separated it from the automobile traffic. An existing local roadway, St. Andrews Road, which connects Montauk Highway on the south to the east side of the Shinnecock Hills Golf Club was chosen. St. Andrews Road consists of one lane in each direction; however, it passes under the Long Island Railroad tracks and under C.R. 39, and thus, did not require an at-grade crossing of the major east/west highway of C.R. 39. Since there was available capacity on St. Andrews Road, players and media personnel were also directed to utilize the eastern access point to enter and exit the golf course.

**Specific Roadway Assignment**

As part of the mail ticket dissemination, directions were provided to advise motorists how to reach their parking destination. Based on the number of season ticket holders, daily ticket holders, preferred parking and the volunteer/staff parking, specific routes were selected to provide the best distribution of traffic along the entire roadway network. The specific roadway assignments also were aimed at diverting traffic away from other critical locations that could create traffic congestion. The assignments were necessary in order to assure that the capacity of the existing roadways with their modified traffic operations would not be exceeded.

**Traffic Flow Control**

An override of the adjacent traffic signals located approximately 1 mile east of the site and 2 miles west of the site was provided to open up the end points of the system so that congestion would not occur on the links between them. Thus, traffic exiting the site during the P.M. peak hours was assured of an unobstructed path to both east and west destinations.

Another key element was the use of a manual coordination movement system with personnel at key locations. These traffic personnel were equipped with radio communications so that they could communicate directly with each other. For instance, in the evening hours, a specific advantage was the metering of the traffic departing the parking lots to assure that traffic was moving efficiently at all times on the roadway network. The manual coordination movement system performed like a progressive traffic signal system without requiring the investment of temporary installations.

**Metering System**

In a traffic surveillance and control system, ramp metering is generally used to break up the entry rate of vehicles joining the main line of the freeway so that the traffic flow on the freeway is enhanced and kept moving. This concept was used in a different manner as part of the traffic management plan for the 1986 U.S. Open. The rate at which vehicles were expected to exit from the parking lot was governed by several factors. First, in terms of the shuttle bus operation, the number of passengers on a bus and the number of buses determined the rate at which motorists would reach the parking lots. Secondly, in terms of the pedestrians exiting directly from the golf tournament and using the pedestrian overpass to reach Parking Lots A and B immediately adjacent to the golf course, the walking time served as a metering factor. In essence, the walking time and the shuttle bus system capacity served as metering rates both in terms of the number of motorists reaching the parking lot and the number of vehicles exiting. These two rates helped to stagger the overall departing times from the lots.

In addition, the exits from the parking lots were metered by the traffic management personnel. Police officers were stationed at the intersections of the parking lots with the major roadway of Montauk Highway and at the intersection of C.R. 39 at Tuckahoe Road. Since several of the parking lots had access onto Montauk Highway (Route 27A), a radio communication network was essential to assure that the metering system permitted the maximum volumes of traffic to depart the lots and enter the roadway network. Traffic personnel visually determined the traffic conditions and when traffic started to back up, stopped the movement out of several parking lots for a minute or two while the traffic on the roadway network was kept moving. The parking lot metering was a key concept that resulted in the occurrence of only minimal, if any, traffic congestion on the roadway network.

## On-Site Traffic Management

On-Site Traffic Management primarily was aimed at minimizeing internal conflicts between pedestrians, police vehicles, media vehicles, and golf carts. A key aspect related to specific routes for use by emergency vehicles, such as ambulances. During the event, relief was provided to one intersection through which a majority of traffic carts, pedestrians and emergency vehicles passed. Traffic engineering principles were followed to provide a parallel roadway network as part of a grid system for diverting golf carts away from this intersection. The golf carts were forced to use a grass path to avoid both the intersection and the heavily used pedestrian areas by the concession stands. By the end of the tournament, this alternate pathway looked as if it had been in existence forever, although some initially doubted that the golf carts could traverse the terrain on this route.

## Key to Success

As a result of the combination and integration of each of the individual elements of the traffic management plan, the horrendous traffic jams that were anticipated by the public and the news media never occurred. Looking back at the successful traffic operations of the 1986 U.S. Open at Shinnecock Hills, New York, five major aspects surfaced as the key to success for the handling of a special event. In summary, these five major aspects were:

- Development of a Good Traffic Management Plan
- Input and Participation of Involved Agencies
- Implementation of Plan
- On Site Traffic Management
- Ability to Modify the Plan to Accommodate Real-Time Traffic

# STARTING INCIDENT MANAGEMENT ON LONG ISLAND - AN UPDATE -

Michael J. Cuddy
New York State Department of Transportation

Today I would like to present an update on the New York State Department of Transportation's activities with regard to incident management and incident response on Long Island. The program has been difficult to organize primarily because of the multi-jurisdictional responsibilities for traffic and roads that is typical of densely populated suburban areas. On our most heavily travelled road, the Long Island Expressway, with average annual daily traffic volumes approaching 160,000, there are potentially dozens of separate jurisdictions and organizations to respond and assist with the management of incidents along the approximate 60 miles of expressway. They include: two county Highway Patrols responsible for law enforcement; the State Department of Transportation responsible for roadway maintenance and traffic operations; the State Department of Environmental Conservation responsible for the necessary cleanup resulting from accidents involving hazardous or toxic materials including spilled gasoline and diesel fuel; numerous volunteer fire and ambulance companies responsible for responding to accidents; private towing companies that respond on a rotational basis to accidents; and state police as well as other elements of the County Police Forces that are called upon when necessary. Each of these organizations has an important role in the response to incidents but none have seen it as "their job" or primary responsibility. Lack of a proprietary attitude in managing incidents had led to informal and ad hoc management of and response to incidents. There had been reluctance for any one organization to assume overall responsibility for directing the cleanup operation or the traffic control. Our efforts over the last few years have been toward coordinating, educating and training members of these organizations so they can work together in a cohesive, effective manner.

We have been urged on to this effort by the growing public concern with traffic congestion and the delays that result from incidents on Long Island's roadways. The local media give a great amount of coverage to the traffic jams that result from these incidents. Thus, our success or failure to respond and manage the incidents is constantly in the public's eye. The public and the media state quite clearly that these are serious occurrences, that they are a tremendous cost to the public, and must be given high priority by government. Most often heard is the comment that someone must take the first step to assume responsibility for addressing the problem in an organized planned manner.

These comments led us to raise other issues and ask ourselves other questions:

Who should be responsible? Which agency should be in charge? Does a highway maintenance supervisor tell a police officer what to do? Is a police officer expected to have the traffic engineering knowledge to help him determine how to divert traffic and develop detours? Is there any way the incidents can be cleaned up sooner? Should there be concurrence from a local town or village before their roads are used as detours to an incident? How much of an inconvenience is it to the public? Is the public getting the service they expect? The questions are practically endless.

Our initial action was to contact the two highest level elected officials in the region, the County Executives, and suggest that the counties and the State Department of Transportation sit down and begin to answer some of these questions. The potential list of subjects and questions to be addressed at that first meeting was substantial, so it was decided that there were only two issues that need to be resolved immediately. The first was that there be total agreement that this is a serious matter and it would receive priority and attention at the highest level of state and local government. This simple statement and understanding gave the departments and bureaus of the counties and the state the license and direction to devote time and personnel to work on solutions. It served as a way to raise the consciousness of employees that is absolutely necessary before any progress in the matters can be made.

It should be noted that to get the attention of the elected officials we presented an analysis that showed it cost the public two million dollars for the first hour of a Long Island Expressway complete closure and one million dollars for the subsequent hours due to lost time, fuel and automobile operating costs. They were already aware of the public relations and political costs.

The second issue to be addressed was who would be primarily responsible for incident management and in charge during incident response. The resolution of this issue was that all parties are responsible, and all parties simply must work together. The Multi-Jurisdictional circumstances would not allow one agency to take the lead and direct other agencies of various levels of government. It was recognized that each governmental agency possessed expertise and knowledge that was unique. What was missing was the coordination of those resources in an open and mutually supportive manner. It was felt that coordination could be best achieved by heightened awareness of the importance of incident management within each agency, providing further incident management training within each agency, and by mutual understanding of each other's resources as well as the limitations to respond to incidents.

The two county executives and the Department of Transportation formed a task force with representatives from the various police departments, traffic departments, maintenance divisions, emergency service representatives, as well as environmental conservation representatives, all with an interest in incident management. The goals of the task force were to develop better coordination among organizations, become familiar with each organization's resources and personnel, and over a period of time develop standard operating procedures which would ensure that the groups work together well. In addition, each representative to the task force would bring back to his organization suggestions for additional training within his own organization that would augment and make more efficient their incident management capabilities.

The task force is now a committee that meets on a monthly basis to review incidents which have occurred and that constantly modifies agency coordination.

The Long Island incident management committee has become so institutionalized that they even had a Christmas party last year. They have become the central body that discusses general traffic management issues, - not just incident management and response.

Surprisingly, much of what has come out of those meetings since 1985 has been great improvements to incident management on Long Island at little or no cost. For example, in the Department of Transportation, we have directed that some maintenance crews start work at 4:30 a.m. and others work until 7:30 p.m. to be immediately available to assist the highway patrol in cleaning up after an incident. This has been accomplished primarily through shifting existing personnel. It results in a direct savings of approximately one hour in response time for incidents that could affect the morning or evening rush hours, because there are people standing by in the area of responsibility and it is not necessary to call them out from their homes. Also, since the complete crew is available, all the necessary resources arrive at the scene as quickly as possible.

In summary, the experience on Long Island has shown that it is very important to establish the policy that incident management is a critical activity, and have that policy announced by the highest level of local and state governments; that in a multi-jurisdictional situation a coordinated incident management effort must work if the efforts are to be successful; and that the efforts made to improve incident management are appreciated by the public and their elected representatives.

The Long Island incident management committee is presently enhancing and fine-tuning its activities primarily through the use of the integrated motorist information system capabilities that have recently come on line and are now operational 24 hours a day, 7 days a week.

# ANALYTICAL PROCEDURES FOR ESTIMATING FREEWAY TRAFFIC CONGESTION

Juan M. Morales
Federal Highway Administration

## Introduction

A freeway incident--an accident, stalled vehicle, spilled load, or any other event that reduces the normal capacity of the roadway--causes motorist delay. Freeway incident management techniques are directed at reducing this delay, which varies with traffic volume, number of lanes, and the duration of the incident.

The Federal Highway Administration (FHWA) funded research in the late 1970's to develop guidelines and recommendations to help highway departments, police agencies, and other organizations select, plan, design, and implement low-cost measures to deal with incidents that cause freeway congestion. The research results were published in a six-volume report, which presented an overview of the nature and magnitude of the freeway incident management problem and summarized possible solutions. (1) An analytical procedure to estimate traffic delay and congestion and assess the tradeoffs in cost-effectiveness among many alternative measures also was included in the reports. Computational examples and delay, time, and queue tables for typical conditions were provided.

This article summarizes the basic analytical procedures presented in these reports and describes a new, user-friendly microcomputer model for quickly and easily computing delay, time-to-normal flow (TNF), and maximum queue ($Q_{max}$) caused by freeway incidents.

## Representation of Incident Delay

The procedures presented in this article rely heavily on the development of a simple technique for estimating total vehicle-hours of delay. Any freeway incident can cause delay by reducing the number of vehicles that can pass the incident in a given period of time. Even vehicles removed to the freeway's shoulder will reduce capacity as motorists slow to stare at the emergency activities.

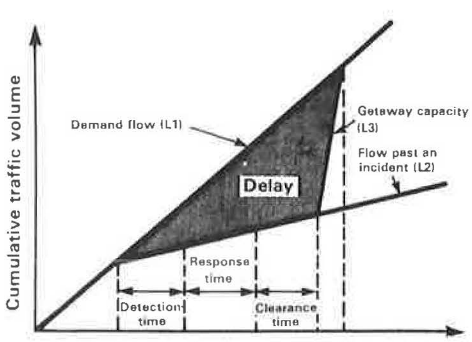



*Figure 1. - Quantifying delay caused by a freeway incident.*

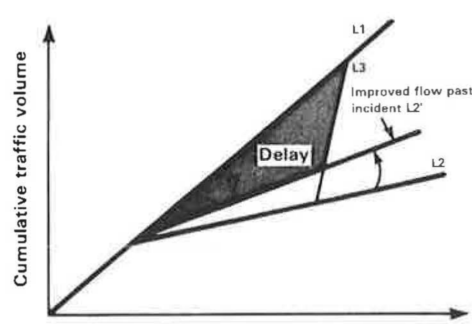



*Figure 2. - Delay reduction caused by increasing flow past the incident.*

To quantify this delay, traffic volumes and incident durations can be graphically represented, as shown in Figure 1. The horizontal axis is a timeline indicating the occurrence of incident-related events and the overall duration of their impact on traffic flow. The vertical axis is the cumulative traffic volume--the sum of the vehicles passing any given point on the freeway in a defined time period.

The demand flow or volume--the total number of vehicles using the freeway at a given time--is represented by the slope of L1. When an incident occurs (Time A), the reduced roadway capacity (L2) is less than the demand flow because of a lane blockage. This reduced capacity remains in effect until the incident is cleared from the freeway (Time B). At that time, the queued traffic can begin to flow at a "getaway" capacity (L3) approaching the freeway's capacity. When the last vehicle in the queue reaches the normal flow speed and traffic resumes flowing at the demand volume (Time C), the effects of the incident are over.

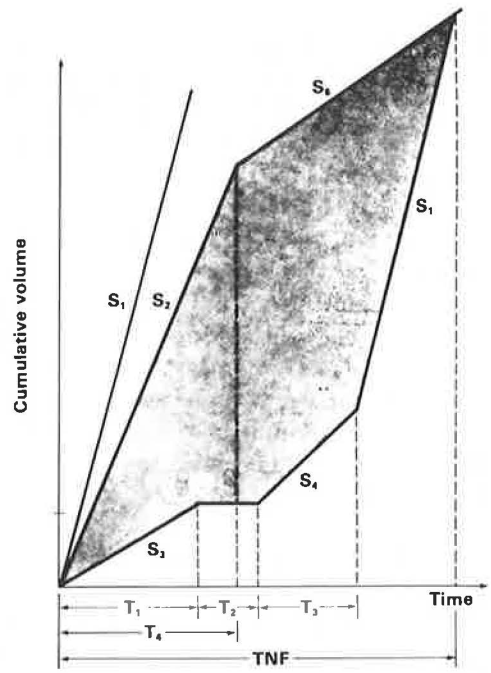
The getaway capacity, or the rate at which vehicles can depart a standing queue, is, in some cases, less than the typical capacity rate (under ideal conditions) of 2,000 passenger cars per hour per lane (pcphpl). Various observations of freeway getaway rates range from as low as 1,500 pcphpl to as high as 2,000 pcphpl. (2-4) Local driving characteristics have a major influence on this range. The analytical procedures described in this article assume the getaway capacity to be equal to the freeway's capacity.

## Factors Affecting Incident Duration

A number of factors determine the magnitude of incident-caused delay, which is represented by the shaded area in figure 1. Only some of these factors can be influenced by freeway incident management techniques. Other factors, such as the freeway's capacity and demand flow, generally are fixed by external environmental circumstances such as the number of lanes and time of day. Unless an incident occurs just before or at the end of a peak period or traffic is diverted during an incident, the demand flow rate is assumed to remain constant for the duration of the incident.

Two factors that can be influenced by incident management techniques are the reduced capacity past the incident and the incident's total duration. Effective onsite traffic management techniques optimize use of whatever freeway capacity remains after the incident. Graphically, this is represented in figure 2 by an increase of the slope of the reduced roadway capacity L2 to create an improved flow rate L2'.

Another factor influencing total delay is the time from the moment the incident occurs to the time it is cleared from the freeway. This time interval AB can be expressed as the sum of the detection, response, and clearance times as shown in figure 1. Obviously, minimizing any of these times through efficient incident management will result in less total delay.




$S_1$ = Capacity flow rate of the freeway, veh/hr.
$S_2$ = Initial demand flow rate, veh/hr.
$S_3$ = Initial bottleneck flow rate, veh/hr.
$S_4$ = Adjusted bottleneck flow rate, veh/hr.
$S_5$ = Revised demand flow rate, veh/hr.
$T_1$ = Incident duration until first change, min.
$T_2$ = Duration of total closure, min.
$T_3$ = Incident duration under adjusted flow, min.
$T_4$ = Elapsed time under initial demand, min.
TNF = Total elapsed time until normal flow resumed, min.

*Figure 3. — General condition diagram.*

## Procedures for Estimating Delay

Delay can be estimated for a variety of incident management situations from a general condition diagram (fig. 3). From this diagram, the following equation for computing delay can be derived:

$$\begin{aligned}\text{Total delay} = [&T_1^2(S_1 - S_3)(S_5 - S_3) + T_2^2 S_1 S_5 \\ &+ T_3^2(S_1 - S_4)(S_5 - S_4) \\ &- T_4^2(S_1 - S_2)(S_2 - S_5) \\ &+ 2T_1T_2S_1(S_5 - S_3) \\ &+ 2T_1T_3(S_1 - S_4)(S_5 - S_3) \\ &+ 2T_1T_4(S_1 - S_3)(S_2 - S_5) \\ &+ 2T_2S_5(S_1 - S_4) \\ &+ 2T_2T_4S_1(S_2 - S_5) \\ &+ 2T_3T_4(S_1 - S_4)(S_2 - S_5)]/2(S_1 - S_5).\end{aligned}$$

Similarly, an expression for the TNF can be written as follows:

$$TNF=[T_1(S_1-S_3)+T_2S_1+T_3(S_1-S_4)+T_4(S_2-S_5)]/(S_1-S_5)$$

The general equation to compute the maximum queue, $Q_{max}$, is somewhat more complicated and is indicated as follows:

$$Q_{max} = T_aS_2 + T_bS_5 - T_cS_3 - T_dS_4 - T_eS_1.$$

$T_a$, $T_b$, $T_c$, $T_d$, and $T_e$ are functions of the conditions being considered and vary accordingly. However, by definition queue is the algebraic difference between the demand flow L1 and the bottleneck flow L2 at a specific time (figs. 1 and 2). Therefore, $Q_{max}$ can be obtained graphically by computing the maximum difference between L1 and L2.

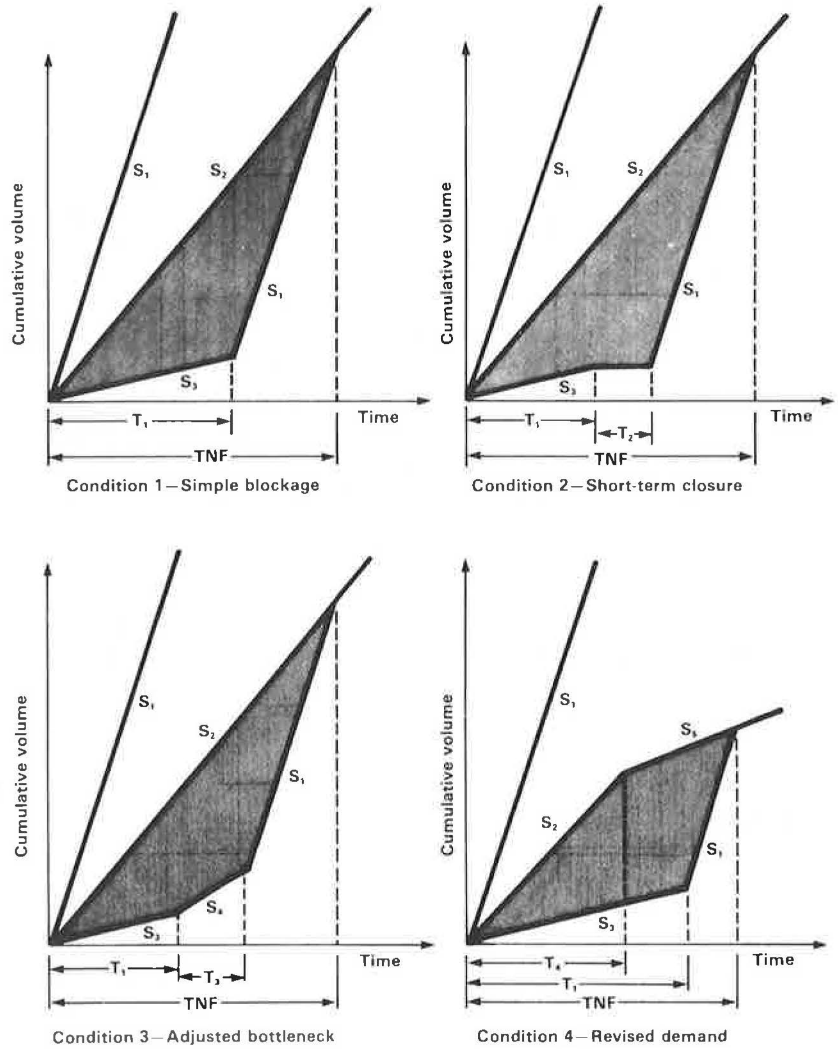



*Figure 4. – Delay conditions*

It should be noted that these expressions do not apply to every imaginable delay condition and should be used carefully. Four specific delay conditions (fig. 4), obtained from the general diagram (fig. 3) for estimating vehicle-hours of delay, are typical. In these conditions, either the demand flow rate or the reduced flow rate changes because of varying incident circumstances.

In condition 1--simple blockage--the number of vehicles that would have gone through a point if the incident had not occurred (the demand flow) is indicated by $S_2$. The actual number of vehicles going through this point at the reduced flow rate is shown as $S_3$. The duration of the incident, from the time of occurrence until the time of clearance, is represented by the time interval $T_1$. After the incident has been cleared, the queue of vehicles delayed by the incident will move past the point at a getaway capacity $S_1$ (assumed to be equal to the freeway capacity). Traffic will continue to flow at this rate until all queued vehicles have gone through-at TNF.

The shaded area shown in Condition 1 represents the total vehicle-hours of delay for all the vehicles affected by this incident. Delay will be accumulated whenever the reduced flow rate $S_3$ is lower than the demand flow rate $S_2$.

Condition 2 is similar to Condition 1 - but includes a short-term closure on the affected freeway. The time interval $T_2$ indicates that the freeway is completely closed and that no vehicles can go through the incident point. Vehicle-hours of delay continue to accumulate as more vehicles join the queue forming behind the closure.

Condition 3 is similar to Condition 2 except at the time interval $T_1$ the bottleneck flow is adjusted, and the onsite flow rate is increased for a period before total clearance by improving the flow of traffic through effective traffic management (such as police officers directing traffic) or by reopening lanes previously blocked by debris and wreckage. The time interval $T_3$ indicates how long this improved flow rate $S_4$ is in effect before the getaway capacity $S_1$ can be attained.

Condition 4 is created when the demand flow rate $S_2$ is reduced during the incident. This condition typically is caused by natural or artificial upstream traffic diversion or by typical fluctuations in traffic volumes, such as those that occur at the end of a peak period. The demand flow rate drops from $S_2$ to $S_5$ at time $T_4$.

With the appropriate substitutions, these four conditions can, of course, be derived from the general equations. For example, under Condition 1, $T_2=T_3=T_4=0$, $S_4=S_3$, and $S_5=S_2$.

Table 1. - Typical flow rates (veh/hr)

| Number of lanes in one direction | Freeway capacity ($S_1$) | Bottleneck capacity<br>One Lane blocked ($S_3$) | <br>Shoulder blocked ($S_3$) |
|---|---|---|---|
| 2 | 3,700 | 1,300 | 3,000 |
| 3 | 5,550 | 2,700 | 4,600 |
| 3 | 7,400 | 4,300 | 6,300 |

## Application of Procedures

Total delay is a function of three variables: Remaining capacity, traffic demand, and incident duration. At least three and up to five flow rates (depending on delay conditions) must be known or estimated to calculate delay. Some of these flow rates can be measured easily in the field for particular freeway sections. Average volumes based on historic data also can be used. Table 1 presents typical capacity flow rates $S_1$ and bottleneck capacity flow rates $S_3$ for both in-lane and shoulder incidents for freeways of two, three, and four lanes. (1)

Once the necessary flows and durations are known, total delay, TNF, and $Q_{max}$ are computed by solving the general equations presented previously or by using the interactive spreadsheet. The spreadsheet uses LOTUS 1-2-3 running on an IBM-compatible microcomputer with at least 128k of memory. The program interactively guides the user through a series of screens to enter the required data (flows and incident durations) and computes the total delay, TNF, and $Q_{max}$. In addition, the delay condition being specified is graphically displayed. The results and graph can be printed as well.

Individual entries can be changed to determine the hypothetical effect of variations in traffic demand and/or incident duration.

Consider the following example:

At 8:15 a.m., a three-lane freeway with a capacity of 5,550 veh/hr carries a demand flow of 4,500 veh/hr. At this time, an accident occurs and a vehicle blocks one lane, which creates a bottleneck flow of 2,700 veh/hr. It takes 25 minutes for the incident management crew to learn of the incident and arrive at the site. While the vehicle is removed, the entire freeway is closed for 5 minutes. Once the vehicle is removed, the bottleneck flow improves to 3,500 veh/hr for 10 minutes before reaching its getaway capacity (5,550 veh/hr). Hourly volumes indicate that a decrease in the demand flow (to 2,800 veh/hr) is expected at 9 a.m.

This example uses all the variables needed to compute delay and TNF as expressed in the general equation:

- o $S_1$--the capacity flow rate of the freeway--is 5,550 veh/hr.

- o $S_2$--the demand flow at the time of the incident--is 4,500 veh/hr.

- o $S_3$--the initial bottleneck flow rate--is 2,700 veh/hr, which remains in effect during the 25 minutes it took the incident management crew to learn of the incident and arrive at the site ($T_1$).

- o $S_4$--the adjusted bottleneck flow rate--is 3,500 veh/hr, which lasts 10 minutes ($T_3$).
- o $S_5$--the revised demand--is 2,800 veh/hr, which is expected to occur at 9 a.m., or 45 minutes ($T_4$) after the incident.

- o The entire freeway is closed for 5 minutes ($T_2$).

Under simpler conditions, some of these variables do not apply and are substituted with zeros.

The data are entered in the microcomputer model, and the results are obtained (fig. 5). The total delay caused by this incident is 803 vehicle-hours, and it would take 71 minutes for the effects of the incident to dissipate.

A METHOD FOR CALCULATING DELAY, TIME AND QUEUE FOR TRADE-OFF ANALYSES

Any Place, U.S.A.

| | | |
|---|---|---|
| Number of Lanes: | | 3 |
| Capacity flow rate of the facility, veh/hr............ | S1 = | 5550 |
| Initial demand flow rate, veh/hr...................... | S2 = | 4500 |
| Initial bottleneck flow rate, veh/hr.................. | S3 = | 2700 |
| Adjusted bottleneck flow rate, veh/hour............... | S4 = | 3500 |
| Revised demand flow rate, veh/hr...................... | S5 = | 2800 |
| Incident duration until first change, min............. | T1 = | 25 |
| Duration of total closure, min........................ | T2 = | 5 |
| Incident duration under adjusted flow, min............ | T3 = | 10 |
| Elapsed time under initial demand, min................ | T4 = | 45 |

| | | |
|---|---|---|
| RESULTS: | Total Delay, veh-hrs = | 803.4 |
| | Time to Normal Flow (TNF), min = | 71.3 |
| | Maximum extent of queue, veh = | 1375 |
| | Maximum length of queue, miles = | 2.60 |

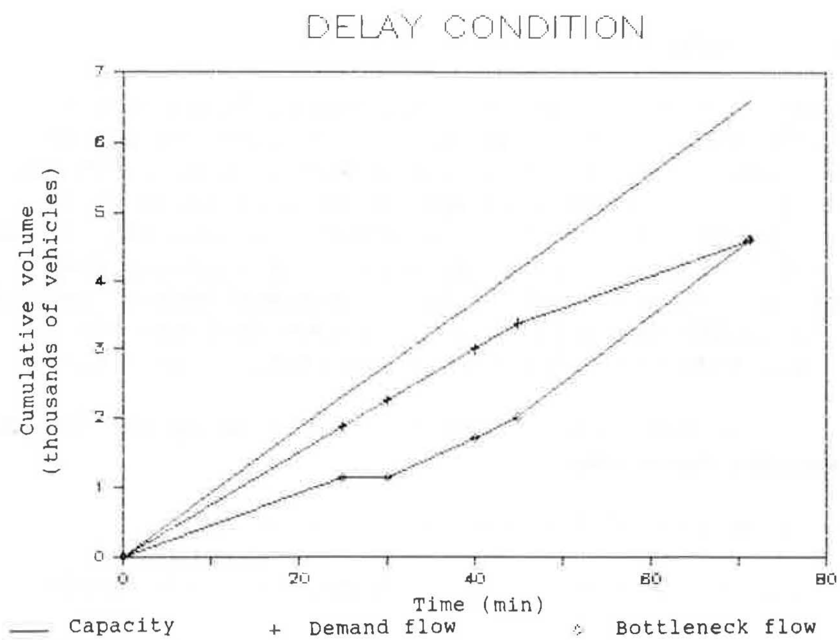



Figure 5. - Sample printout-25 minute detection and arrival time.

If it took only 15 minutes for the incident management crew to learn of the incident and arrive at the site, $T_1$ would be changed to 15 minutes (fig. 6). Total delay then would be reduced to 572 vehicle-hours, and TNF would be reduced to 61 minutes.

## Summary

This article describes analytical procedures to estimate delay, TNF, and the $Q_{max}$ caused by freeway incidents and discusses the availability of an interactive LOTUS 1-2-3- spreadsheet for fast computations. This microcomputer tool easily can be used to estimate the impact of planned incidents (that is, lane closures during construction or maintenance

A METHOD FOR CALCULATING DELAY, TIME AND QUEUE FOR TRADE-OFF ANALYSES

Any Place, U.S.A.

| | | |
|---|---|---|
| | Number of Lanes: | 3 |
| Capacity flow rate of the facility, veh/hr............ | S1 = | 5550 |
| Initial demand flow rate, veh/hr...................... | S2 = | 4500 |
| Initial bottleneck flow rate, veh/hr.................. | S3 = | 2700 |
| Adjusted bottleneck flow rate, veh/hour............... | S4 = | 3500 |
| Revised demand flow rate, veh/hr...................... | S5 = | 2800 |
| Incident duration until first change, min............. | T1 = | 15 |
| Duration of total closure, min........................ | T2 = | 5 |
| Incident duration under adjusted flow, min............ | T3 = | 10 |
| Elapsed time under initial demand, min................ | T4 = | 45 |

| | | |
|---|---|---|
| RESULTS: | Total Delay, veh-hrs = | 572.5 |
| | Time to Normal Flow (TNF), min = | 60.9 |
| | Maximum extent of queue, veh = | 1242 |
| | Maximum length of queue, miles = | 2.35 |

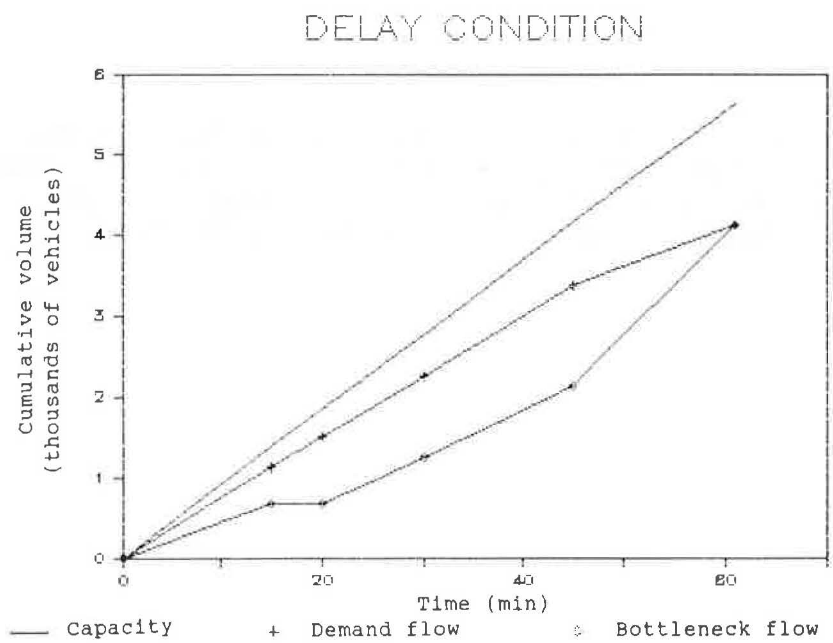



Figure 6. Sample printout--15 minute detection and arrival time.

operations) and the consequences of freeway incidents for immediately determining the optimum traffic control strategy.

This spreadsheet can be obtained, without charge, by mailing an IBM-formatted, 5 1/4-in floppy disk to:

Juan M. Morales
Federal Highway Administration
Traffic Safety Research Division, HSR-30
6300 Georgetown Pike
McLean, VA 22101-2296
Telephone (703) 285-2499

**References**

(1) "Alternative Surveillance Concepts and Methods for Freeway Incident Management," Report Nos. FHWA-RD-77-58/63, Federal Highway Administration, Washington, DC, March 1978.

(2) J.A. Lindley and S.C. Tignor, "Getaway Flow Rates for Freeway Incident and Geometric Bottlenecks," Public Roads, vol. 43, No. 1, June 1979, pp. 1-7.

(3) J. Duke, J. Shofer, and A. May, "A Statistical Analysis of Speed-Density Hypotheses," Highway Research Record 154, Transportation Research Board, Washington, DC, 1967.

(4) "Highway Capacity Manual--Special Report 209," Transportation Research Board, Washington, DC, 1985, p. 6-7.

**Juan M. Morales** is a highway research engineer in the Traffic Safety Research Division, Office of Safety and Traffic Operations R&D, Federal Highway Administration. Since 1983 he has been working FCP Project 1A, "Traffic and Safety Control Devices," and FCP Project 1M, "Rural Two-Lane Highways."

Note: Conference attendees were presented with the following two case studies of actual incidents in order to improve their grasp of principles related to effective incident management.

## Case Study A-88

### Description of Events: US 36 Train Accident

On Friday evening August 2, 1985, about 10:30 pm, the Department of Highways began setting up barricades at the two interchanges of Wadsworth and Sheridan on US 36. A formal detour was established using 88th Ave, Sheridan Blvd, 120th Ave and Wadsworth Blvd. Local traffic engineers were contacted to retime signals along these routes. By 2:00 am, on Saturday August 3, 1985, signing for the detour was completed.

Since the road was going to be closed for an indeterminate period of time, sign shop personnel were asked to report to work at 6:00 am, Saturday August 3, 1985 to begin fabricating signs for a permanent closure. By 2:00 pm, August 3, 1985, the signs had been erected on I 25 and along US 36 to warn motorists of the road closure and advising them to take alternate routes.

During the night of August 2, 1985, approval was obtained from the Chief Engineer to begin construction on a bypass of the damaged bridges. The bypass was to run adjacent to US 36 on undeveloped land on the east side of the Highway. Once the fire had been controlled and the dead had been removed, railroad crews worked around the clock to clear the train wreckage and remove the damaged bridges.

The two construction companies with projects in the area were notified to have equipment and crews available at 6:00 am, Saturday, to begin work on the detour. Road Crews worked from Saturday morning August 3, 1985 until 6:00 am, Monday morning August 4, 1985, to complete the detour. The news media were continually monitoring the events at the accident site. On Sunday evening August 4, 1985, they were notified that the detour would be open for traffic the next day at 6:30 am. By Wednesday, August 7, 1985, railroad crews had opened the tracks for use including gates and warning devices at a temporary grade crossing on the detour.

## Description of Events: I-80 Cluster Bomb Accident

On Monday evening, November 24, 1986 at 10:45 PM, the Pennsylvania Department of Transportation was called to detour traffic. I-80 was closed immediately at Exit 24 WB, and traffic diverted to PENNDOT`s primary road system. Shortly thereafter, the Pennsylvania State Police requested that Interstate 80 be closed completely Eastbound and Westbound, and also close Routes U.S. 220 and PA 150 at the Exit 23 Interchange.

Pennsylvania State Police utilized troopers from five different troops across the state to shut down all major roads and interchanges leading to Exit 23 of Interstate 80, until the Pennsylvania Department of Transportation completed detour signing. At this time I-80 was closed between Exits 19 and 24, approximately 41 miles. Although PENNDOT had signing in place along I-80 and all detour routes for emergency closures, this signing scheme could not be fully utilized, because the Exit 23 interchange was completely closed.

The following routes were used to detour traffic. All I-80 Westbound traffic was diverted at Exit 24 onto PA 26 South for 12.8 miles to US 322 West, where it then followed US 322 38.6 miles to Exit 19, there returning to I-80.

Eastbound traffic on I-80 was removed at Exit 19 and followed the same routes to Exit 24. Although detour signing was in place, the Pennsylvania Department of Transportation also had personnel at key locations to assist travelers who became lost or wished to take alternate routes. Pennsylvania Highway maps were handed out at these locations to assist them.

At approximately 7:00 PM, Tuesday, November 25, 1986, I-80, US 220 and PA 150 were reopened to traffic.

# CONFERENCE ON TRAFFIC MANAGEMENT AND PLANNING FOR FREEWAY EMERGENCIES AND SPECIAL EVENTS

OMNI SHOREHAM HOTEL

January 10, 1988

<u>Sunday, January 10, 1988</u>

| | |
|---|---|
| 7:45 a.m. | REGISTRATION, East Lobby |

HAMPTON ROOM

| | |
|---|---|
| 8:30 a.m. | WELCOME AND OPENING REMARKS, R. Sonntag, Wisconsin Department of Transportation |
| | THE URBAN TRAFFIC CONGESTION PROBLEM, J. Lindley, Federal Highway Administration |
| 9:00 a.m. | THE SCOPE OF THE TRAFFIC PROBLEM GENERATED BY INCIDENTS AND SPECIAL EVENTS, C. L. Dudek, Texas A&M University System |
| | Problem Definition<br>Nature and Magnitude of Problem: Reduced Capacity and Excess Demand<br>Concepts of Some Categories of Solutions with Emphasis on Planning and Response |
| 9:20 a.m. | FILM: TRAFFIC MANAGEMENT FOR FREEWAY INCIDENTS, S. C. Tignor, Federal Highway Administration |
| 9:40 a.m. | ORGANIZATION OF WORKSHOP GROUPS - CASE STUDIES, S. C. Tignor |
| 10:00 a.m. | Coffee Break |
| 10:15 a.m. | INTRODUCTION OF SPEAKERS, Capt. J. Yeasted, Baltimore County Police Department |
| | INCIDENT DETECTION AND RESPONSE, J. M. McDermott, Illinois Department of Transportation |
| | Detection: Detectors, CCTV, Patrols, Call Boxes, CB Radio, and Mobile Communications |
| | Response: Service Patrols, Special Equipment, and Public Information |
| 10:45 a.m. | INCIDENT MANAGEMENT, D. H. Roper, California Department of Transportation |

Route Diversion Plans
Incident Management Teams
Interagency Coordination
Staffing, Costs, Benefits

11:15 a.m. POLICE PERSPECTIVES ON TRAFFIC MANAGEMENT OF FREEWAY EMERGENCIES,
D. Hinton, California Highway Patrol;
J. Walsh, Ohio State Highway Patrol

Timely Response
Traffic Coordination
Multiagency Communications and Interaction

12:00 noon LUNCHEON, DIPLOMAT ROOM

HAMPTON ROOM

1:00 p.m. INTRODUCTION OF SPEAKERS,
J. E. Clark, Clemson University

REAL-TIME TRAFFIC CONTROL FOR MAINTENANCE WORK ZONES,
S. Levine, Texas State Department of Highways and Public Transportation

1:30 p.m. TRAFFIC MANAGEMENT TEAMS,
B. Ray Derr, Texas State Department of Highways and Public Transportation;
G. C. Price, Florida Department of Transportation

Purpose and Objective
Organization
Functions

2:00 p.m. TRAFFIC MANAGEMENT FOR SPECIAL EVENTS
1986 U.S. Open Golf Tournament,
W. M. Dunn, Dunn Engineering Associates

2:30 p.m. CASE STUDIES - WORKSHOP
S. C. Tignor, Moderator

L. Lipp, Colorado Department of Transportation

A. Surovec, Pennsylvania Department of Transportation

3:30 p.m. HOW TO GET STARTED: EXPERIENCE OF TWO AGENCIES,
M. Cuddy, New York State Department of Transportation; M. Edelman, TRANSCOM

4:00 p.m. DEMONSTRATION: COMPUTER ANALYSIS PROGRAM FOR FREEWAY TRAFFIC CONGESTION,
J. Morales, Federal Highway Administration

4:30 p.m. Adjournment

## COMMITTEE ON FREEWAY OPERATIONS

Ronald C. Sonntag, Chairman

Glen C. Carlson
Patrick J. Athol
B. Beukers
Elmer N. Burns
Donald G. Capelle
Conrad L. Dudek
Walter M. Dunn, Jr.
John W. Erdman
Herman E. Haenel
Dennis C. Judycki
Jack L. Kay
Clifford L. Kurtzweg
Jeffrey A. Lindley
Louis E. Lipp
Adolf D. May, Jr.
William R. McCasland
Joseph M. McDermott
David Rios Olivarez
Gordon F. Paesani
Gary C. Price
Colin A. Rayman
David H. Roper
Joseph Treiterer
Thomas C. Werner
Philip Zove

David K. Witheford, TRB Staff

## COMMITTEE ON TRAVELERS SERVICES

J. Edwin Clark, Chairman

Robert F. Dale
Bernard Adler
Kay Colpitts
Allen R. Cook
Frank M. Croft, Jr.
Michael S. Della Rocca
Cheryl Gribskov
Wayne T. Gruen
Robert B. Helland
Leon F. Jackson
Harold E. Morgan
Henry C. Rockel
Elizabeth D. Scullin
Samuel C. Tignor

James K. Williams, TRB Staff

## COMMITTEE ON TRAFFIC LAW ENFORCEMENT

Olin K. Dart, Jr., Chairman

John W. Billheimer
George W. Black, Jr.
Quinn Brackett
Stephen S. Caruso
Richard L. Downey
Ted E. Dudzik
William D. Glauz
Kent B. Joscelyn
Roy E. Lucke
Judson S. Matthias
Anthony Dormer May
Jerry G. Pigman
Richard A. Raub
Henry C. Rockel
Brian G. Traynor
Jack Walsh
James W. Yeasted

James K. Williams, TRB Staff