INFLUENCE OF INCIDENTS ON FREEWAY QUALITY OF SERVICE

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Disabled vehicles in moving traffic have a significant effect on freeway operations, particularly during peak periods. This report quantifies, for the Gulf Freeway in Houston, the impact on operations by relating frequency, duration, and flow passing freeway incidents. Data were collected for weekdays only during daylight hours by utilizing the 6½-mile coverage of the Gulf Freeway television surveillance system. During a 2-year period, 1,154 accidents and 1,117 stalls in moving lanes were observed. It was found that the average accident required 19 min from the time of reporting to removal from traffic lanes and an additional 26 min for police investigation. Stalled vehicles were removed within 18 min after being reported to the police. One-minute traffic volumes were measured for normal conditions and at bottlenecks created by incidents. The study section has 3 lanes in each direction of travel with a normal directional peak-period flow of 5,560 vehicles per hour. It was found that incidents created a reduction in flow disproportionate to the physical reduction in roadway width. The average flow rate was 2,750 vehicles per hour with 1 lane blocked by an accident; 2,880, with 1 lane blocked by a stalled vehicle; 4,030, with an accident on the shoulder; and 1,150, with 2 lanes blocked by an accident. Delay for hypothetical morning peak-period incidents are presented to illustrate the magnitude of motorist delay. A stalled vehicle caused a delay of of 1,610 vehicle-hours, while the 1-lane accident and 2-lane accident caused delays of 2,940 and 4,620 vehicle-hours respectively.

•ONE of the greatest losses of efficiency experienced on urban freeways results from disabled vehicles in moving traffic lanes. The congestion and accompanying delay to other freeway vehicles resulting from a reduction in capacity are, in most cases, more significant than the incident that causes the congestion. This paper correlates 2 studies relating to traffic incidents on the Gulf Freeway in Houston. These studies were conducted by the Texas Transportation Institute as part of the research project, Freeway Control and Driver Information Systems, sponsored by the Texas Highway Department in cooperation with the Federal Highway Administration. The studies were concerned with the frequency and characteristics of lane-blocking freeway incidents, and the measurement of traffic flow through the bottlenecks created by freeway traffic incidents. A correlation of the 2 studies gives an indication of the total impact of traffic incidents on freeway operation.

STUDY SITE

The Gulf Freeway in Houston was selected for the studies because of the extensive surveillance system existing there. The Gulf Freeway Surveillance and Control System includes an entrance ramp control system, a data acquisition and control computer, and a 14-camera, closed-circuit television system with video tape recorder. In the 6½-mile study section, the Gulf Freeway cross section consists of six 12-ft lanes and a 4-ft wide median with guardrail.

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STUDY METHOD

Incident Characteristics Study

An accurate log of freeway incidents was maintained for 2 years (1968-1969) on the 6½-mile section of the Gulf Freeway under television surveillance. A high degree of accuracy in maintenance of the log was possible because of the existence and use of the television system. Police officers assigned to the center maintained the log on weekdays between 6:00 a. m. and 6:00 p. m. When an incident occurred, and during its handling and clearance, the officer made appropriate entries in the log of time, events, and conditions (Fig. 1). If police action was required at the scene for incidents such as accidents and vehicles stalled in traffic lanes, the officer used a base station radio to report the incident to the police dispatcher. An accurate time trace of events was then available for all incidents occurring during daylight hours on weekdays. Data from the incident logs for 1968 and 1969 were coded, keypunched, and analyzed by digital computer.

Flow Study

This study measured traffic flow through the bottleneck created by an incident. Because the freeway incident is an unscheduled and essentially random event, the collection of data in similar studies has been difficult, if not infeasible (1). The television surveillance system, equipped with a video tape recorder, provided a means of studying an incident almost from the time of occurrence. When an incident was observed, the appropriate remotely controlled television camera was positioned on the scene, and the video tape recorder was switched on. Normally the recorder was on within 2 to 3 min after the incident occurred. The incident scene was recorded while the vehicles were in moving lanes and, in the case of accidents, while the accident remained on the freeway shoulder during police investigation. It was then possible to manually transcribe flow data from the video recording at a later time. These volume counts taken from the video recording were summarized for 1-min periods. In order that flow through

HOUSTON POLICE DEPARTMENT
GULF FREEWAY TRAFFIC - SURVEILLANCE

DATE June 18, 1968 DAY OF WEEK Tuesday

OFFICER R.G. Gartman HOURS 6:30-3 OFFICER E.E. Ellis HOURS 3:00-6:30 OFFICER _____ HOURS _____

TYPE INCIDENT	LOCATION & DIR. OF TRVL.	LANES INVOLVED	LANES BLOCKED	TIME OF DAY OBSERVED	UNIT ARRIVED	OBSTRUCTION REMOVED	TOTAL TIME OBSTRUCTED	TRAFFIC NORMAL	INVEST. COMPLETED	WEATHER CONDITIONS	REMARKS
Stall Truck	EB Griggs Ramp	Ramp	Ramp	7⁴⁰ AM	8⁰¹ AM	9⁰² AM	82 min.	9⁰⁵ AM	9⁰⁵ AM	Dry/Clear	Mech. Prob.
Minor Accident	EB Griggs	#1	#1	8³⁵ AM	8³⁸ AM	8⁵⁵ AM	10 min.	9¹² AM	9¹⁶ AM	Dry/Clear	4 veh. Rear End
Minor Accident	OB Lombardy	#1	#1	10⁵⁰ AM	—	10⁵⁷ AM	7 min.	10⁵⁹ AM	10⁵⁹ AM	Dry/Clear	2 veh. Left scene
Minor Accident	OB Wayside	#1	#1	2²⁰ PM	2:27 PM	2³¹ PM	11 min.	2⁵⁵ PM	3¹² PM	Dry/Clear	3 veh. Guard rail
Minor Accident	OB Lombardy	#3	#3	2⁵⁸ PM	3⁰⁰ PM	3⁰⁰ PM	2 min.	3⁰⁸ PM	3³¹ PM	Dry/Clear	Rear End

Form No. 18259 7/68

Figure 1. Daily incident log for Gulf Freeway Surveillance and Control Center.

TABLE 1

INCIDENT SUMMARY FOR 1968-1969 ON WEEKDAYS FROM 6:00 a. m. TO 6:00 p. m.

Incident	Frequency	Percent
Stalls	1,117	47.6
Injury accidents	63	2.7
Noninjury accidents	1,091	46.6
Lost load	37	1.6
Other	35	1.5

TABLE 2

LANES BLOCKED BY INCIDENTS

Lane Blocked	Stalls		Accidents	
	Number	Percent	Number	Percent
Outside	432	38.7	244	21.2
Center	231	20.7	204	17.7
Median	299	26.8	284	24.6
Two lanes	8	0.7	111	9.6
Three lanes	0	0.0	22	1.9
Ramp	134	12.0	238	20.6
Other	13	1.1	51	4.4

the bottleneck would be a reflection of capacity rather than demand, volume counts were made only when a queue of unsatisfied demand existed upstream from the incident.

DATA ANALYSIS

Freeway Incident Log

Results of an analysis of the incident log for a 2-year period are presented in this section. The magnitude of the disabled vehicle problem is given in Table 1. It should be remembered that the log was maintained on weekdays from 6:00 a. m. to 6:00 p. m. and does not include night or weekend incidents on the Gulf Freeway. Lane-blocking accidents and stalls are approximately equal in frequency. Approximately 4.5 lane-blocking incidents occur each weekday during daylight hours.

The number of lanes blocked by stalls and accidents is given in Table 2. A greater proportion of stalls occur in the outside lane, whereas accidents are more uniformly distributed across the 3 lanes and ramps.

The average noninjury accident directly affects traffic for approximately 45 min. The sequence of events of a typical accident with average duration of each step is as follows: (a) detection and reporting of accident to police, estimated to be 1.0 min by using television; (b) location, dispatch, and travel by police to scene unit, 12.0 min; (c) clearing of accident vehicles from traveled lanes, 7.0 min; and investigation by police, 25.6 min.

Statistical data for these elapsed times are given in Table 3. Accident data were not stratified for weather conditions, accident severity, police work load, or other factors that influence accident removal. These factors contributed to the relatively high variances given in Table 3. Data for stalled vehicles were treated in a similar manner, and the results are also given in Table 3.

Flow Study

Bottleneck flow data were available for 27 incidents that yielded 1-min volume counts for a total of 517 min. Flow data were classified into 6 categories of incidents for analysis: 1a, noninjury accidents blocking outside lane only; 1b, noninjury accidents blocking center lane; 1c, noninjury accidents blocking median lane; 2, stalled vehicle blocking 1 lane; 3, accident blocking 2 lanes; and 4, accident removed to shoulder. In

TABLE 3

ELAPSED TIME STATISTICAL DATA FOR ACCIDENTS AND STALLS

Time Interval	Sample Size	Mean Time (min)	Standard Deviation
Accidents			
Observed to police arrival	810	12.0	10.8
Police arrival to accident removal	597	7.0	11.9
Removal to investigation complete	903	25.6	19.1
Stalls			
Observed to police arrival	314	9.4	9.8
Police arrival to stall removed	285	8.9	14.5

TABLE 4

SUMMARY OF FLOW DATA AT FREEWAY INCIDENTS

Condition	Sample Size (no. of min)	Range (veh/min)	Average Flow (veh/min)	Standard Deviation (veh/min)	Average Flow Rate (veh/hour)
Normal flow	312	70 to 108	92.6	6.3	5,560
Noninjury accident, 1 lane blocked					
Outside lane	46	28 to 75	48.1	11.7	2,880
Center lane	42	18 to 77	42.7	11.4	2,560
Median lane	79	21 to 77	46.1	8.8	2,770
Combined	167	18 to 77	45.8	10.5	2,750
Stalled, 1 lane blocked	43	30 to 77	47.9	8.6	2,880
Accident, 2 lanes blocked	53	4 to 39	19.1	7.3	1,150
Accident on shoulder	254	20 to 102	67.1	13.1	4,030

TABLE 5

RESULTS OF F- AND t-TESTS FOR 1-LANE BLOCKAGES

Hypothesis[a]	F-Test			t-Test		
	F	$F_{0.05}$	Result	t	$t_{0.95}$	Result
Outside-center lane accident	1.05	1.47	Accept	2.07	1.99	Reject
Outside-median lane accident	1.80	1.53	Reject	1.12	1.98	Accept
Median-center lane accident	1.72	1.52	Reject	1.88	1.98	Accept
Any lane accident-any lane stall	1.46	1.55	Accept	1.23	1.96	Accept

[a]Flows passing the incidents are equal when lanes indicated are blocked.

addition to the incidents, 312 min of normal flow were measured downstream of the inbound Telephone Road entrance ramp (a geometric bottleneck) to provide a frame-of-reference service volume for the incident flow data collected. Table 4 gives the statistical data for each condition.

A 1-lane blockage by a minor accident or stall reduces flow by 50 percent, even though the physical reduction is only 33 percent (Table 4). The presence of an accident on the freeway shoulder reduces flow by 33 percent of normal flow because of the effect of the "gapers-block" phenomenon. An accident that blocks 2 lanes reduces flow by 79 percent (compared to 67 percent reduction of available freeway width). Thus, freeway incidents create a reduction in capacity that is disproportionate to the physical reduction of the facility.

Data indicated the possibility that flow past a 1-lane accident was independent of the lane blocked by the accident. To test this hypothesis F- and t-tests were conducted on paired data by lane (Table 5). This hypothesis was rejected by one or both of the tests at the 95 percent confidence level for all 3 pairs, indicating that it does make a difference which lane is blocked. The data for accidents blocking 1 land and for stalls were combined, and the hypothesis was tested that there was no significant difference in flow between accidents and stalls. This hypothesis was accepted at the 95 percent confidence level.

DISCUSSION OF RESULTS

The studies have defined, in operational terms, lane-blocking incidents (1-lane accidents, 2-lane accidents, and stalls) as well as the effect on flow of an accident removed to the freeway shoulder. A plot of cumulative volume versus time (2) was used to illustrate the time-flow-delay relationships.

Illustration of the effect of a 1-lane accident is shown in Figure 2 by using peak-period demand data for the inbound Gulf Freeway at Telephone Road. The slope of the service volume curve was derived from the average flow determined in the flow studies.

TABLE 6
DISTRIBUTION OF INCIDENTS BY TIME OF DAY ON WEEKDAYS

Hour Ending	Stalls (percent)	Accidents (percent)	Hour Ending	Stalls (percent)	Accidents (percent)
7:00 a. m.	4.4	3.8	1:00 p. m.	4.8	5.0
8:00 a. m.	13.8	11.7	2:00 p. m.	4.4	6.6
9:00 a. m.	8.5	10.1	3:00 p. m.	4.7	7.0
10:00 a. m.	3.3	3.9	4:00 p. m.	8.2	10.6
11:00 a. m.	3.2	6.0	5:00 p. m.	16.9	16.9
12:00 noon	4.7	5.2	6:00 p. m.	23.1	13.3

The area between the demand and service volume curves is an aggregate delay. Elapsed times for police incident-handling shown on the abscissa are averages obtained in the analysis of incident logs. It should be pointed out that these elapsed times are characteristic of the operation of a single police department only and no attempt was made to compare them with those in other cities. The time between occurrence of an incident and reporting it to the police was very short in this study because a police officer in the control center observed and reported the incident before the motorists reported it. Reporting time by motorists has been found to be on the order of 5 min (3).

For the 1-lane accident shown in Figure 2, delay to other motorists is 2,940 vehicle-hours. Similar computations for the other 2 incident types yield delays of 4,620 vehicle-hours for a 2-lane accident and 1,610 vehicle-hours for a stall. These examples are extreme, although not unrealistic, because they represent peak-period incidents. Incidents occur throughout the day (Table 6), and delay from them is highly variable, depending on demand. In addition, the estimated delay is liberal because no diversion of demand from the freeway was assumed. It has been observed that diversion of demand from the freeway to arterial streets frequently occurs when freeway level of service deteriorates below normal.

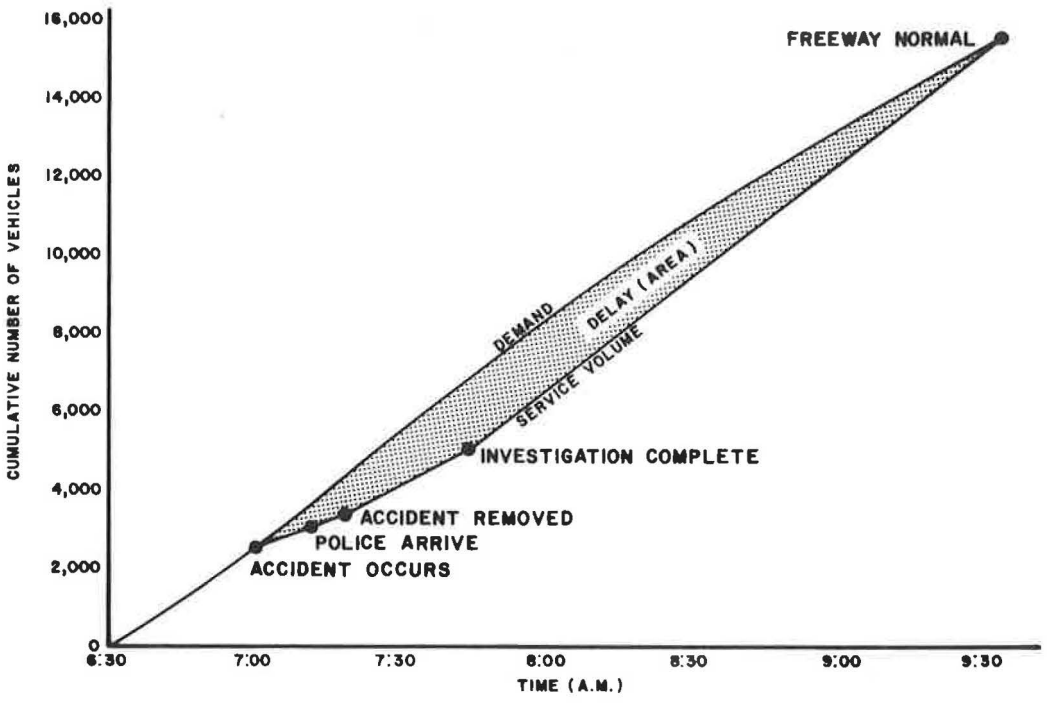

Figure 2. Example of time-flow delay relationships for an accident blocking one lane.

Operational procedures that reduce the time a freeway incident affects traffic will lead to substantial reductions in motorist delay. For example, a reduction of 2 min in the time required for accident detection or police response results in motorist savings of 411 vehicle-hours for the 1-lane accident shown in Figure 2.

SUMMARY

This report has quantified the frequency of incidents and illustrated the magnitude of motorist delay resulting from them on the Gulf Freeway. Even the most insignificant incidents that momentarily block traffic lanes may have a profound influence on freeway operations. An accident or stall that blocks 1 lane causes a reduction in capacity of 50 percent, even though the physical reduction is only 33 percent. The gapers-block phenomenon reduces capacity 33 percent, even though no physical obstruction exists.

Softening the impact of incidents can be accomplished in several ways: (a) rapid detection methods such as police patrols, surveillance systems, and motorist-aid systems; (b) reduction of reaction and response times of servicing agencies; and (c) streamlined handling and clearance procedures such as improved wrecker service, motorist removal of minor accidents, and accident investigation away from the freeway (4). Every means for reducing the frequency and impact of freeway incidents must be explored if freeways are to function as the high type of facility they were designed to be.

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