CHAPTER 4
Incident Management

4.1 FREEWAY INCIDENT-MANAGEMENT SYSTEMS

Nonrecurring problems (incidents) consisting of traffic accidents, vehicle breakdowns, spilled loads, adverse weather conditions, rubbernecking, etc., are caused by random events and thus, are unpredictable. Freeway incident management is the coordinated and preplanned approach used to restore freeway traffic to normal operation as quickly as possible after an incident by using human and mechanical resources.

Incident management provides an organized and functioning system for quickly identifying and clearing crashes, disabled vehicles, debris, and other nonrecurring flow impediments from area freeways. Roadways are cleared and flow restored as rapidly as possible, minimizing frustration and delay to travelers while at the same time meeting the requirements and responsibilities of the agencies involved. The various jurisdictions and agencies responsible for operations and enforcement are working together to develop a policy and operations agreement that defines specific responsibilities of incident management. Such an agreement includes detection, verification, response, clearance, scene management, and traffic management and operation.

The multi-jurisdictional operating agreement ensures cooperation, coordination, and communication among all agencies including law enforcement, fire, ambulance, highway traffic control, and maintenance, as well as environmental and other public agencies. Interagency cooperation also reduces duplication of effort in coordinating incident management activities. In addition, private sector businesses that do towing and recovery may be involved in incident clearance.

SOURCES:

- *Traffic Control Systems Handbook*, February 1996, Publication No. FHWA-SA-95-032, Prepared for FHWA by Dunn Engineering Associates.
- *Freeway Management Handbook*, FHWA Publication, available Spring 1997.
- *Inform Evaluation, Vol. 1: Technical Report*, 1991, Publication No. FHWA-RD-91-075.
- *Inform Evaluation, Vol. 2: Executive Report*, 1991, Publication No. FHWA-RD-91-076.
- *Framework for Developing Incident Management Systems,* Executive Summary, August 1991, Publication No. WA-RD-224.1.
- *Freeway Incident Management Handbook,* July 1991, Publication No. FHWA-SA-91-056.
- *A Comprehensive System for Incident Detection on freeways and Arterials,* March 1995, ITS America.
- *Automating incident Management with GIS Technology,* April 1994, Paper presented at 1994 ITS America Annual Meeting.
- *Massachusetts Incident Management Conferecnce Proceedings,* June 1991, Publication No. DOT-T-92-05.

- *Incident Management, Challenges, Strategies, and Solutions for Advancing Safety and Roadway Efficiency, Executive Summary,* January 1997, American trucking Association

4.1.1 TECHNIQUES/STRATEGIES

Detection

Incident detection determines if an incident of some sort has occurred. This subsystem is responsible for identifying possible events and reporting them to system users for further disposition. The incident-management subsystem will accept processed detector data, evaluate the data based on an appropriate algorithm, generate communications log entries for identified events, and enter them into the system. The information has to reach the location where response can be initiated.

The most common techniques for detecting incidents are electronic surveillance, CCTV, aerial surveillance, motorist call systems (which include emergency call boxes and emergency telephones), cooperative motorist-aid systems, cellular telephone, CBs, and police and service patrol vehicles. Incident detection by electronic detectors (inductive loops) involves real-time computer monitoring of traffic data obtained from these detectors. Section 2.6 provides a thorough discussion of available detection technologies.

Verification

Since the nature for the incident cannot be determined by electronic detectors, some form of confirmation is required to determine the necessary response. This can be performed by such systems as CCTV, aerial surveillance (helicopters and small airplanes), call boxes, patrol vehicles, CB radio, cellular telephone, etc. Section 2.7 provides a thorough discussion on video technologies.

Response and Clearance

Once an incident is detected and verified, the key to minimizing congestion or other adverse impacts is the timely, safe removal of the incident and restoration of the freeway to its full traffic capacity. The longer the duration of response and clearance, the more severe the resulting congestion and delay. The single most cost-effective incident-management strategy is to reduce the response and clearance time. A response plan must be implemented immediately after detection and verification as part of the incident-management process. This plan should be developed beforehand and include, as a minimum, the following elements.

a. *Participating Agencies and Partners*

All participating agencies and partners involved in incident management must be identified with names and phone numbers. For each agency, an incident-management coordinator should be selected for notificatin during an incident.

b. *Interagency Communications*

Communication links among the participating agencies and partners need to be established. These links may take one or a combination of several forms, including: phone (e.g., leased commercial, cellular); dedicated cable; radio; commercial pager; Internet. Care must be taken to ensure that the chosen communication link(s) is reliable and, if more than one is used, that they have a common functionality. For example, it is very important that an operator at a transportation-management center be able to communicate with a police officer in the field regarding the nature of the incident and the extent of the assistance (e.g., medical, rescue, hazardous material) necessary. The frequency, channel, or line for communications must be shared, as must the codes used to communicate types of incidents and assistance needed.

c. *Traffic-Management Procedures*

Establishing traffic-management and operational procedures is vital to the prompt response to and clearing of an incident. The collection of information at the transportation-management center (traffic operations center) and the coordination of activities are key elements in managing the response of incidents. Facilities and management strategies used for responding to and clearing the incident include the following.

1. *Traffic Operations Center.* This is a facility where, for the most part, all information is received, managed, and disseminated to various locations. This includes the communications center, the traffic-control center, the traffic-management and information center, the State police dispatch center, the maintenance dispatch center, etc. Real-time traffic information (e.g., incident location and severity) is received at this location. All communications to and from participating agencies and partners occur at this center.

2. *Resources and Responsibilities.* The resources to be provided by and responsibilities of each participating agency, once identified, are assigned. It is important to identify in the management plan the resources required to respond to and clear the incident. It is equally important, at the scene of the incident, for every entity involved with the incident response to know its purpose and responsibilities.

3. *Securing the Scene.* Securing the incident scene is particularly important in managing incidents. The field command (usually a trained service patrol) manages the scene and provides leadership in the activities that take place. He or she, with the assistance of the personnel at the scene as well as at the traffic operations center, cordons off an area, directs traffic at the scene, sets up traffic control for possible route diversion, provides emergency assistance, coordinates communications with the various participating parties, and assures that the efforts at the incident scene, as well as the traffic impacted, are operating in an orderly fashion.

4. *Accident-Investigation Sites.* These are special designated areas, off the freeway, where drivers exchange necessary information and police officers perform an investigation of the incident and complete all necessary reports. These areas are generally located out of the view of the freeway, so as to reduce rubbernecking and braking by passing vehicles. The benefits of an accident investigation site include reduced motorist delays, reduced vehicle-operating costs, reduced secondary accidents, reduced pedestrian exposure, and more efficient use of the public agency's personnel.

5. *Emergency Response.* Emergency response techniques and strategies hasten emergency vehicles to an incident site when traffic has queued behind the incident, and help facilitate an order to the many response vehicles parked in travel lanes at the incident site. Freeway design barrier gates and emergency ramps provide emergency freeway access. These facilities are closed to regular traffic, but can be utilized by authorized vehicles through manual or electronic gate systems.

6. *On-Site Traffic Control.* Traffic control is required to facilitate the orderly movement of traffic past the incident site, or to coordinate route-diversion techniques due to lane closures. Channelization of traffic can be accomplished with technologies similar to those discussed in Section 2.5, Transportation Management During Reconstruction.

7. *Traffic-Management and Control Strategies.* These are activities to assist in the response and clearing of the incident during the incident-management process. Information on several parameters must be obtained before a response plan, consisting of the magnitude of the traffic-management and control strategies, can be selected and implemented. This information may include:

   - Period of incident.
   - Severity of incident.
   - Anticipated duration of incident.
   - Requirement of medical assistance.
   - Hazardous material.
   - Blocked lanes.

Several action plans may be selected, depending on the nature of this information. Table 4.1 shows two examples of Response Action Plans for two types of incidents: one simple, not severe, and the other severe, high priority. Depending on the incident type and severity, a compromise of these two plans may be selected and implemented.

Table 4.1 Response Action Plans for Different Types of Incidents

Description of Incident	Action Plan
The incident occurred during the off-peak period, is not severe, clearing is not anticipated to have a long duration, has no injuries, does not require medical assistance, and can be cleared to the side of the road with no lanes being blocked.	The actions to be taken might include: • Device action (e.g., commands to DMSs). • Message for device (e.g., HAR). • Text script (e.g., building of database, media). • Communications with involved parties (e.g., police).
The incident occurred during the peak period, is severe, clearing is anticipated to have a long duration, has injuries, requires medical assistance, multiple lanes are blocked, high priority.	The actions to be taken might include (*): • Device action (e.g., commands to CMSs). • Message for device (e.g., HAR, radio). • Text script (e.g., building of database, media). • Transmission of video (e.g., local TV, media). • Communications w/involved parties (e.g., police, EMS). • Route diversion for motorists. • Selection of appropriate signal-timing plans. • Selection of appropriate ramp-metering rates. • Communication w/other TMCs and possible control.

(*) In this type of Response Action Plan, a diversion route may be needed. Through the field processing units and interface with the Transportation Management Center (TMC), the status of each intersection or groups of intersections on arterials of that route, as well as timing plans needed, will be communicated to the respective TMC (e.g., signal Traffic Control Center (TCC), jurisdictional TMC, or TCC). Depending on the signal-control system controlling the intersections (e.g., closed loop), an interface to allow the TMC to poll the intersections, or masters, and to modify timing of intersections by sending a controller command request to the signal-control system is very important to manage the corridor. The TMC must be able to extract intersection status, detector data and status, and timing in effect from the signal-control system or TCC. The signal-control system or TCC must be able to extract freeway or link status and incident information from the TMC.

The dynamic nature of the incident can affect the response plan through changes indicated by monitoring of the response effort. If traffic conditions are getting worse as a result of the selected response plan, modifications to the plan may be in order.

The following response actions portray a typical scenario of incident management.

A freeway TMC detects an incident that creates a major bottleneck downstream of the off- and on-ramps. With the use of the video surveillance cameras (used and controlled from the TMC workstation) and an incident-management decision support system, the operator of the workstation can select an appropriate response plan and issue appropriate commands to DMSs and other traveler-information systems on the freeway to direct traffic to alternative routes. Commands are also sent from the freeway TMC workstation to workstations of surface streets (e.g., traffic-signal control center, local traffic control center), to adjust signal-timing patterns, local advisory radio messages, and DMSs on the parallel arterial roadways to which traffic typically diverts during such an incident. Computer workstations in the TMC or other TMCs and/or TCCs may be able to continuously and automatically exchange data, thereby allowing a workstation to monitor the operation of and issue commands to any device managed by any other workstation. Specification for the type of data to be exchanged, under what circumstances, and what commands will be sent from one workstation to the other(s) must be designed in advance. A particular workstation will have to determine what data or information it needs for a particular purpose at any given time. It will then request that information from the appropriate workstation(s). The signal-timing patterns implemented are designed in advance to meter diverting traffic and provide maximum capacity for the diversion route, to avoid gridlock. The signal-coordination pattern selection in response to traffic volumes building and dissipating during the incident may be made by either the freeway or the local arterial workstations. Either workstation may be able to manage and control traffic and devices on the surface streets. DMSs on the arterial roadway and local advisory radio messages can be used to direct traffic to the first clear on-ramp downstream of the incident, to minimize any unnecessary off-freeway travel by motorists who are not aware of the exact location and conditions of the incident. These DMSs and any other traveler information may be controlled by either the freeway or surface street workstation.

This type of a platform demonstrates not only the integration of technologies and the management and control of devices from a single point (the workstation), but also the integration of traffic-operation systems and the networking of workstations, which really demonstrates the network and integration of multiple traffic-management centers.

Field devices could also operate in a network fashion. For example, a field device connected to a specific local workstation but which another workstation (freeway) needs to monitor or control for regional application can be treated as a system. The system can use the integration network for communication with such a device, rather than using a direct communication channel. In this manner, the workstation will not be communicating directly with the remote device but with the workstation that has direct connection to the device, which in turn will relay the information to the other workstation.

Depending on the actions taken for a response plan, a diversion-route selection may result in various coordinated plans where the integration of ramp meters with signal control is realized. Following are several examples of coordination plans.

Coordination Plan Example 1: No Coordination.

The conditions as they exist will be used. The ramp-metering rates and signal-timing plans stored in the controllers for that time of day, at each site, will be used. There will be no coordination between the freeway ramp and arterial street system.

Coordinated Plan Example 2: Minimum Coordination.

Traffic-responsive ramp control will be applied at the location upstream of the incident. As levels (occupancy or volumes) on the mainline freeway change, the metering rates on the ramp are changed accordingly. This approach utilizes nearby detectors on the freeway and the entrance ramp, and a controller to determine an appropriate metering rate.

Traffic-signal timing will be adjusted on the arterials. After occurrence of an incident, one-way arterial progression plans will be used to maximize the traffic operations.

Coordinated Plan Example 3: Maximum Coordination.

Integrated area-wide ramp control will be in effect. Queue override will also be implemented for each entrance ramp. The entrance ramp immediately upstream from the incident area will be closed after the incident occurrence. Maximum priority will be given to the ramp traffic both from the exit ramps and onto the entrance ramps, as shown below.

- Off-Ramp Priority - The traffic-signal settings will be adjusted to provide the maximum time possible to the signal phases that serve the off-ramp traffic, and less green time to the other signal phases. The cycle lengths and offsets will remain the same. However, the split will be adjusted.
- On-Ramp Priority - This will provide maximum possible flow onto the freeway. The diverted traffic will return back onto the freeway through an interchange downstream from the incident. Ramp metering immediately downstream of the incident will be shut off, and the signal timing plan will favor the phases that facilitate traffic flowing on the on-ramp. All ramp controllers downstream of the incident will be assigned the maximum allowable metering rates using the area-wide control system.

The exit-ramp queue detector will be monitored to avoid spillback onto the freeway. This detector activates the signal at the interchange to allow vehicles on the ramp to dissipate faster. On the arterials, maximum one-way signal progression will be provided for the diverted priority traffic coming from the freeway. The cross streets will receive less green time. Traffic flows and patterns along the diversion path will be monitored regularly during incident management, and signal-timing plans will be updated as necessary. Queue detectors on the on-ramps in the diversion area will be activated to avoid any possible vehicle spillback from the on-ramp onto the surface streets.

8. *Vehicle Removal and Towing.* This involves the fast removal of disabled, abandoned, or damaged vehicles by tow trucks. Towing is most commonly provided by a rotation call out. Rotation towing should include both heavy-duty and light-duty rotation lists. Many larger urban areas are entering into contract towing. Contracts are usually awarded on a zone basis and cover response-time requirements, training, equipment, insurance, storage, and other items.

   The cooperation of the public is vital in removing vehicles involved in minor accidents. Fast vehicle-removal legislation policies have been enacted to reduce the impact of incidents and increase motorist safety. There are two types of vehicle-removal legislation, one addressing motorists involved in minor accidents and one addressing agencies involved with incident management. The first type, often included in State vehicle laws, requires motorists involved in noninjury accidents to move their vehicles off the roadway. Texas adopted a “Move-It” public education program to encourage drivers involved in minor accidents (e.g., no injuries, drivable vehicles) to move the vehicles from the travel lanes before exchanging information or calling the police. Other States have followed with similar programs. Georgia, for example, has a program called “Steer It—Clear It.” Several examples of removal legislation are provided below.

Section 42-4-1602 of the Colorado Motor Vehicle Code is vehicle-removal legislation intended for motorists and States:

(1) The driver of any vehicle directly involved in an accident resulting only in damage to a vehicle which is driven or attended by any person shall immediately stop such vehicle at the scene of such accident or as close thereto as possible but shall immediately return to and in every event shall remain at the scene of such accident, except in the circumstances provided in subsection (2) of this section, until the driver has fulfilled the requirements of section 42-4-1603. Every such stop shall be made without obstructing traffic more than is necessary. Any person who violates any provision of this subsection (1) commits a class 2 misdemeanor traffic offense.

(2) When an accident occurs on the traveled portion, median, or ramp of a divided highway and each vehicle involved can be safely driven, each driver shall move such driver's vehicle as soon as practicable off the traveled portion, median, or ramp to a frontage road, the nearest suitable cross street, or other suitable location to fulfill the requirements of section 42-4-1603.

Section 42-4-1603 of the Colorado Motor Vehicle Code is vehicle-removal legislation intended for incident-management agencies and States:

Whenever any sheriff, undersheriff, deputy sheriff, police officer, marshal, Colorado state patrol officer, agent of the Colorado bureau of investigation or an agency employee finds a motor vehicle, vehicle, cargo, or debris, attended or unattended, standing upon any portion of a highway right-of-way in such a manner as to constitute an obstruction to traffic or proper highway maintenance, such officer or agency employee is authorized to cause the motor vehicle, vehicle, cargo, or debris to be moved to eliminate any such obstruction: and neither the officer, the agency employee, nor anyone acting under the direction of such officer or employee shall be liable for any damage to such removal. The removal process is intended to clear the obstruction, but such activity should create as little damage as possible to the vehicle, or cargo, or both. No agency employee shall cause any motor vehicle to be moved unless such employee has obtained approval from a local law enforcement agency of a municipality, county, or city and county, the Colorado bureau of investigation, or the Colorado state patrol.

A Texas Senate Bill, 312 Article 6673g, intended for incident-management agencies and States:

The state Department of Highways and Public Transportation may remove obstructions from the roadway without the consent of the owner or carrier of spilled cargo or other personal property on the right-of-way or any portion of the roadway of the state highway system in circumstances in which, as determined by the department, the cargo or property is blocking the roadway or may otherwise be endangering public safety.

The department and its officers and employees are not liable for any damages or claims of damages to removed cargo or personal property that resulted from removal or disposal by the department unless the removal or disposal was carried out recklessly or in a grossly negligent manner.

Virginia Section 46.2-1212.1. Authority to provide for removal and disposition of vehicles and cargos of vehicles involved in accidents, for States:

A. As a result of a motor vehicle accident or incident, the Department of Sate Police and/or local law enforce ment agency in conjunction with other public safety agencies may, without the consent of the owner or carrier, remove:

1. A vehicle, cargo or other personal property that has been (1) damaged or spilled within the right-of-way or any portion of a roadway in the state highway system, and (2) is blocking the roadway or may otherwise be endangering public safety; or

2. Cargo or personal property that the Department of Transportation, Department of Emergency Services, or the fire officer in-charge has reason to believe is a hazardous material, hazardous waste or regulated substance as defined by the Virginia Waste Management Act or a hazardous waste or regulated substance as defined by the Hazardous Materials Transportation Act, or State Water Control Act, if the Department of Transportation or applicable person complies with the applicable procedures and instructions defined either by the Department of Emergency Services or the fire officer in-charge.

B. The Department of Transportation, Department of State Police, Department of Emergency Services, local law enforcement agency and other local public safety agencies and their officers, employees and agents, shall not be held responsible for any damages or claims that may result from exercising authority granted under this section, provided they are acting in good faith.

C. The owner and carrier, if any, of the vehicle, cargo or personal property removed or disposed of under the authority of this section shall reimburse the Department of Transportation, Department of State Police, Department of Emergency Services, local law enforcement agency and local public safety agencies for all costs incurred in the removal and subsequent disposition of such property.

Driver Information

As part of the incident-management plan, the dissemination of accurate information to the motorist in a timely manner is crucial. The motorist needs to be informed as to the nature and the extent of any delays that he or she encounters. Warning the motorist well in advance of an incident will result in greater tolerance for any delay, will encourage the motorist to take alternate routes, and will reduce the number of secondary incidents, as motorists are more alert.

4.1.2 TECHNOLOGIES

Detection and Verification

a. *Detection Algorithms*

Automatic vehicle detection consists of two major elements: a traffic-detection system that provides the data (such as volume, speed, occupancy); and an incident-detection algorithm that interprets the information and determines changes in certain traffic-flow variables, thus determining presence or absence of capacity-reducing incidents. Loop detectors and video detectors are used extensively for data acquisition.

In general, incident-detection algorithms are grouped into three main categories:

1. *Pattern-Recognition Algorithms.* Pattern-recognition algorithms use data concerning current traffic patterns, such as traffic occupancies, to sense congestion changes (e.g., the California comparative algorithm). This algorithm consists of three simple comparisons to some predetermined thresholds. An incident is detected when upstream occupancies are significantly higher than downstream relative to upstream occupancy thresholds, and the downstream occupancies have decreased significantly during the past two minutes. The algorithm takes the occupancy data and calculates the following traffic measures:

   - Spatial difference in occupancies;
   - Relative temporal difference in downstream occupancy;
   - Relative spatial difference in occupancies; and
   - Downstream occupancy.

2. *Time-Series (Smoothing) Algorithms.* Such algorithms use forecasting techniques to identify traffic changes. Significant differences between the observed and the forecasted values are the result of incidents (such as the Autoregressive Integrated Moving Average [ARIMA], by which a 95-percent confidence interval of the forecasts is constructed for comparison purposes and any observed value outside the confidence interval is considered an incident).

3. *McMaster Algorithm (Point-Based Detection*). The McMaster Algorithm separates the flow-occupancy diagram into four areas corresponding to different states of traffic conditions. Changes of the different states of traffic in a short time represents incidents.

Statistical data smoothing has been performed on data for incident detection to suppress the randomness in the data (variations). Various smoothing techniques have been used, such as simple running averages (the California algorithm) and exponential smoothing. Travel time is the primary statistic (variable) in an incident-detection algorithm for all loop configurations, due to a smaller dispersion present in the raw data.

In addition, on-line decision support systems, such as KBES (Knowledge-Based Expert Systems) have been used (as a series of rules or heuristics) by control center personnel to detect, verify, and respond to traffic incidents. These expert systems have been designed (e.g., Santa Monica Smart System) to solve problems whose solutions require expertise. It is a real-time, on-line computer system supporting the traffic manager in: screening large amounts of data; analyzing the real-time traffic data and responding consistently across the operators; and as a training tool used off-line by managers for a variety of traffic-incident scenarios. These systems use incident-detection algorithms based on real-time volume and occupancy data from the mainline detector stations, and compare data against user-specified thresholds for incident identification.

Advantages:

- Incident-detection algorithms use traffic parameters and data to identify incidents.
- They use detectors to provide quick indication of incidents.

Disadvantages:

- Incident-detection algorithms do not detect incidents; they use traffic data to detect congestion.
- Incident-detection algorithms have a high false-alarm rate as recurring congestion increases.
- They can only detect incidents that impact traffic flow.

Detection Algorithm Case Studies

TransGuide - From the TransGuide ITS Design Report (transguidewwwserver.datasys.swri.edu:80/articles/designreport.html)

Detection Algorithms

Various algorithms have been used to detect incidents in systems based on loop detectors. Manyof the algorithms are flexible in some ways and each has advantages and disadvantages. The designers of the TransGuide system have designed the system so the data necessary for several of the available algorithms is continuously collected. The system was also designed so the specific algorithm being used to detect an incident could be investigated using real-time data and, if desired, could easily be changed.

The selection of an initial incident detection algorithm focused specifically on the ability of the algorithm to rapidly detect incidents, even at the risk of a relatively high level of false alarms. The capability of the TransGuide system to verify incidents via the video subsystem is another reason that rapid detection of incidents has a higher priority than making sure that each alarm is actually an incident. Since the video subsystem is used for classifying incidents, there is also no requirement for the selected algorithm to do so. It is sufficient for the algorithm to detect incidents.

The algorithm used to generate alarms is flexible and can be tuned to trade off detection time and false alarm rate. The computer polls each LCU on a periodic basis þ the period of the poll defaults to 20 seconds, but can range from 10 to 60 seconds in 10 second increments. The computer generates an alarm based on a moving average of speed or occupancy þ the period of the moving average can range from 1 to 10 minutes, but defaults to 2 minutes. The moving average is compared with a threshold, which can be a default value or a defined value. Thresholds can be defined for detectors based on the specific time of day, day of the week, or day of the year.

For each detector or set of detectors, there are up to four thresholds at which alarms are generated. A minor alarm will be generated when the average speed is less than the speed minor alarm threshold. The speed minor alarm threshold defaults to 45 mph. A minor alarm will also be generated if the occupancy is greater than the occupancy minor alarm threshold, which defaults to 25 percent. A major alarm will be generated when the speed is less than the speed major alarm threshold, which defaults to 30 mph. A major alarm will also be generated if the occupancy is more than the occupancy major alarm threshold, with a default of 35 percent. These thresholds can be adjusted at 15-minute intervals to values derived from historical data. The algorithm described is expected to provide flexible, rapid detection of traffic incidents. Ananalysis being conducted as a separate part of the current operational test includes additional work on optimizing the detection algorithm. This analysis will also consider properties and capabilities of other existing algorithms.

Divert

Divert, a Minnesota Guidestar project, redirects traffic around freeway incidents by sending motorists off the freeways onto surface arterials and than back again. The system uses inductive loop detectors, CCTV, DMSs, and signal timing devices to direct traffic and lighten congestion (ITS World, Jan/Feb 1997).

Montgomery County

To rapidly identify and clear incidents, Montgomery County has established an advanced transportation management system that supports up to 1,500 traffic signals, 200 video surveillance cameras, and 3,000 sampling detectors in the roadways. Enhancing the monitoring capabilities of this system with a critical bird's-eye view is an aerial surveillance program, in action each morning and afternoon, that transmits live video footage of incidents and bottlenecks directly to the county's transportation management center.

Staffed with a pilot and a traffic technician, a government airplane circles the county, spotting incidents and quickly identifying their locations and circumstances. This instantaneous and precise information, fed automatically to the police and fire computer-aided dispatch system, alerts emergency agencies to the need for immediate response. The real-time information may also direct the transportation management center to optimize traffic flow with changes to traffic signals and variable message signs. During snowstorms or other crises, the transportation management center takes over a local cable television channel and updates conditions around the clock with video footage from aerial and ground cameras, sharing real-time traffic information with the traveler. Radio also broadcasts current traffic conditions.

b. *Electronic Sensors*

Electronic sensors are devices placed along the roadway to detect the presence of vehicles, speeds, occupancies, etc. This real-time data is then processed, using automatic processing techniques (e.g., detection algorithms, knowledge-based expert systems) to identify congestion resulting from incidents (nonrecurring congestion). The types of sensors used can be found in Section 2.6. The most commonly utilized detector for incident management is the inductive loop.

Advantages:

- Capable of continuously monitoring entire roadway section.
- Provides rapid detection, especially in high-volume conditions.

Disadvantages:

- Requires large capital investment.

- Long lead time involved in designing and implementing system.
- High maintenance costs.
- High false alarms in congested areas.
- Cannot detect non-congestion-causing incidents.
- Verification is necessary before any response plan is implemented.

c. *Motorist Devices*

Motorists use such devices as call boxes, CB radios, cellular phones, and other telephones at road-side to report incidents using special numbers.

Advantages:

- The devices that the motorist uses to report incidents are very accessible.
- Fast identification of incidents.
- Low false-alarm rate.
- High detection rate.

Disadvantages:

- Dependent on motorist input.
- Multiple calls may be received at the control center for the same incident.
- Information provided concerning the location and severity of incident may be unreliable.

d. *Freeway Service Patrol and Courtesy Vehicles*

These are special vehicles that patrol or circulate throughout an area to report incidents to the control center, as well as to assist vehicles that experience minor breakdowns.

Advantages:

- Such vehicles provide continuous patrol.
- Detect and verify incidents that occur on their path.
- Provide reliable information on location and severity of incidents.
- Can address minor incidents with no further assistance.

Disadvantages:

- A large amount of personnel is required to cover congested areas.
- Detection of incidents is a function of the headway between patrols in an area.
- Cannot detect incidents not on their route.
- Patrol vehicles also affected by congestion.
- May not be able to reach an incident if delayed by congestion.

e. *Fixed Observers*

These are personnel stationed in towers and/or tall buildings along congested highways for the purpose of observing traffic and identifying incidents. These observers report incidents to the control centers for further action.

Advantages:

- Fixed observers are a useful interim measure.
- Useful for special events or highway reconstruction.
- Reliable information.

Disadvantages:

- A large amount of personnel is required to cover congested areas.
- Detection of incidents is a function of the area covered.
- Detection is affected by severe weather conditions.
- May require construction of facilities where observers are stationed.

f. *Aerial Surveillance*

Aerial surveillance systems use fleets of aircraft (e.g., helicopters, small planes), usually retrofitted with video cameras, circulating above a metropolitan area during peak periods, to identify and report incidents, as well as to provide live video pictures.

Advantages:

- Aerial surveillance can cover a large area.
- Identifies and verifies incidents with the aid of video images.
- Reliable information.

- Can be used not only for detection of incidents, but also for obtaining information concerning traffic conditions on other roadways for possible traffic diversion.
- Can assist media in disseminating traffic information to the motorist.

Disadvantages:

- High capital cost.
- Costly to cover a large area for long periods of time.
- Affected by severe weather conditions.
- Time of detection is a function of headway of aircraft.

g. *CCTV*

CCTV surveillance systems, installed at numerous locations in the highways, use television cameras to detect and verify incidents. Section 2.7 provides a thorough discussion of these systems.

Advantages:

- CCTV systems can cover a large area, depending on installations.
- Effective verification method.
- Provide reliable information.
- Current technology of cameras has made it possible to receive good video images in severe weather conditions.
- Can use video images in disseminating information to motorist.

Disadvantages:

- High capital cost to cover a large area.
- Incident identification is a function of coverage.
- Can be used for incident identification, but this is a labor-intensive process.

CCTV Case Studies

TransGuide - From the TransGuide ITS Design Report (transguidewwwserver.datasys.swri.edu:80/articles/designreport.html)

Video as Incident and Message Verification

Once an alarm has been generated, the TransGuide video facilities will be used to verify and characterize the incident and to drive the dispatch of any necessary emergency services. The video capabilities of the system are based on a user controllable camera and lens system, which is used by the operators to view the scene of the incident. The video signal generated by the camera is converted for communications to the control center by video coder decoders (codecs). The video signal is reconverted and displayed on workstation Cathode Ray Tube (CRT) screens or on arrays of screens making up the video wall in the control room.

The video system provides the operators with a color, detailed view of an incident in daylight or at night. Multiple operators, such as police and VIA Metropolitan Transit Authority dispatchers, as well as TxDOT operators, can access a view of the scene simultaneously. The use of the system's video capabilities is fundamental to the successful operation of TransGuide. Several combinations of cameras, lens systems, codecs, monitors, and video display units were investigated by TxDOT. The subsystems selected satisfy the demanding video requirements of the TransGuide ITS.

Response and Clearance

a. *Communications*

The inability to communicate at the incident scene or to coordinate response among the agencies is one of the most common problems in incident response. It is caused by the absence of compatible communications equipment and by lack of knowledge of the response and communications protocols and procedures of other responding agencies. Jurisdictional and institutional turf issues often prevent or inhibit on-scene and off-scene communication necessary for the incident to be cleared efficiently, between participating agencies. A lack of understanding of the roles, resources, and abilities of the other agencies contributes significantly to the lack of willingness to communicate. Incompatible or antiquated communications equipment or lack of equipment prevents communication. Furthermore, the types of communications needed by agencies working together at the scene of an incident may be different or may require different protocols than those needed for routine communications within an agency.

Communication links needed to convey information quickly and accurately include: field-to-field (communications among personnel at the scene); field-to-dispatch (communications between personnel at the scene of an incident and personnel at their agency's dispatch or operations center); and dispatch-to-dispatch (communications between dispatch or operations centers of responding agencies).

1. *Conventional Radio* - often incompatible among agencies and may be antiquated. In addition, agencies need to coordinate purchases to ensure compatibility

2. *800 MHz Radio* - increasingly popular, with many agencies using this method of communication. It provides more capacity. There are, however, some compatibility problems and agencies still need to coordinate purchases to ensure compatibility. Also, this frequency makes it difficult for traffic reporters to scan communications.

3. *Single Emergency Frequency* - used to facilitate management of major incidents; however, protocols and conditions for use need to be defined.

4. *Cellular Phone* - can be of particular benefit for command-level persons to facilitate communications.

Driver Information

a. *Media*

Most motorist information is now broadcast over commercial AM and FM radio stations or on television newscasts. Cable television stations in some markets carry traffic information. In most major urban markets there are one or more radio/television stations that provide aerial coverage of traffic. Private traffic-reporting firms collect, package, and sell traffic information to the broadcast media in many urban areas. The media market is extremely competitive and many media outlets find that maintaining their own traffic-reporting services (e.g., airplanes) is too costly.

b. *Highway Advisory Radio*

These stations are primarily broadcast at 530 or 1610 kHz on the AM broadcast band, although the FCC will allow the use of other frequencies that are available. There are many users of traditional HAR frequencies in urban areas (e.g., airports, amusement parks) that can conflict with highway usage, and the range of broadcasts is usually limited. For more information on HAR, see Section 2.9.

c. *Dynamic Message Signs*

Dynamic message signs can be at fixed locations or they can be portable. They provide guidance information about diversions (e.g., local and regional information, alternate route information), warning of conditions ahead (e.g., incidents, congestion, long delays, lane closure), and dynamic information regarding unusual conditions (e.g., incidents, construction and maintenance activities, special events). For more information on DMSs, see Section 2.8

d. *In-Vehicle Displays*

These systems provide real-time information in the vehicle about traffic and road conditions to drivers by voice, video, or combination messages. For more information on in-vehicle displays, see Section 2.11.

e. *Videotext*

Videotext is the use of the vertical blanking interval in television broadcasts to transmit information.

f. *Telephone Dial-In*

Some areas (e.g., Boston) have telephone numbers for traffic information prepackaged to be route- or trip-specific. Listeners do not have to listen to traffic conditions across an entire area to choose the routes of interest. Other areas (e.g., Chicago) have traffic telephone numbers providing area-wide real-time information.

g. *Information Kiosks*

These are automated traffic-information units usually displayed on video monitors. They are typically located at shopping centers, employment centers, airports, hotels, car rentals, etc.

h. *Internet*

The Internet is fast becoming *the* information medium. Real-time traffic and road conditions are beginning to appear on the Internet as State and local agencies attempt to use this fast-expanding resource to provide motorists with information.

4.2 SURFACE ARTERIAL INCIDENT-MANAGEMENT SYSTEMS

Unlike freeway incident management, not much work has been performed in the research, development, and implementation of surface street incident-management systems. The issues involved in the detection of incidents on surface streets have not been clearly defined. As previously discussed, freeway-incident detection employs algorithms to identify incidents by using real-time traffic information (e.g., volume, occupancy, speed). On surface streets, such measures of traffic flow fluctuate continuously due in part to traffic signals, driveways, and other stops that disturb traffic flow. Other characteristics of surface streets that make incident detection at those locations different than freeways include: multiple access, interrupted flow, geometric constraints, control measures, operating conditions, and detector configurations.

With the development of and increasing interest in the deployment of the metropolitan intelligent transportation infrastructure, there is a push toward integrated systems. In a workshop on Surface Street Incident Detection held in Scottsdale, Arizona, on August 4-6, 1996 (sponsored by the FHWA and hosted by Oak Ridge National Laboratory), the need for research and development on incident-management systems for surface streets was the theme. Under the emerging concept of integrated traffic-management systems, surface street incident detection is receiving increasing attention. It is envisioned as an integral part of the metropolitan intelligent transportation infrastructure. Also, the evolving technologies and popularity of them on detection and surveillance systems (e.g., video image processing, wide area detection, cellular telephones, fuzzy logic) are providing new and exciting potential for the development of these systems.

Several algorithms have been developed for surface street incident detection. One such incident-detection system has been developed for the ADVANCE project discussed by Bhandari et al (1995). The components of the incident-detection system follow.

- Fixed-detector algorithm uses real-time and historic data provided by fixed detectors located on major arterials to classify conditions on the detectorized street as incidents or non-incidents.
- Probe vehicle algorithm uses travel time reports by probe vehicle and historic travel times on these links to interpret traffic conditions as incident or non-incident.
- Anecdotal algorithm uses information provided by emergency personnel and other motorists on the network to detect incidents in real time.
- Data fusion algorithms combine the output from the fixed detector, probe vehicle, anecdotal algorithms, and the operator interface.

- Duration and impacts module determines the expected duration of the incident and the impacts on the incident link travel times.
- Operator interface allows the Traffic Information Center personnel to view the output from the data algorithms, and to key-in incident reports from other sources. The output from the duration and impacts module will be available to the operator for review.

The Smart Diamond project by the Texas A&M University, ITS Research Center of Excellence, is a research project on incident detection in a real-time traffic-adaptive control system using a fuzzy logic modeling technique. The model distinguishes abnormal conditions from random fluctuations under normal conditions by looking for abrupt changes in traffic measures. Measures employed include: queue length, speed, occupancy, and turning movements.

4.2.1 CASE STUDIES

Smart Corridor

The official opening of the Santa Monica Smart Corridor in Los Angeles was October 1996. The key element of this ITS demonstration project is incident management and the interagency coordination that occurs to make this happen. The agencies that have access to the Smart Corridor system are Los Angeles DOT, Caltrans, California Highway Patrol, Culver City, Beverly Hills, Santa Monica, and the Los Angeles County Metropolitan Transportation Authority. The surface street incident-detection system covers 800 instrumented links and more than 1,900 detectors. An expert decision support system develops incident responses in realtime that are based on changing traffic conditions. Alternative route diversions are displayed on DMSs, broadcast on HARs, and publicized through the media. In addition, signal timing plans and ramp-metering rates are changed to accommodate diversions.

The Arterial incident Detection system works by a method of time weighted data analysis. Volume and occupancy data from each system detector is gathered from the real-time traffic control system on a minute-by-minute basis and transmitted to the Smart Corridor system. The detector data is then combined into link data which is smoothed with data from the previous four minutes to obtain a sliding five minute average link value. This five-minute average link data is then compared to a matrix which represents the normal, congested, and maximum traffic values expected on this particular link. Data values outside the acceptable range are ignored, and those within range are given a persistence value. Over time, if traffic conditions warrant, the persistence value will increase, and ultimately an incident will be identified (David Roseman and Sean Skehan, 1995).

4.2.2 EVOLVING TECHNOLOGIES

Incident Management Algorithms

Automatic incident detection involves the collection of real-time traffic information and algorithms that interpret this information and establishes the presence of incidents. The algorithms most commonly used today are: the California and the McMaster algorithms. These algorithms have not been received and used widely by the traffic management industry as they have not performed favorably. New algorithms have been and are continuously being developed to overcome the deficiencies of the other algorithms. These are: statistical test (time-series smoothing analysis and filter theory to model traffic flow); knowledge-based expert systems (automated response); neural networks; image processing with artificial intelligence; fuzzy set theory.

SOURCES:

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