Incident Surveillance and Control on Chicago-Area Freeways

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Chicago Area Expressway Surveillance Project

Since 1961, Illinois has had considerable operational experience with surveillance and control of incidents occurring on Chicago-area expressways. In that year, the Illinois radio communications center was joined by two new units, the Emergency Traffic Patrol and the Expressway Surveillance Project, whose duties are to handle expressway incidents and increase expressway efficiency and safety by means of electronic traffic aids. The initiation and subsequent expansion of these three units recognized that urban freeways did not operate by themselves and that attention to continual maintenance and operational responsibilities was needed. This report describes various portions of the Illinois Department of Transportation program for reducing congestion, improving flow, increasing safety, expediting emergency responses, and providing motorist information. The considerable operational experience and refinements to date, as related to handling Chicago-area freeway incidents, are reflected in the contents.

As early as 1920, the importance of emergency traffic vehicles was recognized (1):

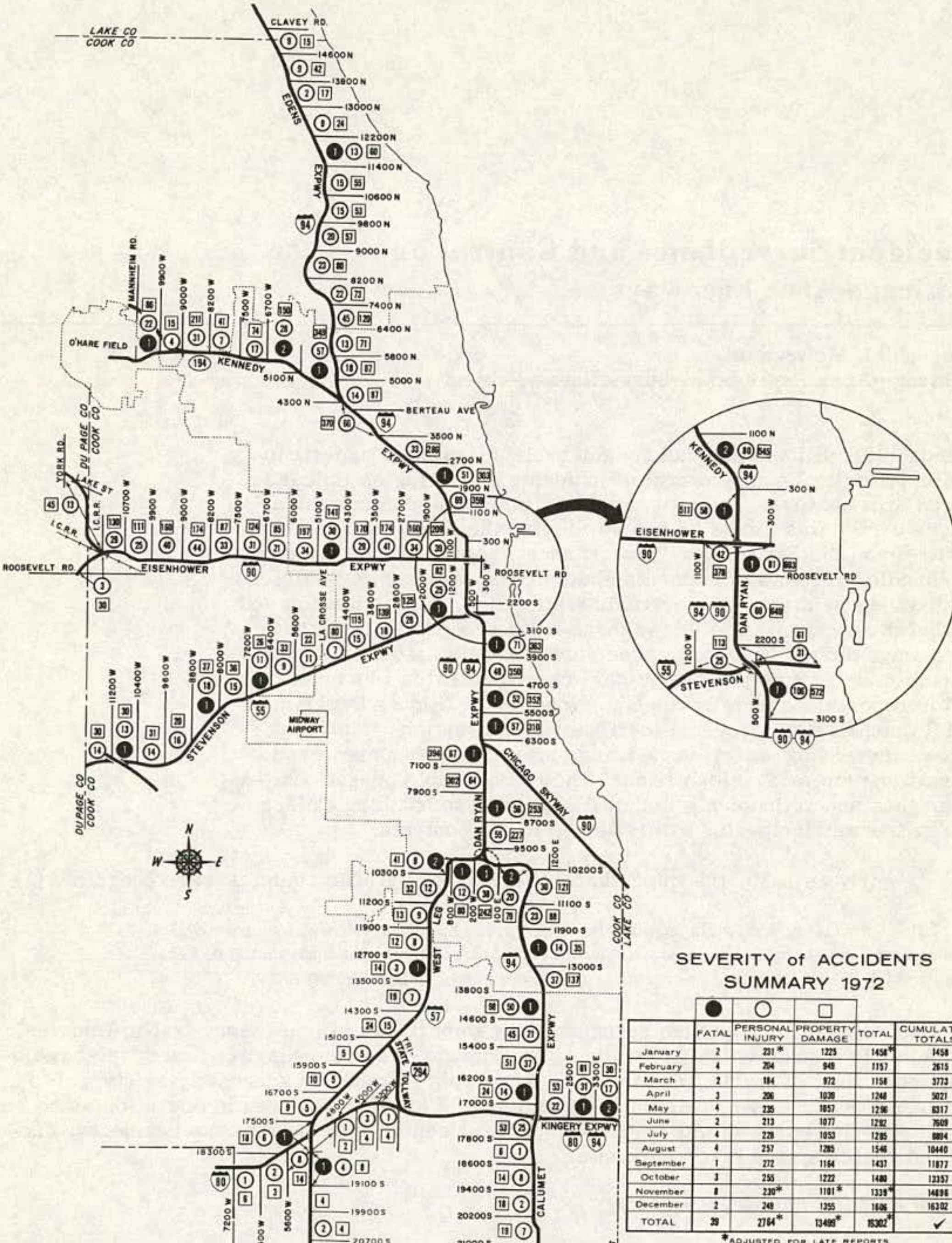
> Often vehicles break down in crowded thoroughfares at busy hours causing expensive delays. Emergency repair vehicles equipped with derricks and other suitable appliances should be kept on hand by all large cities as an economical measure to quickly relieve the trouble.

The state of Illinois also recognizes the importance of emergency traffic vehicles. The key to managing traffic incidents on Chicago-area expressways is a special radio-equipped fleet of trucks, continuously on patrol to promote expressway safety and to expedite traffic flow. This unique public patrol service has been in operation since 1961 and serves as an international model for coping with expressway accidents, disabled vehicles, and other incidents.

EMERGENCY TRAFFIC PATROL

The Emergency Traffic Patrol or minutemen provide mobile surveillance of 135 miles of the Chicago-area expressway system (Fig. 1) 24 hours a day, 7 days a week. In 1972, a complement of 135 people including 88 drivers and 21 foremen helped the patrol and its 56 vehicles log nearly 3,000,000 annual patrol-miles and assisted at more than 68,000 incidents.

Figure 1. 1972 Chicago-area expressway system accidents.



SEVERITY of ACCIDENTS
SUMMARY 1972

	FATAL	PERSONAL INJURY	PROPERTY DAMAGE	TOTAL	CUMULATIVE TOTALS
January	2	231*	1225	1458*	1458
February	4	204	949	1157	2615
March	2	184	972	1158	3773
April	3	206	1039	1248	5021
May	4	235	1057	1296	6317
June	2	213	1077	1292	7609
July	4	228	1053	1285	8894
August	4	257	1285	1546	10440
September	1	272	1164	1437	11877
October	3	255	1222	1480	13357
November	8	230*	1101*	1339*	14696
December	2	249	1355	1606	16302
TOTAL	39	2764*	13499*	16302*	✓

*ADJUSTED FOR LATE REPORTS

The primary objective of the emergency patrol fleet is to keep moving lanes clear of accident vehicles, disablements, and debris. Secondary patrol duties include

1. Assisting at accident scenes by rendering first aid, calling for police, fire, ambulance, or special equipment services, helping to extricate trapped or injured persons, and supplementing police traffic control;
2. Removing accident and nonaccident debris from the roadway by calling for extra clean-up help or special equipment, sanding oil slicks, and removing or assisting with removal of dead animals, large or small dropped items, and spilled loads;
3. Assisting motorists by towing disabled vehicles and abandoned vehicles from hazardous locations, providing gasoline, tire changing aid, and water for overheated radiators, calling for repair service, lending tools for minor repairs, getting other help, and notifying other parties;
4. Establishing emergency traffic detours and controls by placing appropriate temporary traffic cones, barricades, signs, and lights and closing ramps or lanes;
5. Assisting at special expressway maintenance or construction work and traffic routings by protecting workmen placing traffic controls and helping to route presidential motorcades;
6. Reporting traffic information to the Communications Center for distribution to operations personnel and the news media;
7. Reporting faulty state property including damaged signs, fencing, and guardrails, inoperative signals and lighting, pavement defects, and drainage problems;
8. Warning pedestrians to keep off the expressway and notifying enforcement authorities when persons or vehicles do not voluntarily comply with patrol requests; and
9. Providing travel information such as directions and road conditions and map reading assistance to motorists seeking aid.

Services

The patrol vehicles are equipped and the drivers are trained to handle almost any emergency incident likely to occur on Chicago-area expressways, including accidents, disabled vehicles, and small fires. The service is termed emergency because assistance is directed toward actual emergencies and hazardous situations. Enough help is provided to remove or reduce the exposure to high-volume, high-speed traffic. Towing, for example, is only for moving vehicles to shoulders or frontage roads; the motorist must arrange for private towing from there.

The patrol drivers are not mechanics and do not repair disabled vehicles. However, they do provide gasoline, water, air for tires, and the loan of some small tools, which help many disabled motorists get to a service station or garage. All patrol services are free of charge except for gasoline. Upon receipt of 2 gallons of emergency gas, a motorist is presented with an invoice requesting that $2.50 be mailed to the state. More than 75 percent of these charges have been voluntarily paid.

Operations

The patrol fleet of 56 vehicles includes 27 tow, 14 flatbed, and 12 pickup trucks. The basic truck for 41 units has a 1½-ton chassis capable of handling a gross weight of 18,000 pounds (Fig. 2). Equipped with two-way radio, public address system, tow rig, pusher bumpers, rear pintle hooks, and numerous truck and driver equipment items (Tables 1 and 2), each unit represents an expenditure of nearly $9,000. The 1974 budget for patrol personnel and equipment was nearly $1.5 million.

In 1972, the 88 drivers operated over 18 routes on overlapping shifts, which provided a minimum of 25 rush-period patrols. The patrol routes also overlap (Fig. 3) to increase coverage of high-incident sections, such as a 2-mile-long bridge without shoulders on the Dan Ryan Expressway. Foremen patrol the entire system, usually in

Figure 2. Emergency patrol vehicles and operations.

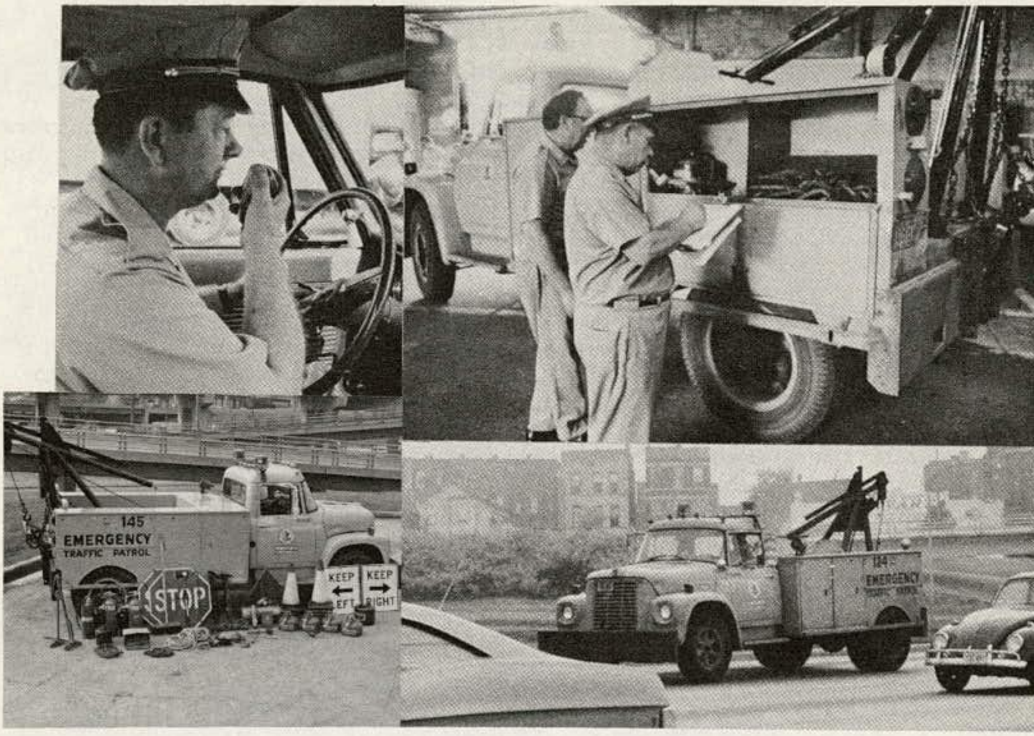


Table 1. Patrol truck equipment.

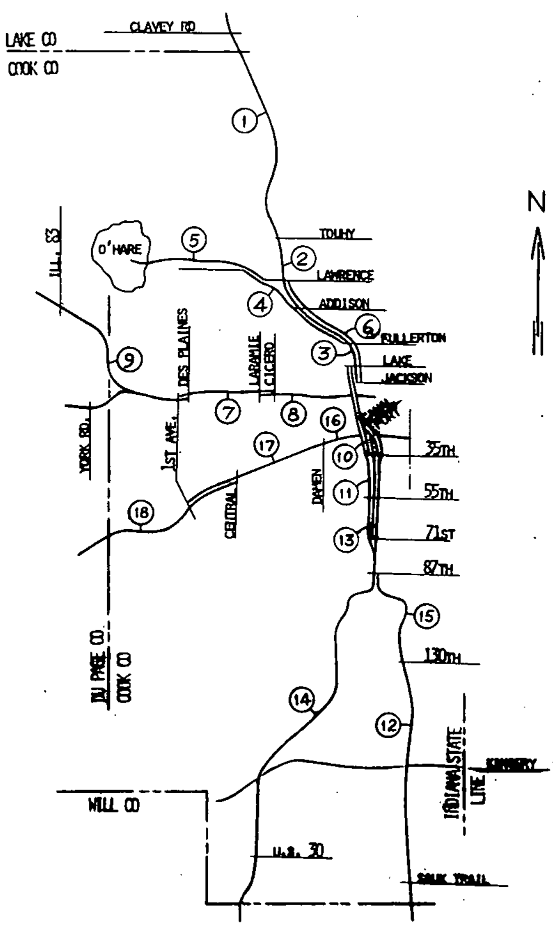
Item	No.	Item	No.
Overhead carrier	1	Snatch blocks	2
Mars lights	2	100 ft of $^{3}/_{8}$-in. rope	1
Dietz lights, No. 510	2	50 ft of $^{5}/_{8}$-in. rope	1
Spot mirrors	2	$^{1}/_{4}$-in. rope	1
12-S flasher can	1	$^{3}/_{8}$-in. tow chain	1
Push-pull switches	2	$^{1}/_{2}$-in. tow chain	1
Fuse block	1	Long wrench	1
Complete first aid kit	1	Rubber mallet	1
$2^{3}/_{4}$-lb purple K powder fire		Tire chocks	1
extinguisher	1	Tripod	1
20-lb CO_2 fire extinguisher	2	Bumper jack	1
Fire axe	1	Traffic signs	
Pry bar	1	KEEP RIGHT	1
5-gal water can (summer)	1	KEEP LEFT	1
2-gal emergency gas cans	4	STOP	2
Air pressure tank	1	Traffic cones	10
Toolbox	1	Red flag	1
Hammer	1	Fuses	36
Common pliers	1	Highway maps	10
Channel lock pliers	1	Whisk broom	1
Wire cutter	1	Paper towel	1
Adjustable 10-in. wrench	1	Shovel	1
Phillips screwdrivers	2	Street broom	1
Screwdrivers	2	Bags of sand	10
Linoleum knife	1	Bags of salt (winter)	10
Electric tape	1	Hand cleaner	1
Wire (stove pipe)	1		

Table 2. Patrol driver equipment.

Item	No.	Item	No.
Utility coats	2	Flashlight	1
Zip-out lining	1	5-in. wand	1
Winter cap	1	Flashlight batteries	2
Garrison cap with 2 covers	1	Clipboard	1
Winter trousers	3	Code cards	2
Winter shirts	3	Badge and shield	1
Summer trousers	5	State shoulder patches	12
Summer shirts	5	Rain jacket	1
Eisenhower jackets	2	Rain pants	1
Neckties	3	Rain cap cove:	1
Safety vest	1		

Note: Uniforms have been replaced with coveralls with reflective safety stripes and hard hats.

Figure 3. Emergency patrol routes (day shift).



pickup trucks, and provide supervision, guidance, and assistance to the patrol drivers. They also help direct special traffic operations, such as changing the coning and barricades for reversing the flow on the Kennedy Expressway.

Driver Training

To handle the various duties and hazards common to urban freeway operations, patrol personnel receive special training in patrol procedures and operational techniques. Periodic classes provide training in basic first aid, fire fighting, state and city police coordination, radio communications, basic traffic control, equipment use and emergency procedures, Chicago Transit Authority operation (rail transit in expressway medians), highway nomenclature and area geography, expressway design and operation essentials, and other related subjects. Completion of a trainee's curriculum requires a month of on-the-job training in a patrol vehicle with an experienced professional.

Assist Characteristics

The patrol reported 68,474 assists in 1972 for the following causes:

Problem	Percent
Vehicle disabilities	77.2
Accidents	14.9
Abandoned vehicles	3.0
Nondisabilities	1.1
Pedestrians	0.4
Fires	0.3
Debris/other	3.1

Vehicle disabilities were of the following problem types:

Problem	Percent
Fuel/mechanical	34.0
Tire	27.3
Out of gas	12.7
Cooling system	10.3
Electrical system	7.4
Unknown/other	8.3

Incident Coordination

Unlike units that must be activated for emergencies, the patrol is always on the job but may or may not be in the right place at the right time. The Illinois Department of Transportation Communications Center serves as the coordination unit for the patrol, handles all incoming reports of incidents, and, through a separate patrol radio frequency, directs the nearest available patrol unit to the scene. The Communications Center maintains radio or direct telephone links with the Chicago police, the state police, Chicago Fire Department, Expressway Surveillance Project, Chicago Traffic Engineering Center, Illinois Tollway Commission, other Illinois DOT vehicles on two additional radio frequencies, and local radio stations operating private traffic helicopters or with traffic hotlines. More than 20,000 radio messages a month are logged by the patrol fleet.

The electronic surveillance network, described later, picks up problems that disrupt expressway traffic flows and that may or may not have been reported by the patrol or other sources. After electronic surveillance identifies troubled expressway sections, the patrol is directed by radio to the problem site to expedite the removal of flow-reducing incidents. There have been cases in which electronic incident detection has resulted in response action beginning 15 to 20 min before the problem was reported through another source. On the other hand, the patrol assists at thousands of incidents that do not noticeably disrupt traffic flows, possibly because the patrol action prevents minor but hazardous situations from developing into more serious problems.

ELECTRONIC SURVEILLANCE AND CONTROL

The Expressway Surveillance Project was established to investigate electronic techniques of achieving more efficiency and safety on existing expressways, particularly in regard to the problem of rush-period traffic congestion. The initial efforts of the project were directed toward installation and use of a pilot detection system for monitoring traffic flow on a short section of the Eisenhower Expressway. In 1962, a total of 25 ultrasonic detectors were installed to monitor the outbound flow along 5 miles of the Eisenhower Expressway. Each detector in the study section was connected via telephone lines to its own analog computer located in the nearby surveillance center. This initial electronic surveillance effort led to the collection of detailed data, which helped to define specific problems and their relations to traffic flow characteristics.

Congestion Causes

There were three general causes for congestion on urban freeways: (a) numerous random incidents, such as accidents, disabled vehicles, and debris on the pavement, that occur at any time at any place; (b) overloading during rush periods (especially at particular entrance ramps or along certain sections where several ramps contributed to the overloading); and (c) highway geometrics that, for one reason or another, create weaknesses in the traffic stream, particularly at high demand levels.

An example of poor geometrics is a lane reduction in which traffic demands approaching the lane reduction exceed the capacity of the downstream section, such that the lane reduction is a physical bottleneck. Another example is an upgrade crossing a river or some physical barrier that requires changing from a depressed to an elevated cross section. Although such upgrades may be 3 percent or less (within design standards), under peak flows with trucks in the traffic stream the geometrics in such sections obviously impose a much lower capacity than adjacent level, tangent sections that may be feeding the traffic.

The problem does not simply involve finding solutions to the three general causes for traffic congestion, primarily because the causes can operate either independently of or in combination with one another. In rush periods, for example, all three causes may compound congestion to the extent that the relative contribution of each cause is difficult to ascertain.

Congestion Solutions

To develop solutions for the congestion problem, however, requires that each cause be approached independently. In the case of poor geometrics, parts of the highway system can be changed or reconstructed to deemphasize the impact of deficient geometrics. A lane reduction, for example, can be corrected by adding an extra lane. Because the expressway surveillance effort has been based on trying to get more efficiency and safety with the existing geometrics, however, attention has been directed primarily toward the other two causes of congestion.

Solving the overloading problem requires techniques that decrease expressway traffic demand or increase expressway capacity or both. The most practical effort thus far has been management of expressway demand by controlling entrance ramp traffic. Experiments on metering entrance ramps, initiated in 1963, have resulted in an operational program that now covers 48 ramps.

Figure 4. Electronic surveillance and control network.

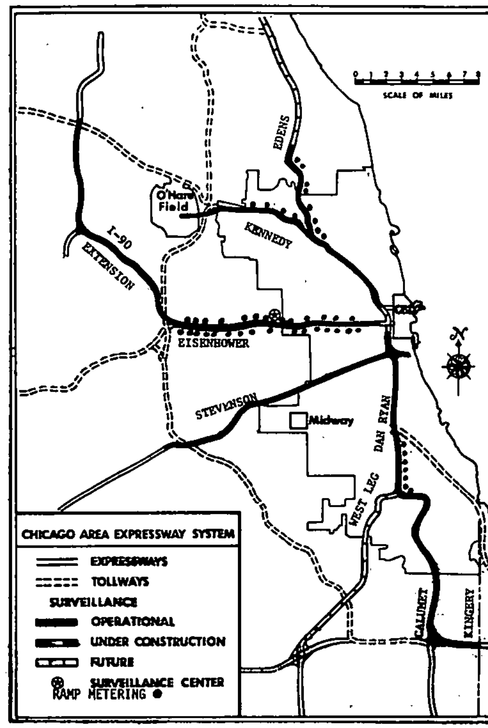
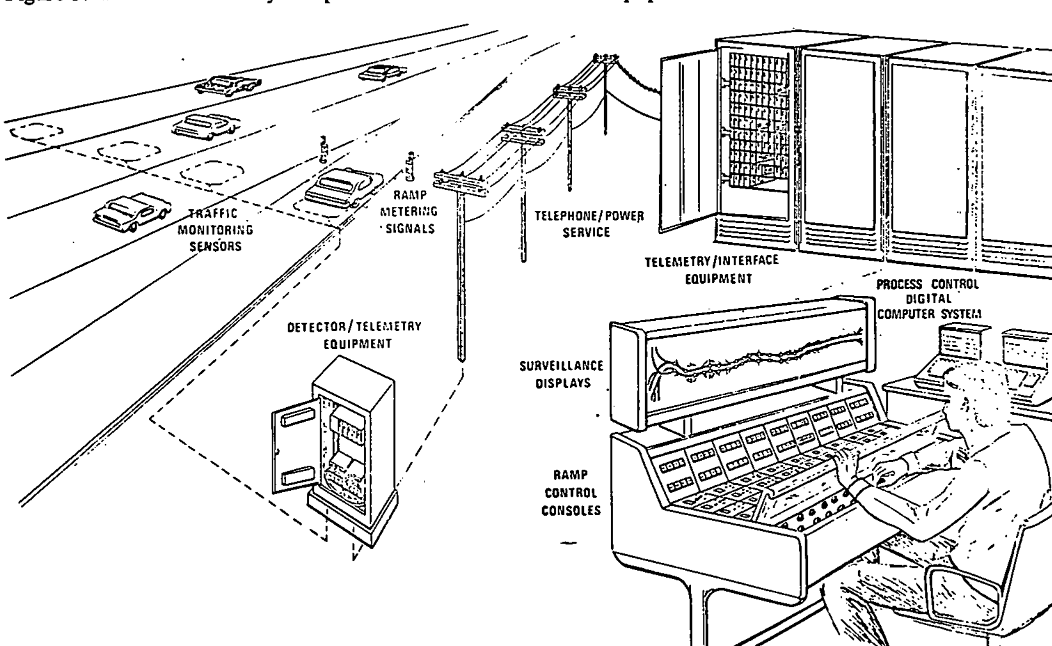


Figure 5. Detector-telemetry-computer surveillance and control equipment.



Solving the incident problem requires surveillance and service: surveillance to find out that there is a special incident to take care of and service to respond to that incident as quickly as possible with the resources needed to restore normal conditions. Describing the electronic and patrol surveillance and control systems and the capabilities and procedures for detecting and handling operational incidents represents the major portion of this report.

Coverage

From the pioneer experiments with blind detector-telemetry-computer surveillance of traffic flow and the development of ramp metering, the Expressway Surveillance Project has provided the Chicago area with the world's largest computerized freeway surveillance and control network. The 1962 pilot detection system has been expanded to monitor traffic flow at more than 1,300 main-line and ramp points along 90 miles of expressway (Fig. 4). This network handles up to 267,000 vehicles per day at some points and serves approximately 13 million vehicle-miles of travel daily.

Eventually, electronic surveillance will cover all 110 miles of freeway nearest the central city. All instrumented routes are radial with Chicago's CBD and handle extensive commuter trips in both directions during the rush periods. The central computer system for handling this network has been operational since January 1971. Design of a building to house surveillance equipment and staff is currently near completion for a site near the present leased facility.

Instrumentation

Freeway surveillance and control are accomplished through a detector-telemetry-computer network. All the detectors used in the system are presence induction loops embedded in the pavement. The loops are located in each of the main-line traffic lanes at about 3-mile intervals. At approximately ½-mile intervals, one of the center lanes is sampled with a loop. Loops are also provided on all entrance and exit ramps. This detector arrangement gives a surveillance of flow on the main line at about ½-mile intervals and produces a closed subsystem every 3 miles in which all main-line and ramp input and output counts are recorded. Such an arrangement facilitates multipurpose use for surveillance, ramp control, and system evaluation.

The field locations of detectors depend on the availability of phone and power service, which is usually readily available around urban interchange areas. All surveillance and control points in a particular service area are brought to a roadside cabinet through underground interconnect systems. Each roadside cabinet contains detector amplifiers, power supplies, and telemetry equipment for placing detector signals onto leased telephone lines (Fig. 5). By using frequency-division multiplexing techniques, as many as 22 channels can be used for data transmission on each telephone line. Because there may not be 22 detector or other signals for any one service location, multipoint techniques are used to connect adjacent locations to one phone line, so as to maximize use of the telephone line and to minimize leased line costs.

Each detector location has a tone transmitter in the roadside cabinet to encode the detector presence pulse from the detector amplifier on the phone line at a selected frequency. The leased telephone lines (C-1 conditioned) transmit detector signals to the surveillance center, located centrally to minimize communications costs. At the surveillance center, the signals are decoded by tone receivers at the matching frequency for each detector. The tone telemetry equipment in the office decodes and identifies each detector signal and interfaces each pulse into a known position in the surveillance computer.

The digital computer, an industrial process control machine of the type commonly used in steel mills and paper plants, scans the status of each traffic detector 60 times a second. Inasmuch as all detectors are of the presence type, for each scan the computer interrogates the binary status of each detector: Is there a vehicle present or not?

By keeping track of the changes of state from yes to no, the computer records vehicle detection data and calculates volume and lane occupancy for each detection point.

Lane Occupancy

The basic measurement at each surveillance point is lane occupancy, i.e., the percentage of time the detection zone is occupied by a vehicle. The loop detection equipment for measuring lane occupancy also produces lane volume. Although speed is not measured directly, it can be calculated from lane volume and lane occupancy by assuming an average vehicle length for vehicles in the traffic stream (Fig. 6).

Lane occupancy is a most convenient measurement, for it is a summary parameter that includes all the basic aspects of the traffic stream. It considers the volume, speed, and composition (vehicle lengths) of the traffic stream as a whole. Lane occupancy can range from 0, when there is no traffic present, to 100 percent, when there are vehicles continuously in the zone of detection. There should always be some traffic, even at 4:30 a.m., such that the normal operational range is above 0 percent. It is also rare to reach 100 percent lane occupancy, even under stoppage conditions, because there are always gaps between vehicles and usually some movement of the traffic stream.

The basic measurement of lane occupancy gives an indication of traffic stream operations at each detection point. With detectors along each roadway at about ½-mile intervals, sampling the flow at points along the route gives an estimate of overall system operations.

Flow Characteristics

Generalized traffic operations curves show that the optimum peak-period flow condition is 20 percent lane occupancy where traffic speeds near the speed limit coincide with the highest flow rates. Occupancies less than 20 percent indicate flow generally near the speed limit; the corresponding volumes represent demand ranging from zero up to the maximum. This 0 to 20 percent range of flow conditions is referred to as green or free flow.

To sustain the rush-period ideal of 20 percent lane occupancy requires that 80 percent of the traffic stream consist of gaps to keep vehicles moving at high volume and high speeds. Although volume can maintain its maximum throughput, an increase in lane occupancy from 20 to 30 percent causes speed decreases because of (a) fewer and shorter gaps available between vehicles, (b) the increasing difficulty of lane changing, and (c) generally more restrictive flow conditions. These 20 to 30 percent flow conditions are referred to as yellow or impending congestion.

In excess of 30 percent lane occupancy, traffic flow conditions are referred to as red or congested. Speeds continue to degenerate, and volume also decreases. In this red zone, the higher the lane occupancy is, the worse the situation is. High percentages of lane occupancy indicate serious operational problems, such as an accident, a disabled vehicle, or other obstruction to the traffic stream.

Traffic Status Displays

The green-yellow-red zones of operation are used as a convenient on-line expressway surveillance output. The central computer system is used in real time to drive map display panels that indicate through colored lights the green-yellow-red zone of operation for one main-line detector at ½-mile intervals along each expressway direction. A glance at the map displays gives an instant overview of current operations for the entire instrumented expressway system. In off-peak periods, the complete system should operate in the green zone. Any exceptions are clues to operational incidents that require response. In rush periods, a normal pattern of congestion is expected at recurrent bottlenecks. Patterns different from normal indicate operational incidents.

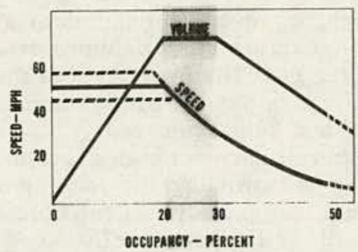
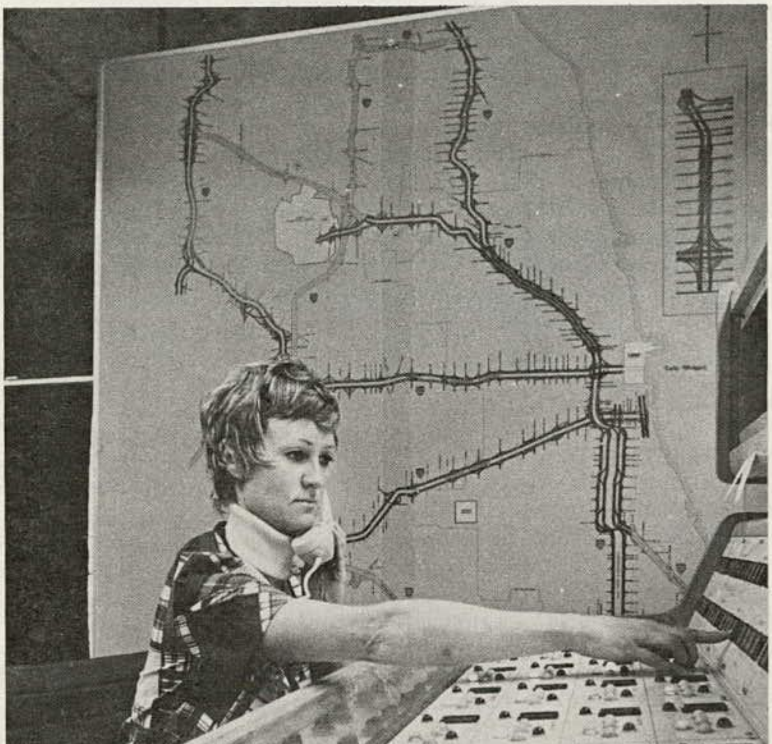


Figure 6. Generalized freeway traffic flow characteristics (one lane).

Figure 7. Map display and ramp control console at surveillance center.



The traffic status displays, however, only summarize the prevailing conditions for main-line traffic. For further information or more detail, the computer system has several peripheral devices for real-time retrieval of the actual traffic flow data. A red condition, for example, can be inspected to determine whether the actual lane occupancy is a 32 percent red or a 74 percent red.

Because the electronic surveillance network grew one expressway at a time, there initially was one map display unit provided for each expressway. Recent expansions consolidated all the individual map panels into one Chicago-area display (Fig. 7). A duplicate area map display allows the green-yellow-red conditions, generated at the suburban Oak Park Surveillance Center, to be repeated via phone line and time division scanning techniques at the Illinois DOT Communications Center in downtown Chicago at Marina City, about 8 miles distant. The Communications Center operates three radio frequencies, coordinates all traffic and maintenance information and operations, including the Emergency Traffic Patrol vehicle fleet, and is staffed 24 hours a day, 7 days a week. Remote duplication of the area map displays at the Communications Center allows the surveillance office to staff only during rush periods and normal working hours, usually each weekday from 5:30 a.m. to 7:00 p.m.

The electronic surveillance displays are the primary sources of expressway traffic condition information disseminated to the public. Both the surveillance center and the Communications Center handle numerous daily telephone requests for traffic information, primarily from commercial radio stations incorporating the information into traffic broadcasts. In March 1974, computer-generated expressway congestion reports were made available to commercial radio stations providing their own remote teleprinters and interconnect with the surveillance computer.

Traffic Control

Traffic flow problems, pinpointed through the electronic surveillance system or reported through other sources, are responded to by a fleet of expressway emergency patrol trucks, operated by the Illinois DOT. These trucks are continuously on patrol and provide mobile surveillance and assistance for all incidents and potentially hazardous situations. When trouble is initially spotted through the electronic surveillance system, the Communications Center dispatcher requests the closest available patrol truck to investigate the site of the traffic flow disruption.

In addition to detection of and response to incidents during rush periods, the direct control of entering traffic demands is effected through expressway ramp metering at 48 entrance ramps on five expressways. In the morning rush period, all 23 inbound and 10 outbound ramps are metered; in the afternoon, all 25 outbound and 8 inbound are metered. The surveillance computer is programmed to operate each ramp metering signal in an automatic one-vehicle-at-a-time mode, which varies the entrance ramp flow rate in response to prevailing traffic conditions on the expressway and ramps. Signal timing is accomplished in the surveillance center, and the commands for ramp signal changes are transmitted to the field via the same phone line feeding detector data to the computer.

Although aimed primarily at recurrent rush-period overloads, ramp metering can provide additional relief during expressway incident situations, particularly where bypass routes are readily available. The amount of relief, however, usually cannot overcome major losses in system capacity.

Computer Capabilities

The process of traffic surveillance, incident response, and ramp metering produces beneficial effects on the traffic stream. Such effects become measurable through changing the traffic flow data, which become a new input to the surveillance system. The computer capability for recording data is the basic source for evaluating the impact of particular control measures on the traffic stream.

The central processor unit has a 32-K memory with a 24-bit word. Most of the data collected through the central processor is transferred to bulk storage on two magnetic disks that have 1,000,000-word capacity each. The primary function of the computer system is to drive the on-line, real-time components, such as the surveillance map displays, ramp metering control rates, and real-time data output or retrieval peripherals. Two CRT video units, two typers, and a line printer allow data to be continuously presented or retrieved through the keyboard from the computer in real time and displayed either on the CRT screens or as hard copy on the typers or the line printer. Most real-time information has a time base of 1 min or less, is used for operational purposes, and is not retained per se unless needed for some particular application.

The surveillance computer system also has a free-time feature that allows data processing and analysis in time periods not required by on-line, real-time functions. The system peripheral devices, particularly a card reader and card punch, are in free-time periods.

Daily Printouts

The usual practice is to store summary data from all detectors for a 24-hour period on the two disk units. Each day three printouts are routinely dumped out on the line printer. The first of these is a printout of traffic counts by hour for each detector in the surveillance system. These data serve as quantitative traffic trend records, as answers to requests for traffic count data from various agencies and researchers, and as a means for locating equipment problems for maintenance. The other two daily printouts are traffic operations performance records for each of the two rush periods.

For the 5 to 10 a.m. rush period, the lane occupancy readings from one main-line expressway detector, at each ½-mile interval, are summarized into 5-min averages. Printouts for each direction for each expressway are similarly retained for the 2 to 7 p.m. rush period. The lane occupancy data on these printouts give a picture of the overall performance for each rush period in terms of the distance versus clock-time pattern of traffic flow, including the effects of any incidents (Fig. 8). Each rush-period printout is further summarized by computing the total minute-miles of congestion, which is a convenient tag for rating the performance each day relative to every other day.

Implementation Philosophy

Implementation of freeway surveillance and control in the Chicago area reflects the experience gained since 1961. The surveillance system, featuring the basic loop presence detection, leased phone line interconnect with the central computer, and tone telemetry signal communications, is installed as the initial backbone component. When operational, the surveillance system provides real-time incident detection, which aids the emergency patrol service, and data collection and evaluation capabilities, which help define overloading conditions warranting ramp control or geometric improvements.

Ramp control can be added later to the backbone surveillance system by installing two ramp traffic signals, two additional ramp detectors, buried interconnect, cabinet, and tone equipment at each entrance ramp. Additional freeway and ramp detection can be provided if research demonstrates that increased sophistication is worth the cost. The backbone surveillance system can be used to evaluate the operational effect of ramp control implementation and other electronic traffic aids added on an experimental or operational basis. Examples of other electronic components are changeable-message signs, automatic reversible roadway control, and motorist aid systems.

AUTOMATIC INCIDENT DETECTION

Illinois has had considerable experience with developing and using various large-scale, real-time incident detection strategies. The electronic surveillance system is used to continuously scan various traffic flow parameters, in an attempt to automat-

Figure 8. Typical rush-period lane occupancy printout.

10-13-72 FRI
OUTBOUND EISENHOWER EXPRESSWAY OCCUPANCY CONTOUR MAP

<- <- TRAFFIC <- <-

ENVIRONMENTAL DATA

62°, DRY
PARTLY CLOUDY

TIME	WLF	HLL	WMN	EMN	ADD	25	17	5	1	DPR	DPA	HAR	EST	AUS	CEN	LAR	CIC	KOS	IND	NOM	SAC	WES	OAK	PAL	RAC	MOR	M/W MMILE
1405	0	11	14	12	13	19	12	16	13	18	21	17	11	15	9	16	9	13	10	11	16	15	14	15	17	12	0,0
1410	0	10	13	11	11	18	11	15	11	16	21	15	12	18	10	18	11	15	11	12	17	12	12	14	16	12	0,0
1455	0	9	13	11	12	18	12	16	12	18	24	18	15	28	10	19	12	16	13	18	21	14	14	14	34	14	2,5
1500	0	9	13	11	12	20	14	19	13	18	24	16	13	35	13	19	13	17	16	14	19	16	14	15	17	12	2,5
1505	0	11	15	12	15	22	13	16	12	18	24	18	16	34	25	25	15	18	13	13	16	16	15	15	15	13	2,5
1510	0	11	14	12	13	19	12	17	13	25	26	19	15	32	29	24	20	17	13	15	20	18	16	13	37	9	5,0
1515	0	11	15	12	14	21	14	18	14	22	25	19	17	33	25	25	16	18	13	13	18	16	14	14	26	11	2,5
1520	0	11	17	13	15	24	16	18	14	21	27	18	14	33	29	25	19	17	14	14	19	16	14	13	35	11	5,0
1525	0	10	18	14	14	22	15	18	14	20	26	19	14	33	38	33	17	16	12	13	18	14	14	15	28	12	8,4
1530	0	12	19	14	16	25	15	18	13	19	24	17	15	39	32	30	20	15	13	16	25	15	14	15	24	11	8,4
1535	0	13	16	12	14	22	13	19	13	19	26	20	15	38	41	35	17	17	15	16	23	13	13	12	27	9	8,4
1540	0	13	20	21	15	24	15	18	14	19	24	17	14	35	38	32	26	17	16	14	19	15	14	13	15	10	8,4
1545	0	14	24	22	15	22	16	20	14	19	29	19	16	32	34	42	25	28	20	13	18	15	16	16	18	12	8,4
1550	0	14	22	19	16	27	17	19	13	21	27	20	15	37	27	34	23	29	23	16	21	17	16	16	15	13	8,4
1555	0	13	19	16	15	24	15	17	14	19	25	18	15	38	30	30	22	21	27	23	23	17	16	20	15	12	8,4
1600	0	13	19	18	15	23	14	20	15	18	24	17	15	36	30	30	18	28	25	18	27	27	16	14	15	10	8,4
1605	0	11	20	19	16	24	15	21	13	17	27	19	15	33	32	34	25	28	20	21	26	20	18	11	12	9	8,4
1610	0	16	24	24	18	23	13	23	20	23	33	18	15	33	26	31	24	29	17	21	29	16	15	13	37	11	13,4
1615	0	14	24	27	20	29	16	26	23	21	34	19	16	40	24	32	21	30	21	25	28	27	15	15	34	12	19,1
1620	0	14	24	28	24	28	23	23	22	22	38	19	14	39	36	34	20	29	23	19	31	29	21	15	35	12	15,9
1625	0	15	21	20	27	35	27	21	15	20	40	31	15	35	30	28	24	28	25	26	28	29	24	14	46	10	21,3
1630	0	14	19	16	26	39	31	27	16	20	34	23	15	36	25	31	23	35	21	26	32	28	23	14	49	11	26,6
1635	0	12	19	16	30	37	32	25	23	33	40	17	16	38	34	30	23	42	24	27	26	28	22	11	53	9	28,5
1640	0	13	22	17	33	40	32	28	28	26	34	27	15	37	31	33	28	32	24	27	25	24	17	16	49	13	25,6
1645	0	15	22	20	27	38	30	26	27	26	41	36	16	41	32	34	24	33	25	32	34	21	17	16	44	11	40,3
1650	0	14	22	17	28	35	32	27	25	26	40	37	23	37	33	38	34	37	21	24	31	32	16	12	48	12	38,6
1655	0	20	21	18	28	36	29	25	30	26	36	42	22	40	33	33	31	35	25	28	28	26	22	15	32	11	34,6
1700	0	14	25	28	26	32	29	25	25	24	37	44	29	35	35	38	23	33	24	32	39	24	15	13	53	10	37,8
1705	0	13	26	26	29	37	30	27	25	21	38	36	32	51	39	34	23	37	25	25	29	31	14	12	43	9	34,8
1710	0	17	26	29	28	42	30	27	23	28	41	35	17	42	51	39	21	32	32	30	30	23	14	13	38	11	40,3
1715	0	15	29	27	28	41	32	29	35	26	37	42	16	42	46	40	32	39	23	33	46	28	16	13	28	[illegible]	45,2
1720	0	14	28	27	27	39	37	33	32	25	36	44	27	44	42	44	34	41	26	22	24	35	27	13	26	11	39,7
1725	0	14	24	27	26	34	31	30	40	25	42	42	38	44	40	40	36	37	30	31	31	21	18	13	33	[illegible]	47,7
1730	0	15	24	22	28	39	33	26	32	25	36	33	31	43	40	38	28	41	32	33	33	28	15	11	[illegible]	9	47,7
1735	0	13	23	22	27	28	37	36	37	25	35	43	27	48	37	40	28	33	27	27	31	17	12	12	20	10	37,2
1740	0	15	25	27	25	31	27	27	41	31	36	38	35	40	39	40	30	41	30	27	28	12	10	11	10	9	36,0
1745	0	15	22	26	30	32	29	31	32	23	37	46	26	48	32	41	40	40	31	29	24	12	11	12	12	11	42,7
1750	0	13	24	23	23	29	29	26	32	22	37	36	35	43	43	38	25	36	29	18	16	12	11	10	11	10	29,6
1755	0	13	22	25	26	30	26	27	28	22	36	42	29	39	45	36	27	26	17	14	13	11	10	11	12	10	21.6
1800	0	13	24	26	25	31	26	24	35	25	32	31	32	43	38	31	19	10	7	18	15	11	10	11	11	9	26,4
1805	0	15	27	27	27	34	26	33	36	27	38	35	27	41	37	28	8	10	8	20	13	11	10	10	10	8	28,8
1810	0	13	22	28	25	31	13	25	36	31	36	44	15	43	23	13	9	13	13	23	14	11	12	11	11	10	20,5
1815	0	13	24	28	24	31	18	25	17	21	37	38	17	40	30	18	12	14	12	12	14	13	13	12	11	10	18,8
1820	0	16	26	24	24	32	16	18	14	21	34	29	38	20	44	22	10	13	11	12	16	12	12	12	25	9	18,8
1825	0	13	25	24	28	33	24	16	14	22	34	25	20	44	19	25	10	12	10	11	14	10	10	11	11	9	7,5
1830	0	17	23	28	25	31	27	16	14	22	39	29	15	36	17	13	8	12	10	9	12	12	11	11	11	9	7,5
1835	0	14	21	21	21	24	16	20	16	20	33	28	14	14	9	16	10	12	9	10	13	10	11	12	10	10	5,0
1840	0	14	26	23	18	23	16	19	19	17	33	16	14	21	7	13	8	11	9	10	13	11	11	11	13	8	2,5
1845	0	16	26	27	25	27	16	18	13	16	20	14	10	12	8	14	9	11	9	10	13	11	11	12	10	9	0,0
1850	0	13	28	26	23	27	14	15	12	15	19	12	10	13	8	14	8	11	9	10	14	10	9	9	10	8	0,0
1855	0	13	30	27	16	24	15	14	11	15	21	14	10	13	7	15	9	12	9	9	12	12	11	12	11	8	2,5
1900	0	9	26	15	6	9	7	25	18	14	20	12	10	13	7	13	8	10	9	8	12	9	9	10	11	9	0,0

ically identify locations of possible traffic incidents as quickly as possible, with a minimum of false alarms.

Although the traffic status displays of the surveillance system are available for monitoring by operational personnel and further traffic data, both current and prior, can be retrieved for analysis, particularly through use of CRT devices, automatic incident detection is aimed at converting as much manual observation and data checking as possible to computer logic. Such logic analyzes available real-time data to quickly and reliably signal occurrence of a traffic incident. The following general criteria are important to any automatic incident detection scheme:

1. Highest possible detection rate,
2. Fastest possible response time,
3. Lowest possible false alarm rate, and
4. Minimum manual input.

On-Line Experience

Initial automatic incident detection efforts were based on operational experience in spotting traffic incidents from the surveillance map display conditions, particularly sudden significant differences in traffic flow characteristics between adjacent mainline expressway stations. To develop computer logic for detecting incidents required that we determine which basic traffic data (occupancies and volumes of various possible time bases) and features derived from them would most effectively quantify the incident occurrence pattern. The threshold values that, when attained by these features, define the occurrence of a traffic incident could then be optimized. Also considered in initial phases were various checks on data validity and means for evaluating the performance of logic using different time bases, features, and threshold values.

The electronic surveillance network includes nearly 400 main-line incident detection subsystems, i.e., pairs of adjacent sampling detector stations approximately ½ mile apart. Based on the traffic volume and occupancy for each station and the time base variations available, the size of the surveillance network suggests concentration on subsystem upstream and downstream station changes.

One problem with signaling incidents is the wide range of normal operations common to daily traffic flows. Such normal conditions as rush-period overloads, environmental changes, geometric conditions, and faulty surveillance equipment components can mimic the traffic flow characteristics associated with the random traffic incidents requiring detection and response. In addition, there are incidents that self-correct or become removed before response arrives on the scene. In these cases, however, there is no way of knowing at the time of detection, for example, whether a stalled vehicle blocking the pavement will remain until the response arrives.

Primarily by using subsystem station occupancies, 14 variations of basic pattern recognition schemes have been tested and calibrated on-line. Various modifications in time base, features, and threshold values have been implemented. The computer output typer automatically signals possible incidents and prints associated pertinent data. The primary result of on-line, systemwide experimentation with various schemes has been the identification of inputs needed for formulating, evaluating, calibrating, and refining candidate models for operational use.

Logic Evaluation

Although on-line testing has served to define the traffic incident detection framework, it has been impossible to evaluate various schemes because field verification and documentation of all signaled incidents are not possible. Therefore, we plan to use off-line testing of various schemes on a standardized and fully documented data base, including incidents and verified nonincident periods. The off-line efforts will enable comparison of different logic schemes on the same data base as well as optimization of each logic's parameters on the same data.

Effort, in addition to logics, will be made to formulate and test logic schemes based on forecasting and time series analyses. Other specific objectives on the off-line testing will be intensive study of the two major difficulties encountered on the on-line work: electronic equipment malfunctions and highway geometric problems that mimic traffic incident situations. One approach to handling the locations with geometric weaknesses is to determine special threshold values. For the equipment problems, faulty equipment characteristics will be identified to signal maintenance needs and to remove stations from incident consideration.

The experience with on-line testing of incident detection models has pointed out the unreality of most reported off-line tests. One example of the difference between on-line and off-line environments is seen in the acceptance of a 1 percent false alarm level in much of the literature. This rate would produce 17,280 false messages a day for a 20-sec base logic scheme using 400 detector subsystems. Thus, although the more easily documented off-line testing approach will be pursued, contact will be maintained with the on-line environment in which the operational model must perform.

Applications

For the Chicago area, the initial response to expressway incidents is the radio-equipped emergency patrol vehicles. The primary application of automatic incident detection is deployment of these vehicles to reduce response time. Secondary applications include incorporation into ramp metering strategies and driver information techniques such as changeable-message signing and advisory traffic reports.

Currently two interim logic schemes for automatic incident detection are being used on-line. Although problems with regard to their completely automatic operation remain to be solved, these logics provide relatively reliable incident occurrence information, when supplemented with various manual checks.

MOTORIST INFORMATION

Illinois has conducted comprehensive driver attitudinal surveys and has had operational experience with real-time motorist information techniques. One of the requirements for management of traffic incidents is to give drivers information on changing traffic conditions.

Radio Traffic Reports

Since the research surveys pointed out that most commuting drivers listen to radios at home and en route, a great potential for reaching motorists appeared to be through traffic reports on commercial radio stations. Historically, several Chicago-area radio stations have provided public service traffic reports, based either on private ground and helicopter surveillance or on information obtained through the state Communications Center or from various other sources and techniques.

With expansion of the electronic surveillance network, several radio stations requested the current traffic conditions depicted on the traffic status displays, and the Expressway Surveillance Project prepared for directly outputting basic computer-generated traffic information on a remote teleprinter network serving commercial stations. Such communications appeared to have great potential for improving the timeliness, accuracy, and quality of expressway traffic reports, particularly since the electronic surveillance covers all routes in real time and is not limited by the frequency of other coverage methods.

In March 1974, the state notified all Chicago-area radio and TV stations of the availability of a teleprinter service consisting of receive-only, computer-generated traffic reports, as often as each 5 minutes, listing only the significant expressway congestion areas. In effect, this report averages the surveillance map display readings every 5 minutes, on a continuous 24 hour-a-day basis, and prints out the location limits when two or more adjacent, or once removed, locations are congested (red) (Fig. 9). Each radio station provides its own teleprinter, modems, and leased phone lines for hookup with the surveillance computer. Thus far, five of the major AM radio stations are using this service as a source of motorist information reports.

As part of the automatic teleprinter network, the state plans to add two transmit-receive units, one each at the Oak Park Surveillance Center and at the Marina City Communications Center. These units will allow the addition of manual keyboard messages for incidents confirmed by the Emergency Traffic Patrol and for other supplemental data. Each of the state centers would communicate back and forth with each other, particularly with regard to investigating suspected incidents, with selective confirmed information released to the receive-only network.

Off-Freeway Signing

In connection with 1965 ramp control experiments in the Chicago area, the Expressway Surveillance Project installed advisory information signs at four surface street locations in advance of nearby expressway interchanges. The purpose of the signs was to advise expressway-bound motorists of real-time expressway and ramp traffic conditions. When conditions warranted, the motorist could be diverted to parallel alternate routes. At each sign, color-coded information depicted current conditions for the nearest interchange and for the next downstream interchange. In cases where traffic congestion was depicted, the motorist could consider taking an alternate route to the

Figure 9. Typical remote teleprinter traffic congestion report.

```
                    CONGESTION LIMITS 05-03-74 FRI
0600
IB RYAN EXP     ROOS   ->TYLOR*
0610
IB RYAN EXP     87TH  -> 83RD      21ST  -> ROOS
0615
IB RYAN EXP     90TH  -> 83RD      26TH  -> ROOS
0620
IB RYAN EXP     * 95TH -> 83RD
0625
OB KENNEDY      KIMBAL ->ADDSON
OB IKE          CENTRL ->AUSTIN
IB RYAN EXP     * 95TH -> 79TH     29TH  -> 21ST
0630
OB KENNEDY      KIMBAL ->ADDSON
OB IKE          CENTRL ->AUSTIN
IB IKE          W.MANN ->E.MANN
IB RYAN EXP     90TH  -> 87TH      29TH  -> 21ST
0635
OB KENNEDY      KIMBAL ->ADDSON
OB IKE          CENTRL ->AUSTIN
IB IKE          HILSDE ->E.MANN
IB RYAN EXP     90TH  -> 83RD      29TH  -> 21ST
IB RYAN LOC     55TH  -> 51ST
0640
OB KENNEDY      DIVRSY ->SACRAM
OB IKE          LARAME ->AUSTIN
IB IKE          HILSDE ->E.MANN
IB RYAN EXP     * 95TH -> 75TH     29TH  -> ROOS
0645
OB KENNEDY      WESTRN ->DIVRSY    KIMBAL ->ADDSON
OB IKE          LARAME ->AUSTIN
IB IKE          HILSDE ->E.MANN     9TH  ->  1ST
IB STEVENSON    HARLEM ->6900 W    5100 W ->PULASK
IB RYAN EXP     * 95TH -> 83RD     26TH  -> 21ST
IB RYAN LOC     55TH  -> 51ST
0650
OB KENNEDY      BELMNT ->ADDSON
OB IKE          LARAME ->AUSTIN
IB IKE          W.MANN ->E.MANN     9TH  ->  1ST
IB STEVENSON    HARLEM ->6900 W    CENTRL ->PULASK   HOYNE  -> WOOD
IB RYAN EXP     * 95TH -> 79TH
0655
OB KENNEDY      BELMNT ->ADDSON    NAGLE  ->HARLEM
IB KENNEDY      W.CUMB ->E.HAR
IB IKE          HILSDE ->E.MANN
IB STEVENSON    7500 W ->6900 W    CENTRL ->PULASK   HOYNE  -> WOOD
OB RYAN EXP     *TYLOR -> 16TH
IB RYAN EXP     * 95TH -> 71ST     29TH  -> 16TH
IB RYAN LOC     55TH  -> 51ST
0700
OB KENNEDY      SACRAM ->ADDSON    AUSTIN ->HARLEM
IB KENNEDY      E.HAR  ->SAYRE
IB IKE          W.MANN ->E.MANN     9TH  ->  1ST
IB STEVENSON    7500 W ->PULASK    CALIF  -> WOOD
IB RYAN EXP     * 95TH -> 79TH
0705
IB EDENS        WILSON ->MONT *
OB KENNEDY      SACRAM ->ADDSON    FOSTER ->NAGLE
IB KENNEDY      CANFLD ->SAYRE     CICERO ->MONTRE
```

EXAMPLE

At 6:35am, the outbound Kennedy Expressway congested from Kimball Ave. through Addison St., the outbound Eisenhower, Central thru Austin, etc.

next interchange, or at least to the next sign, where additional advisory information was available.

These advisory signs, aimed at repeat users in rush periods, produced marginal results. Although motorists passing the signs responded in a questionnaire survey that they understood and used the signs, actual traffic pattern changes due to information shown on the signs were not perceivable enough to be significant. After 5 years of experimental use, the four signs were deactivated from real-time surveillance computer operation. Three months later, without any interim public inquiries in regard to nonoperational signs, the signs were removed. There also have not been any public inquiries about the signs since their removal.

On-Freeway Signing

In followup driver information research, two attitude surveys (totaling 940 Chicago-area motorists) indicated that drivers feel that freeway traffic information is desirable and that on-freeway changeable-message signs are a preferred means of presentation. Because such signing would be added to the electronic surveillance and control network, Illinois has a research project for testing and evaluating one real-time, changeable-message, on-freeway sign in the Chicago area.

Current efforts consist of monitoring other changeable-message sign projects and preparing signal tests for demonstrating remote prototype sign control via interface with the surveillance computer and through manual override. After signal tests and experimentation are conducted with one actual sign, the results will determine the utility of future traffic information aids of this type.

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REFERENCES

1. Eno, W. P. The Science of Highway Traffic Regulation, 1899-1920. Brentano's, April 1920.
2. McDermott, J. M., Kolenko, S. J., and Wojcik, R. J. Chicago Area Expressway Surveillance and Control: An Interim Report. Chicago Area Expressway Surveillance Project, Report 25, March 1975.
3. McLean, C. H. Public Information Problems in Urban Interstate Operation. Institute of Traffic Engineers, Compendium of Technical Papers, 42nd Annual Meeting, 1972.
4. McLean, C. H. Chicago Expressway Traffic Patrol. Presentation to HRB Freeway Operations Committee, July 1970.
5. McLean, C. H. Illinois "Minutemen" Keep Traffic Moving on Expressways. Traffic Safety, January 1964.
6. Dudek, C. L., Messer, C. J., and Nuckles, N. B. Incident Detection on Urban Freeways. Transportation Research Record 495, 1974.
7. Cook, A. R., and Cleveland, D. E. Detection of Freeway Capacity-Reducing Incidents by Traffic Stream Measurements. Transportation Research Record 495, 1974.
8. Hoff, G. C. Development and Evaluation of Experimental Information Signs. Chicago Area Expressway Surveillance Project, Report 18, 1968.
9. Heathington, K. Interim Report: On the Development of a Freeway Driver Information System. Chicago Area Expressway Surveillance Project, August 1969.
10. Hoff, G. C. A Comparison of Selected Traffic Information Devices. Highway Research Record 366, 1971.
11. Heathington, K. W., Worrall, R. D., and Hoff, G. C. An Evaluation of the Priorities Associated With the Provision of Traffic Information in Real Time. Highway Research Record 336, 1970.
12. Heathington, K. W., Worrall, R. D., and Hoff, G. C. An Analysis of Driver Preferences for Alternative Visual Information Displays. Highway Research Record 303, 1970.
13. Heathington, K. W., Worrall, R. D., and Hoff, G. C. Attitudes and Behavior of Drivers Regarding Route Diversion. Highway Research Record 363, 1971.
14. Everall, P. F. Urban Freeway Surveillance and Control: The State of the Art. Federal Highway Administration, U.S. Department of Transportation, June 1973.