TRAFFIC IMPACT DUE TO INCIDENT ON EXPRESSWAY: A CASE STUDY OF THE BANGKOK'S FIRST AND SECOND STAGE EXPRESSWAY SYSTEM

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Abstract: Incidents affect both mobility and safety to motorists. They occur in a variety of forms such as road traffic accidents, vehicle breakdowns, or other unexpected events. The accidents and other types of the incidents frequently reduce capacity to be lower than the level of demand. Past studies have shown that these non-recurring events account for more than half of the traffic congestion on expressways, thus placing efficiency as well as safety concerns to transportation system operators. This study aims at investigating the problems of incidents and their impacts to traffic flow on expressways, using a case study of the first and second stage expressway system in Bangkok, Thailand. The data are obtained by direct observation within limited time through video and radio surveillance system and secondary data of operator's records. Several incident characteristics such as type, frequency, location, severity, and duration are then explored. Several statistical techniques are applied to draw the conclusion on incident occurrence and rate. Moreover, information such as the classification of incident types, the frequency of unreported incidents, methods of incident management activities, clearing time, and the impacts on delay to other traffic is reported. Using a popular traffic impact model on the freeway, the effect of an incident on traffic delay can be assessed. The study presents the loss due to overall traffic delay and leads to suggestion on better incident management system.

Key Words: Incident, Impact, Expressway, Bangkok

1. INTRODUCTION

The congestion and accidents are probably the most recognized traffic problems in cities. Both hinder the fulfillment of transport objective, the fast and safe travel. One of the major contributions to the problems is the disruption created by incidents. Incidents are unexpected events on the roads. The occurrences are unknown in space and time. The incidents include traffic accidents, vehicle breakdowns, dropped objects, and even roadwork (which is unknown to drivers). The unexpected, unplanned events create congestion to overall traffic. Dudek (1987) displayed that congestion due to the incidents, called non-recurrent congestion, justifies 50-75 percent of the overall delay on the freeways. This figure shows the importance of the incidents to the traffic operations and it is significant for traffic managers to place attention on the matter (Holmes and Leonard,1993).

This paper investigates the incident characteristics, including types of occurrence and duration. The research also examines the impact of the incidents to other traffic, in terms of delay. The study is conducted on the first stage (Chalermmahanakorn) and second stage(Srirat) expressway system in the Greater Bangkok area.

2. PAST STUDIES

The importance of incident studies has long been recognized by transport agencies. The information on incidents has been recorded on most urban freeway systems in the United States and other countries using a transportation team or a traffic surveillance system. Early incident data were recorded by officials (De Rose, 1964; Goolsby and Smith, 1971; and Giuliano, 1989). Then the data were analyzed to find frequencies, patterns of the incidents as well as the "blackspot" of accidents. The studies correlated an incident occurrence with independent (explanatory) variables such as time of day, month, severity, and other physical attributes.

The duration of incident was also explored by these studies. Typically, the duration of incidents is broken into four time periods as shown in Figure 1.

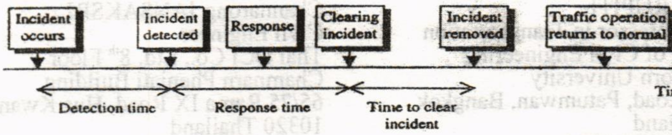


Figure 1. Duration of incidents

The detection time is the time between the occurrence of the incident and the first time incident reported to the traffic manager. The officer discovers the incident through a radio report, video surveillance, mobile telephone, or emergency telephone. Newer freeway systems may incorporate an automatic detection system and software that could detect incidents from changing traffic patterns. The response time is the time between the officer retrieving incident existence and the access of emergency unit to the incident scene. The clearance time is the duration of work by the emergency unit to move away the incident from the traffic lane, or to cease the disruption of the incident to other traffic. The recovery time is the time since the first termination of the incident disturbance until the traffic condition becomes normal, such as the queue of traffic is cleared.

Since more recent inident data were obtained from the Freeway Surveillance System, through CCTV or freeway service patrol observations, the measurement of each incident duration is unfortunately difficult in reality, especially the incident occurrence time. The summary of incident durations by past studies are thus broken by other factors, such as types of incidents, traffic volume, position of incident occurrence, rather than the partitioning of duration into components and the averages of the entire incident duration are present (Holmes and Leonard, 1993; Giuliano, 1989; and Beaubien, 1994).

The impact of the incident on traffic flow can be analyzed by queuing model. Many researches employ the deterministic queuing analysis to estimate the queue and delay as a result of a reduced capacity due to an incident. The incident reduces number of the passing vehicles below the arrivals, thus creating a slow down or stopping queue. Figure 2 illustrates this concept. A recent study argues that the application of this technique with average arrival flow (per hour) would underestimate the delay figure and suggests a modifying factor to it (Olmstead, 1999). New models for predicting freeway incidents and incident delays are also presented by Sullivan (1997) and Garib, Radwan, and Al-Deek (1997). Nonetheless, this impact representation gives a good estimate of delay in short duration and is used for delay impact estimation of the entire road network (Morale, 1997 and Roper, 1990).

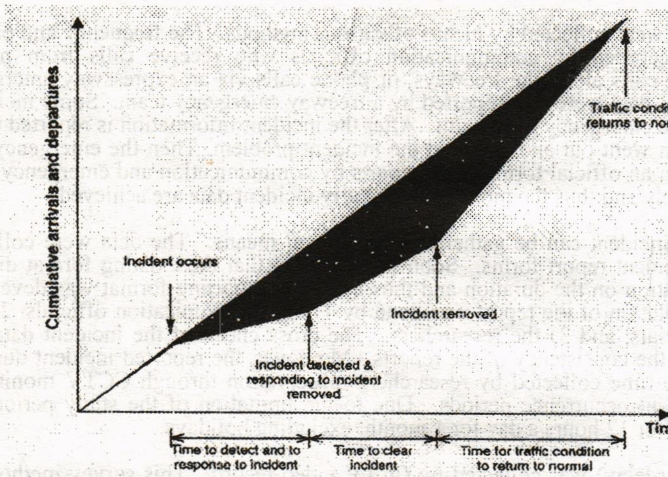


Figure 2. Delay model on freeway due to an incident (Chung and Rosalion, 1999)

3. STUDY LOCATION AND DATA COLLECTION METHOD

The study was carried out on the first (Chalermmahanakorn) and the second (Srirat) expressway systems in the Greater Bangkok area. Both sections are freeway-typed facilities with controlled access and have 2, 3, or 4 traffic lanes in each direction. The distances of the expressways are 27.1 and 33.2 km for the first and second expressway, respectively. Figure 3 displays the configuration of the location. The yearly data in 1998 and 1999 were gathered from the database while the direct observation was performed for 24 working days in October 1999.

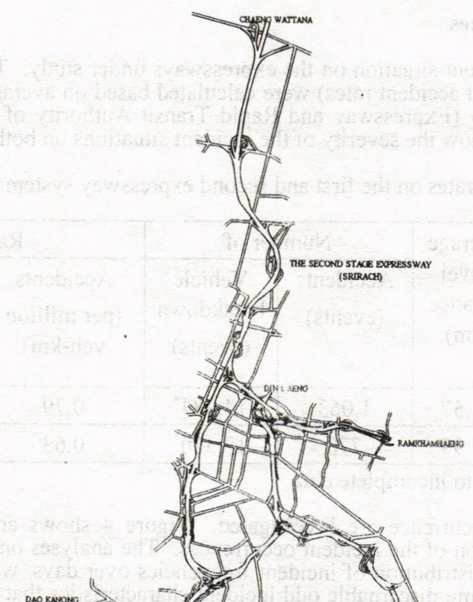


Figure 3. The first and second expressway system in Bangkok, Thailand

Several incident data were collected by means of various methods. The frequency and pattern of incidents were recorded by communication officials who receive calls from police, emergency telephone calls along the freeways, or phone calls via an expressway emergency number. The incident data were also reported by a freeway emergency team. Some incidents might be found by the emergency patrol unit. After the incident information is reported to the rescue team, the team went out and resolved the incident problem. Then the emergency unit reported their work in an official form. Both reports by communication and emergency units are completed routinely and thus the monthly and yearly incident data are achieved.

The duration of the incident can be gathered from several means. The data were collected from the existing incident report forms. Soon it was found that the existing format did not have enough information on the duration and thus a revised reporting format was developed and used. The completion of the report was done by 1) the communication officials, 2) the emergency unit officials, and 3) the researchers. The cross check of the incident data was carried out to obtain the consistency of the reports. Moreover, the reported incident duration was compared to the time collected by researchers' observation through CCTV monitoring throughout the incident occurrence periods. Due to the limitation of the study period, the researchers surveyed for 12 hours a day for 1 month, excluding holidays.

The incident impact (delay) was collected by CCTV video record. This survey method has two main limitations: 1) the CCTV locations do not cover the entire expressways and 2) the incidents may not be reported in a timely manner. Therefore, the incident delay data can only be collected by accidental sampling. However, this survey method is acceptable in the study since it could collect the most reliable actual data in the field and it utilizes the available surveillance system, spending minimal resources. In this data collection method, the images of traffic queue were recorded on a video recorder as many as possible. Attempts were made to tape the incidents at incident scenes and the downstream sections of the expressway at the same time. Then the data were reduced manually to get arrival, departure counts, and other incident data.

4. STUDY RESULTS

4.1. Incident pattern analyses

Table 1 gives the brief incident situation on the expressways under study. The incident rates (vehicle breakdown rates and accident rates) were calculated based on average travel distance from another previous study (Expressway and Rapid Transit Authority of Thailand, 1998). The average incident rates show the severity of the incident situations on both freeway routes.

Table 1. Incident rates on the first and second expressway system (1999)

Expressway system	Traffic volume (million veh)	Average travel distance (km)	Number of		Rate of	
			Accidents (events)	Vehicle breakdown (events)	Accidents (per million veh-km)	Vehicle breakdown (per million veh-km)
First	116.95	11.57	1,063	14,984*	0.79	11.07
Second	87.40	13.99	770	12,320*	0.63	10.08

Note: * estimate figures due to incomplete data

The patterns of incident occurrence are investigated. Figure 4 shows an example of the monthly and daily distribution of the incident occurrences. The analyses on incident patterns give understanding on the distribution of incident frequencies over days, weeks, and months (seasons) and help detect some discernable odd incident characteristics that might have. The differences on incident patterns between the two expressway systems can also be known. All results show that the incident occurrence is related to time factor. The highest frequencies of incidents on both expressways occur on weekdays. The frequencies of incidents vary by times-of-day, weeks, months (and seasons). These differences are statistically significant at 95% level. The patterns of the accidents and the vehicle breakdowns are also statistically distinct. The incident patterns on the two systems differ from each other. Note that the distributions of incident occurrence on the two expressway systems cannot be directly compared due to dissimilar traffic composition, traffic volume (and possibly the purpose of travel), geometric, and environment, and thus they are treated as two distinct entities.

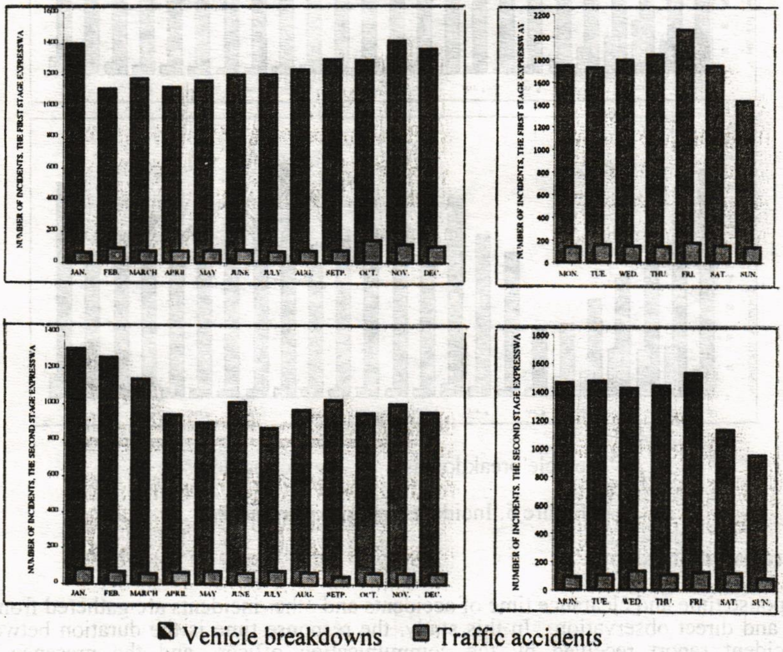


Figure 4. Monthly and daily distribution of the incidents

Attention is paid to the rates of incidents. It is found that the weekend has the highest vehicle breakdown rates (number of disabled vehicle per vehicles traveled) and accident rates on both expressways. When the rates are plotted over times of day, as shown in Figure 5, it is clear that the accident rates are highest at night (00:00-06:00) on both expressways while there is no conclusion on the highest rate period for vehicle breakdowns. The further study shows that the accident frequencies are more dependent to the volume of traffic.

The incident data show many other useful data such as 1) the number of accidents under responsibility of each rescue team, 2) time of occurrence, 3) the spatial distribution of the incident occurrence by type of incident on the expressway systems (incident spot map), 4)cause of accidents and vehicle breakdowns, and 5) severity of accidents. This information will be used to manage incidents and determine better emergency operations.

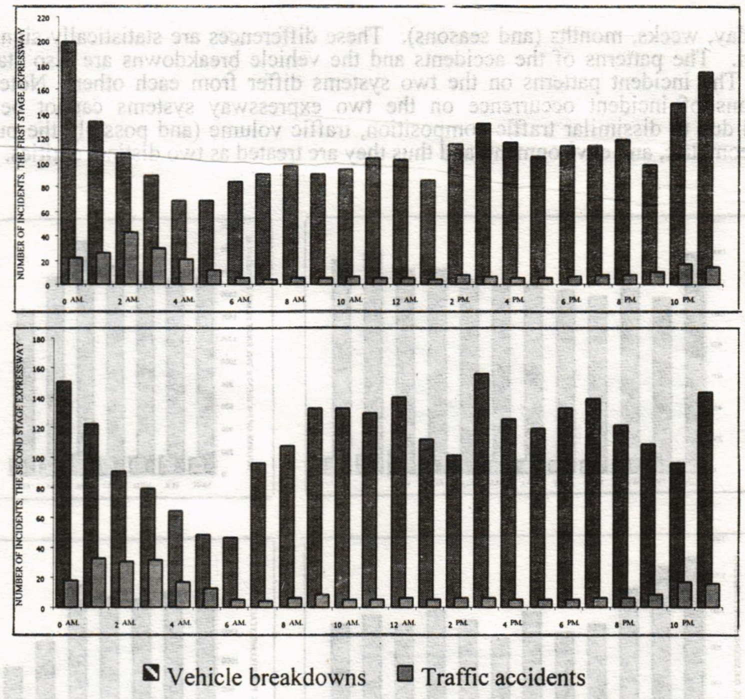


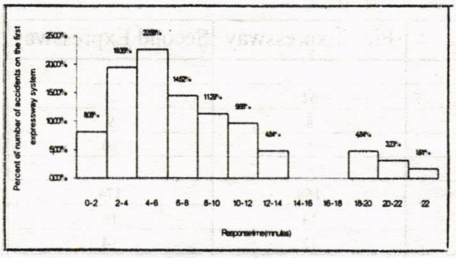
Figure 5. Incidents rate on expressways

4.2. Duration of incidents

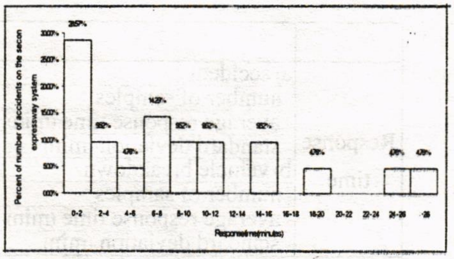
The response time and clearance time of accidents and other incidents are gathered from video records and direct observation. In this study, the response time is the duration between the first incident report received by the communication officers and the presence of the emergency team at the incident location. The response time depends on several circumstances, from the quickness of the emergency team response to the location of the incident on the expressway. The results are shown in Figure 6. The current emergency unit policy is to respond to the incident with less than 10 minutes. The results show that approximately 70% of the accidents and 46% of other incidents are reached within 10 minutes.

The clearance times on both expressways are shown in Figure 7. The clearance time directly reflects the emergency unit operations. The duration of clearance activities depends on method, equipment, and the skill of the patrol.

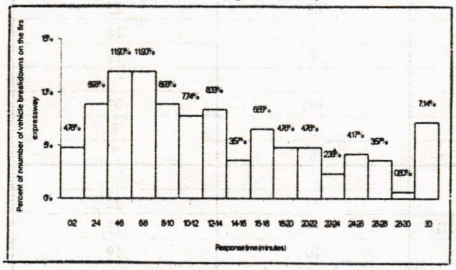
The "observed" incident duration time, or the summation of the response and clearance time, is displayed in Table 2. The table shows all incident time components. It is noted that the period of incident may not exactly be equal to the summation of response and clearing time due to different data set and also the number round-off. The investigation on the distribution of the total duration time shows that 92 percent and 73 percent of the accidents have duration shorter than 30 minutes on the first and second expressway, respectively. Eighty four percent and 70% of the other incidents have duration shorter than 30 minutes on the first and second expressway. The Mann-Whitney U statistical test indicates that the average duration of other incidents in both expressway system is significantly different, while there is no discernable difference in accident duration on both expressways. The log-normal distribution is found a good fit to the incident duration using Kolomogorov-Smirnov test at 95% confidence



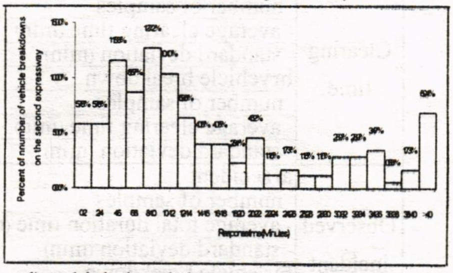
a) accidents, first expressway



b) accidents, second expressway

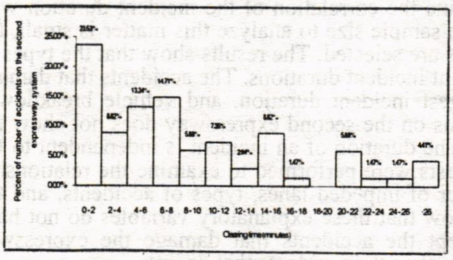


c) vehicle breakdowns, first expressway

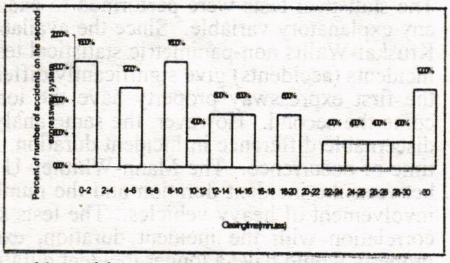


d) vehicle breakdowns, second expressway

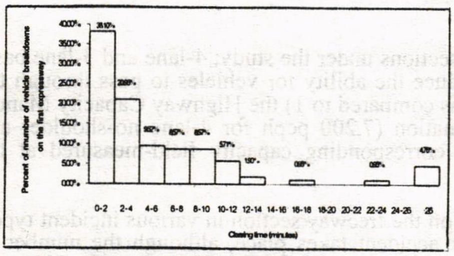
Figure 6. Distribution of response time



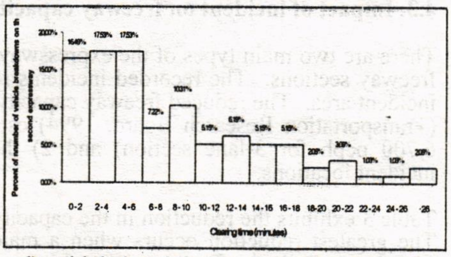
a) accidents, first expressway



b) accidents, second expressway



c) vehicle breakdowns, first expressway



d) vehicle breakdowns, second expressway

Figure 7. Distribution of clearing time

Table 2. Summary of incident duration

		First Expressway	Second Expressway
Response time	a) accident		
	- number of samples	62	21
	- average response time (min)	8	9
	- standard deviation (min)	5	10
	b) vehicle breakdown		
	- number of samples	168	174
	- average response time (min)	14	16
	- standard deviation (min)	12	14
Clearing time	a) accident		
	- number of samples	68	25
	- average clearing time (min)	9	18
	- standard deviation (min)	8	19
	b) vehicle breakdown		
	- number of samples	105	97
	- average clearing time (min)	6	8
	- standard deviation (min)	8	7
Observed incident duration	a) accident		
	- number of samples	72	22
	- average total duration time (min)	15	23
	- standard deviation (min)	10	19
	b) vehicle breakdown		
	- number of samples	103	114
	- average total duration time (min)	19	26
	- standard deviation (min)	18	26

The statistical tests were performed to examine the correlation of the incident duration with any explanatory variable. Since the available sample size to analyze this matter is small, the Kruskal-Wallis non-parametric statistical tests are selected. The results show that the types of incidents (accidents) give significantly different incident durations. The accidents that damage the first expressway property have the longest incident duration, and vehicle breakdowns come the second. However, the same analysis on the second expressway does not show the discernable difference in incident duration. The duration of an incident is independent to the time of occurrence. The Mann-Whitney U tests were performed to examine the relationship between the incident duration and the number of impeded lanes, types of accidents, and the involvement of heavy vehicles. The tests show that these explanatory variables do not have correlation with the incident duration, except the accidents that damage the expressway property would have a longer incident duration than the accidents that do not.

4.3. Impact of incident on freeway capacity

There are two main types of the expressway sections under the study; 4-lane and 3-lane basic freeway sections. The recorded incidents reduce the ability for vehicles to pass through the incident area. The reduced freeway capacity is compared to 1) the Highway Capacity Manual (Transportation Research Board, 1994) estimation (7,200 pcph for 4-lane no-shoulder and 6,700 pcph for 3-lane section) and 2) the corresponding capacity field-measured at the incident locations.

Table 3 exhibits the reduction in the capacity on the freeway section in various incident types. The greatest reduction occurs when a major accident takes place, although the number of samples is limited. The two-lane closure reduces the capacity by approximately 70%, not 50% as simple calculation.

Table 3. Capacity of the expressway with 4 lanes per direction (no shoulder)

Event	Number of events	Sample size	Range (PCU/min)	Average (PCU/min)	Standard deviation(PCU/min)	Percent reduction from original capacity
Normal	29	296	90.0 – 198.0	133	21	-
Accident closing 1 lane	17	132	38.0 – 110.4	70	14	47.4* 41.7**
Accident closing 2 lanes	3	17	27.0 – 53.0	39	7	70.7* 67.5**
Vehicle breakdown	16	133	46.2 -106.4	84	11	36.8* 30.0**

Note: PCU is passenger car unit
* compared to field capacity
** compared to HCM capacity

The similar results of capacity reduction for the 3-lane freeway sections are shown in Table 4. It is interesting that the percentages of reduction in capacity in the 3-lane freeway sections are comparable to those of the 4-lane (no shoulder) sections. In the same situation, for example an accident with 2-lane closure, both freeway sections result in a similar capacity. This is because it is normal that motorists will use the shoulder as a runaround to escape the congestion and the accident.

Table 4. Capacity of the expressway with 3 lanes per direction (with shoulder)

Event	Number of events	Sample size	Range (PCU/min)	Average (PCU/min)	Standard deviation(PCU/min)	Percent reduction from original capacity
Normal	6	29	80.2-143.0	99	31	-
Accident closing 1 lane	6	77	32.0-89.8	53	12	46.5* 52.5**
Accident closing 2 lanes	1	12	24.2-42.6	30	5	69.7* 73.1**
Vehicle breakdown	1	6	52.0-81.0	68	11	31.3* 39.1**
Vehicle breakdown on shoulder	5	72	41.0-147.2	69	18	30.3* 38.2**

Note: PCU is passenger car unit
* compared to field capacity
** compared to HCM capacity

Since there were only a few incidents on the 2-lane freeway section during the study period, the results are somewhat not sufficient. However, the 1-lane closure reduces 67% of the original capacity, similar to the figures in the 3-lane and 4-lane sections.

The statistical testing shows that the reductions in the capacity in all cases are significant.

4.4 Impact of incidents on delay

Due to limitation on the CCTV locations and data availability, only few incidents can be recorded from one or two adjacent CCTVs and the direct field measurement of delay can be carried out. The major problem is the starting time of the incident occurrence. The study indicates that the time an incident first takes place from various sources is not reliable. The video recording also starts after the incident is reported to the center. Thus, the direct field measurement will be used for only the validation of the freeway delay model, which employs the queuing analysis. The delay can be estimated by two methods:

1) use the cumulative traffic counts entering the incident location and passing the incident to average the arrival and departure and then construct the delay model, and
2) use the counts to develop linear regression lines representing arrival and departure and construct the delay model.

Four incident cases provide a good data set since the two adjacent CCTVs can cover the whole queue backing up from the occurrence. The result is shown in Table 5. The analysis of mean square error, MSE, shows that the delay estimation using regressed lines yields closer figure to the direct field measurement. However, the construction of delay model from average flows provides closer incident duration estimate. It is noted that the limited data provides only the rationale for model selection. After the model is selected, the delay model is tested on the total of 51 specimens.

Table 5. Estimation of delay, queue length, and incident duration

Types of incidents	Incident duration (min)	Total travel delay (PCU – min)			Maximum number of vehicles in queue (PCU)			Incident duration (min)		
		Field	Method 1	Method 2	Field	Method 1	Method 2	Field	Method 1	Method 2
1. disabled	10	1,248	1,832	1,196	169	224	166	17	16	14
2. accident	22	26,814	4,584	27,762	845	813	832	59	60	67
3. disabled	11	2,029	1,403	1,954	237	168	203	18	17	19
4. disabled	25	3,806	3,495	2,694	269	215	172	34	32	31

4.6. Estimation of Total Delay Impacts on Freeway

Using the entire incident records, the total time loss due to incidents can be computed for the first and second expressway system. The figures are shown in Table 6. Using the 1999 data, the total time loss (economic) due to incidents is 78 million bahts (US 1.85 million dollars) per year. Note that the value of time is obtained from the previous feasibility study of the third expressway system in Bangkok (Expressway Authority of Thailand, 1992).

Table 6. Economic Value of Time due to Incident Delay

Expressway	Cost of delay due to incidents (million bahts)		
	Accidents	Vehicle breakdowns	Total
The first expressway system	7.8	32.1	39.9
The second expressway system	5.1	32.6	37.7
Total	12.9	64.7	77.6

4.7 Implication of the Improvement to the Incident Handling Operations

The study not only makes understanding on the patterns of incidents and estimation of the incident delay, but also suggest further improvement in the incident handling operations. First, the conventional operation of communication is evaluated. Many new formats and procedures are suggested to overcome the weaknesses.

The distribution of the incident durations (Figure 6 and 7) suggests the type of incidents to be put in attention. Several long responded and clearing incidents oought to be reviewed in their handling activities. They may suggest different techniques and procedures for incident management and operations. Moreover, a suitable criterion to measure the effectiveness in incident operations, such as time to access to incidents, can be proposed properly to evaluate the activities.

An incident potential plot on the freeway map (as an example in the Figure 8) is used to identify the possibility of incident occurrence and the severity of incident impacts. This map is used in assigning the patrol and emergency vehicles to station nearby. The map suggests the locations to place a special traveler information system, such as a variable message sign, to inform drivers on the traffic disturbance.

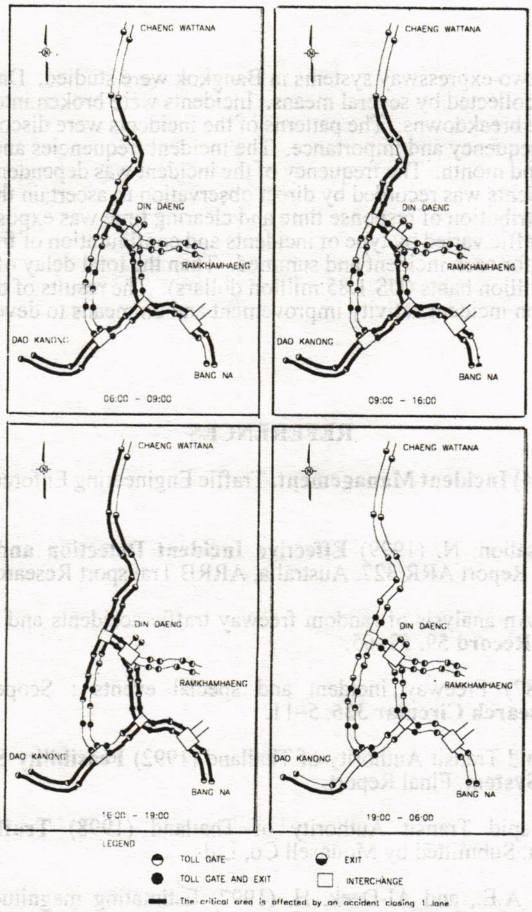


Figure 8. The incident potential area in each period of time

The assessment of the future operations can also be made from the developed model. The operation can be improved in two major parts; the reduction in clearance time, and the limitation of arrival to reduce the queuing effect and after-incident traffic control (management) to speed up the recovery. Based on the entire 1999 data as an amount of incidents in the developed model, the range of improvement is shown in Table 7. It is noted that the shortening of the incident blockage time by 3 minutes will reduce the delay by 30 percent. The figure can be used to economically justify any incident activity development.

Table 7. Percent of reduction in delay cost due to an improvement in incident management

Decrease in Incident duration	Decrease in recovery time			
	0 min	1 min	2 min	3 min
0 min	0	2.6	5.1	7.6
1 min	9.8	12.3	14.7	17.0
2 min	19.1	21.4	23.6	25.8
3 min	27.8	30.0	32.1	34.1

5. CONCLUSION

Traffic incidents on two expressway systems in Bangkok were studied. Data on incident characteristics were collected by several means. Incidents were broken into two main types; accidents and vehicle breakdowns. The patterns of the incidents were discovered and would be used for assess the frequency and importance. The incident frequencies and rates varied by time-of-day, week, and month. The frequency of the incident was dependent on traffic volume. The duration of incidents was recorded by direct observation to ascertain the data reliability. The duration and distribution of response time and clearing time was exposed. The degree of disruption to other traffic varied by type of incidents and configuration of freeway section. The delay was estimated for each incident and summed. Then the total delay of the entire year is estimated to be 78 million bahts (US 1.85 million dollars). The results of the study lead to several suggestions on incident activity improvement and on means to develop better incident management.

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