UCI-ITS-WP-88-7

Incident Characteristics, Frequency, and Duration on a High Volume Urban Freeway

UCI-ITS-WP-88-7

Genevieve Giuliano

Institute of Transportation Studies
University of California, Irvine

June 1988

Institute of Transportation Studies
University of California, Irvine
Irvine, CA 92697-3600, U.S.A.
http://www.its.uci.edu

1. INTRODUCTION

The management of congestion on the freeway system has become increasingly critical. Over the past decade, freeway demand has exceeded capacity in many areas. Constantly increasing travel demand generated by population and economic growth has been met with an essentially fixed infrastructure, as prohibitive costs and environmental concerns brought the highway building boom to an end. In some areas, congestion has reached critical proportions: "rush hour" conditions may prevail eight or more hours every weekday.

The regular or predictable congestion generated by excess demand is only part of the problem, however. Congestion is also generated by irregular occurrences, e.g., traffic accidents, vehicle disablements, and spilled loads. The few studies that have attempted to quantify the magnitude of this problem estimate that "non-recurrent" congestion constitutes somewhere between one-half to three-fourths of the total congestion on U.S. urban freeways (Kolenko and Albergo, 1962; Lindley, 1987). That is, traffic incidents generate at least as much motorist delay as peak-period congestion.

Traffic incidents reduce traffic flow either directly via lane closures or indirectly via "gawkers block"--motorists slowing down to look at the incident. As capacity is reduced, a queue of unmet demand develops. The extent of the queue depends on the level of demand during the incident, the duration of the incident, and the degree of capacity reduction. The larger the queue, the longer it takes for normal operation to be restored.

In response to rapidly deteriorating travel conditions in major metropolitan areas, there is renewed interest in developing better methods for managing non-recurrent congestion. Better methods can reduce either the duration of incidents or their effect on capacity, thereby reducing total delay. Despite the importance of this issue, however, few empirical studies of incident impacts have been conducted, and available information is limited.

The purpose of this paper is to analyze incident characteristics in a contemporary urban setting. Using data from the I-10 Freeway in Los Angeles, California, the analysis develops a model of incident duration as a function of incident characteristics. The results provide the basis for estimating congestion impacts of incidents on heavily traveled urban freeways. Section 2 of the paper presents a review of the previous literature. Section 3 presents the conceptual basis of the study, and the data are described in Section 4. Incident characteristics and frequency are discussed in Section 5; model development and duration analysis are presented in Section 6. The paper concludes with a discussion of the research findings and their implications for incident management policy.

2. PREVIOUS RESEARCH

The impact of incidents on freeway operation depends on many factors including their frequency, location, severity, time of day, and the level of usage of the facility. An incident is defined here as any occurrence that affects roadway capacity, either by obstructing travel lanes or by causing gawkers block. An extensive literature search revealed that surprisingly little data on incident characteristics is available.* Moreover, study results vary due to differences in study approach, data collection methods, study environment, and incident categorization.

Incident Rates

Incident rates vary widely from one location to another. Differences are due to factors such as land and road geometry, congestion, weather, grade, and shoulder availability (Lari, Christianson, and Porter, 1982). Definition problems and means of detection also contribute to variation. For example, incident rates from three U.S. studies are given in Table 1. Although

TABLE 1

INCIDENT RATES

Source	Location	Rate[a]
DeRose, Jr., 1964	John Lodge Expressway, Chicago	.014
Goolsby and Smith, 1971	Gulf Freeway, Houston	.010
MacCalden, Anderson, and Morshed, 1973	Bay Bridge, San Francisco[b]	.036

a Lane-blocking incidents/hour/lane-mile.
b No shoulders on Bay Bridge.

* A great deal of aggregate information on accidents is available in federal and state records. Studies of incident characteristics and impacts, however, are scarce.

incident rates are generally expressed as a rate per million vehicle-kilometers (MVKM), the only comparable measure that could be calculated for these case studies is incidents per hour per lane-mile. In all cases, these are lane-blocking incidents of all types, observed via closed-circuit television (CCTV). The substantially higher Bay Bridge rate is most likely due to the absence of shoulders. Differences are also due to traffic conditions, facility characteristics, etc.

Incident Type

Incidents can also be characterized by type. Categorization of incidents is not standardized, but generally two categories are distinguished--accidents and other incidents. Reported relative frequencies of incident types are highly varied, as illustrated in Table 2. Accidents are

TABLE 2

RELATIVE FREQUENCY OF INCIDENT TYPE

Source	Accidents	Other Incidents
Lane-Blocking Incidents		
DeRose, Jr., 1964	25%	75%
Goolsby and Smith, 1971	49%	51%
All Incidents		
MacCalden, Anderson, and Morshed, 1973	9%	91%
Juge and Thompson, 1978	6%	94%

less frequent than other incidents. The higher share of accidents among lane-blocking incidents is not surprising. Other incidents (e.g., vehicle disablements) often allow the driver to leave the traveled way immediately, or to reach the shoulder before the vehicle is completely disabled. The differences in Table 2 also may reflect reporting bias, as minor incidents (e.g., a vehicle that stops on the shoulder and leaves before any response occurs) may not have been included in the first study.

Incident Duration

More relevant to the issue of congestion impacts is incident duration. Duration data are very costly to collect, because field surveillance is required. Duration data can be constructed from highway police log records. However, these are difficult to access and may not include all incidents. The literature search revealed only three sources of U.S. duration data. As part of the John Lodge Freeway project, duration data were collected from logs kept by CCTV observers between June 1962 and June 1963. A total of 927 lane-blocking incident durations was analyzed. Accidents had an average duration of 6.14 minutes; vehicle disablements averaged 5.24 minutes (DeRose, 1964). It should be noted that these are durations for the time the vehicle remained in the travel lanes only, rather than duration of the entire incident. Furthermore, the sample includes many very short incidents which required no response, and thus would not be reported in highway police logs or be discovered by electronic detectors.

Goolsby and Smith, (1971) collected duration data from police logs for weekdays only, over a two-year period (1968-1969). A mean duration time of 45 minutes for non-injury accidents and 18 minutes for vehicle stalls was reported. In this case, duration was measured from the time of detection to the time when the incident was cleared. Large standard deviations were observed in both cases. The authors cited weather conditions, incident severity, and police work load as contributing factors to the observed high variances.

The most recent data on incident duration was collected by the California Department of Transportation (Juge, Kennedy, and Wang, 1974).* A comparative study of incident duration was performed in an evaluation of tow trucks and helicopters for freeway surveillance. A total of 196 incidents were viewed via time lapse camera over a 17-month period in 1973-1974. The mean reported duration of all incidents was 42 minutes.

Impact of Incidents on Capacity

Previous studies indicate that the impact of incidents on facility capacity is quite consistent. Their effect depends on facility characteristics, as well as the characteristics and location of the incident itself (Goolsby and Smith, 1971; Kelleway and Tucker, 1981; Lari, Christianson, and Porter, 1982; Urbanek and Rogers, 1978). Incidents affect capacity even when no lane blockage occurs. Estimates of the impact of gawkers block are on the order of 25 percent (Lari, Christianson, and Porter, 1982; Goolsby and Smith, 1971). This impact is independent of the nature of the incident (i.e., stall versus accident). Lane-blocking incidents have a more than proportional impact. For example, the blockage of a single lane on a three-lane facility (33 percent spatial extent) reduces freeway capacity by 40 to 45 percent.

---

* Other later studies of incident duration have been published; however, in every case the data is taken from one of these earlier studies, e.g., Urbanek and Rogers, 1978.

This brief review has shown that incident characteristics, patterns, and durations are location specific and subject to large variation. In addition, most of the research was conducted a decade or more ago, when urban freeway traffic conditions were less congested than they are today.

3. RESEARCH APPROACH

Incidents are a key issue in freeway system management because of their negative impact on capacity. The presence of an incident, no matter what type, and whether lane blocking or not, adversely affects capacity and thus cause delay. The amount of delay generated by an incident depends on the duration of the incident, the extent of capacity reduction, and the level of demand at the time of the incident. If an incident occurs at a time when demand is light, and no traffic lanes are blocked, the incident may have little effect. On the other hand, if an incident blocks lanes at a peak demand period, the delay may be quite extensive. Incidents are generally characterized as being composed of two intervals. The primary interval is the duration of the incident itself, from the time of detection to the time when the incident is cleared. The secondary interval extends from the time the incident is cleared to the time when the facility has resumed normal operation. Delay occurs during both intervals: during the time the incident affects capacity, and during the time required to eliminate the queue caused by the capacity reduction.

In order to analyze the impact of incidents, information on frequency, characteristics, and duration is required. Incidents can be categorized based on capacity impact (e.g., whether lane blocking or not) and duration.

Characteristics associated with these factors can then be identified. For example, a simple model of incident duration can be expressed as,

d_i = $f(I)$, where

d_i = duration of incidents of category i

I = vector of incident characteristics.

Incident characteristics would include incident type, number and type of vehicles involved, presence of injuries, etc. Total duration associated with incidents of category i is simply a function of frequency over the given time period:

$$D_i = d_i F_i,$$

and for n categories of incidents,

$$D = d_i F_1 + d_2 F_2 + \ldots d_n F_n$$

$$= \sum_i D_i$$

These duration functions can be used in conjunction with traffic demand data to estimate congestion impacts. This paper focuses on the estimation of appropriate duration models.

4. DATA

The case study area is a 12-mile section of the I-10 Freeway, located in Los Angeles, California. It connects downtown Los Angeles with the Westside area, and traverses the most densely developed corridor in the region. It is a very heavily used facility, with weekday average daily traffic of 250,000 to 275,000. It operates at or near capacity throughout the day, as illustrated in Figure 1.

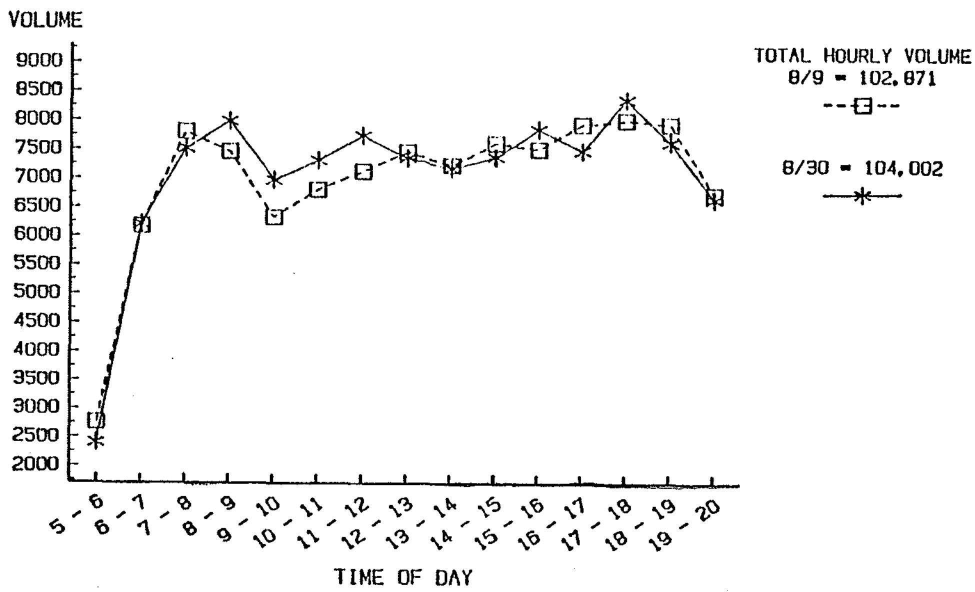

FIGURE 1

I-10 FREEWAY EASTBOUND AT LA BREA,
HOURLY VOLUMES, 1984

Data on all types of incidents were required for this research. The basic data source for accidents is the TASAS* file, which contains records of all reported accidents. It is maintained by the California Highway Patrol. The TASAS data provide descriptive information on the nature, location, and time of the accidents. However, no information on duration is provided.

---

* TASAS = Traffic Accident Surveillance and Analysis System.

Incidents that are not accidents are not contained in the TASAS file. The only available source of data for incidents is the California Highway Patrol (CHP) dispatch logs. These are the reports from field personnel as recorded by the CHP dispatcher. The logs contain all incidents either observed by or reported to the CHP. Descriptive information is highly variable and depends on factors such as the amount of information available to the officer, the level of activity at the time of the incident, and the severity of the incident. The CHP logs are also the only available source of duration data, as each log entry is recorded by time of day.

Three different incident data samples were used in the analysis. The first is a sample of TASAS data which contains records for all accidents in the case study area from September 1983 through June 1984 and from September 1984 through June 1985.* The entire TASAS sample contains a total of 1,728 accidents. The second data source is a random sample of 22 days of CHP dispatch log data for the same time periods and location as the TASAS sample. The 22 days were randomly drawn from the two time periods, and all reported incidents occurring on these days were recorded, yielding a sample of 652 incidents. Because the log sample contained only 71 accidents, it was necessary to generate an additional sample in order to develop a sufficiently large sample of accident durations for statistical analysis. This was accomplished by collecting CHP log data for a random subsample of TASAS accidents. This accident duration sample contains a total of 224 accidents. All of the duration data was screened to eliminate bad weather days.

* The months of July and August 1984 were omitted in order to avoid statistical problems due to changes in traffic patterns during the 1984 Los Angeles Summer Olympics.

5. INCIDENT CHARACTERISTICS AND FREQUENCY

This section provides a summary of incident characteristics within the case study area. Accidents are discussed first.

Accidents

A total of 607 days of accident data was collected; 432 were weekdays and 175 were weekend days. Of the 1,728 accidents recorded, 1,340 (78 percent) occurred on weekdays and 388 (22 percent) occurred on weekend days. Accidents are more frequent on weekdays. The daily average weekday rate is 3.1; and the weekend daily rate is 2.2. Friday has the highest daily rate at 3.77, while the lowest daily rate of 1.98 occurs on Sunday.

Accident frequency also varies by time of day, as shown in Table 3. The last column in the table standardizes by the different number of hours in the

TABLE 3

ACCIDENT FREQUENCY BY TIME OF DAY

Time of Day	Number of Accidents	Percent of Accidents	Standardized Percent Share
Midnight - 6 a.m.	212	12	9
6 a.m. - 9 a.m.	250	15	21
9 a.m. - 3 p.m.	454	26	19
3 p.m. - 6 p.m.	404	23	34
6 p.m. - Midnight	408	24	17

intervals. The highest accident frequency occurs in the afternoon peak. Accidents are more frequent during the day and less frequent at night, with the fewest accidents occurring between midnight and 6 a.m.

Accident severity can be expressed in terms of injuries, number of vehicles involved, or lane closures. Table 4 shows that about 63 percent of all accidents involve no injuries, and relatively few involve more than one injury. The majority of accidents (58 percent) involve two vehicles. Lane closures are relatively uncommon: 59 percent of all accidents do not involve lane closures.

TABLE 4

ACCIDENT SEVERITY CHARACTERISTICS

INJURIES			VEHICLES			LANES CLOSED		
Number	No. of Accidents	% of Accidents	Number	No. of Accidents	% of Accidents	Number	No. of Accidents	% of Accidents
None	1,094	63%	1	333	18%	None	174	59%
1	417	24%	2	997	58%	1	83	28%
2	139	8%	3 or more	418	24%	2 or more	38	13%
3 or more	78	5%						

Cross tabulations revealed that accident characteristics in the case study area vary significantly by time of day and day of week. Injury accidents are more frequent on weekends and at night. The largest proportion of injury accidents occur between midnight and 6 a.m. on weekends, as shown in Table 5. It is also worth noting that all seven fatalities in the sample occurred at night. In contrast, the smallest proportion of injury accidents occurs during the day on weekdays.

TABLE 5

SHARE OF INJURY ACCIDENTS BY TIME, DAY

	WEEKDAY			WEEKEND		
Type	Day 6 a.m.- 6 p.m.	Night 6 p.m.- 6 a.m.	Row Total	Day 6 a.m.- 6 p.m.	Night 6 p.m.- 6 a.m.	Row Total
Injury	.16	.21	.37	.20	.24	.44
Non-Injury	.34	.29	.63	.30	.26	.56
Column Total:	.50	.50		.50	.50	

Type of collision also varies by time and day. Rear-end accidents are by far the most frequent (53 percent of all accidents in the sample), followed by sideswipes (19 percent) and hit objects (19 percent). Broadsides (4 percent) and overturns (2 percent) are quite rare. Table 6 shows how collision type varies by time of day and week. As would be expected given the high daytime traffic volumes and congested conditions in the case study area, rear-ends are the most frequent type of daytime accident; they account for about 56 percent of all daytime accidents. Rear-ends and hit objects are the

TABLE 6

COLLISION TYPE BY TIME OF DAY

	ALL WEEKDAY ACCIDENTS				ALL WEEKEND ACCIDENTS			
	Day		Night		Day		Night	
	No.	%	No.	%	No.	%	No.	%
Sideswipe	181	15%	57	5%	9	5%	15	8%
Rear-End	471	38%	203	16%	40	23%	33	19%
Broadside	35	3%	18	1%	4	2%	5	3%
Hit Object	103	8%	109	9%	26	15%	27	16%
Overturn	9	<1%	9	<1%	5	3%	3	2%
Other	20	2%	13	1%	3	2%	2	1%
Total:	819		409		87		85	

most common nighttime accidents, followed by sideswipes. Broadsides and overturns are more evenly distributed. Table 6 also shows that weekday accidents occur about twice as frequently during the day than during the night, but weekend accidents are rather evenly distributed between day and night. In sum, daytime-weekday accidents are relatively more frequent and involve more vehicles, but weekend-nighttime accidents involve more injuries.

Incidents

Incidents taken from the CHP logs described in Section 4 were divided into accidents, disablements, and other. Table 7 gives incident frequency by type, and shows that accidents account for only 11 percent of all incidents in

TABLE 7

INCIDENTS BY TYPE, FREQUENCY

Type	Number	Percent	Average Daily Frequency
Accidents	71	11%	3.2
Disablements	519	80%	23.6
Other*	62	9%	2.8
Total:	652		**29.6**

* Includes: fixed objects on freeway, flooding, pedestrians or animals on freeway, police activities.

the case study area. Accidents are only slightly more frequent than other incidents, which include fixed objects, animals, or pedestrians on the freeway; police activity; flooding; etc. The vast majority of incidents are vehicle disablements. Despite the small sample size (22 days), the daily average accident rate (3.2) is comparable to the rate calculated from the TASAS data. The incident rate is about 30 per day and ranges from 19 to 37 per day. It should be noted that these are all reported incidents, and not necessarily all actual incidents. Incident patterns are similar to accident patterns; about two-thirds occur during the day, and the highest frequency occurs during the p.m. peak.

The CHP log file also provides data on lane closures. About four-fifths of all incidents do not involve lane closures, and only 2 percent involve closures of two lanes or more.

The small proportion of lane closures is due to the high proportion of disablements in the 22-day file sample, and disablements rarely cause lane closures. For the sample as a whole, only 13 percent of all disablements closed at least one lane, in contrast to 41 percent for accidents and 32 percent for other incidents.

6. DURATION ANALYSIS

Previous research has shown that the severity of the impact of an incident is a function of duration and extent of lane closures, rather than the nature of the incident itself. Thus a stalled vehicle left in the roadway will have a greater impact than a rear-end collision that moves immediately to the shoulder. Similarly, a multi-vehicle accident that is rapidly cleared will have less impact than a spilled load that requires extensive clean-up.

A number of hypotheses can be advanced regarding factors that could affect incident duration. The first factor is incident type. Accidents are more likely to require a response than disablements, and the more severe the accident, the longer the duration may be. Thus, number of injuries, number of vehicles involved, and lane closures may affect duration. Accident type may also be correlated with duration, with rear-ends and sideswipes representing relatively minor accidents, and broadsides and overturns representing more major accidents. Among disablements, location on the roadway may be a key feature. Disablements on the shoulder may have longer durations than those that occur in the travel lanes because of the high priority given to clearing obstructions from travel lanes. Other incidents are difficult to generalize, but obvious hazards are more likely to generate a quick response.

Traffic conditions may be either negatively or positively correlated with incident duration. On the one hand, there is more urgency to clearing incidents during peak hours because of the congestion they cause. On the other hand, peak hour congestion may make access to incidents more difficult, particularly for tow trucks and other large vehicles.

The availability of incident management resources could also have an impact on incident duration. The principle factor in incident management is the state highway police (CHP). Thus, incident duration may be affected by the CHP's ability to reach the scene once an incident has been detected. If incidents occur close together in time, response would be more difficult and duration would increase. Factors that could affect incident duration are listed in Table 8.

A number of hypotheses can be advanced regarding factors that could affect incident duration. The first factor is incident type. Accidents are more likely to require a response than disablements, and the more severe the accident, the longer the duration may be. Thus, number of injuries, number of vehicles involved, and lane closures may affect duration. Accident type may also be correlated with duration, with rear-ends and sideswipes representing relatively minor accidents, and broadsides and overturns representing more major accidents. Among disablements, location on the roadway may be a key feature. Disablements on the shoulder may have longer durations than those that occur in the travel lanes because of the high priority given to clearing obstructions from travel lanes. Other incidents are difficult to generalize, but obvious hazards are more likely to generate a quick response.

Traffic conditions may be either negatively or positively correlated with incident duration. On the one hand, there is more urgency to clearing incidents during peak hours because of the congestion they cause. On the other hand, peak hour congestion may make access to incidents more difficult, particularly for tow trucks and other large vehicles.

The availability of incident management resources could also have an impact on incident duration. The principle factor in incident management is the state highway police (CHP). Thus, incident duration may be affected by the CHP's ability to reach the scene once an incident has been detected. If incidents occur close together in time, response would be more difficult and duration would increase. Factors that could affect incident duration are listed in Table 8.

TABLE 8

POSSIBLE EXPLANATORY VARIABLES FOR INCIDENT DURATION

Accident Type (sideswipe, rear-end, etc.)
Disablement Type (engine problem, flat tire, etc.)
Number of Injuries
Number of Vehicles Involved
Vehicle Type (auto, truck)
Incident Postmile Location
Roadway Location (lane, shoulder)
Number of Lanes Closed
Time of Day (peak, off peak)
Day of Week
Time Interval from Previous Incident

Duration Data

The duration data were collected from CHP dispatch log records. The sample of 876 observations contains 295 accidents, 519 disablements, and 62 other incidents. There is a strong reporting bias in the data, with the more severe incidents having the most complete data. Both a start time and an end time is required in order to compute duration, and one of the most frequently missing data items was ending time. As would be expected, accidents most frequently have duration information, and within the accident category more injury accidents have complete data (93 percent) than non-injury accidents

(80 percent). Disablements are least likely to have complete duration data (39 percent). The resulting sample used in the duration analysis consists of 270 accidents, 202 disablements, and 40 other incidents. Duration is measured as the elapsed time from the reporting of the incident to the time it is reported cleared. In some cases, there was more than one period of duration. Duration periods are determined by lane closures. For example, an accident which blocks a lane until tow trucks push vehicles to the shoulder is counted as having two durations. The first duration period occurs while the lane is blocked, and the second duration period occurs until the incident is reported cleared. In the duration analysis, lane closures are determined by the relative proportion of the total duration represented by each period. For example, if two lanes are closed for 30 minutes and one is closed for 15 minutes, the lane closure value associated with the incident is "two lanes closed."

General Observations on Duration

The mean duration of all incidents is 37 minutes; the standard deviation is 30 minutes. The distribution is heavily skewed: just over half of the sample has a duration of 30 minutes or less, and 82 percent of the durations are one hour or less. Only 2 percent of the incidents are longer than two hours. Previous theoretical work suggests that incident duration has a log normal distribution (Golob, Recker, and Leonard, 1987). The Kolmogorov-Smirnov statistical test was performed to test for the log-normal distribution in this sample, and the log-normal form was confirmed. The actual and estimated cumulative distributions for the entire sample are shown in Figure 2.

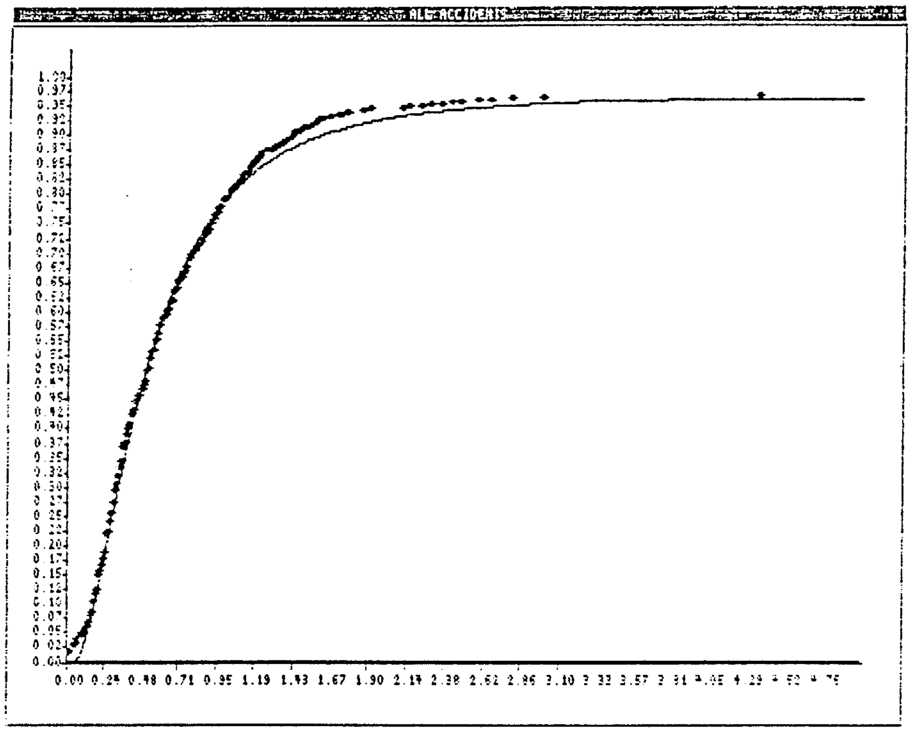

FIGURE 2

CUMULATIVE DISTRIBUTION FUNCTION OF DURATION
FOR ALL INCIDENTS

Duration Models

Analysis of variance was used to estimate models of duration as a function of various incident characteristics. Analysis of variance was selected because the independent variables are largely categorical, and thus tests for differences between groups are most appropriate. Moreover, differences between groups identified can be used directly to establish appropriate incident categories. The basic model is,

$$d = f(I),$$

where I is the vector of incident characteristics. Because of data limitations, it was not possible to estimate a fully specified model of duration for the entire sample of incidents. Rather, separate models for subsets of incidents were estimated, and these models were used to identify incident categories.

Separate models for all incidents and for accidents only were estimated using the measures listed in Table 8. Variables were entered based on goodness-of-fit criteria. The analysis yielded two models, one for all incidents (Model I), and one for accidents (Model II). The dependent variable in both cases is the natural log of duration. Independent variables are defined in Table 9. The categories established for these variables are based

TABLE 9

INDEPENDENT VARIABLE DEFINITIONS

Name	Number of Categories	Categories
Incident Type	3	Non-Injury Accident, Injury Accident, Disablement or Other
Lanes Closed	2	No Lanes Closed, One or More Lanes Closed
Time of Day	2	Day (6 a.m.-6 p.m.), Night (6 p.m.-6 a.m.)
Accident Type	2	Non-Injury Accident, Injury Accident
Truck Involvement	2	No Trucks Involved, One or More Trucks Involved

on tests of significance. For example, disablements and other incidents are combined because their duration distributions are indistinguishable. Similarly, the time of day variable was reduced to two categories because no significant difference was found between peak and non-peak incident duration. Results for Model I are given in Table 10. Three variables affecting duration are identified: incident type, lane closures, and time of day. No other variables tested either individually or jointly were found to be significant. All main effects are significant, but only incident type and lane closures are

TABLE 10

ANALYSIS OF VARIANCE MODEL I:
DURATION BY INCIDENT TYPE,
LANE CLOSURES, AND TIME OF DAY

Dependent Variable: ln (duration)

Source of Variation	Mean Square	F
Main Effects	22.26	50.52**
Incident Type	37.51	85.13**
Lanes Closed	11.14	25.29**
Time of Day	2.89	6.55**
Two-Way Interactions	3.12	7.07**
Incident by Lanes	6.86	15.57**
Incident by Time	.37	.84
Lanes by Time	.31	.71
Explained	11.63	26.38**

Number of Cases = 512

** Significant at $\geq$ 99%

jointly significant. This is caused by the very short duration of lane-blocking disablements.

Model II results are given in Table 11. Model II is estimated on accident duration, and it consists of three independent variables: accident type (injury or non-injury), time of day, and presence of trucks. None of the

TABLE 11

ANALYSIS OF VARIANCE MODEL II:
ACCIDENT DURATION BY TYPE,
TIME OF DAY, AND TRUCK INVOLVEMENT

Source of Variation	Mean Square	F
Main Effects	4.31	11.01*
Accident Type	4.41	11.27*
Time of Day	2.38	6.08*
Truck Involvement	6.14	15.69*
Two-Way Interactions	.21	.53
Accident by Times	.20	.50
Accident by Truck	.02	.04
Time by Truck	.45	1.15
Explained	2.26	5.77*
Number of Cases = 270		

* Significant at $\geq$ 99%

joint effects were found to be significant. As with Model I, no other variables were found to be significant in other model specifications.

The overall explanatory power of Model II is weaker than that of Model I, and the difference in means between incident categories is smaller. Model results indicate truck involvement is a highly significant factor in incident duration. Of the 270 accidents in the sample, only 20 involved trucks, and these had a significantly longer mean duration (63 minutes) and larger standard deviation than non-truck accidents (mean = 39 minutes). Thus a very small number of observations is generating a large proportion of the total variance in the dependent variable. Presence of trucks was not included in Model I because no data on truck involvement in disablements and other incidents were available.

Incident Categories

Results of the analysis of variance were used to generate 12 categories of incidents based on incident type, lane closures, and time of day. Because of their small number, truck accidents were not categorized separately. Duration means and standard deviations are given in Table 12. Several interesting observations are evident. First, the standard deviations are quite large for all categories, and particularly large for disablements and others. Thus the range of duration for each incident category is large. Second, nighttime incidents are longer than daytime incidents in each category. Longer nighttime durations may be the result of less intensive freeway surveillance, different incident response policies and procedures during light traffic conditions, or greater incident severity. Third, lane closing accidents generally have longer durations than accidents with no lanes closed, whereas lane closing disablements and other incidents have shorter

TABLE 12

DURATION MEANS AND STANDARD DEVIATIONS
FOR 12 INCIDENT CATEGORIES

	Incident Type			$\bar{X}$ *	S.D.*	No. of Cases
1	Non-Injury Accident	--No lanes closed	--night	47	24	41
2			--day	41	24	79
3		--Lanes closed	--night	66	41	10
4			--day	38	22	20
5	Injury Accident	--No lanes closed	--night	62	40	33
6			--day	47	29	39
7		--Lanes closed	--night	66	58	21
8			--day	54	28	27
9	Disablement/Other	--No lanes closed	--night	30	24	73
10			--day	29	22	104
11		--Lanes closed	--night	18	22	12
12			--day	14	11	53
	Total:					**512**

* In minutes.

durations. This pattern is again likely related to severity; disablements can easily be moved to the shoulder, whereas accidents may require extensive response (e.g., tow truck, ambulance) and police investigation. Moreover, it may be recalled that duration was measured by CHP records, and disablements do not necessarily require CHP presence until the incident is cleared.

Further statistical tests were conducted to determine the appropriate form of the distribution of each category, and to determine whether the duration categories are significantly different from one another. The Kolmogorov-Smirnov test for log-normal distribution was conducted for each category. With the exception of category 10 (disablements and others, no lanes closed, daytime), the hypothesis of log-normal distribution could not be rejected. Further tests for other likely distributions (e.g., uniform) revealed that no other distributional form was more appropriate. Difference between duration categories was checked via the Kruskal-Wallis test. The resulting Chi-square value of 161 was significant at p = .001. The Kruskal-Wallis test can be interpreted as indicating that overall differences between categories are significant. However, pairwise differences between some categories (for example 1 and 2) are not necessarily significant.

As discussed earlier in Section 2, these duration categories can be used to estimate total incident duration. An example is given here using the 22-day CHP log sample for the case study area. It may be recalled that the sample yielded 71 accidents and 581 disablements and other incidents. Table 13 gives frequency by category both in raw form and percentages. Weighting these frequencies by the mean duration for each category yields an estimate of the duration share by category.*

The overwhelming dominance of disablements and others is quite evident, although these categories represent a slightly less than proportionate share

* Note that although the category means provide the best estimate, the confidence interval around each estimate is quite large. In addition, if these categories were used for prediction, incident frequencies would have to be expressed as probabilities based on repeated observations. Such a procedure is beyond the scope of this paper.

TABLE 13

INCIDENT FREQUENCY AND DURATION SHARES

	Incident Type			Fre-quency	% Fre-quency	Ave. Dura-tion (Min-utes)	Ave. Duration Share %
1	Non-Injury Accident	--No lanes closed	--night	14	2.1%	47	3.3%
2			--day	21	3.2	41	4.5
3		--Lanes closed	--night	6	.9	66	2.0
4			--day	15	2.3	38	3.0
5	Injury Accident	--No lanes closed	--night	4	.6	62	1.3
6			--day	4	.6	47	1.0
7		--Lanes closed	--night	5	.8	66	1.8
8			--day	2	.3	54	.5
9	Disablement/Other	--No lanes closed	--night	171	26.2	30	26.8
10			--day	322	49.4	29	48.9
11		--Lanes closed	--night	19	2.9	18	1.8
12			--day	69	10.6	14	5.1

Number of Cases = 652.

of total duration. Conversely, accidents make up 11 percent of the incidents but 17 percent of the total duration, reflecting their longer average duration. Incidents involving lane closures have a frequency of about 18 percent, but represent about 14 percent of duration, reflecting the short duration of lane-closing disablements.

7. IMPLICATIONS FOR INCIDENT MANAGEMENT POLICY

The key factor in incident management is delay, and the delay generated by any given incident depends on traffic conditions as well as duration and the degree to which capacity is affected. Given that traffic volumes are high and relatively constant throughout the day in the case study area, it follows that daytime lane-blocking incidents will cause the most delay--and probably the most potential for secondary accidents. While 13 percent of all incidents fall into this category, these incidents make up only 8.6 percent of the duration. Of particular note is the disproportionately small share of duration in the lane-blocking daytime disablement category, suggesting that current management policy emphasizes rapid removal of these incidents.

The results of this research show that accidents are a minor part of all the incidents that can cause non-recurrent congestion. The single largest category of incidents is daytime, non-lane-closing disablements and other incidents, accounting for almost half of all incident duration. Although quite minor, these could have a significant effect on traffic congestion via gawkers block on heavily traveled urban freeways.

Research results also show the duration of incidents to be heavily skewed: over half of all incidents have a duration of 30 minutes or less, and only 2 percent of all incidents are longer than two hours. Lane-blocking incidents falling into this longer-than-two-hours category make up an even smaller proportion (.6 percent) of all incidents. Since the delay impact of incidents is cumulative, this very small proportion of incidents generates a disproportionately large share of delay.

Characteristics of the distribution of incidents suggests several alternative policy responses for more effective incident management. One is to focus on the 2 to 5 percent of outliers--the longest incidents--and develop special quick-response capabilities in order to clear such incidents as rapidly as possible. This strategy has been implemented in several urban areas with the development of "major incident response teams." This is also an attractive strategy from a political standpoint, as these major but rare events are also the most visible because of the publicity they generate.

A second alternative is to develop better overall incident management capabilities that could lead to shorter durations for all incidents. Improvements in overall effectiveness of incident management have been the subject of extensive investigation (e.g., Urbanek and Rogers, 1978), and constraints on further effectiveness are likely financial rather than technical for most metropolitan areas.

Research results presented here also suggest a third alternative: focus on the largest category of incidents, namely disablements. Although most disablements are quite minor, some subset may cause significant delay, such as car fires or stalls on the median that require towing off the freeway. More research is necessary to examine the nature of disablements and their impact on traffic flow. Because of their large numbers, any reduction in the average duration of disablements would significantly reduce total incident duration. It bears noting that the impact of disablements could not only be reduced by more intensive incident management, but also by regulatory changes. For example, about 10 percent of all disablements are caused by the vehicle being out of gas, and about 5 percent are due to flat tires without having a spare. Fines and citations could be instituted to reduce these types of disablements. However, the effectiveness of any such strategy would depend on the delay impacts of disablements.

Finally, research results showed that over 80 percent of all incidents do not cause any lane blockages. This is obviously related to the availability of shoulders.* In response to increased travel demand, however, adding lanes by eliminating shoulders is an increasingly attractive traffic management strategy. It is likely that this trend will continue. Heavily congested urban freeway segments will have less emergency stopping area in the future and consequently a greater proportion of lane-blocking incidents. The net congestion effects of restriping strategies thus merits further analysis.

8. CONCLUSIONS

This paper has presented an overview of the frequency, patterns, and duration of incidents on a high volume urban freeway. This case study provides the first comprehensive analysis of duration data collected during this decade. Models of incident duration were estimated and used to identify incident categories. The analysis showed that incident duration varies by type of incident, lane closures, and time of day, and that the variance within each category is quite large. Disablements and other incidents are the most common incident type, have the shortest average duration, and account for most of the total incident duration. Further research is indicated to quantify the delay impacts of incidents. Statistical models can be developed to estimate incident frequencies by category, and traffic simulation models can be used to estimate the associated delay. Results would provide a valuable basis for evaluating alternative incident management and traffic management policies. The results presented here provide the basis for such a study.

---

* A right shoulder of at least 10 feet is available over most of the length of the case study area. However, large portions of the median shoulder have been lost to restriping projects.

ACKNOWLEDGMENT

This research was supported by the California Department of Transportation, and the Institute of Transportation Studies, University of California, Irvine. Views expressed are those of the author, and not necessarily those of the sponsoring agencies. All errors and omissions are the responsibility of the author.

REFERENCES

DeRose, Jr., F. "An Analysis of Random Freeway Traffic Accidents and Vehicle Disabilities," Highway Research Record 59, 1964, pp. 53-65.

Golob, T.F., W.W. Recker, and J.D. Leonard. "An Analysis of the Severity and Incident Duration of Truck-Involved Freeway Accidents," Accident Analysis and Prevention, Vol. 19, No. 2, 1987, pp. 375-395.

Goolsby, M.E., and W. Smith. "Influence of Incidents on Freeway Quality of Service," Highway Research Record 349, 1971, 41-46.

Juge, J., K. Kennedy, and T. Wang. Early Detection and Rapid Removal of Disabled Vehicles and Other Hazards from the Freeway, Final Report, California Department of Transportation and Department of California Highway Patrol. June 1974.

Juge, J., and R. Thompson. Service for the Stranded Motorist Project, California Department of Transportation. July 1978

Kelleway, R.C., and D.A. Tucker. "Provision for Accidents and Breakdowns--A Basis for Decision-Making Where Space is at a Premium," Proceedings of PTRC Summer Meeting, Seminar P, Highway Planning and Design, University of Warwick, July 1981, pp. 127-139, p. 214.

Kolenko, S.J., and J.A. Albergo. Study of Disabled Vehicles and Accidents on the Congress Expressway, Chicago Surveillance Project. May 1962.

Lari, A., D. Christianson, and S. Porter. I-35W Incident Management and Impact of Incidents on Freeway Operations, Minnesota Department of Transportation, Office of Traffic Engineering. January 1982.

Lindley, J.A. "Urban Freeway Congestion: Quantification of the Problem and Effectiveness of Potential Solutions," ITE Journal. January 1987, pp. 27-32.

MacCalden, M.S., R.W. Anderson, and M.M. Morshed. Feasibility Study of Closed-Circuit Television for Traffic Surveillance, Report # DOT-HS-845016, National Highway Traffic Safety Administration, Bus & Transportation Agency, Department of Public Works, Division of Bay Toll Crossings, Sacramento, 1973.

Urbanek, G.L., and R.W. Rogers. Alternative Surveillance Concepts and Methods for Freeway Incident Management, Volume 1: Executive Summary, Federal Highway Administration. Report # FHWA-RD-77-58. Washington, DC: Peat, Marwick, Mitchell and Co. March 1978.