

SCHOOL OF  
CIVIL ENGINEERING

INDIANA

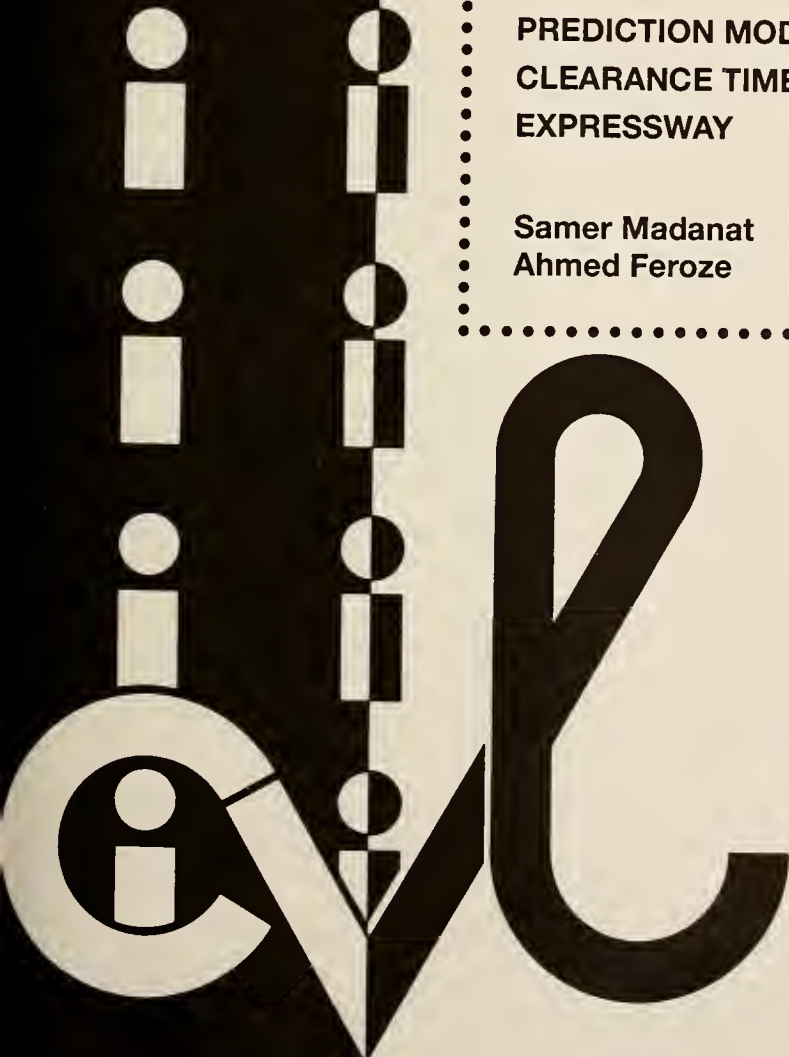
DEPARTMENT OF TRANSPORTATION

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-96/10  
Final Report

PREDICTION MODELS FOR INCIDENT  
CLEARANCE TIME FOR BORMAN  
EXPRESSWAY

Samer Madanat  
Ahmed Feroze



PURDUE UNIVERSITY



**Final Report**  
**FHWA/IN/JHRP-96/10**

**PREDICTION MODELS FOR INCIDENT CLEARANCE**  
**TIME FOR BORMAN EXPRESSWAY**

by

Dr. Samer Madanat  
Associate Professor

and

Ahmed Feroze  
Graduate Research Assistant:

Purdue University  
Department of Civil Engineering

Joint Highway Research Project

Project No.: SPR 2114  
File No.: 8-9-4  
(Vol. 1)

In Cooperation with the  
Indiana Department of Transportation and  
U.S. Department of Transportation  
Federal Highway Administration

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration and the Indiana Department of Transportation. This report does not constitute a standard, specification, or regulation

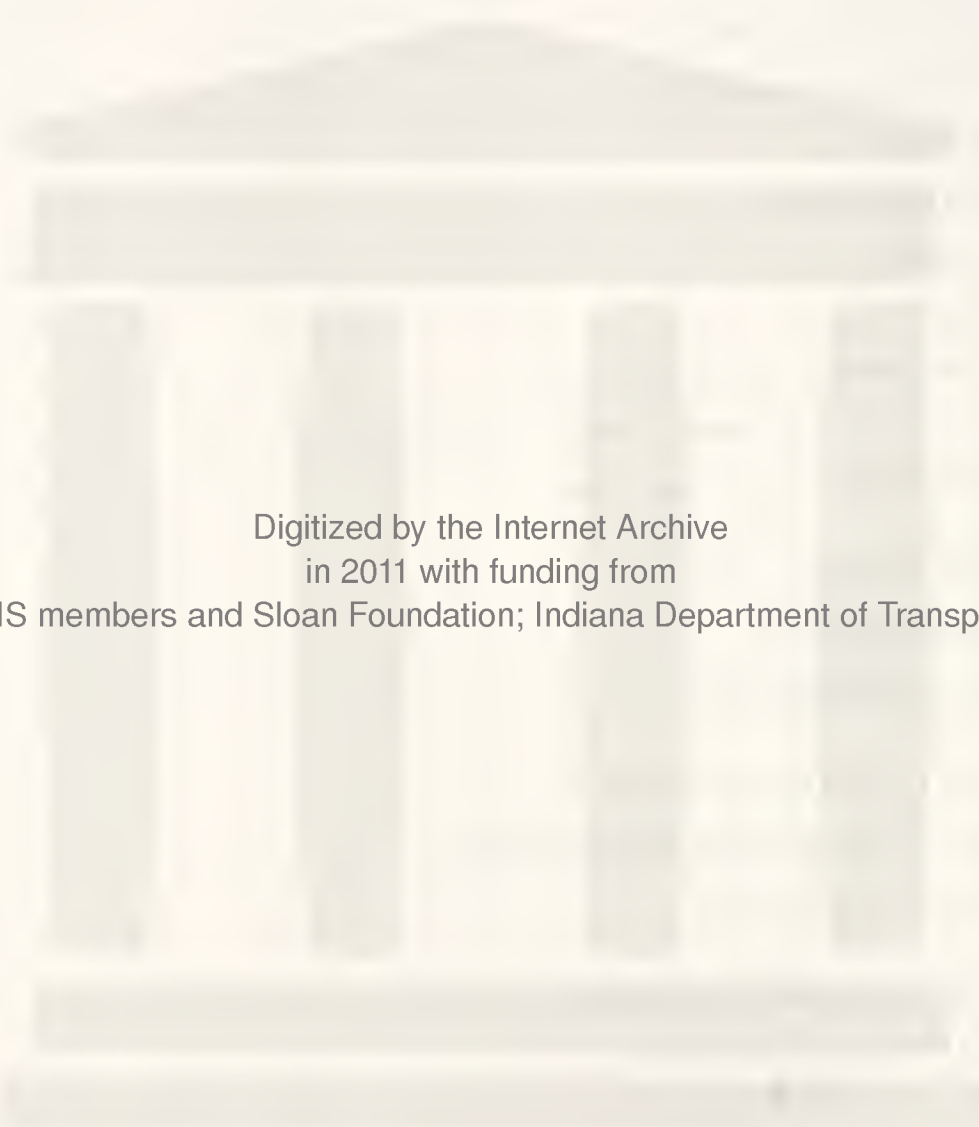
Purdue University  
West Lafayette, IN 47907  
March, 1997

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA/IN/JHRP-96/10		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Prediction Models for Incident Clearance Time for Borman Expressway				5. Report Date March, 1997	
				6. Performing Organization Code	
7. Author(s) Samer Madanat and Ahmed Feroze				8. Performing Organization Report No. FHWA/IN/JHRP-96/10	
9. Performing Organization Name and Address Joint Highway Research Project 1284 Civil Engineering Building Purdue University West Lafayette, Indiana 47907-1284				10. Work Unit No.	
				11. Contract or Grant No. SPR-2114	
12. Sponsoring Agency Name and Address Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204				13. Type of Report and Period Covered Final Report	
				14. Sponsoring Agency Code	
15. Supplementary Notes Prepared in cooperation with the Indiana Department of Transportation and Federal Highway Administration.					
16. Abstract This research consisted of two parts; this report is Volume 1 of 2 Volumes; Volume 2 is Report No. FHWA/IN/JHRP-96/11. The first part developed a set of incident clearance time prediction models for the Borman Expressway. The second part consisted of modeling driver's route choice behavior under the influence of advanced traveler information systems.  Volume 1 of this report describes the incident clearance time prediction models for the Borman Expressway. The prediction of incident clearance time from these models can facilitate in efficient incident management and support traveler information systems.  The products of this research project will be incorporated in the Advanced Traffic Management System that is being implemented on the Borman Expressway, a 16-mile segment of I-80 in northwest Indiana.					
17. Key Words Freeway traffic management; incident response; decision-making system.			18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 60	22. Price

## TABLE OF CONTENTS

	Page
LIST OF TABLES.....	vi
LIST OF FIGURES.....	vii
IMPLEMENTATION REPORT.....	viii
Incident Detection and Verification.....	viii
Incident Response.....	ix
Incident Site Management.....	ix
Incident Clearance.....	ix
Incident Recovery.....	ix
Incident Management on Borman Expressway.....	x
Application of Prediction Models in Incident Management System.....	xi
Building New Relationship with the commuters.....	xi
 CHAPTER 1 INTRODUCTION.....	 1
Background and Motivation.....	1
Components of Incident Duration.....	2
 CHAPTER 2 LITERATURE REVIEW.....	 5
Brief Review of Previous Incident Duration Studies.....	5
Lessons from Literature Review.....	9
 CHAPTER 3 PROBLEM STATEMENT.....	 11
Traffic Flow During Incident Duration.....	12
 CHAPTER 4 OBJECTIVES OF STUDY.....	 15
Factors Affecting Incident Clearance Time.....	15
Incident Characteristics.....	15
Traffic Characteristics.....	16
Environmental Characteristics.....	16



Digitized by the Internet Archive  
in 2011 with funding from  
LYRASIS members and Sloan Foundation; Indiana Department of Transportation

Operational/Response Characteristics.....	16
CHAPTER 5 WORK PLAN.....	19
Estimation of Truncated Regression Model.....	21
CHAPTER 6 ANALYSIS OF DATA.....	23
Overheating Vehicles Incidents Data Set.....	27
Debris on Roadway Incidents Data Set.....	28
Crashes Data Incidents Set.....	28
CHAPTER 7 MODELS ESTIMATION RESULTS.....	29
Model Building Approach.....	29
Model Estimation Results.....	29
Prediction Model for Overheating Vehicle Incidents.....	30
Prediction Model for Debris on Roadway Incidents.....	33
Prediction Model for Crash Incidents.....	35
Discussion on Estimated Results.....	37
Computer Program for the Prediction of Incident Clearance Time.....	38
Data Requirement for the Computer Program.....	38
CHAPTER 8 CONCLUSIONS AND RECOMMENDATIONS.....	40
Systems Approach to Incident Management.....	41
Recommendations.....	43
LIST OF REFERENCES.....	46

**LIST OF TABLES**

Table	Page
6.1 Summary Statistics of Incident Data.....	25
6.2 Sample of Data Set Prepared for this Study.....	26
6.3 Description of the Variables in the data set.....	27
7.1 Estimated Results for Overheating Vehicle Incidents.....	31
7.2 Estimated Results for Debris on Roadway Incidents.....	34
7.3 Estimated Results for Crash Incidents.....	36
8.1 Factors Influencing Incident Clearance Time.....	43



## LIST OF FIGURES

Figure	Page
1.1 Components of Freeway Incident Duration.....	3
1.2 Comprehensive Freeway Incident Operation and Decision Process.....	4
3.1 Queuing Diagram for Traffic Flow during an Incident.....	14
5.1 Comparison of Incident Clearance Time Predictions Obtained by Ordinary Least Squares and the Method of Maximum Likelihood for Crash Incidents.....	22
6.1 Profile of 1992 Incident Data on Borman Expressway.....	24
7.1 Plot of Predicted Values Versus Residuals from Incident Clearance Times Prediction Model of Overheating Vehicle Incidents.....	32
7.2 Plot of Predicted Values Versus Residuals from Incident Clearance Times Prediction Model of Crash Incidents.....	35

## IMPLEMENTATION REPORT

Incident management system means a systematic process that provides information on transportation system performance alternative strategies to alleviate nonrecurring congestion and enhance the mobility. The objective of incident management system is to implement necessary actions to alleviate congestion and enhance the performance of the transportation system. Freeway incident management system requires addressing of certain issues, taking decisions and actions to efficiently normalize traffic flow on the freeway after occurrence of an incident. A formal “incident management system” may actually reduce the resources used to react to incidents by decreasing overheads. Various incident related studies have shown that benefits of an extensive incident management program will be well worth its construction and implementation costs. Such programs have a significant potential to reduce accidents and the vehicle hours of delay.

Incident management system is not limited to a single action or program, instead it is a combination of actions that allow the responding agency to tailor its response, for incident clearance, within the agency’s resource limitations. Incident management systems encompass five basic tasks which are:

1. Incident Detection And Verification
2. Incident Response
3. Incident Site Management
4. Incident Clearance
5. Motorist Information

### Incident Detection and Verification

Incident detection is the process that brings an incident to the attention of the agency or agencies responsible for maintaining traffic flow and safe operation on the facility. Generally the speed with which an incident is detected affects the speed with which it is cleared and the amount of disruption it causes the remainder of the traffic stream. Thus fast, accurate detection often results in generally reduced traffic disruption and consequent savings. However, false detection of incidents can result in wasted response resources.

Incident detection can be done by using: electronic traffic monitoring devices (loop detectors), video cameras, Probe vehicles and other means.

### Incident Response

After an incident has been detected, response depends on understanding the cause of the incident and the steps and/or resources that are necessary to return the facility to normal conditions. Traffic management teams representing state and local agencies and highway engineers are gaining popularity as a way to develop incident response plan and traffic diversion routes. Decreasing the time required for personnel and equipment to reach a site, decrease the time required to clear an incident.

### Incident Site Management

Once the selected personnel and equipment have begun to arrive at the incident scene, the effectiveness of the response is a function of both how well suited the response technique is to that incident and how well the personnel at the scene manage the incident site.

### Incident Clearance

There is seldom a problem associated with minor incidents, such as stalls, but frequent problems are associated with major traffic incidents, especially those involving large trucks. Though large truck incidents are much less frequent, but require adequately experienced (trained in truck clearance techniques) special commercial vehicle safety enforcement units. Clearance problems associated with severe incidents if not taken care of efficiently can double or triple the time required to clear an incident.

### Incident Recovery

Recovery consists of three steps: restoring traffic flow at the site of the incident, preventing more traffic from flowing into the area and getting trapped in the upstream queue, and preventing congestion from spilling across the vicinity of incident zone.

Even in the absence of the formal incident management process, above five functions still take place, However less effectively and more slowly than if they had been conducted as part of a well planned procedure. The five tasks of incident management usually occur simultaneously and are often performed in an iterative fashion. That is the response to an incident may begin with preliminary information about the incident and then change as the incident is understood more clearly. The time saved by an incident management program depends on how well the stages of an incident: detection, response, clearance and recovery are managed.

As mentioned in the chapter three of this study, the vast majority of incidents are vehicle disablement's and minor accidents. During off-peak periods when traffic volumes are low, these incidents have little or no impact on freeway traffic. But when traffic volumes are high, their cumulative effect is substantial. Police and private tow operators can clear these incidents rapidly and efficiently, but usually this work is not given high priority. Incident congestion can be reduced considerably by assigning higher priority to the detection and clearance of minor incidents.

Major incidents are relatively few, but they require immediate attention, and rescue crew with special training and experience. In major incidents, congestion could be reduced considerably by improving clearance and recovery capabilities.

#### Incident Management on Borman Expressway

INDOT detects and verifies incidents by patrol vehicle of the traffic service (Hoosier helper program). When a major traffic incident occurs on the Borman Expressway, the incident is managed by Hoosier helpers, who are continuously patrolling in the area. Hoosier helpers perform an important aspect of the incident management, that is the servicing and the removal of the incidents. Depending on the type of the incident they redirect traffic, help with relocating vehicles, pick up debris, supply needed fuel/minor repairs, etc. Also a formal and informal rotation lists are used to distribute work among tow operators. The Hoosier helper program is one of the entrepreneurial initiatives, its vehicles (light pick-up trucks) with gas, water and light repair equipment patrol 18 miles of Borman Expressway. They rescue stranded motorists and remove stalled cars. If needed

vehicles and equipment are dispatched by the Borman Expressway traffic managers to the incident site. Other agencies, such as the police and medical service, are contacted if the incident involves injuries and require the services of these agencies. The incident management personnel also maintain a log of the incident information which is archived as incident reports, (the source of data used in this study).

### Application of Prediction Models in Incident Management System

Timely information about incidents and traffic conditions is valuable because the Borman Expressway is already saturated specially during peak hours, and even moderately severe incidents can trigger substantial congestion. Incident clearance time prediction models can be integrated in the incident management system. To do this, the first step is to apply the real time information collected by the control center to make incident clearance time predictions. These predictions then can be disseminated to drivers by public/commercial radio systems and highway advisory radios. As drivers receive the incident clearance time information they should be able to make better route choices or follow instructions to avoid delay. Overall, this will result in shortening of incident durations and delay experienced by the motorists.

### Building new relationship with the commuters

Traffic information and traffic reports are discounted because they are often inaccurate. In part this is because the duration of majority of the incidents is short, and by the time the traffic information is broadcast the situation is often cleared. In addition in our area (Borman Expressway), where the average commuter time is short, many commuters are already committed to their routes before traffic radio spots can warn them of an incident. A contributing problem is that until these prediction models are used there is no way that commercial stations could get real time data to feed into their traffic reports. These prediction models when incorporated in the traffic management system will help Highway Advisory Radio to broadcast reliable live traffic reports.



## CHAPTER 1

### INTRODUCTION

#### Background and Motivation

Freeway traffic congestion is recognized as a serious problem and a source of frustration and anxiety for million of travelers. Traffic statistics show that in 1981 only 16 percent of urban interstate miles were severely congested. By 1988, this ratio had increased to over 30 percent (U.S.DOT. 1990). Traffic congestion is a problem of growing public concern because congestion substantially increases the highway user's costs. A study sponsored by the Federal Highway Administration estimated that during 1984 urban freeway congestion caused 1.2 billion vehicle-hours of delay, 1.3 billion gallons of wasted fuel, and 9 billion in excess user costs.

Congestion can be categorized into two categories: a) recurrent congestion, the predictable delay caused by high volume of vehicles and inadequate capacity of the highways, b) nonrecurrent or incident congestion, the unpredictable delay caused by incidents. Recurrent congestion is predictable and follows well-defined temporal and spatial patterns. Whereas nonrecurring congestion occur randomly in time and space and can be of variable severity.

Traffic incidents include crashes, flat tires, spillovers, debris on roadway, minor mechanical problems and other events that can disrupt the normal flow of traffic. Traffic incidents reduce capacity and cause travel delay. The California Department of Transportation reported that in Los Angles an extra minute of incident duration during

the off-peak period would cause five minutes of delay to each motorist using the facility. This delay would be more pronounced during the peak period (Roper 1989).

For a given freeway, the delay caused by incident depends on:

- i) the demand flow at the time of the incident;
- ii) the remaining capacity of the freeway after the occurrence of an incident;
- iii) the total incident duration and the queue dissipation rate after the clearance of an incident.

The goal of any incident-management program is the minimization of incident delay through the rapid restoration of the freeway capacity. Reduction in incident clearance time reduces the total delay experienced by travelers, and thus can result in substantial savings for the roadway users.

### Components of Incident Duration

When a traffic incident occurs and it has been detected/verified by the traffic control center personnel, rescue crew is dispatched to the incident site to clear the incident and restore the normal traffic flow. The time period from the occurrence of an incident to the time when the normal traffic conditions are restored on the freeway is called incident duration. Incident duration consists of several components: detection/verification time, response time of rescue crew, and incident clearance time, as shown in figure 1.1, which is adapted from Zografos et al. (1993).

Incident detection time ( $T_1$ ) is the time between the occurrence of the incident and its detection by the TCC. Response time ( $T_1+T_2+T_3$ ) is the lag between incident occurrence and the arrival of the rescue crew. Clearance time ( $T_4$ ) is the time between

the start of the on-site rescue operation and the end of clean-up operation. This includes emergency medical service (if needed), incident investigation, and debris/spill removal.

Figure 1.1

Components of Incident Duration (adapted from Zografos et al. (1993).)

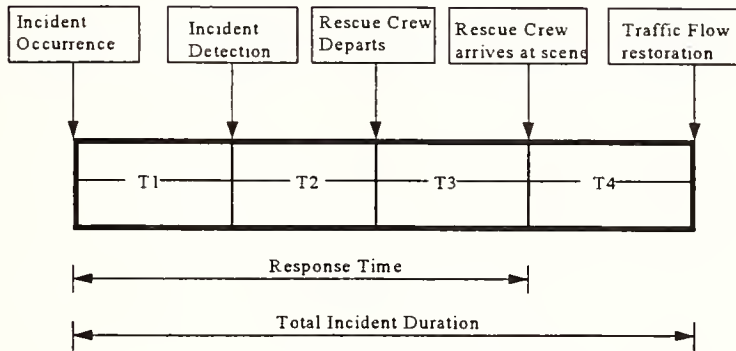
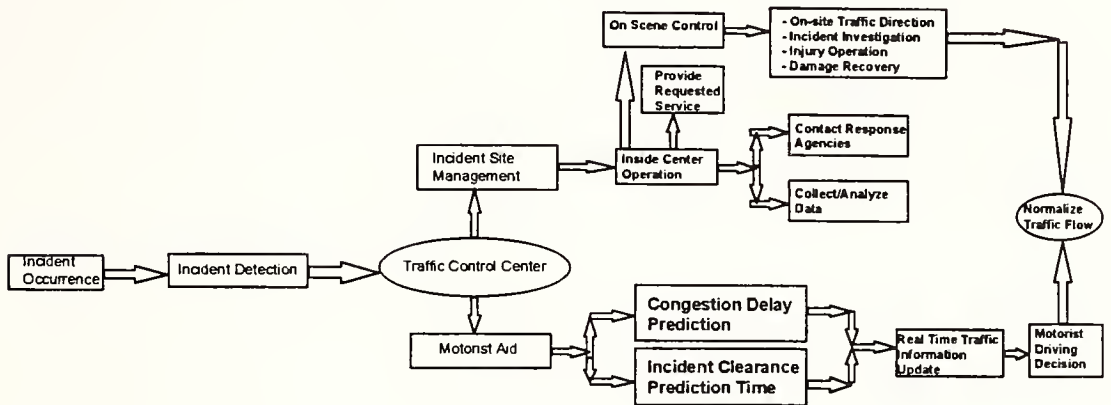


Figure 1.2, gives a conceptualization of a comprehensive freeway operation and decision process. When a major incident occurs, it can be detected through a multitude of information sources. After detection, the incident is “managed” both at the traffic control center and on the scene. The traffic control center staff dispatch the needed vehicles and equipment and contact other agencies, if needed. Further, the traffic control center personnel can disseminate incident information by using information systems (Highway Advisory Radios, Changeable Message Signs, or dedicated radio channels) as well as through commercial radio and television stations. Traffic control center also maintains the



incoming incident information which is analyzed and archived as incident reports. Meanwhile, the on-site incident management team perform the necessary operations to restore the normal traffic conditions.

Figure 1.2  
Comprehensive Freeway Incident Operation and Decision Process



The incident management procedure includes two types of activities: inside center operation and an on-scene management. Inside center control involves i) providing services for on-site operations, ii) Contracting other response agencies, iii) Collecting/Analyzing on site data. Whereas on scene management includes i) On site traffic direction, ii) incident investigation iii) processes of rescue, medical and firefighting, iv) damage recovery and clean up.

## CHAPTER 2

### LITERATURE REVIEW

An extensive literature search revealed that surprisingly little data on incident characteristics is available. Incident clearance time data is very costly to collect, because field surveillance is usually required. Aggregate information on accidents is available in federal and state records, but studies of incident characteristics and impacts, are scarce. Though this type of data can be constructed from highway police log records, but is difficult to access and may not include all incidents, or the required variables to develop incident clearance time prediction models.

Previous studies on incident duration models have identified some variables which affect incident duration. The average duration of incidents varies widely across these studies, in part due to differences in: incident types, locations, study environments, and methodologies used for data collection. The differences in incident durations across these studies may also be due to variation in the definition of incidents or in the definition of the duration variable (Giuliano 1989).

#### Brief Review of Previous Incident Duration Studies

In a study of Incident durations on John Lodge freeway, Detroit Michigan, a total of 927 lane blocking incident were analyzed. The results showed that clearance times related to crashes had an average duration of 6.14 minutes; vehicle disablement's averaged 5.24 minutes (DeRose, 1964). These were the durations for the time the vehicle remained in the travel lanes only, rather than the duration of the entire incident. Furthermore, in this

study the sample included many short incidents which required no response, and thus should not have been included in the sample because, in real operations they had already been cleared, before the rescue crew arrives at the incident scene.

Goolsby and Smith (1971) collected duration data from police logs for weekdays only, over a two year period (1968-1969) on Gulf freeway, Houston Texas. A mean duration time of 45 minutes for non injury accidents and 18 minutes for vehicle stalls was reported. In this study the duration was measured from the time of detection (by observers) to the time when the incident was cleared. Large standard deviations (19 minutes for accidents, 15 minutes for stalls) were observed in both cases. The author cited weather conditions, incident severity, and police work load as contributing factors to the observed high variances.

Another data was collected by California Department of Transportation (Juge, Kennedy, and Wang, 1974), and a comparative study of incident duration was performed in an evaluation of tow trucks and helicopters for freeway surveillance. Duration was measured from the time the incident was observed to the time it was cleared. 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.

Golob et al. (1987) studied a sample of 332 incidents involving large trucks and combination vehicles during a two year period (1983-1984) on the freeway system in Southern California and performed analysis relative to collision factors, accident severity, incident duration and lane closures. Homogenous groups of truck accidents were categorized according to type of collision and incident severity. These durations of crash incidents were found to be log-normally distributed. Incident durations were calculated

from the logged time at which obstructions and hazards were cleared and police left the scene. The average duration of all incidents ranged between 40 to 144 minutes. This study included the duration of all type of incidents like crashes, stalls, spillovers. The longer durations were typically associated with overturns and spillovers.

Guiliano (1989) performed a study on incident characteristics, frequency, and duration on a high volume urban freeway (12 mile section of the I-10 freeway) located in Los Angeles, California. Incident patterns were described, and incident duration's were analyzed as a function of incident characteristics. In this study an incident was defined as any occurrence that effects roadway capacity. Duration was measured as the elapsed time from the reporting of the incident to the time it was reported cleared. The study provided a comprehensive analysis of duration data collected. 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, time of the day. The mean duration of all incidents was 37 minutes and the standard deviation was 30 minutes.

Jones et al. (1991) performed a statistical analysis of urban freeway accident frequency and duration. The sample studied comprised of 2156 incidents of various types obtained from state records of Washington. In this study duration was measured from the time the police officer was notified of the accident to the time the officer left the accident scene. This study showed that the incident durations followed a log logistic distribution. Accident duration models were developed, the seasonal effects, daily variations, special events, driver and vehicle characteristics and accident severity measures were taken into account in this study. The study also found that peak-period incidents were cleared sooner than off-peak incidents, possibly due to the Washington State Department of

Transportation's policy of using tow trucks only during the peak period. The average accident duration of all incidents computed in this study was 50 minutes.

Another study was done by Paselk et al. (1994) to predict vehicular delay, in which they demonstrated the application of duration modeling techniques to find the best independent variables by analyzing several combinations of variables. The model with the highest log likelihood at convergence was considered the best model, provided that the signs of the variables were plausible and the variables could be explained intuitively. The four available modelling distributions (i.e. exponential, Weibull, log-logistic and log normal) were compared. The study demonstrated that the log-logistic model was the best, as its log-likelihood was highest, and the signs of estimated coefficients were as expected. The study also showed that each model improved as relevant explanatory variables were added, signifying that the model was explaining more of the dependent variable.

Khattak et al. (1994) developed models for predicting freeway incident durations. Data for this study was provided by the Illinois Department of Transportation from Chicago area freeways. The sample size in this study comprised of 109 incidents, with the average duration of all incidents equal to 72 minutes. Truncated regression models of incident duration were developed, using the following explanatory variables: weather, response time of the rescue crew, location, damage caused, number of trucks involved, number of injuries, type of load spill and the use of Highway Advisory Radio (HAR) and Changeable Message Signs (CMS). This study presented an idea of time sequence of these factors, and devised a method to successively improve incident clearance time predictions, as time progresses.



Studies of incident characteristics on incident duration found that longer durations were more likely if the incident involved injuries (Golob et al. 1987; Guiliano 1989; Jones et al. 1991), if there was an overturned vehicle (Golob et al. 1987), if lanes were blocked (Golob et al. 1987; Jones et al. 1991), if the accident occurred during night time (Jones et al. 1991), if the facility was congested (Wilshire and Keese 1963) and if high-demand special events such as sporting events were taking place (Jones et al. 1991). Furthermore, Jones et al. (1991) found that peak-period incidents were cleared sooner than off-peak incidents, possibly due to the Washington State Department of Transportation's policy of using tow trucks only during the peak period. Alcohol involvement was associated with shorter incident clearance times, possibly because of higher level of police response to such incidents (Jones et al. 1991). Khattak (1994) showed that as the incident clearance operation proceeds more information on the explanatory variables becomes available and therefore, better predictions of incident clearance times can be obtained. Overall, incident duration is influenced by incident characteristics, environmental conditions and location and traffic flow conditions.

### Lessons from Literature Review

The main factors which influence incident clearance time, are: incident characteristics, environmental conditions, roadway/flow characteristics and operational/response factors. It has been observed that incident clearance times are longer for: incidents involving injuries, adverse weather conditions, occurrence of incident in work zone, longer time taken by rescue team to reach incident site, higher flow rates of traffic (due to peak hours, special event, tourist activity etc.). Incident

clearance time can be reduced by implementation of special ramp metering on freeways, early dissemination of information regarding the incident, encouraging mode and route diversion.

The literature survey reveals deficiencies in the process of predicting incident clearance time. Incident management related studies reveal the need for improved methods for predicting incident duration on the freeways for an effective Advanced Traveler Information System. Previous studies also indicate the complexities of the incident clearance time prediction phenomena. The time to clear the incident varies from case to case. The possible factors affecting clearance time are complicated and their relationships are ambiguous. Detailed information on various variables is required for the accurate prediction of incident clearance time. It is a challenging process to collect incident data and therefore until now very little work has been done to model incident clearance time.

## CHAPTER 3

### PROBLEM STATEMENT

The objective of this research is to develop a practical capability to predict incident clearance time. To keep freeway congestion under control, there is a need for implementing an Advanced Traffic Management System (ATMS). To implement an ATMS, predictive information is required about incident clearance time so that the drivers can divert to alternative routes or otherwise change travel patterns rather than joining the queue.

Growth in travel demand has increased the stress on the highway infrastructure, making freeway networks larger and more complicated; many decisions which were previously based on the experience and judgment of the traffic control personnel now require better understanding of incident induced traffic congestion. One way to mitigate the congestion problem on freeways is to respond quickly to traffic incidents and divert travelers away from nonrecurrent congestion. This highlights the need for developing models for short-term prediction of incident clearance times, which can serve the purpose of providing the drivers with accurate incident information.

Although substantial attention has been directed to incident detection and motorist information systems components of freeway incident management, there has been little emphasis on the incident-remedy component. This further highlights the need of accurate prediction models to develop an integrated decision-making framework for reducing freeway incident delay, through the minimization of the duration of the incident. The magnitude and the importance of the problem related to incident congestion has



prompted a number of state transportation agencies to establish freeway incident management programs.

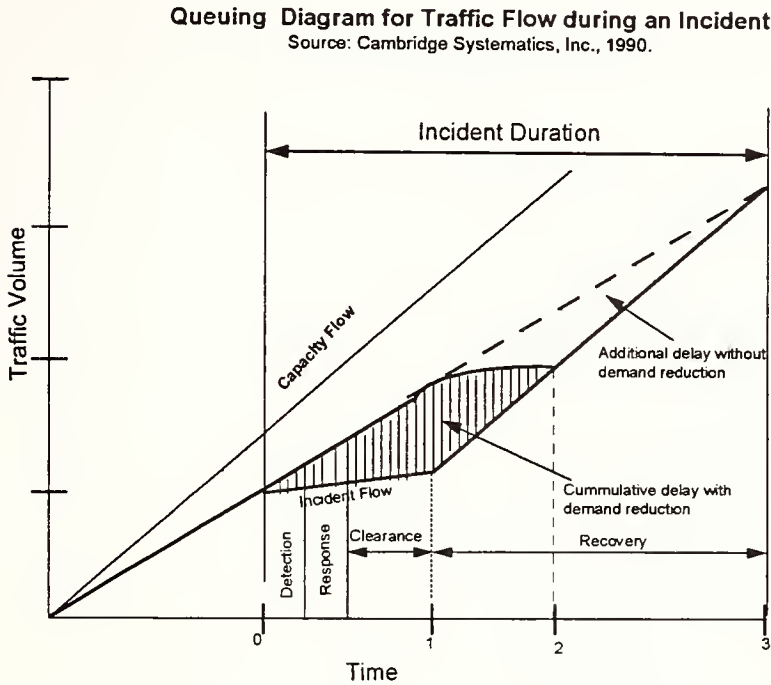
Timely information about incidents and traffic conditions is valuable because the Borman Expressway is already saturated specially during peak hours, and even moderately severe incidents can trigger substantial congestion. Incident clearance time prediction models can be integrated in the incident management system. To do this, the first step is to apply the real time information collected by the control center to make incident clearance time predictions. These predictions then can be disseminated to drivers by public/commercial radio systems and highway advisory radios. As drivers receive the incident clearance time information they should be able to make better route choices or follow instructions to avoid delay. Overall, this will result in shortening of incident durations and delay experienced by the motorists.

#### Traffic Flow During Incident Duration

When an incident blocks a lane, it restricts the flow of traffic and a queue builds upstream of the incident. The queue will continue to grow until the incident is cleared and traffic flow is restored. Once the incident is cleared, traffic will discharge through the incident site until the queue is dissipated; however, the discharge flow is limited by the "normal capacity of the freeway". The arrival rate at the incident bottleneck exceeds the processing rate for the duration of the incident (Makigami et al. 1971; Al Deek and Kanafani 1991). The delays experienced by motorists in the queue are represented in the figure 3.1 by the area (hatched by vertical lines) that lies between the normal flow rate and the lower incident flow rate. If the normal flow of traffic into the incident site is reduced

by diverting traffic to alternate routes, then the vehicle-hours of delay are minimized. If normal traffic flow is not diverted, then additional vehicle-hours of delay (hatched area by inclined lines) are accrued.

Figure 3.1



When an incident blocks a lane of traffic it chokes down the flow of traffic, and a queue of traffic builds upstream of the incident. Traffic flow studies have shown that blocking one out of three lanes can cut traffic flows by fifty percent; blocking two out of three lanes can cut traffic flow by eighty percent. The queue and vehicle hours of delay will continue to build until the incident is cleared and traffic flow is restored.

This study analyzes incidents which occurred on the Borman Expressway in Indiana based on real time measurements of traffic and weather variables. To quickly compute incident clearance time a computer program has been developed, which incorporates the incident clearance time prediction models.

The research study was conducted in the following five stages: (1) Literature Review and Assessment of Existing Incident Duration Related Studies, (2) Data Sets Preparation (3) Methodology Development, (4) Computer-Based Program Design, and (5) Results and Conclusions.

## CHAPTER 4

### OBJECTIVES OF STUDY

The main objective of this study was to develop econometric models for predicting incident clearance time. Econometric models have been developed for incident clearance time, which will help freeway incident management agencies to rationalize the deployment of their incident-response resources. The predicted values of incident clearance time from these models can be used in the formulation of appropriate traffic management strategies to mitigate the adverse impacts of traffic incidents and will facilitate traffic managers in improving on-site incident management. Some a priori knowledge of the factors affecting incident clearance time has been discussed below.

#### Factors Affecting Incident Clearance Time

The parameters that influence incident clearance process can be grouped into four categories: incident characteristics, traffic data, environmental factors and the operational/response factors. Within these groups many factors contribute in determining the time taken to clear an incident. The following sections explain the role of each category on the incident clearance process.

#### Incident Characteristics

These include the type of incident, location of incident (freeway, the ramp or the shoulder lane), time of the occurrence of an incident, type/number of vehicle involved; severity of an incident and various other parameters related to the incident. It has been

observed that incident clearance times are longer for: incidents involving injuries, incidents involving more than one vehicle, occurrence of incident on the ramp, occurrence of incident in work zone.

### Traffic Characteristics

These include the traffic volume, average speed of traffic, the average percentage of trucks on the freeway during incident clearance process. Traffic characteristics significantly affect the incident clearance time. Higher flow rates of traffic (due to peak hours, special event, tourist activity etc.) increase the time taken by the rescue team to reach incident site and thus prolongs the incident clearance process. High average speeds greatly reduces the efficiency of the rescue team, (as the rescue crew has to be more cautious about safety), and thus result in longer incident clearance times.

### Environmental Characteristics

The environmental factors that influence incident clearance time are weather (rain, snow, thunderstorm, fog, temperature, visibility etc.). Adverse weather during rescue operation increase the clearance time of an incident.

### Operational/Response Characteristics

These include the variables like the work load of the rescue crew at the time of rescue operation, type of equipment used to clear an incident, efficiency of the incident clearance team, whether advanced information systems (HAR or CMS) were used or not. Incident clearance time can be reduced by implementation of special ramp metering on freeways,

early dissemination of information regarding the incident, encouraging mode and route diversion.

The data sets prepared for developing these models is explained in the chapter five of the report. Based on these data sets three separate truncated regression models were estimated, for the three types of incidents: overheating vehicles, Debris on roadway, and Crashes.

## CHAPTER 5

### MODEL DEVELOPMENT

#### Introduction

The main objective of this study was to develop econometric models for predicting incident clearance time. The data sets prepared for developing these models have been explained in the chapter 3 of the report. Based on these data sets three separate truncated regression models were estimated, for the three types of incidents: overheating vehicles, Debris on roadway, and Crashes. Limdep econometric software was used for the estimation of these models and the results obtained are shown in the following pages.

#### Prediction Model for Overheating Vehicle Incidents

The data set for overheating vehicle incidents consisted of 96 incidents. The mean clearance time of these incidents was 12.44 minutes, with a standard deviation of 9.85 minutes. The estimation results for overheating vehicle incidents are shown in table 5.1.

The truncated regression model obtained for the overheating vehicle incidents had these significant variables: temperature during the incident clearing, average percentage of trucks on the expressway during the clearing operation, and average speed during the incident clearing process.

The coefficient of temp has a negative sign indicating that the clearance times of overheating vehicle incidents are shorter at high temperatures. This may be due to the fact that at extremely low temperatures (winter months) it becomes difficult to work



outside on the freeway to clear an incident, and this leads to longer incident clearance time. Secondly if the overheating vehicle incident takes place due to hot temperature, it can be managed by the driver himself by just bringing his vehicle in the shoulder lane and cooling the engine, by adding water in the radiator etc.

Table 5.1. Estimated Results for Overheating vehicle Incidents

**Model Command:**

TRUNCATED; LHS = Clt2; RHS = One,Temp,Avpr,Avsp \$  
 Limited Dependent Variable Model - TRUNCATED regression  
 Ordinary least squares regression Dep. Variable = Clt2  
 Observations = 96 Weights = ONE  
 Mean of LHS = 0.1244792E+02 Std.Dev of LHS = 0.9849253E+01  
 \*\*\*\*\*

Limited Dependent Variable Model - TRUNCATED regression  
 Maximum Likelihood Estimates  
 Log-Likelihood -331.7221  
 Threshold values for the model: Lower= 0.0000 Upper=+Infinity

Variable	Coefficient	t-ratio
Constant	-144.14	-1.489
Temp[Temperature at the time of the incident]	-0.23994E-02	-1.260
Avpr[Av. %age of trucks during rescue operation]	-0.26868	-1.097
Avsp [Av. traffic speed, during rescue operation]	2.4248	1.673
$\sigma$	16.177	4.774

\*\*\*\*\*  
 L(0) = -352.60

L( $\beta$ ) = -331.72

$\rho^2$  (corrected) = 0.050

\*\* Likelihood ratio test was performed to check if all the slope parameters are significant.

$H_0: \beta_1 = \beta_2 = \beta_3 = 0.$   $H_a: \beta_1, \beta_2, \beta_3 \neq 0.$

Test Statistic:  $-2(-352.6 - (-331.72)) = 41.76$

Critical value  $\chi^2_{(3,0.95)} = 7.81.$

As the test statistic is greater than the critical value, so reject  $H_0.$

**Prediction Model for Debris on Roadway Incidents**

A total of 286 incidents of debris on the roadway were observed on the road lanes. The mean clearance time for this type of incidents was 3.95 minutes with a standard deviation of 3.31



minutes. 16% of these debris on roadway incidents were on the freeway ramps. The incidents of debris on the shoulder or median lane were not taken in the data set because they do not cause any obstruction in the flow of traffic. Majority of the incidents of debris on the roadway occurred during the day time. Table 5.2 gives the results for the prediction model for the debris on roadway incidents. This model has only two significant variables: wead and ramp. Both of these are binary variables with 0 or 1 values: [Wead =1 if adverse weather condition, and 0 otherwise] and [Ramp = 1 if incident is on ramp, and 0 otherwise]. The positive coefficient of variable Wead, indicates that adverse weather increases the incident clearance time.

Table 5.2: Estimated Results for Debris on Roadway Incidents

**Model Command:**

```
TRUNCATED,LHS=CLT5;RHS=ONE,WEAD,RAMP $
Limited Dependent Variable Model - TRUNCATED regression
Ordinary least squares regression. Dep. Variable = Clt5
Observations = 286 Weights = ONE
Mean of LHS = 0.3360140E+01 Std.Dev of LHS = 0.3305448E+01
*****
```

```
Limited Dependent Variable Model - TRUNCATED regression
Maximum Likelihood Estimates
Log-Likelihood..... -627.6394
Threshold values for the model: Lower = 0.0000 Upper = +Infinity
```

Variable	Coefficient	t-ratio
Constant	-43.362	-1.983
Wead[1 if adverse weather condition, 0 otherwise]	10.741	1.699
Ramp[1 if incident is on ramp , 0 otherwise]	15.489	1.879
$\sigma$	11.840	4.337
*****		
L(0)	= -741.72	
L( $\beta$ )	= -627.64	
$\rho^2$ (corrected)	= 0.151	

\*\* Likelihood ratio test was performed to check if all the slope parameters are significant.

$H_0: \beta_1 = \beta_2 = \beta_3 = 0.$   $H_a: \beta_1, \beta_2, \beta_3 \neq 0.$   
 Test Statistic:  $-2(-741.72 - (-627.64)) = 228.16$   
 Critical value  $\chi^2_{(2,0.95)} = 5.99.$   
 As the test statistic is greater than the critical value, so reject  $H_0.$

Another important variable in the model was the location of the debris, if the debris incident was on the ramp of the freeway, incident clearance time was longer, than compared to the clearance time of debris incidents on the traffic lanes. This may be due to the fact that clearance of debris on ramps takes more time because the sight distance is less and the traffic is difficult to control on ramps.

#### Prediction Model for Crash Incidents

Table 5.3 gives the estimation results for the prediction model of crash incidents. Wead and Avsp (average speed on freeway) during incident clearance were the significant variables in the model. The coefficient of Avsp was positive, indicating that higher the average speed more will be the incident clearance time. This may be because the crash incidents are likely to be more severe at high average speeds and severe incidents take longer to clear. The positive sign of the estimated coefficient of the binary variable wead, again indicates that adverse weather increases the incident clearance time.

Table 5.3: Estimated Results for Crash Incidents.

#### Model Command:

```
TRUNCATED;LHS=CLT7; RHS=One,Wead,Avsp,List $
Limited Dependent Variable Model - TRUNCATED regression
Ordinary least squares regression. Dep. Variable = CLT27
Observations = 77 Weights = ONE
Mean of LHS = 0.2059740E+02 Std.Dev of LHS = 0.2090848E+02
```

\*\*\*\*\*

Limited Dependent Variable Model - TRUNCATED regression

Maximum Likelihood Estimates

Log-Likelihood..... -307.3095

Threshold values for the model: Lower = 0.0000 Upper = +Infinity

Variable	Coefficient	t-ratio
Constant	-510.96	-4.553
Wead [1 if adverse weather condition, 0 otherwise]	93.256	1.613
Avsp [Av. traffic speed, during rescue operation]	5.5112	3.749
$\sigma$	59.693	3.296
*****		
L(0)	= -340.24	
L( $\beta$ )	= -307.31	
$\rho^2$ (corrected)	= 0.091	

\*\* Likelihood ratio test was performed to check if all the slope parameters are significant.

$H_0: \beta_1 = \beta_2 = \beta_3 = 0.$        $H_a: \beta_1, \beta_2, \beta_3 \neq 0.$

Test Statistic:  $-2(-340.24 - (-307.31)) = 65.86$

Critical value  $\chi^2_{(2,0.95)} = 5.99.$

As the test statistic is greater than the critical value, so reject  $H_0.$

### Discussion on Estimated Results

While estimating the models, most of the variables could not pass the t statistical test. However, from the perspective of improving freeway surveillance and control systems those variables might be important. For example the occurrence of an incident during the day or night can significantly represent how well the current system works.

Comparison of incident clearance times observed in this study with earlier similar studies indicate that sample used for this study include incident with lower values of average clearance times. This may be due to the fact that all types of incidents were not included in this study, and secondly in this sample there was a higher fraction of the shorter duration incidents. Larger and more representative samples would be needed to make the models more precise.

Moreover the models are underspecified in terms of operational/response variables. Information on variables like severity of incident (damage caused or number of injuries), response time of rescue vehicle, number of trucks involved, whether advanced traveler information systems were used, can result in precise prediction models. These variable can be obtained, if the existing method of recording incident data also account for operational/response characteristics, and this requires some improvements in the existing incident recording system.

## CHAPTER 6

### ANALYSIS OF DATA

In order to develop appropriate models for predicting incident clearance time, the key concern is the acquisition of an appropriate data set. The data set should contain explanatory variables such as temperature, visibility, general weather conditions, occurrence of incident during the day or night, volume of traffic, average speed of vehicles, the percentage of trucks during the incident clearance operation etc. To develop accurate prediction models data is also required for operational/response factors. Operational/response factors include variables like time taken by the rescue crew to reach the scene of incident, type of equipment used to clear the incident, dissemination of incident information by Highway Advisory Radio (HAR) to the motorist.

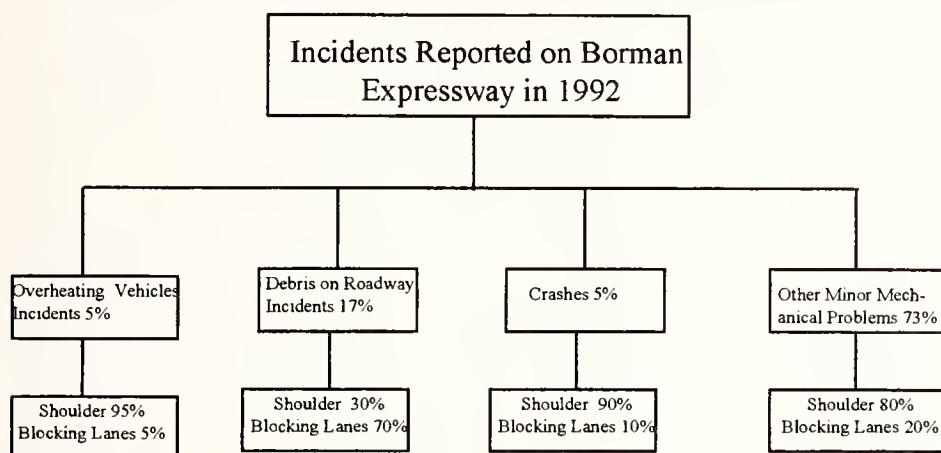
It is estimated that 70 percent of all freeway incidents are recorded by state agencies, usually as brief annotations in communication logs. The other 30 percent go unreported and, as such, are estimated to be minor incidents having little impact on traffic (Grenzeback, Champion & Schoen 1992).

The available incident data for the Borman Expressway in 1992 provided us with incident characteristics such as the type of incident, location of incident, time at which the rescue crew arrived at the scene of incident, time taken to clear the incident. A total of 3922 incidents were recorded on the Borman Expressway in year 1992. The incident,

weather and traffic data for 1992 on the Borman Expressway were carefully analyzed and the possible explanatory variables for the incident clearance time prediction model were sorted out.

Figure 6.1

Profile of 1992 Incident Data on Borman Expressway



After summarizing, the data were sorted into seven incident types: tire repair, overheating vehicles, minor mechanical problems, abandoned vehicles, debris on roadway, driver pulled out, and crashes. Figure 6.1 gives a composite profile of incidents drawn from limited available data. Incidents data by each type indicates that 78% of incidents were disabled vehicles (flat tire, overheating vehicles, minor mechanical problem, and abandoned vehicles). Crashes amount to only 5% of the reported incidents, most of them were the results of minor collisions. Remaining 17% incidents were incidents of debris on roadway, driver pulled out etc.

Table 6.1 give a compact summary of the incident data. The statistics have been calculated by using the statistical analysis software (SAS). The distributions, of clearance time of each type of incident were plotted by using SAS.

Table 6.1

## Summary Statistics of Incident Data

Type of Incident	Number of Incidents	Mean CLT (Minutes)	Std Dev of CLT	Percentage of Total incidents	Best Fit Distribution
Tire Repair	795	15.31	13.34	20%	Lognormal
Overheating Vehicles	192	12.73	10.81	5%	Lognormal
Other Minor Mech Problems	947	14.04	16.1	24%	Gamma
Abandoned Vehicle	1053	3.41	7.21	26%	Normal
Debris on Roadway	683	5.55	10.38	17%	Weibull
Driver Pulled Out	93	2.98	1.84	2.5%	Gamma
Crash	159	25.59	27.25	5%	Weibull **
*ClT:Clearance time					

The best fit distributions for the tire repair and overheating vehicles incident are the Lognormal distributions as these have the lowest Chi- square value. The distribution for the clearance time of abandoned vehicle incidents was normally distributed, whereas the distribution of the debris on roadway incident clearance times had a Weibull distribution. The clearance times for the incidents (other mechanical problems and driver pulled out) had Gamma distribution with the lowest Chi-square value. These



distributions are skewed, indicating that the distributions of clearance times for these incidents are not symmetrically distributed. The best fit distribution for the clearance time of vehicle crash clearance times is Weibull. This is the only distribution which passed the Chi Square test for goodness of fit.

Table 6.2 gives the description of the relevant explanatory variables obtained from the data set prepared for this study, by including a section from the data file.

Table 6.2

Sample of data set prepared for this study

Clc	Type	Loc	Visi	Temp	Wead	D/N	Tvol	Tper	Avsp
7	1	1	5.5	37	0	0	690	56.96	64.36
10	3	1	2	38	1	0	143	52.82	65.81
4	1	1	7	22	0	0	603	56.35	65.73
10	1	1	7	22	0	0	740	53.33	65.03
6	1	1	15	21	0	0	1079	36.89	64.55
7	1	5	6	31	1	1	2350	16.06	64.47
5	2	1	10	40	1	0	778	51.04	65.07
8	1	1	7	33	0	0	715	56.72	65.31
12	3	1	4	40	1	0	1187	13.45	64.69
12	1	1	15	78	0	1	3263	29.13	66.94
15	4	1	10	68	0	0	1011	17.2	67.89
7	1	1	15	47	1	0	1135	40.25	64.32

The variable average traffic speed was selected in the data set to evaluate the effect of speed trends on the clearance time of an incident. It was obtained from the spot speeds measured by using weigh in motion scale installed at mile marker 5.5 in both east and west bound directions on the Borman Expressway. These speeds were measured by observing instantaneous speeds of a sample of vehicles at the specified location, and is expressed in miles per hour. Final data sets were prepared for three types of incidents found

relevant to this study: overheating vehicles, debris on the roadway and crash incidents. The brief description of each of the three types of data sets is given below:

Table 6.3  
Descriptions of the variables in the data set

Variable	Description
Clt	Incident clearance time (minutes)
Type	Type of vehicle
Loc	Location of incident
Visi	Visibility
Temp	Temperature (°F)
Wead	Dummy variable for adverse weather
D/N	Dummy variable for day/night
Tvol	Total volume of vehicles
Tper	Average percentage of trucks
Avsp	Average traffic speed (miles/hour)

#### Overheating Vehicle Incidents Data Set

A total of 96 overheating vehicle incidents were observed. Overheating vehicle is a common problem, especially during the hot summer days when the travelers in their vehicles have their vehicle air conditioners on, and are caught in traffic congestion. The mean clearance time of overheating vehicle incidents was 12.5 minutes with a standard deviation of 9.85 minutes. In about 95% of the overheating vehicle incidents driver were able to bring their vehicle on the shoulder or the median lane.

#### Debris on Roadway Incidents Data Set



A total of 286 incidents of debris on the roadway were observed on the road lanes. The mean clearance time for this type of incidents was 3.95 minutes with a standard deviation of 3.31 minutes. 16% of these debris on roadway incidents were on the freeway ramps. The incidents of debris on the shoulder or median lane were not taken in the data set because they do not cause any obstruction in the flow of traffic. It was observed from the data set that majority of the incidents of debris on the roadway were cleared during the day time.

#### Crash Incidents Data Set

This data set comprised of 83 crash incidents, including six incidents with clearance time equal to zero, this was because these incidents had already been cleared before the rescue crew arrived at the scene of incident. The average clearance time for the crash incidents was about 20 minutes, with standard deviation of 21 minutes. Crashes were almost equally distributed during the day and night. In 60% of the crashes the drivers were able to move their vehicle in the shoulder lanes.

## CHAPTER 7

### MODEL ESTIMATION RESULTS

#### Model Building Approach

All available relevant variables were included in the model estimation approach to select the best model specification. Statistical criteria and a priori beliefs were relied on to make sure whether a particular variable should be included or excluded from the model. Several model specifications were checked and different independent variable combinations were tried before settling on the final models for the incident clearance times. The number of alternative model specifications were tried and this procedure was adopted to eliminate the explanatory variables, which were not statistically significant, not in conformity with a priori considerations, or were highly intercorrelated. Some of the variables with plausible signs and suggested by a priori beliefs were kept in the model even if their t statistics were slightly lower than the acceptable.

#### Model Estimation Results

Limdep econometric software was used for the estimation of these models and the results obtained are shown in the following pages. Truncated regression for normal distribution was run for all the incident clearance time models: overheating vehicles, Debris on roadway and crashes, because the econometric software available lacked the capability to run truncated regression models for other distributions. The residuals for all the three truncated regression models fulfilled the normality assumption.

### Prediction Model for Overheating Vehicle Incidents

The data set for overheating vehicle incidents consisted of 96 incidents. The mean clearance time of these incidents was 12.44 minutes, with a standard deviation of 9.85 minutes. The estimation results for overheating vehicle incidents are shown in table 7.1.

The truncated regression model obtained for the overheating vehicle incidents had these significant variables: temperature during the incident clearing, average percentage of trucks on the expressway during the clearing operation, and average speed during the incident clearing process. The coefficient of temp has a negative sign indicating that the clearance times of an overheating vehicles are shorter at high temperatures. This may be due to the fact that at extremely low temperatures (winter months) it becomes difficult to work outside on the freeway to clear an incident, and this leads to longer incident clearance time. Secondly if the overheating vehicle incident takes place due to hot temperature, it can be managed by the driver himself by just bringing his vehicle in the shoulder lane and cooling the engine, by adding water in the radiator etc. Whereas if the cause of the overheating vehicle is mechanical rather than the hot weather, then the clearance time of an incident is longer as this needs the towing of the vehicle to the nearby garage or a place where the cause of overheating vehicle can be fixed. The variable Tper represent the average percentage of trucks on the freeway at the time of incident clearance operation. The coefficient of Tper has a negative sign indicating that higher the percentage of trucks in the traffic stream, shorter is the clearance time. This may be due to the fact that the truckers try to avoid congestion, by avoiding to travel during the peak hours.

Table 7.1. Estimated Results for Overheating vehicle Incidents

```

*****
Model Command
TRUNCATED; LHS = CIt2; RHS = One,Temp,Avpr,Avsp$
Limited Dependent Variable Model - TRUNCATED regression
Ordinary least squares regression. Dep. Variable = CIt2
Observations = 96 Weights = ONE
Mean of LHS = 0.1244792E+02 Std.Dev of LHS = 0.9849253E+01
*****

```

```

Limited Dependent Variable Model - TRUNCATED regression
Maximum Likelihood Estimates
Log-Likelihood -331.7221
Threshold values for the model: Lower= 0.0000 Upper=+Infinity
Degrees of freedom: Regression 3, Residual 92, Total = 95

```

Variable	Coefficient	t-ratio	P value
Constant	-144.14	-1.49	0.137
Temp[Temperature at time of the incident]	-0.0024	-1.26	0.207
Avpr[Av. %age of trucks]	-0.269	-1.10	0.272
Avsp [Av. traffic speed]	2.425	1.67	0.094
$\sigma$	16.18	4.77	0.000

### Summary Statistics

L(0)	= -352.60
L( $\beta$ )	= -331.72
$\rho^2$ (corrected)	= 0.050

\*\* Likelihood ratio test was performed to check if atleast one of the slope parameters is significant.

$H_0: \beta_1 = \beta_2 = \beta_3 = 0.$   $H_a: \text{Atleast one } \beta \neq 0.$

Test Statistic:  $-2(-352.6 - (-331.72)) = 41.76$

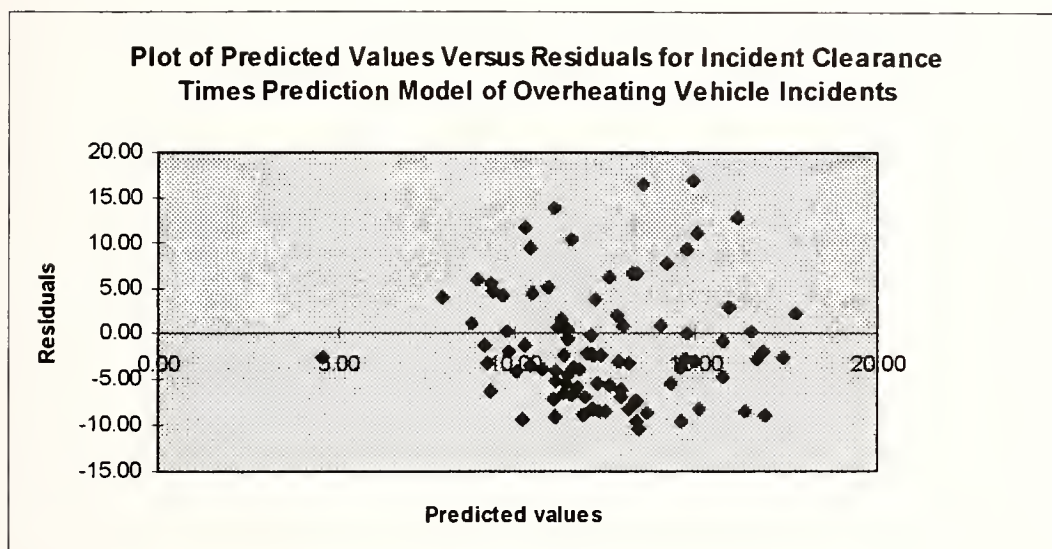
Critical value  $\chi^2_{(3,0.95)} = 7.81.$

As the test statistic is greater than the critical value, so reject  $H_0.$

The percentage of trucks is higher during the night, when the overall traffic flow is lower, and at lower traffic flows it takes less time to clear an incident. The variables total traffic volume and the binary variable for the occurrence of an incident during the day or night were tried in the model, but their coefficients were not statistically significant. This may be due to the fact that measured traffic volumes in the data set for developing these

models were not precisely measured. Therefore in this model variable Tper (average percentage of trucks) serves as a proxy for traffic volume. Another important variable that influences clearance time of overheating vehicle incident is average speed (Avsp). Avsp has a positive sign and is statistically significant indicating that the higher the average speed, the longer the incident clearance time. The efficiency of the rescue team is significantly reduced, when the average speeds are high on the freeway, and this leads to an increase in incident clearance time.

Figure 7.1.



A residual analysis was performed, to check for the bias in the model of overheating vehicle incidents. Figure 7.1, shows that the residuals (observed values - Predicted values) when plotted against the predicted values of the incident clearance times do not show any regular pattern. Residuals are uniformly distributed above and below the mean value zero, indicating that the variability in the residuals do not depend in any way on the predicted values obtained from the model. That is the model gives unbiased results.



### Prediction Model for Debris on Roadway Incidents

A total of 286 incidents of debris on the roadway were observed on the road lanes. The mean clearance time for this type of incidents was 3.95 minutes with a standard deviation of 3.31 minutes. 16% of these debris on roadway incidents were on the freeway ramps. The incidents of debris on the shoulder or median lane were not taken in the data set though they do cause some distraction to the drivers, due to rubbernecking effect, especially when the rescue crew is clearing these incidents. Majority of the incidents of debris on the roadway occurred during the day time.

Table 7.2 gives the results for the prediction model for the debris on roadway incidents. This model has only two significant variables: wead and ramp. Both of these are binary variables with 0 or 1 values: [Wead =1 if adverse weather condition, and 0 otherwise] and [Ramp = 1 if incident is on ramp, and 0 otherwise]. The positive coefficient of variable Wead, indicates that adverse weather increases the incident clearance time. Another important variable in the model was the location of the debris, if the debris incident was on the ramp of the freeway, incident clearance time was longer, than compared to the clearance time of debris incidents on the traffic lanes. This may be due to the fact that clearance of debris on ramps takes more time because the sight distance is less and the traffic is difficult to control on ramps.

Table 7.2: Estimated Results for Debris on Roadway Incidents

#### **Descriptive Statistics**

DSTAT;OUTPUT=3;RHS=CLT5,TVOL,TPER,AVSP\$

Variable	Mean	Std. Dev.	Minimum	Maximum	Cases
Cl5	3.3601	3.3054	1.000	36.00	286
Tvol	1834.5	1302.4	4.000	4742.	286
Tper	35.987	13.691	4.510	81.07	286
Avsp	64.591	4.2749	17.50	70.32	286

\*\*\*\*\*

### Model Command

TRUNCATED;LHS=CLT5;RHS=ONE,WEAD,RAMP \$

Limited Dependent Variable Model - TRUNCATED regression

Ordinary least squares regression. Dep. Variable = Clt5

Observations = 286 Weights = ONE

Mean of LHS = 0.3360140E+01 Std.Dev of LHS = 0.3305448E+01

\*\*\*\*\*

Limited Dependent Variable Model - TRUNCATED regression

Maximum Likelihood Estimates

Log-Likelihood -627.6394

Threshold values for the model: Lower = 0.0000 Upper = +Infinity

**Degrees of freedom:** Regression 2, Residual 283, Total = 285

Variable	Coefficient	t-ratio	P-value
Constant	-43.362	-1.98	0.0474
Wead[1 for adverse weather, 0 otherwise]	10.741	1.70	0.0893
Ramp[1 if incident is on ramp, 0 otherwise]	15.489	1.88	0.0601
$\sigma$	11.840	4.34	0.0001

\*\*\*\*\*

### Summary Statistics

$L(0)$  = -741.72

$L(\beta)$  = -627.64

$\rho^2$  (corrected) = 0.151

\*\* Likelihood ratio test was performed to check if atleast one of the slope parameters is significant.

$H_0: \beta_1=\beta_2=\beta_3=0.$   $H_a: \text{Atleast one } \beta \neq 0.$

Test Statistic:  $-2(-741.72 - (-627.64)) = 228.16$

Critical value  $\chi^2_{(2,0.95)}=5.99.$  As the test statistic > the critical value, reject  $H_0.$

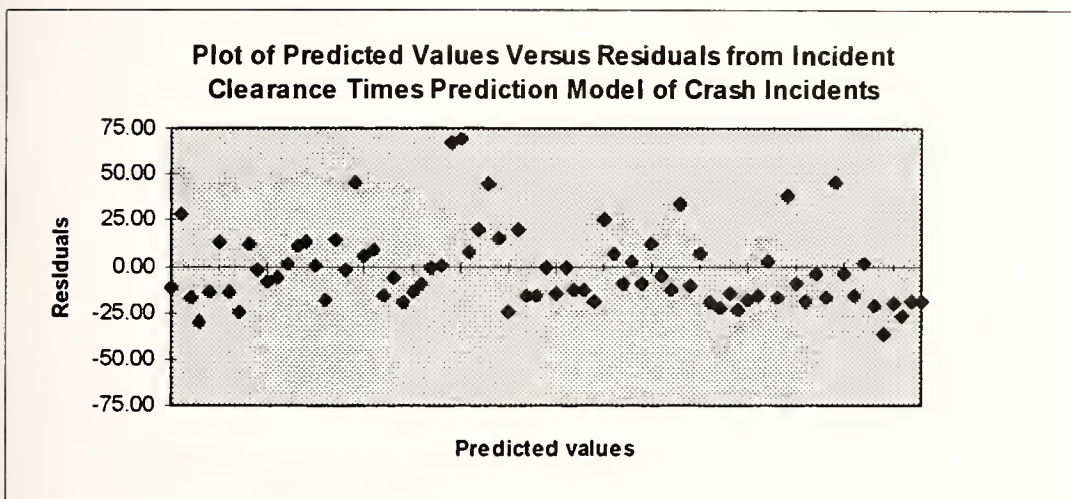
### Prediction Model for Crash Incidents

Table 7.3 gives the estimation results for the prediction model of crash incidents. Wead and

Avsp (average speed on freeway) during incident clearance were the significant variables in the

model. The coefficient of Avsp was positive, indicating that higher the average speed more will be the incident clearance time. This may be because the crash incidents are likely to be more severe at high average speeds (the speed measured before the detection of incident) and severe incidents take longer to clear. The positive sign of the estimated coefficient of the binary variable wead, again indicates that adverse weather increases the incident clearance time. Again the longer time to clear a traffic incident in adverse weather can be attributed to the higher severity of crashes in adverse weather, and lower efficiency of the rescue crew to clear an incident.

Figure 7.2.



A residual analysis was performed, to check for the bias in the model of crash incidents. Figure 7.2, shows that the residuals (observed values - Predicted values) when plotted against the predicted values of the incident clearance times do not show any regular pattern. Residuals are uniformly distributed above and below the mean value zero, indicating that the variability in the residuals do not depend in any way on the predicted values obtained from the model. That is the model gives unbiased results.



Table 7.3: Estimated Results for Crash Incidents.

**Model Command**

```
TRUNCATED;LHS=CLT7; RHS=One,Wead,Avsp>List $
Limited Dependent Variable Model - TRUNCATED regression
Ordinary least squares regression. Dep. Variable = CLT27
Observations = 77 Weights = ONE
Mean of LHS = 0.2059740E+02 Std.Dev of LHS = 0.2090848E+02
*****
```

```
Limited Dependent Variable Model - TRUNCATED regression
Maximum Likelihood Estimates
Log-Likelihood..... -307.3095
Threshold values for the model: Lower = 0.0000 Upper = +Infinity
Degrees of freedom: Regression 2, Residual 74, Total = 76
```

Variable	Coefficient	t-ratio	P-value
Constant	-510.96	-4.55	0.00001
Wead [1 for adverse weather, 0 otherwise]	93.26	1.61	0.10684
Avsp [Av. traffic speed]	5.511	3.75	0.00018
$\sigma$	59.70	3.30	0.00098

**Summary Statistics**

$L(0) = -340.24$   
 $L(\beta) = -307.31$   
 $\rho^2$  (corrected) = 0.091

Likelihood ratio test was performed to check if atleast one of the slope parameters is significant.

$H_0: \beta_1 = \beta_2 = \beta_3 = 0.$   $H_a: \text{Atleast one } \beta \neq 0.$

Test Statistic:  $-2(-340.24 - (-307.31)) = 65.86$

Critical value  $\chi^2_{(2,0.95)} = 5.99.$

As the test statistic is greater than the critical value, so reject  $H_0.$

**Discussion on Estimated Results**

While estimating the models, most of the variables could not pass the t statistical test.

However, from the perspective of improving freeway surveillance and control systems

those variables might be important. For example the occurrence of an incident during the day or night can significantly represent how well the current system works. It can be seen from the individual t-statistics and corresponding P-values, for all the three models that the estimated coefficients are statistically significant. Comparison of incident clearance times observed in this study with earlier similar studies indicate that sample used for this study include incident with lower values of average clearance times. This may be due to the fact that not all types of incidents were included in this study, and secondly in this sample there was a higher fraction of the shorter duration incidents. Larger and more representative samples would be needed to make the models more precise. Moreover the models are underspecified in terms of operational/response variables. Information on variables like severity of incident (damage caused or number of injuries), response time of rescue vehicle, number of trucks involved, whether advanced traveler information systems were used, can result in precise prediction models. These variables can be obtained, if the existing method of recording incident data also account for operational/response characteristics, and this requires some improvements in the existing incident recording system. After the incorporation of above mentioned variables, the models can be accurate enough to be used by the Borman traffic managers to optimize incident response and to provide reliable real time traffic information to motorists.

#### Computer Program for the Computation of Incident Clearance Time:

After the prediction models for the incident clearance time were developed, there was a need for a user friendly computer program to accurately and quickly compute the

duration of the incident. Computer program was required because the incident clearance time models contain the non linear correction terms which include the standard normal probability distribution function ( $\phi$ ), and the standard normal cumulative function ( $\Phi$ ). The computer program has the built in required statistical functions to compute the correction term and thus the person responsible for computing incident clearance times does not have to consult statistical tables or perform any computations. The computer program uses the estimated models to calculate the incident duration (travel time of rescue crew + on site incident clearance time). The results from the computer program can help incident management staff to obtain real time decision support during incident clearance operations. The computer program written for the quick computation of the incident clearance is an important component of this research, and it can add value to the incident response plan. The program calculates the time from the dispatching of rescue crew to the time when the roadway is cleared and the response crew has left the incident scene.

#### Data Requirement for the Computer Program

A relatively small amount of data is required to run the program. The inputs required for the program, include: location of the incident on the freeway, location of the Hoosier helper, general weather conditions, temperature during incident clearance operation, traffic volume on the freeway at the time of incident detection, average speed of traffic (at the time of incident detection), percentage of trucks, location of incident (roadway or on the ramp). The program is designed to be robust enough to perform under a wide variety of data availability scenarios. The program uses real-time data for the predictions of the incident duration. In the absence of adequate real time data, the program can be run with

the built in default values, based on historical data. Though the models used in the computer program are specifically for the Borman Expressway, but the computer program can be used in other situations if appropriate adjustments are made in the code by incorporating the models based on new data.

## CHAPTER 8

### CONCLUSIONS AND RECOMMENDATIONS

This chapter discusses the results drawn from this study and make recommendations for effective incident management on Borman Expressway, and recommends the type of decisions and actions that must be considered to create a smoothly functioning incident management process.

Incident management is a system-wide process to reduce the time to detect and verify that an incident has occurred, to initiate an appropriate response, to clear the incident to communicate appropriate information to motorists, and to divert and manage traffic until full capacity is restored. In the incident response and clearance operations, two basic concerns emerge: whether or not prediction models for incident clearance time can be effectively applied to freeway incident management, the credibility of their computations and the reliability of the decisions based on the results of these models.

A sound incident management program can yield many benefits such as reduced user costs associated with incident delays. Freeway control and operating strategies are essential for successful system operations. Being an integral component of the freeway control system, incident management is especially important while freeways are operating near, at, or beyond their physical capacities.

Traffic managers must make decisions concerning operational effectiveness and tradeoffs, and control decisions may be bound by physical constraints, traffic characteristics or traffic control practices.

Borman Expressway because of its high traffic volumes and mix of traffic provides a host of incident management challenges. During the peak hours the freeway operates at or above capacity. On average 11 incidents are recorded daily on Borman Expressway.

As mentioned in the chapter five of this study, the vast majority of incidents are vehicle disablement's and minor accidents. During off-peak periods when traffic volumes are low, these incidents have little or no impact on freeway traffic. But when traffic volumes are high, their cumulative effect is substantial. Police and private tow operators can clear these incidents rapidly and efficiently, but usually this work is not given high priority. Incident congestion can be reduced considerably by assigning higher priority to the detection and clearance of minor incidents. Major incidents are relatively few, but they require immediate attention, and rescue crew with special training and experience. In major incidents, congestion could be reduced considerably by improving clearance and recovery capabilities.

#### Systems Approach to Incident Management

In the future, there is a need for unifying incident investigation methods that will overcome some practical and theoretical uncertainties that might always confuse on scene incident operators. To unify incident investigation methodology means to organize the operation process and simplify some unnecessary actions. The benefit for unifying incident investigation methods is to provide a standard environment for incident management. On scene operators should always cooperate with the control center, and they should know what information is necessary and should be sent back to the traffic control center.



Traffic incidents cause unexpected congestion on freeway even when surveillance, communication and control systems are in operation. All type of incidents on roadway on or near mainlines can significantly affect system performance and create hazardous situations for involved motorists, approaching commuters and passing traffic. Generally traffic incidents fall into several sizes or severities. Some incidents require a longer clearance time and other are cleared in a relatively shorter time. Therefore determining the size or severity of specific incidents is part of understanding the problems an incident management process is intended to solve.

A major issue related to the applicability of the proposed methodology is the availability of incident data. Literature research revealed that incident-generation data are very sparse. Moreover, most of the available incident reports, do not differentiate between the various types of incidents, i.e. number of lanes closed, duration of the closure, and so forth.

Although many factors are considered in incident clearance alternative evaluation, few have the publicity impact of being able to say that a specific incident management program has reduced the average duration of incident by  $x$  minutes and thus has saved commuters  $y$  hours of travel time. Unfortunately arriving at statistically accurate values of  $x$  and  $y$  is an exceedingly difficult task. For example in determining the reduction in incident duration resulting from a specific alternative, it is important to take into account all naturally varying, non-alternative related factors (e.g., seasonal variations in traffic flow, weather conditions, the presence of special events, traffic growth, changes in operational procedures). Determination of travel time savings resulting from reductions in incident



duration requires expensive monitoring of queues and travel times or alternatively, the use of a fairly sophisticated traffic simulation model.

The estimated models and the statistical analysis was conducted over a single cross-sectional period. While single period data can reveal weaknesses in this study, multiperiod or continuously collected data are needed to develop more precise incident clearance time prediction models. The procedure is to simply estimate before and after econometric models of incident clearance time and conduct a likelihood ratio test (which is Chi-squared distributed, to test for the time stability or model parameters (see Ben Akiva and Lerman 1985)), as well as the magnitude and statistical significance of the reduction in incident resulting from the implementation of the incident clearing alternative.

Table 8.1

Factors Influencing Incident Clearance Time

<b>Factors Increasing Incident Clt</b>	<b>Factors Decreasing Incident Clt</b>
Incident involving injuries	High average percentage of trucks
Night conditions	Higher Temperature
Accident involving trucks or buses	
Incidents blocking ramps	
Winter months	
High average traffic speed	
Adverse weather conditions	

Recommendations

- There is a need to conduct more detailed study on the effect of applying real time incident information on driver behavior. Such a study will reveal the relationship between incident clearance time and the application of real time traffic information.

- Work on time sequential prediction models in freeway system management can be very useful. From a traffic management perspective the predicted incident clearance time can serve as an important base for other management designs, for example dynamic traffic flow assignment, in which as time progresses, the incident clearance time predictions will be updated dynamically and so are the traffic flow assignments accordingly.

- Incident congestion can be minimized by diverting upstream traffic and clearing incidents as quickly as possible.

- To mitigate the impacts of minor incidents or disablement's, an emphasis should be placed on providing space for temporary vehicle storage in the form of a holding area or off- road accident investigation site.

- Existing incident clearance procedure on Borman Expressway demonstrates difficulty in clearing large accidents. It is recommended to improve response to large traffic incidents on the Borman Expressway by providing additional personnel/equipment and access of necessary incident-clearing equipment to the scene.

- Strong rational approach is required to approach the complex issues inherent in incident management. Because incidents can be cleared with many techniques and pieces of equipment.

- While data on incident occurrence and duration are generally available from accident and police dispatch reports, the traffic related impacts of an incident are more difficult to measure, video monitoring and loop detectors may assist in this regard, the use of a traffic simulation model may also be of value. The use of such a simulation model will allow the traffic impacts to be determined by the incident's location, extent (number of lanes blocked), duration and time of day.

With further model validations and verification with realistic incidents, the incident duration predictions can be updated or made more precise. Also there is need to explore other important factors and to test existing variables by different definitions. These efforts will help in improving prediction results and enhance validity in practical application.

## REFERENCES

## LIST OF REFERENCES

- Al-Deek H., "The role of Advanced Traveler Information Systems in Incident Management," PhD Dissertation, UCB-ITS-DS-91-5, Department of Civil Engineering, Institute of Transportation Studies, University of California at Berkeley, 1991.
- Al-Deek, H., and Kanafani, A., "Incident Management with Advanced Traveller Information Systems", PATH paper UCB-ITS-91-5, Institute of Transportation Studies, University of California at Berkeley, 1991.
- Ben Akiva M. and Lerman, S.R., "Discrete Choice Analysis, theory and applications to travel demand", The MIT Press, 1985.
- DeRose, F., "An Analysis of Random freeway Traffic accidents and Vehicle Disabilities", Highway Research Record, 59, Washington, DC., pp. 53-65, 1964.
- Giuliano, G., "Incident characteristics, Frequency and Duration on High Volume Urban Freeway", Transportation Research A, Vol. 23A, No. 5, pp. 387-396, 1989.
- Golob, T., Recker, W., and Leonard, J., "An Analysis of the severity and Incident Duration of Truck Involved Freeway Incidents", Accident Analysis and Prevention, Vol. 19, No. 5, pp. 375-395, 1987.
- Goolsby, M., "Influence on Freeway Quality of service", Highway Research Record, HRR 349, Washington, D.C., pp. 41-44, 1971.
- Greene, W. H., "Econometric Analysis", Macmillan Publishing Co., New York, New York, 1993.
- Grenzeback, L.R., Champion, R.S., & Schoen, J.M., "Highway incident management" paper presented at the Transportation Research Board, 70<sup>th</sup> annual meeting, Washington D.C., January, 1992.
- "Incident Management Workshop relieving traffic congestion through Incident Management", U.S. Department of Transportation, Federal Highway Administration Demonstration Project No. 86, April, 1994. "Incident Management", Final Report, Trucking Research Institute, ATA foundation, Inc., Cambridge Systematics, Inc., October, 1990.
- Jones, B., Jensen, L., and Mannering, F., "Analysis of the Frequency And Duration Of Freeway Accidents in Seattle", Accident Analysis and Prevention, Vol. 23, No. 4 pp. 239-255, 1991.

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

Khattak, A.J., Schofer, J.L., and Wang, M. "A Simple Time Sequential Procedure for Predicting Freeway Incident Duration", IVHS journal, Vol No. 4, 1994.

Liu, P.C. , "Incident Likelihood Prediction Models: Development and Applications to Advanced Traffic Management and Information systems", Upcoming Ph.D. dissertation, School of Civil Engineering, Purdue University, November, 1995.

Madanat, S.M. and Liu, P.C., "A Prototype System for Freeway Incident Prediction Models", final report to the ITS-IDEA Program, TRB, February, 1995.

Madanat, S.M., Cassidy, M., Teng, H.L. and Pan, H.Y., "Sequential Hypothesis Testing Based Freeway Incident Response", presented at the 75th TRB January, 1996.

Makigami, Y., Newell, G., and Rothery, R., "Three-Dimensional Representation of Traffic Flow", Transportation Science, ORSA, Vol 5, No. 3, pp 302-313, 1971.

Paselk, T.A., and Mannering, F., "Use of duration models for predicting vehicular delay at a US/Canadian border crossing". Transportation Vol.21, pp. 249-270, 1994.

"Quantification of urban freeway congestion and analysis of remedial measures." Rep No. FHWA/RD/87/052, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1990.

Roper, D., "Freeway incident management." National cooperative highway research program, synthesis of highway practice, No 156, Transportation research Board, Washington, D.C., 1989.

Train, K., "Qualitative Choice Analysis, Theory, Econometrics and an application to Automobile Demand", MIT Press, Cambridge, Massachusetts, 1986.

Wilshire, R. and Keese, C., "Effect of Traffic Accidents on Freeway Operations", Research report, Texas Transportation Institute, Texas A & M University, College Station, Texas, 1963.

Zografos, K. G., Nathanail, T., and Michalopoulos, P., "Analytical Framework for Minimizing Freeway-Incident Response Time", ASCE Journal of Transportation Engineering, Vol 119, No. 4, 1993.





COVER DESIGN BY ALDO GIORGINI