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Assessing the Safety Benefits of Automated Freeways

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EXECUTIVE SUMMARY

The original proposal to fund this research was based upon a type of comparable systems analysis, seeking to use rail transit service safety analysis as comparable systems. A literature search at the ITS library in UC Berkeley could find no useful references for comparable rail systems. At this point, the research team consulted with PATH staff to identify a more suitable and productive research scope.

The automated highway scenario considered in this research is one in which the freeway is partially automated, that is, only the left or median lane is automated. The analysis is concerned with accidents that originate outside the left lane and result in a vehicle or debris being deposited in the left lane or on the left hand side median. These accidents are of interest because they can clearly affect the safety of the automated lane, yet are not part of the automated control system itself.

The specific goal of this research is to begin to determine the scope of the safety problem posed by accidents of this type. The necessary objectives in such an investigation include:

1. To develop a method to identify the relevant accidents from the population of reported accidents on California freeways.

2. To test the accuracy of the method by comparing relevant accidents identified by a computer search with those identified by manual review of paper accident reports.

3. To use the method on a test section of California freeway. Compare the characteristics of the relevant crashes to those of the broader accident population.

4. To assess the implications of the accident comparisons for automated highway system design, at least at the concept stage.

As a test case this study uses accident data for I-10, the Santa Monica Freeway, between I-405 and I-I 10 in California in the years 1986 and 1987. The method to identify relevant accidents was found to be sound and a cross-classification analysis was performed on the accidents selected to identify the factors contributing to the accidents of interest. A spatial analysis was conducted to help determine if relevant accidents were clustered near on and off ramps, an issue with important implications for automated highway design.

The analysis revealed a total of 2069 accidents on the section of the I-10 freeway of which 273 were relevant. A subsample of accidents, selected randomly, revealed that the method was accurate in identifying relevant accidents with 95 % confidence. Relevant accident attributes were compared to the attributes of all other accidents in a series of cross classification tables. The comparisons revealed that the accident status was independent of the weather and the month during which the accident occurred, but dependent on the type of collision, time of day, lighting conditions, road surface condition, number of vehicles involved, move preceding collision, primary collision factor, and sobriety / drug / physical condition of driver.

The relevant accidents are differentiated from the other freeway accidents by the following general characteristics:

1. Relevant accidents are very unlikely to involve rear end collision which dominate general freeway collision types (i.e. 57% rear end; the largest other category is 19% sideswipe). Only 14% of the relevant accidents involve rear end collisions.

2. Relevant accidents are much more likely at late night and early morning hours (10 pm to 6 am), are more likely to include an alcohol-influenced driver and are more likely single vehicle crashes which involve an improper turn or run-off-the-road. This constellation of factors is consistent with gross driving errors which result in substantial loss of vehicle control. Fortunately, the data reveal that these types of crashes are much less likely in the peak period when the automated lane is most heavily used.

3. Wet pavement contributes to the occurrence of a small but significant portion of relevant accidents.

4. Relevant accidents are more closely clustered around on/off ramps, particularly freeway connectors, than are other accidents. Sideswipe and hit object accidents predominate near ramps, reinforcing the concept that relevant accidents involve some gross loss of vehicle control, particularly while executing turns near ramps.

It is clear that the relevant accidents (13% of the total) represent a significant risk to the viable operation of an automated median lane. Even though comparatively few relevant collisions occur during peak periods, they are of sufficient numbers to represent a real risk to automated lane operations. Further, the off-peak accidents may be of sufficient severity to close or disable automated lane operations during the subsequent peak period, an eventuality to be avoided as well. Based upon these preliminary findings, it appears that grade separated access/egress to freeway connectors is a necessity and that some form of direct access/egress may be warranted for other ramps as well.

It would be useful to extend the analyses to other freeways with different ramp configurations and levels of congestion to see if these findings are supported. Given the reliability of the computer search procedure in identifying relevant accidents, a relatively large set of accident data drawn from several freeways should be efficiently analyzed.

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ACKNOWLEDGMENT

The authors would like to acknowledge the strong support and encouragement provided by Dr. Anthony Hitchcock of the PATH staff. Tony provided the seminal ideas upon which this study was conducted. His interest, much in the spirit of colleagial research, is greatly appreciated. The authors wish to share with Tony any contribution that this research may make, while assuming all responsibility for shortcomings or errors that may be present.

I. Introduction

1.1 Background

Freeways in the United States are experiencing a great increase in the number of vehicles using them, with the expected result of increased congestion. Opinion surveys in urban areas frequently reveal that people perceive transportation as the number one urban problem. In an effort to solve this problem, transportation engineers have renewed their interest in highway automation. Automation is one technological advancement which promises large increases in the highway capacity along with improvements in travel speed, cost and safety.

The automated highway scenario considered in this research is one in which the freeway is partially automated. Shladover (1989) defines roadway automation as the application of communication and control technology to observe, guide, and/or control the movement of vehicles in a traffic system (or to assist in the performance of those functions). This study takes into consideration that the leftmost lane on the freeway is a dedicated automated lane. The vehicles traveling in this lane would continuously be controlled in terms of their speed and position by sensors, and on-board and roadside computers. Spacing of vehicles, merging and exiting would also be regulated. There is not only communication between the vehicle and its control on the roadside, but also communication between the vehicles in front and behind the vehicle under consideration. In the automated lane the vehicles would be traveling with a short headway between them and probably at a high speed. Once the vehicle leaves the automated portion of the highway the driver would regain conventional control over the vehicle. The automated left lane may be separated from the rest of the freeway by some kind of a physical barrier with some gaps. These gaps would be used by vehicles to enter or leave the automated lane.

The accidents of interest with regard to this study are those in which vehicles or debris resulting from accidents in the non-automated lanes are propelled across the freeway (the accidents are initiated in the middle and right lanes) entering and / or crossing the leftmost lane. These accidents are potentially serious because the automated left lane is likely to operate at a greater speed and at a much higher capacity than the present left lane. Any such intrusion by the vehicles or debris into the automated lane could lead to severe accidents involving a number of vehicles and their occupants.

This research is aimed at the identification of all types of accidents that have occurred on freeways which may affect the vehicle movement in the assumed automated left lane (specifically by intruding into the lane). The emphasis was on six-lane or more urban freeways. The accident data were obtained from the California TASAS (Traffic Accidents Surveillance and Analysis System) data base and were used to identify all the accidents that originated outside the potential automated area (leftmost lane) and which affected movement of traffic in the leftmost lane.

The next section of the chapter describes the objectives of the study and the last section provides a preview to the rest of the report.

I.2 Detailed Objectives of Study

The foremost objective of the study was to develop a method to find the relevant accidents from the TASAS data base. The relevant accidents are those that originate outside the left lane with the vehicles or debris involved ending up in the left lane or on the left hand side of this lane. The technique was checked for its validity by comparing a sample of computer-selected accidents with a manual review of paper accident reports. Unless the accident identification was reasonably accurate further analysis would not be useful. The ability to identify the frequency and relevant attributes of the accidents of interest is critical to the analysis of partially automated highway safety. The method was applied to accidents that occurred on Interstate Highway 10 (I-lo), the Santa Monica freeway between Interstate Highway 405 (I-405) and Interstate Highway 110 (I-I 10) in California.

Finally, it is desirable to understand the relationship if any, between the location of the accidents of interest and on and off ramps. This is because one way of constructing a partially automated facility is to use physical barriers except where traffic must enter or exit to use on and off ramps. A safer, but more expensive option is to construct physically separate ramps for automated lane access and egress. The location of the gaps in the physical barrier are points at which the accidents of interest could propel objects into the automated lane. Any guidance on location for these gaps is likely to improve the safety of the system.

The next section gives a preview to the rest of the report.

1.3 Preview to the Rest of the Report

The second chapter is a summary of the previous work conducted in the area of freeway automation. The TASAS data base used in the study and its characteristics are described in Chapter III. Chapter IV describes the types of accidents that are relevant to the study and the technique involved in the retrieval of these accidents from the data base. Chapter V presents the characteristics of all accidents studied, the results of the preliminary study for the verification of the methodology and statistical analysis used to identify the contributing factors with the most interesting results. The recommendations for future study and conclusions are presented in Chapter VI, followed by the cited references.

The appendices contain some of the statistical analyses performed and the computer programs that were used in the identification and analysis of the accidents of interest. The last appendix is an annotated bibliography of the literature summarized in Chapter 2.

II. LITERATURE REVIEW

11.1 Introduction

This chapter describes a literature search related to highway automation and safety studies that have been conducted in the past to analyze accidents. The literature review was carried out using MELWL, an on-line catalog of the University of California system (all the 9-campuses) which includes all the available literature at the ITS Library, University of California at Berkeley from 1976 to the present. Literature pertinent to the study were also obtained from the Transportation Research Board and Australian Road Research Board records present in the Physical Sciences Library at the University of California at Davis.

Studies related to automation revealed that there is a major need for research in the highway automation area. The literature search did not reveal any study that dealt with accidents that traverse lanes taking into consideration that the left lane is automated or for that matter, accidents that traverse lanes under existing highway conditions. There was no literature on the methods used in the identification and analysis of these types of accidents. A large amount of the literature dealt with accident analysis at the theoretical and empirical levels; but, none directly addressed accidents that are relevant to this study. The search was otherwise very informative.

11.2 Summary of Literature on Highway Automation

The literature search revealed that automation was a viable option that would help reduce congestion and probably enhance the safety of the system. The search also revealed that advances in computers, sensor, and communication technology have reached a stage at which automation can be seriously considered as a means to alleviate congestion.

Shladover (1989) raises the main technical questions that need to be answered in order to make highway automation a reality. The author observed that the components to be considered for an automated roadway included the following: the vehicle being controlled (including its sensors and on-board computer), the driver of the vehicle, the roadway, external objects, other vehicles and their drivers, roadside computers, and roadside traffic signals. The critical technical issues to be considered are some kind of intelligent traffic signaling, traffic information systems (that extend beyond traffic signals to two-way communication between the roadside computer system and the on-board computer, which serves as the interface to the driver), driver warning and assistance systems (with the help of sensors and radars on the vehicle and communication between the on-board and roadside computers), automatic steering and spacing control, obstacle avoidance, automatic trip routing and scheduling, control of merging of strings of traffic, transition to and from automatic control. A fully automated system would incorporate all the capabilities mentioned above.

Davis (1987) researched the adaptation of radar to the automotive environment to increase the safety of the highway system. He believed that radar development would soon make vehicular radar a reality. The radar system would help maintain the vehicle in the lane and also control the headway between the instrumented vehicle and the vehicle in front. This is the basic technology necessary for an automated highway, in conjunction with the computerized control of the brake and the accelerator system in the vehicle, and the communication technology for the constant relaying and receiving of information to and from the on-board and roadside computers.

Sperling, et al (1989) observed that automation is an appealing concept and came up with a plan to implement automation on freeways. The stages included the following:

a) Navigational systems that would provide route guidance and real-time traffic information to drivers. On-board electronic maps that track a vehicle's location and inform drivers of optimal routes to their destination.

b) New technologies that would automatically control the vehicles within freeway lanes laterally and at a specified longitudinal distance behind the vehicle in front to be incorporated into some of the vehicles.

c) The third stage was a partially automated freeway, in which the vehicles in the left hand lanes would be controlled automatically as long as the vehicles are in those lanes and the driver would regain conventional control as soon as he leaves these lanes. The automated lanes would be restricted to the vehicles that have the necessary automation technology on-board.

d) The final stage would be a complete automation of the entire freeway system. It was calculated that an automated lane could potentially carry several times as many vehicles as the present non-automated lanes. Speeds of about 20 mph higher than the present highway speeds were considered a possibility.

Gosling, et al (1983) helped the US Department of Transportation take advantage of advances in computers, software and sensor technology by exploring the application of such tools as command control and information technologies, expert systems and other artificial intelligence techniques, risk analysis, optimization, and simulation. According to the study, safety problems associated with mixing automatically controlled and driver controlled vehicles on the highway have not allowed direct control of vehicle guidance and speed to advance beyond the experimental stage. It was concluded that design and implementation of automated control systems must consider explicitly a large number of issues affecting the way the system is configured and operates.

The study also revealed that the development of new information technologies and new computer hardware capabilities appear to be reaching a stage where these could be applied to improve the performance of transportation control systems. Simulation was considered as the most promising tool for studying proposed systems that cannot be tested by constructing prototypes. This study gives a very good idea about the present technology capabilities and the issues related to automation that need to be researched thoroughly to make automation a reality.

Barwell (1983), in his text, talks about automation and control of trains and the advances in the field of mechanical and electrical engineering. The author also addresses highway automation and control. The aspects that are important to automation include lateral position in the lane (automatic steering), vehicle spacing (headway control by the detection of the presence of vehicle or object in front), on-board and roadside computers and a communication system that links all the computers together, and speed control (through braking and accelerator pedal control).

The common concern raised by all authors was the issue of liability; i.e. who, among the driver, manufacturer and state, is to shoulder the blame if an accident occurs due to a malfunction in the automated highway? Most authors agree that safety of the system is an important issue that has to be studied. The authors perceive complete automation of a freeway as being a phased process, with partially automated freeways (leftmost lane automated) being the first logical step. Before we envision a partially automated freeway we need to first consider the safety in non-automated freeway lanes.

il.3 Summary

The literature review revealed that highway automation could potentially solve the existing transportation problems as long as safety concerns are fully addressed. This literature review also revealed the different methods that have been used in the past to determine the factors contributing to certain types of accidents and that accident occurrence is influenced by a number of factors (like, road conditions, traffic and environmental conditions, driver characteristics and vehicle characteristics). No study was found that dealt with the freeway accidents that traverse lanes. But does congestion in non-automated lanes increase the number of accidents on the left (i.e. automated) lane? This question is answered in this report on an aggregate level, comparing accidents during peak periods with those occurring off-peak. For this study, contingency tables were used to identify the factors contributing to accidents that traverse lanes.

III. Data Base

The data source is the TASAS (Traffic Accident Surveillance and Analysis System) data base maintained by the California Department of Transportation (CALTRANS). This data base contains reports of all accidents that involved police investigations at the scene of the accident on the state highway system. Accident data for the last 16 years are available on the TASAS at the CALTRANS headquarters at Sacramento. A small part of the data, which includes accidents on a segment of freeway l-10 between I-1 10 and l-405 in the Los Angeles district in the years 1986 and 1987, is used in the analysis.

ill.1 TASAS

In 1973 the Traffic Accident Surveillance and Analysis System (TASAS) was implemented by CALTRANS and the California Highway Patrol. The TASAS data base describes accident sites in terms of the geometric design, traffic control measures, and traffic demand. In addition, it also gives accident information including the primary and secondary locations of the accident, time of day, and other variables related to the roadway and accident.

A typical TASAS Selective Record Retrieval of accidents on a freeway contains detailed individual accident information that includes the district, roadway code, location, characteristics of the roadway, date, day and time of accident. These are followed by accident summary fields that include principal collision factor, environmental conditions, road condition, right of way control, type of collision, # of vehicles involved, etc. The file also gives information about the parties involved in the crash including: party type, primary object struck, primary and secondary locations of collision, the movement preceding collision, the sobriety/drug/physical condition of the driver involved, etc.

Finally, for a given roadway segment for a given time period, the accident summary part of the output gives the total number of accidents, # of injury, fatal and property damage only accidents, the number of accidents and percentage by the hour of day, access control, side of highway, year, month, and day of week. The accident number and percentage by each one of the variables like primary collision factor, type of collision, roadway, weather and lighting conditions, right of way control, highway group are also listed, The party summary part of the output contains the number and percentage of accidents by the party type, movement preceding collision, other associated factors, object struck, sobriety / drug / physical, and location of collision.

iii.2 Accident Characteristics, Party Type and Highway Fields

The accident information that is relevant to this study include the time of day, location (along with milepost reading), and a set of information describing accident circumstances including: weather, lighting, and road surface conditions. Data fields for these variables are shown in Table 3.1. In addition, details about the crash itself are coded in another set of fields including: type of collision, primary collision factor, movement preceding collision (Table

3.2), party type (Table 3.3), primary object struck, and primary and secondary locations of collision.

LOCATION OF COLLISION

Code	Description
A	Beyond Median
B	Beyond Shoulder Driver's Left
C	Left Shoulder Area
D	Left Lane
E	Interior Lanes
F	Right Lane
G	Right Shoulder Area
H	Beyond Shoulder Driver's Right
I	Core Area
J	Other
c	Not Stated
'-'	Does not Apply

WEATHER

Code	Description
A	Clear
B	cloudy
C	Raining
D	Snowing
E	Fog
F	Other

ROADSURFACE

Code	Description
A	Dry
B	Wet
C	Snowy, icy
D	Slippery
<	*Not* Stated

LIGHTING

Code	Description
A	Daylight
B	Dusk/ Dawn
C	Dark- Street light
D	Dark- No Street light
E	Dark- Inapp. Street light
F	Dark- Not Stated
<	Not Stated

TABLE 3.1 Summary of Relevant TASAS Location, Weather, Road Surface and Lighting Data Fields

PRIMARY COLLISION FACTOR

Code	Description
1	Influence of Alcohol
2	Following too Close
3	Failure to Yield
4	Improper Turn
5	Speeding
6	Other Violation
B	Improper Driving
C	Other than Driver
D	Unknown
E	Fell Asleep

MOVE PRECEDING COLLISION

Code	Description
A	stopped
B	Proceeding Straight
C	Ran off Road
D	Make Right Turn
E	Make Left Turn
F	Make U-Turn
G	Backing
H	Slowing, Stopping
I	Pass Other Vehicle

Code	Description
J	Change Lanes
K	Parking
L	Enter from Shoulder
M	Other Unsafe Turn
N	Cross into Opposing Lane
0	Parked
P	Merging
Q	Traveling Wrong Way
R	Other

TYPE OF COLLISION

Code	Description
A	Head-on
B	Sideswipe
C	Rear end
D	Broadside
E	Hit Object
F	Overturn
G	Auto- Pedestrian
H	Other
<	Not Stated

Table 3.2 Summary of Relevant TASAS Primary Collision Factor, Move Preceding Collision and Type of Collision Fields

PARTY TYPE

Code	Description
A	Passenger Car
B	Passenger Car with Trailer
C	Motorcycle
D	Pickup
E	Pickup w / Trailer
F	Truck
G	Truck w / Trailer
2	Truck w / 2 Trailers
3	Truck w / 3 Trailers
4	Single Unit Tanker
5	Truck w/ 1 Tank Trailer
6	Truck w/ 2 Tank Trailers
H	School Bus
I	Other Bus
J	Emergency Vehicle
K	Highway Const. Equipment
L	Bicycle
M	Other
0	Spilled Load
P	Disengaged Tow
Q	Uninvolved Vehicle
R	Moped
S	Runaway Vehicle
T	Train
U	Pedestrian
V	Dismounted Pedestrian
W	Animal- Livestock
X	Animal- Deer
Z	Animal- Other

TABLE 3.3

The most important variable that is coded in the TASAS data file is the location of the accident. The primary location of any accident could be either in the left lane, right lane, middle lanes or on either shoulder. This study is interested in primary accident locations that do not include the left lane or the left hand side of the left lane (because this is where the automated lane would be and we assume these collisions would not occur), and secondary locations which include at least the left lane or left shoulder or median as the case might be. The location variable is of critical importance in the identification of relevant accidents.

The time of day of the accidents would help in identifying the presence of patterns if any, in the occurrence of accidents (e.g. during peak or off peak hours). Spatial location gives an idea of where the accidents occur. The spatial distribution could be of use in identifying the segments on the freeway where barrier gaps could be introduced in case there arises the need for barriers to separate the proposed automated and non-automated portions of the freeway. Some unfavorable environmental and / or road conditions could also be significantly represented in these types of accidents and it is important to understand them, even if they **are** not within our direct control (e.g. wet pavement).

The primary collision factor, the party type involved, and the movement preceding collision provide important details about the crash itself. The type of terrain where the accidents occurred could be of significance in the identification of freeway segments where automation may or may not be particular risky (for example, if relevant accidents occur on curves). The types of vehicles involved would have significant effect on the type of barrier that might be needed to separate the automated and non automated lanes on the freeway.

iii.3 Data Base Description

The data were obtained from the CALTRANS headquarters at Sacramento, California. The files from a CALTRANS mainframe computer were downloaded onto a tape for transport to UC Davis. The data were then loaded onto the mainframe and were accessible through terminals at the department computer facility.

The data contained information on highway segments and accidents. Each highway segment or accident record consisted of 5 logical records (80 characters). Highway information was contained in a record of length 400 characters of which 230 characters gave information on the highway while the rest were blanks. The 28th character in the highway record was a '1'. The accident records were also 400 characters long but the 28th character in these records was a '4'. Accident information exists in bytes 1 to 91 for a l-party accident and each additional party adds 25 bytes to the accident information. The maximum is 291 bytes for a **9-party** accident. The records are space filled up to 400 bytes.

IV. Methodology

This chapter describes the procedures followed in the identification of the accidents relevant to this study. This includes a general definition of the accidents that are of interest to the study, a description of the method used in the selection of accidents, and a description of verification tests conducted on a sub sample of the data. The last section of this chapter deals with the cross classification analysis of the categorical data and a discussion of the locational analyses.

iv.1 Accidents of interest

The aim was to develop a method that would select relevant accidents from the data base. The accidents that are of interest are those in which vehicles or debris are propelled across the freeway and so may enter the left lane (i.e. area that is assumed to be automated). The relevant accidents are those that originate from the middle and right lanes and at least one of the vehicle or debris involved ends up in the left lane or to the left of the left lane.

The technique used to identify relevant accidents is based on the location fields of the vehicles involved in the accidents. Accidents in which the location fields included the left lane or the area left of the left lane are the ones that are selected. A computer program has been written based on the location fields of the accidents to select certain type of accidents.

IV.2 Steps to Retrieval of Accidents of Interest

The steps to the selection of accidents of interest with TASAS included the following :

STEP 1 : Find freeway accidents.

Accidents with File Type H (Highway) are the ones that were selected first. The next constraint restricted the search to freeways with 6 or more lanes(The Total Number of Lanes column was checked to see if it was greater than or equal to 6).

STEP 2 : Select accidents with location fields in the left lane. Includes only left lane collisions or penetrations that are initiated by vehicles in lanes other than the left lane. Those accidents in which a vehicle from one of the other lanes goes across the left lane and hits the median or barrier were also considered as relevant. Accidents with the following characteristics were selected from the data set (the letter codes refer to categories of the relevant variables listed in specific tables):

I). Primary location of collision (TABLE 3.1): **E,F,G,H,I** or J (Any one of them).
And Secondary locations of collision (TABLE 3.1): **A,B,C** or D (At least one of them).

The first constraint of the selection selects all accidents in which the first (i.e. primary) location of the collision is on the right hand side of the left lane (i.e. fields E-J). The next constraint further reduces the accident selection to those in which at least one of the secondary locations is on the left hand side of the left lane or in the left lane itself. This selection scheme will include all accidents with initial collision outside the automated lane that may impact the automated lane. These have been designated as Type I accidents and they are sketched in Figure 4.1.

ii). Primary location of collision (TABLE 3.1): C or D.
Type of collision (TABLE 3.2): B or D or E.
Move preceding collision (TABLE 3.2): Any of them except J.
And Special Info : Not C.

The first constraint selects accidents whose primary location of collision is on the shoulder on the left of the left lane or in the left lane itself. The second constraint selects all of the selected accidents in which the type of collision is either broadside, sideswipe or hit object. The third constraint selects only those accidents in which the move preceding collision is not a change of lane (because this movement would not occur with an automated lane), and the fourth and final constraint selects those accidents in which no tire defect or failure is involved in the accident (these are identified with a specific designation - type (iv)). These relevant accidents are designated as Type II and are sketched in Figure 4.2. These accidents while occurring in the left lane, involve vehicle movements in the interior lanes. Gaps in barriers separating automated and non-automated traffic will allow these types of collisions to occur. The accidents that might get included which are not relevant are those in which a vehicle in the left lane hits an object which does not have an origin in the right lanes.

iii). Primary location of collision (TABLE 3.1): A or B.
Move preceding collision (TABLE 3.2): C.
And Special Info. : Not C.

The constraints select all those accidents in which a vehicle runs off the road (move preceding collision) on the left side of the left lane. We are particularly interested in accidents in which a vehicle in the interior lanes runs off the road to the left; accidents due to vehicles in the left lane running off the road to the left may erroneously be included. The accidents selected here are designated as Type III and are sketched in Figure 4.3.

iv). Primary location of collision (TABLE 3.1): A, B, C, or D.
Special Info. : C.

This would select all accidents in which the primary location of collision is on the left of the left lane or in the left lane itself due to a tire blowout. These are Type IV accidents and are sketched in Figure 4.4.

The data file is read and the characters that represent a highway segment or an accident record were identified. Then a computer program 'RELACC.FOR' was written to obtain the relevant accident from the data base (see Appendix C for the actual program).

iv.3 Verification of Computer Search Procedure

After the relevant accidents are identified by the computer program, the next step is to verify the accuracy of relevant accident identification. The CALTRANS office in Los Angeles was visited to verify the original records and check whether the accidents selected in the preliminary analysis were really the ones that are relevant to this study.

A table that identifies the errors that might occur in the selection of accidents (i.e. accidents that are not relevant to the study but that might be selected by this procedure) is presented in Table 4.1. There is a concern for errors which include irrelevant accidents (types **(i),** (ii)) and those that exclude relevant crashes (type (iii)). Manual verification of a subsample can identify logical errors in the computer search procedure as well as errors in coding computer data from the accident report form. There is no way, using historical records, to verify if the accident was properly described by the investigating officer at the scene at the time of the crash. Once the computer search method was verified, the whole data set was used for the final analysis.

	Is a Relevant Accident	Is not a Relevant Accident
Identified as a Relevant Accident	**OK**	**(i) -** A vehicle in the left lane collides with **a** vehicle in an adjacent lane and this leads to further collisions of which at least one of them is in the area left of the middle lane. **(i i) -** A left lane vehicle hits an object in the area left of the median lane.
Identified as not a Relevant Accident	**(i i i) -** This includes all accidents that are relevant but not captured by the method.	**OK**

TABLE 4.1
TYPOLOGY OF CLASSIFICATION ERRORS

IV.4 Cross Classification Analysis

A program **'CLASSIFY.FOR'** was written that identified the relevant accidents from the data and the information saved included only those variables that were relevant to the study. The output file 'CLASSOUT.DAT' was then used in the BMDP 4f analysis of the data. BMDP 4f analysis includes two way classification tables, percentage of column totals and the difference table.

The test of independence was conducted by first estimating the expected values of the cell frequencies and then comparing these values to the observed frequencies. The result is the chi-square test statistic, X2. The assumptions of the chi-square test are as follows, a) separate observations are probabilistically independent, b) all observations are identically distributed, and c) the number of observations is large.

The expected frequency is calculated by multiplying the row and column total for each cell and dividing it by the total number of observations. The observed frequencies should be close to the expected frequencies if the null hypothesis is true i.e. the row variable is independent of the column variable. The test statistic chi-square is large when the null hypothesis is rejected. We reject the null hypothesis if the chi-square statistic is larger than a particular value (based on the degrees of freedom ((a-l)(b-1)) and the significance level say $\alpha=.05$).

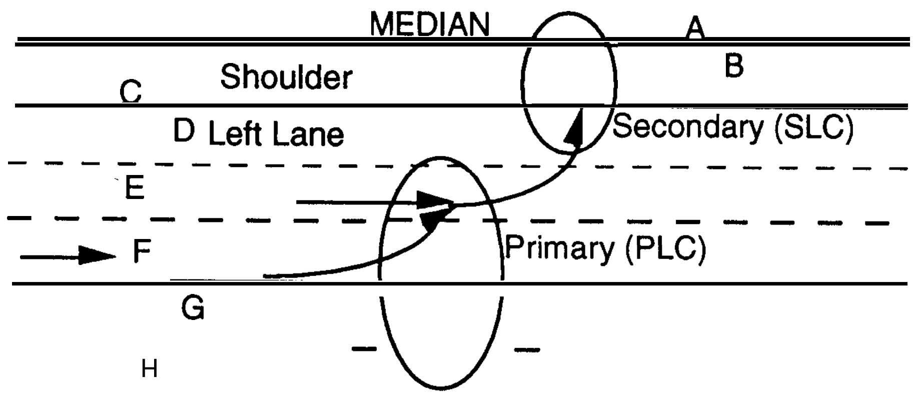
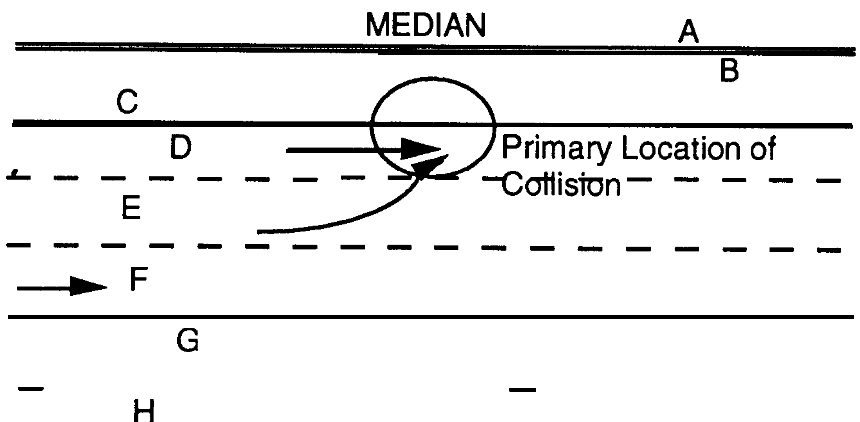
The test statistic is calculated as follows :

$$x^2 = \sum_{\text{cells}} \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$

This analysis was conducted using the BMDP statistical software to obtain the resulting relation of dependence or independence between accident status (relevant or other) and the possible contributing factors.

IV.5 Spatial Analysis of Accidents

The accident data can be used to determine the distance of each accident from the nearest ramp. The milepost readings were useful in achieving this. The ramp milepost readings were stored in a file 'RAMP.DAT', while the milepost readings of accidents were stored in 'CLASSOUT.DAT'. Then a file was prepared which contained the distances of accidents from the nearest ramp in addition to the original accident data. The file was then modified so that the distances from ramps were coded 1, 2, 3 or 4 depending upon that distance (O-50 meters, 50-100 meters, 100-400 meters and greater than 400 meters, respectively). The necessary accident information including the coded distances are stored in a file named 'RESULT.DAT' which is used in the 4f analysis.

SKETCH	HOW CODED	COMMENTS
 [igure 4.1 Type I Accidents	PLC - ε, F, G, H, I, or J (any one). SLC - A, B, C, D (At least one).	Primary collision occurs elsewhere not in left lane or on the left hand side of this lane and vehicle or debris wind up in median / shoulder / left lane.
 Figure 4.2 Type II Accidents	PLC - C or D. TC - B or D or E. MPC - Any except J. SI - Not C.	Primary collision in left lane or left shoulder that is a side swipe, broadside or hit object where the move preceding collision is not lane change and the tire does not blow out.

PLC - Primary Location of Collision
SLC - Secondary Location of Collision
SI - Special Info

TC - Type of Collision
MPC - Move Preceding Collision

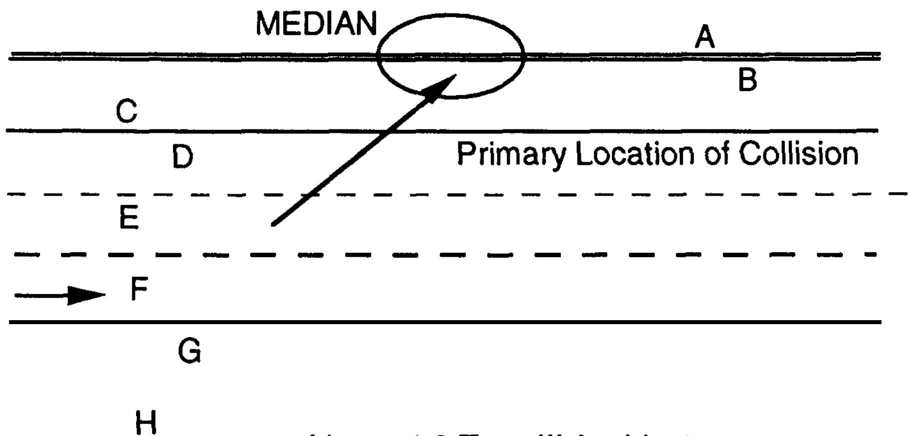
SKETCH	HOW CODED	COMMENTS
	PLC - A or B. MPC - C. SI - Not C.	Primary collision beyond shoulder or median on driver's left and move preceding collision is run off the road. Tire blow out did not occur.

Figure 4.3 Type III Accidents

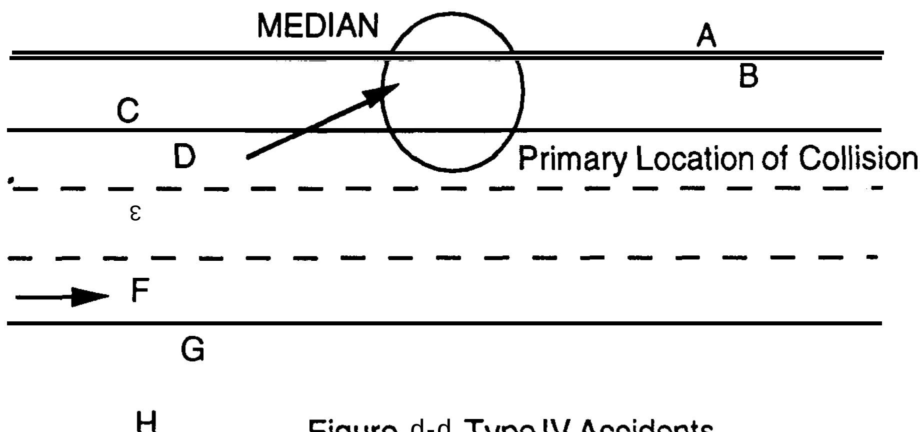
SKETCH	HOW CODED	COMMENTS
	PLC - A, B, C, or D. SI - C.	Primary collision in area to the driver's left including the left lane and the vehicle has a blow out.

Figure d-d Type IV Accidents

PLC - Primary Location of Collision
SLC - Secondary Location of Collision
SI - Special Info

TC - Type of Collision
MPC - Move Preceding Collision

V. Data Analyses

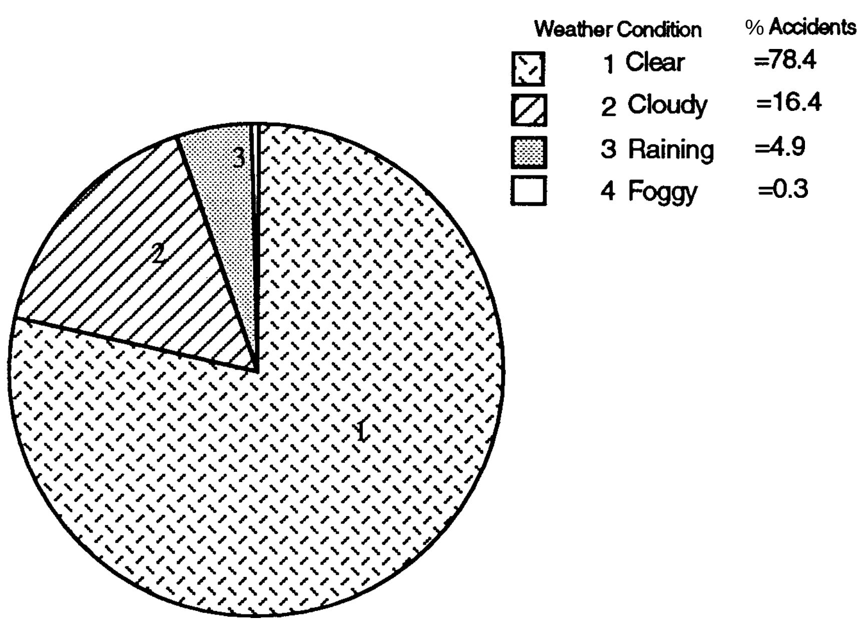
The analyses conducted with the I-1 0 accident data are documented in this chapter. The first section contains summaries of the accident data base as a whole. Next, the results of the computer search verification are repotted. The chapter concludes with the comparison of the relevant accidents to other accidents using contingency tables.

V.1 Results of Classification of all Accidents

There were 2069 accidents on I-1 0 between I-405 and I-1 10 for 1986 and 1987. The general characteristics of these accidents are represented by the pie charts on the pages following.

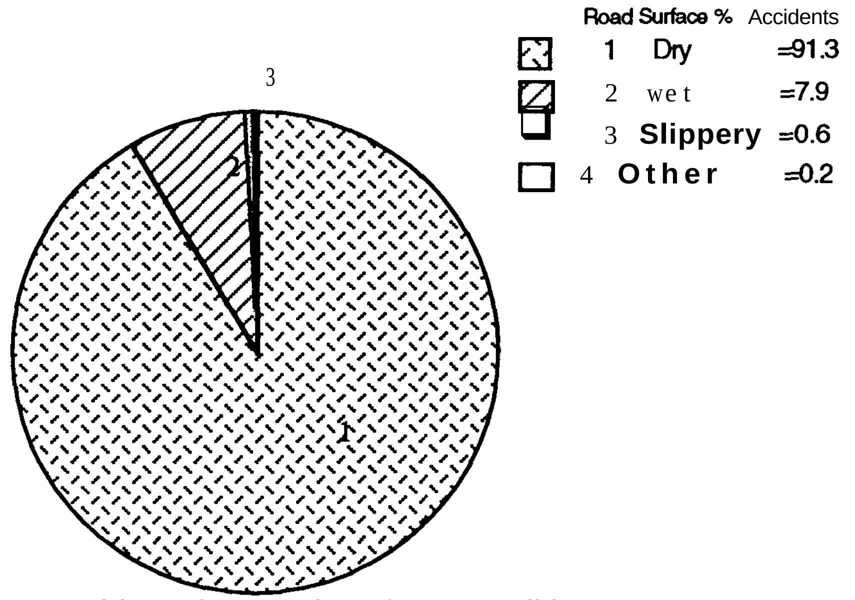
Environmental Condition and Time of Day

As shown in Figure 5.1, most of the accidents (78 %) occurred in clear weather conditions. About 16% of the accidents occurred in cloudy and 5% in rainy conditions. Only 0.3% accidents occurred when the weather condition was foggy.

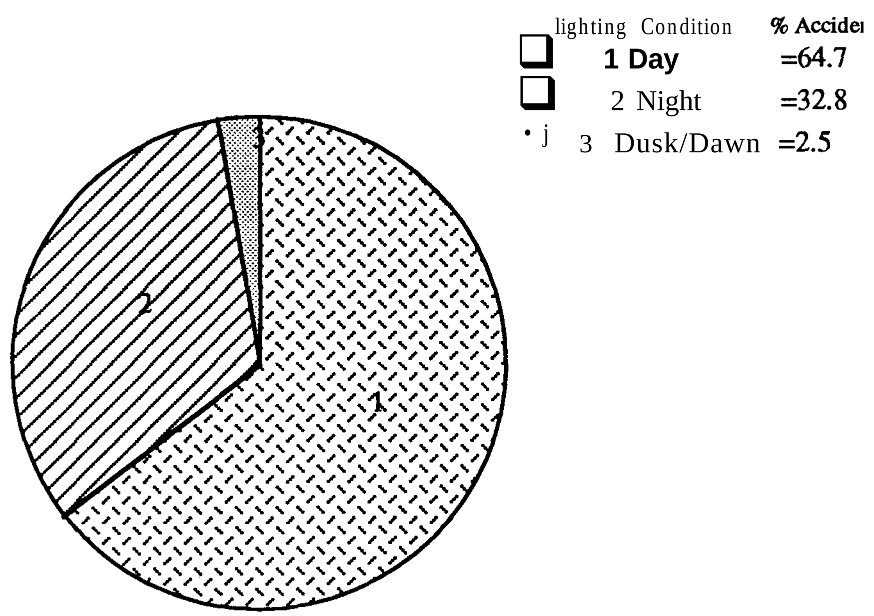


Accidents by Weather Condition
Figure 5.1

Practically, all (9 1.3 %) of the accidents occurred under dry road surface conditions as shown in Figure 5.2. About 8% of the accidents occurred under wet road surface conditions.

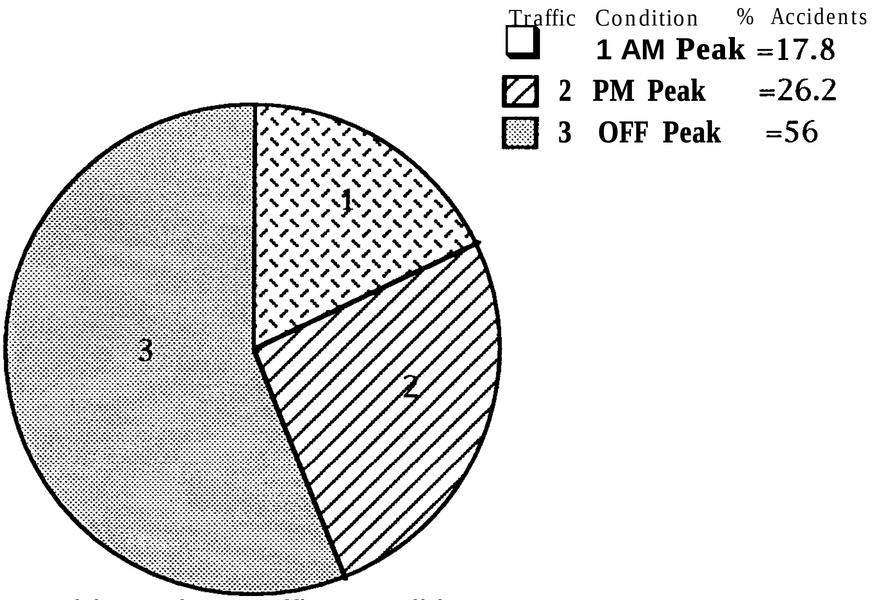


Accidents by Road Surface Condition
Figure 5.2



Accidents by Lighting Conditions
Figure 5.3

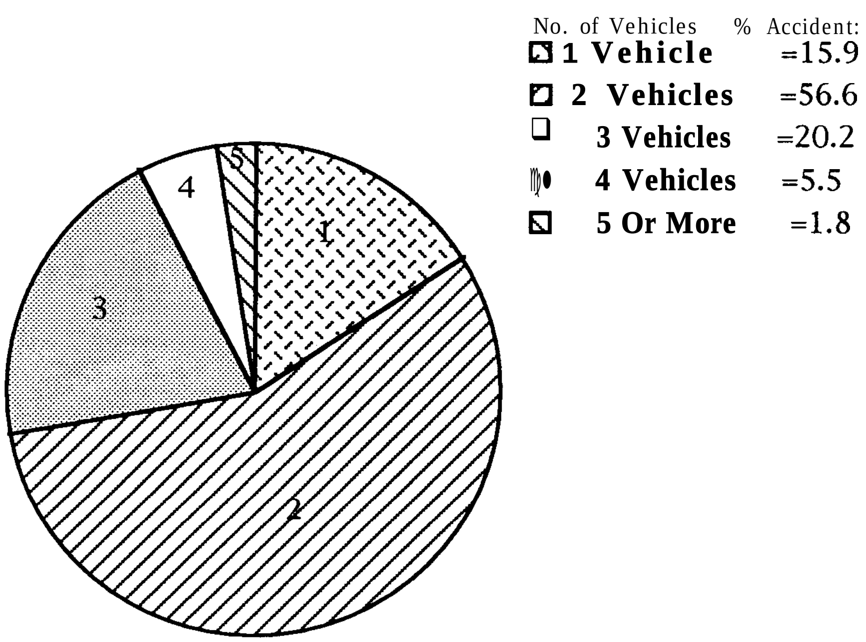
It can also be seen that 65% of all the accidents occurred in day light while 33% occurred in the dark as shown in Figure 5.3. Of the accidents that occurred on I-10 freeway segment, about 17.8 % and 26.2 of them occurred in the morning peak and evening peak periods respectively, as can be seen in Figure 5.4. The rest (56 %) occurred in the off peak periods of the day. These accident characteristics are rather typical of highway accident attributes nationally.



Accidents by Traffic Condition
Figure 5.4

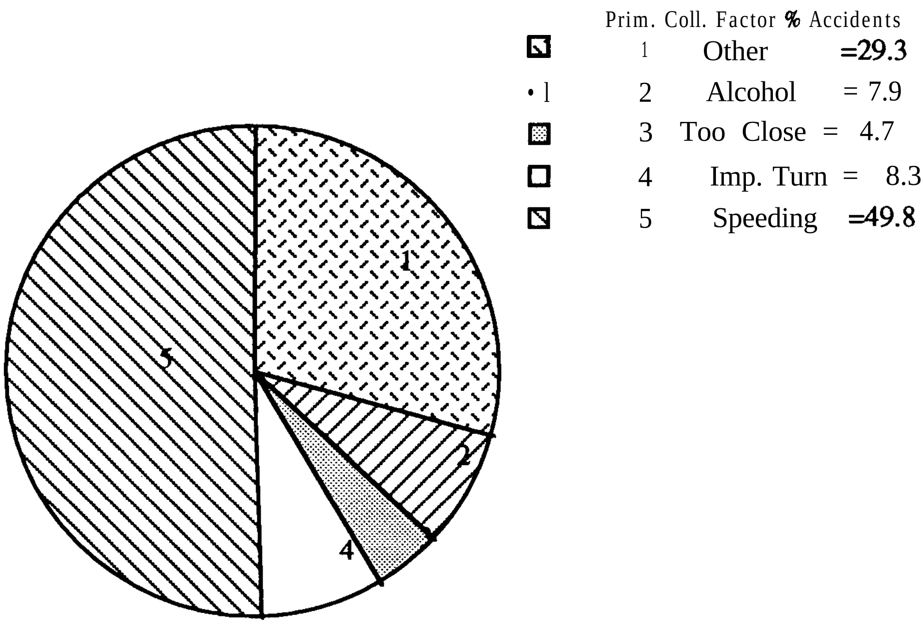
Primary Collision Factor and Type of Collision

The number of vehicles involved in the accidents ranged from 1 to 9. There were 16% accidents that involved only 1 vehicle, as shown in Fiaure 5.5. Furthermore. 56.6 and 20.2 percent of the accidents involved two and three vehicles respectively. The remaining 7% of the accidents involved four or more vehicles as shown in Figure 5.5.



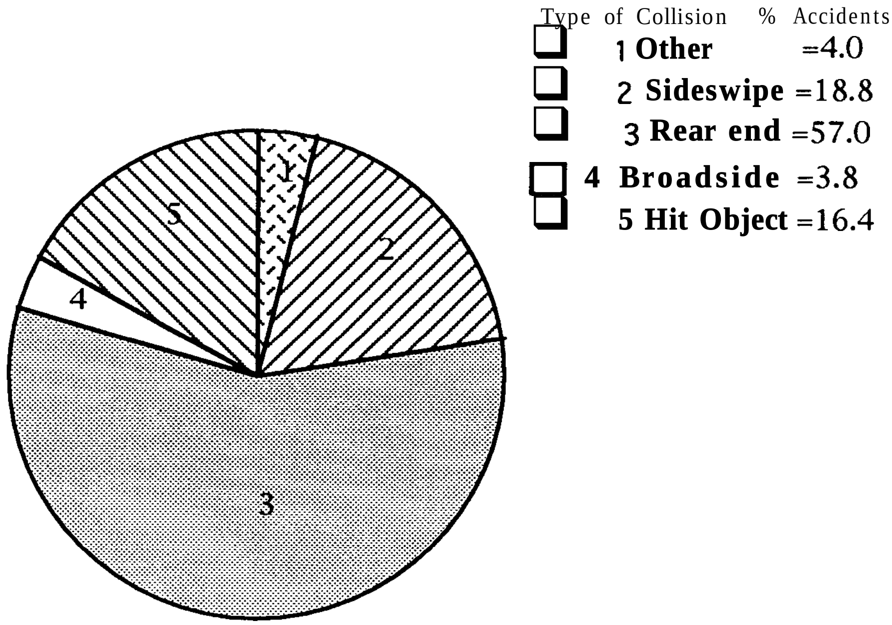
Accidents by No. of Vehicles Involved
Figure 5.5

From Figure 5.6 it is evident that the primary collision factor that accounted for about half (49.8%) the number of accidents was speeding. Approximately 8% and 5% of the accidents were due to driving under the influence of alcohol and following too closely respectively. Interestingly, improper turns occur in 8% of freeway accidents where turning should be minimal. The 'other' accidents involved includes improper driving (1%), failure to yield (0.6%) and in some cases the primary collision factor was not stated (27.7%).



Accidents by Primary Collision Factor
Figure 5.6

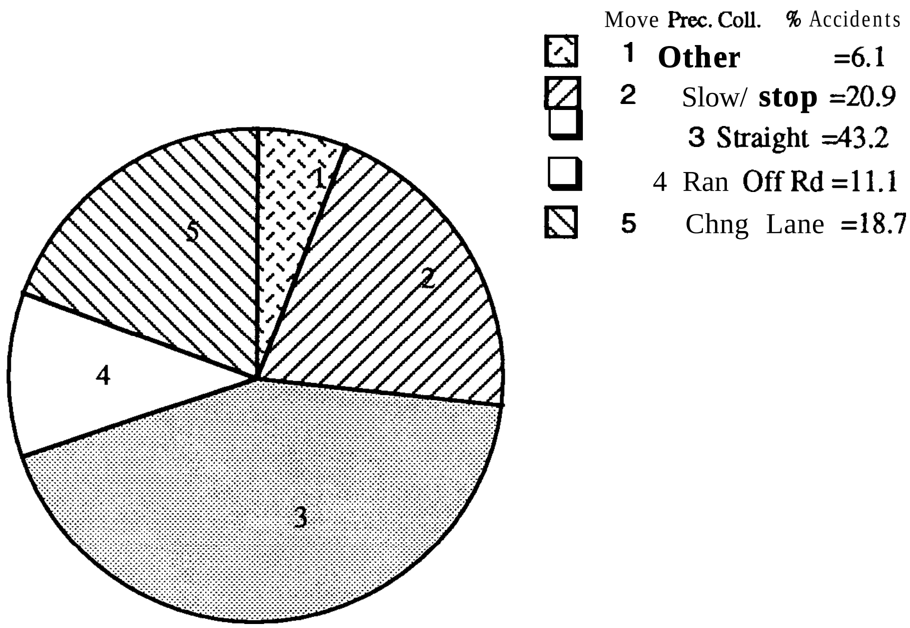
The most common collision type was overwhelmingly rear end collision, which occurred in 57% of the total accidents on the freeway section. It was recorded that 16.4% and 18.8% the accidents were hit object and sideswipe collisions respectively as shown in Figure 5.7. Only 4% of the accidents were broadside collisions, and the rest were either overturn or head-on collisions. In a limited number of accident records, the type of collision for the primary accident was not even stated (2.2%). The frequency of rear end collisions, two-vehicle involvement and speeding as a collision factor can be interpreted as describing a facility with frequent collision within lanes, but relatively rare collisions which propel vehicle laterally across the highway.



Accidents by Type of Collision
Figure 5.7

Descriptions of Accident-involved Parties

Up to 9 parties may be recorded on each accident record. For each party involved in the collision there is a party type, movement preceding collision, primary and secondary locations of collision, physical condition of the drivers involved.



Accidents by Move Preceeding Collision
Figure 5.8

The movement preceding collision was straight in 43.2% of the accidents. From Figure 5.8 it can also be seen that the parties who were either slowing or stopped constituted 21% of the accidents and ran off road accidents accounted for 11% of the total accidents. About 19% of the accidents occurred when the party involved was in the process of changing lanes.

Passenger cars (80.5%) and pickup trucks(13.9%) were the most common type of vehicles that were involved in the accidents. Only 2.8 and 1.9 % of the vehicles involved in the accidents were trucks and motorcycles respectively. Because of the low truck and motorcycle involvements, these types of vehicles were dropped from consideration in subsequent analyses.

V.2 Results of the Search Method Verification

The verification was conducted by utilizing data from a sub sample of accidents selected randomly from 1986 and 1987. A month X accident status two-way analysis (Table B. 1 - See Appendix B) yielded that the accident status did not depend on the month the accident occurred ($p > 0.1$, $p = 0.66$). Accident records from three months selected randomly resulted in the selection of 35 accidents that were relevant to the study. The three months that were selected were March '87 (total = 78, relevant = 1 1), July '86 (total = 97, relevant = 14) and November '87 (total = 97, relevant = 10).

Caltrans office in Los Angeles was visited and the actual highway patrol reports were then checked to verify if the accidents that were selected were relevant. The manual search revealed that 31 accidents out of a total of 273 accidents were identified as relevant to this study, instead of the 35 obtained from the computer program. All the 4 accidents that were wrongly included were single vehicle, ran off the road type of accidents. These accidents involved vehicles that were in the left lane and ran off the highway onto the left shoulder or the median (a type (ii) error in Table 4.1). There were no type (i) or, importantly, type (iii) errors. The procedure may therefore slightly overcount relevant accidents.

The TASAS files are coded in such a manner that one cannot identify ran off the road type of accidents involving vehicles that were in the left lane before this event happened, from those involving vehicles that were in the middle or right lane before a similar incident occurred. The primary accident involving vehicles in the left lane would not occur in that lane in the futuristic case where this lane would be fully automated and hence eliminates this kind of error. One could assume that these 4 accidents could be "transferred" to an adjacent lane. Given the accuracy of the accident identification, this appears to be needless speculation.

The 95 % confidence interval for an estimate of the value of the ratio of the relevant accidents to the total number of accidents is given by (18):

$$[p-z_{\alpha/2}(p(1-p)/n)^{1/2}, p+z_{\alpha/2}(p(1-p)/n)^{1/2}]$$

'p' is the ratio of the actual number of relevant accidents to the total number of accidents, α is the significance level (a= 0.05), and 'n' is the total number of accidents. The distribution is considered binomial as there only two possibilities for each accident i.e. it is either relevant or it is not relevant. For this study sample, taking into consideration only three months data, we have p=0. 114 (3 1/273) and n=273. So the 95 % confidence interval for the estimate of the ratio of the relevant accident over the total number of accidents was found to be[0.076,0.152] as calculated using the above expressions. The ratio of 35 (selected relevant accidents) for 3 months on 273 (total relevant accidents) gives a value of 0.128 which is within the confidence interval [0.076,0.152] and hence the difference is not significant from 31 (actual relevant accidents for those 3 months).

V.3 Results of the Cross Classification Analysis of the Accident Data

Environmental Factors

Accident Status X *Lighting :* The two way analysis between the lighting conditions and the accident status revealed that 48% of the relevant accidents and 67% of the other accidents occurred during the day time and 48% of the relevant and only 30.5% of the other accidents occurred in the night time as seen from Table 5.1 (p=O.OOO).

Accident Status X Lighting

Lighting	Accident		
	Other	Relevant	Total
Day	67.2	48	64.7
Night	30.5	48	32.8
Dusk/Dawn	2.3	4	2.5
Total	100	100	100

TABLE 5.1

The reason for the test of independence failing is that other accidents are twice as frequent during daylight conditions, whereas relevant accidents occur equally during daytime and nighttime.

Accident Status X *Weather* : The accident status was found to be marginally independent of the weather condition at the time of the accident (p=0.08). The relevant accidents appear more likely during rain, although the overall percentage is small (see Table 5.2).

Accident Status X Weather

Weather	Accident		
	Other	Relevant	Total
Clear	79.1	73.6	78.4
Cloudy	16.1	18.3	16.4
Rainy	4.5	7.7	4.9
Fog	0.3	0.4	0.3
Total	100	100	100

TABLE 5.2

Roadwav Related Factors

Accident Status X Road surface condition : The accident status was found to be dependent on the road surface condition (p=0.0006,). Table 5.3 shows that about 85% of the relevant and 92% of the other accidents occurred in dry weather conditions. However, 13% of the relevant accidents occurred with wet pavement while only 7% of the other accidents occurred under similar conditions. This table is consistent with Table 5.2 regarding weather conditions.

Accident Status X Road Surface Condition

Road Surface Condition	Accident		
	Other	Relevant	Total
Dry	*92.2*	85.3	91.3
Wet	7.1	13.2	7.9
Slippery	*0.4*	*1.5*	*0.6*
Other	*0.3*	*0*	*0.2*
Total	100	100	100

TABLE 5.3

Driver related factors

Accident Status X Sobriety / Drug/ Physical : The analysis of the drivers' physical condition (sober, drugged, fatigued etc.) versus the accident status (relevant or other) showed that the accident status was not independent of the physical state of the driver (p=0.00). From Table 5.4 it can be seen that 12% of the relevant accidents had drivers that were under the influence of alcohol, compared to 5.2% for other accidents.

Accident Status X Driver's Condition

Driver Condition	Accident		
	Other	Relevant	Total
Other	17.8	20.5	18.2
NoAlcohol	*77*	*67.4*	*75.7*
HadAlcohol	5.2	12.1	6.1
Total	100	100	100

TABLE 5.4

Time of dav and Accident Characteristics

Accident Status X Time of day : The **status of the accident was found to be dependent on the time of day the accident occurred (p=0.00). Looking at Table 5.5 it can be seen that the while the other accidents were over represented between 0700-0900 and 1400-l 900 hours (includes mostly the peak periods), the relevant accidents were over represented between 2200-0300 hours at night. There is also a large difference in the percentage of accidents between 0500-0700 hours. During this period there are a larger percentage of relevant accidents.**

Accident Status X Time of Day

Time of Day	% age Accidents		
	Other	Relevant	Total
0000 - 0100	2.8	4.4	3
0100 - 0200	2.3	6.6	2.9
0200 - 0300	2.5	6.6	3
0300 - 0400	1.2	2.9	1.5
0400 - 0500	1	2.6	1.2
0500 - 0600	0.8	4	1.2
0600 - 0700	2.6	4	2.8
0700 - 0800	6.2	5.1	6.1
0800 - 0900	6.1	1.1	5.5
0900 - 1000	4	2.9	3.9
1000 - 1100	4.9	3.3	4.6
1100 - 1200	4.7	4.8	4.7
1200 - 1300	4.2	6.2	4.5
1300 - 1400	5	4	4.9
1400 - 1500	5.6	2.2	5.2
1500 - 1600	7.5	5.5	7.3
1600 - 1700	6.5	4.8	6.2
1700 - 1800	7.5	2.9	6.9
1800 - 1900	6.2	3.3	5.8
1900 - 2000	5	5.9	5.1
2000 - 2100	3.5	2.9	3.4
2100 - 2200	2.3	2.9	2.4
2200 - 2300	4	5.5	4.2
2300 - 2400	3.5	5.5	3.8
Total	100	100	100

TABLE 5.5

Accident status X Type of collision : **An analysis of the accident status versus the type of collision revealed that the two were not independent as can be seen from Table 5.6 (p=0.00). The differences table reveals that there were many more rear end collisions in the other accidents category, while there were a larger percentage of hit object and sideswipe accidents in the relevant category.**

Accident Status X Type of Collision

Type of Collision	Accident		
	Other	Relevant	Total
Other	4.2	2.2	4
Sideswipe	16.9	31.1	18.8
Rear end	63.6	13.9	57
Broadside	3	8.8	3.8
Hit Object	12.2	44	16.4
Total	100	100	100

TABLE 5.6

Accident Status X Move preceding collision **: Accident status is not independent of the move preceding collision as seen from Table 5.7 (p=0.00). The table reveals that ran off the road (move preceding collision) accounted for 41.4% of all relevant accidents and only 8.2 % of all the other accidents. Another significant difference is observed in the percentage of collisions with move preceding collision as vehicle slowing/stopped (accounts for 23.4% of other accidents but only 4.8% of the relevant accidents). The table reveals large percentage of other accidents involve slowing / stopping (23%) and proceeding straight (45%) whereas very few relevant accidents involve these movements.**

Accident Status X Movement Preceding Collision

Movement Preceding Coll.	Accident		
	Other	Relevant	Total
Other	5.9	5.1	5.8
Slow / Stopped	23.4	4.8	21
Straight	45.2	31.1	43.4
Ran Off Road	6.5	41.4	11.1
Change Lane	18.9	17.6	18.8
Total	100	100	100

TABLE 5.7

Accident Status X Primary collision factor : The accident status was observed to be dependent on the primary collision factor as shown in Table 5.8 (p=0.0). Improper turn was cited in 20.5% of the relevant accidents but only 6.5% of the other accidents. Speeding was cited in 53.2% of the other accidents and only 27.1% of the relevant accidents.

Acciden Status X Primary Collision Factor

Primary Collision Factor	Accident		
	Other	Relevant	Total
Other	28.4	35.2	29.3
Alcohol	6.7	15.4	7.9
Following Close	5.2	1.8	4.7
Improper Turn	6.5	20.5	8.3
Speeding	53.2	27.1	49.8
Total	100	100	100

TABLE 5.8

Number of Vehicles Involved in Collision

Accident Status X No. *of vehicles* : The analysis of the accident status and the number of vehicles involved in collision revealed a failure of the test of independence as seen from Table 5.9 (p=0.00). Relevant accidents involving one vehicle 38.5% of the time compared to 12.5% for other accidents. There were 41.% relevant accidents that involved two-vehicles and 58.9% of other accidents. Taken as a set, Tables 5.5 through 5.8 indicate fundamental differences between relevant and other accidents. Clearly some of the differences are due to the fact that the criteria used for the identification of relevant accidents involve the use of collision type and movement preceding collision. Nevertheless, the differences in time of day and primary collision factor point to important differences between the two categories of accident status.

Accident Status X Number of Vehicles

Number of Vehicles	Accident		
	Other	Relevant	Total
1 Vehicle	12.5	38.5	15.9
2 Vehicles	58.9	41.8	56.6
3 Vehicles	21.7	10.6	20.2
4 Vehicles	5.4	5.9	5.5
5 or more	1.5	3.3	1.7
Total	100	100	100

TABLE 5.9

V.4 Results of Spatial Analysis

The results of the spatial analysis to determine the distances of accidents from the ramp nearest were quite interesting. From Table 5.10 it can be observed that of the 273 accidents that are relevant, 41% (113 accidents) occurred within 50 meters from the nearest ramp, 7.7% (21 accidents) occurred between 50-l 00 meters of the nearest ramp, 32% (88 accidents) between 100-400 meters and 19% (51 accidents) beyond 400 meters. This indicates that relevant accidents are more likely in the O-SO meters zone from the ramps and this could mean that the openings in the physical barrier (separating the automated and non-automated portion of the freeway) that might be necessary for a safer automated highway be placed anywhere except in that zone. In the O-SO meters zone accidents, it was observed that the accidents were particularly over represented in sections with freeway connectors, the segment of road where other freeways either merge into or exit from the I-l 0.

Accident Status X Distance from Ramp

Distance From Ramp	Accidents		
	Other	Relevant	Total
< 50 meters	33.3	41.4	34.4
50-l 00 meters	9.4	7.7	9.2
100-400 mts.	41	32.2	39.8
> 400 meters	16.3	18.7	16.6
Total	100	100	100

TABLE 5.10

Based upon this important finding, an additional comparison of Accident status X Distance from ramp X Type of collision was conducted (Table 5.1 1). A large percentage of relevant accidents in the O-50 meters zone involved hit object (the vehicles are running off the road and either striking the median or hitting a stationary object on the left shoulder). Rear-end collisions were predominant within this zone in other accidents. There is a large difference between the relevant and other accident types in the percentage of sideswipe accidents within 50 meters of a ramp and particularly within 50-l 00 meters.

It appears that many relevant accidents occur while drivers are attempting to maneuver to or from a ramp (resulting in upstream sideswipe collisions), or when they are very near to the ramp (resulting in hit object crashes). This strong locational trend is not present in the broad accident data indicating a significant risk to automated lane operations posed by the weaving of vehicles through near ramps.

Accident Status X Distance from Ramp X Type of Collision

Distance from Ramp	Type of Collision	Accident		
		Other	Relevant	Total
Less than 50 metres	Other	6.5	3.5	6
	Sideswipe	17.2	22.1	18
	Rear end	52.1	9.7	45.4
	Broadside	6.7	15.9	8.1
	Hit Object	17.5	48.7	22.5
	Total	100	100	100
Less than 100 metres	Other	1.8	0	1.6
	Sideswipe	19.5	42.9	22.1
	Rear end	66.3	4.8	59.5
	Broadside	1.8	0	1.6
	Hit Object	10.7	52.4	15.3
	Total	100	100	100
Less than 400 metres	Other	3.3	1.1	3
	Sideswipe	16.6	36.4	18.7
	Rear end	70.2	17	64.5
	Broadside	1	4.5	1.3
	Hit Object	9	40.9	12.4
	Total	100	100	100
Greater than 400 metres	Other	3.4	2	3.2
	Sideswipe	15.7	37.3	18.9
	Rear end	68.9	21.6	61.9
	Broadside	1.4	3.9	1.7
	Hit Object	10.6	35.3	14.2
	Total	100	100	100

TABLE 5.11

VI. Conclusions and Recommendations for Future Research

VI.1 Conclusions

A technique has been developed and tested to asses the safety consequences of mainline freeway accidents to the operation of a median automated highway lane. The technique utilized a set of accident fields within the computerized accident data base, TASAS, to identify the'subset of relevant accident.

Tests of the validity of the technique using 3 months of 1986 and 1987 accident data from California I-10 (Santa Monica Freeway) between I-1 10 and I-405 revealed that the method slightly over predicted relevant accidents, but not significantly so. Further, no relevant accidents were missed subsequent to the validation of the technique. Analysis of a full two years of data (1986 and 87) from the study site revealed:

1. Relevant accidents are very unlikely to involve rear end collisions which dominate general freeway collision types (i.e. 57% rear end; the second largest category is 19% sideswipe). Only 14% of the relevant accidents involve rear end collisions.

2. Relevant accidents are much more likely at late night and early morning hours (10 pm to 6 am), are more likely to include an alcohol-influenced driver and are more likely single vehicle crashes which involve an improper turn or run-off-the-road. This constellation of factors is consistent with gross driving errors which result in substantial loss of vehicle control. Fortunately, the data reveal that these types of crashes are much less likely in the peak period when the automated lane is most heavily used.

3. Wet pavement contributes to the occurrence of a small but significant portion of relevant accidents.

4. Relevant accidents are more closely clustered around on/off ramps, particularly freeway connectors, than are other accidents. Sideswipe and hit object accidents predominate near ramps, reinforcing the concept that relevant accidents involve some gross loss of vehicle control, at least particularly while executing turns near ramps.

It is clear that the relevant accidents (13% of the total) represent a significant risk to the viable operation of an automated median lane. Even though comparatively few relevant collisions occur during peak periods, they are of sufficient numbers to represent a real risk to automated lane operations. Further, the off-peak accidents may be of sufficient severity to close or disable automated lane operations during the subsequent peak period, an eventuality to be avoided as well. Based upon these preliminary findings, it appears that grade separated access/egress to freeway connectors is a necessity and that some form of direct access/egress may be warranted for other ramps as well.

It would be useful to extend the analyses to other freeways with different ramp configurations and levels of congestion to see if these findings are supported. Given the reliability of the computer search procedure in identifying relevant accidents, a relatively large set of accident data drawn from several freeways should be efficiently analyzed.

VI.2 Recommendations for Future Research

In addition to the findings regarding the level of relevant accidents, the most important outcomes of this research are the validity of the computer search methodology and the finding of significant spatial relationships regarding relevant accidents. Specifically, that relevant accidents appear clustered near ramps, particularly freeway connectors, and that the relevant accidents at these locations differ significantly from other types of accidents at these locations.

Further verification of the findings are needed for a broader range of facilities with different geometric features and levels of congestion. A separate analysis and comparison between additional freeway segments would give greater confidence in the generalizability of the findings. Regional differences, southern to northern California, may be significant. Another interesting comparison may be between accident patterns with median HOV lanes and those without. Comparison of multilane accidents of the type that are relevant may reveal differences not apparent in broader studies of HOV safety. Toward this end, any research with HOV lane safety should use findings from the recently completed Cal Poly study of HOV Lane safety.

The larger accident and freeway segment sample size will allow much more precise understanding of the relationship between ramp location and type, collisions and automated median lane safety. Given the safety and cost implications, the analysis should be undertaken.

REFERENCES

1. Adolf D. May, Michael Yiu-kuen Lau, Accident Prediction Model Development: Signalized Intersections, Research Report, Institute of Transportation Studies, University of California, Berkeley, 1988.

2. Chang-Ing Hsu, Edward C. Sullivan, Accident Rates along Congested Freeways, Institute of Transportation Studies, University of California, Berkeley, 1988.

3. Daniel Sperling, Robert A. Johnston, Mark A. DeLuchi, and Paul P. Craig, A Policy Analysis of Automating Urban Freewavs, Presented at the 1989 ASCE International Conference on Applications and Advanced Technologies in Transportation Engineering, San Diego, 1989.

4. David B. Brown, Cecil W. Colson,"Application of Microcomputer Technology to Local Accident Problem Identification." Transportation Research Record, No.-910, pp-14-18, 1983.

5. Edward C. Sullivan," Estimating Accident Benefits of Reduced Freeway Congestion." Journal of Transportation Enaineerinq, Vol.-l 10, No.-2, pp-167-180, Mar./Apr. 1990.

6. Frederick T. Barwell, Automation and Control in Transport, 2nd rev. ed., Oxford, New York, Pergamon Press, 1983.

7. Geoffrey D. Gosling, Stephen L. M. Hockaday, Control Strateaies for Automated Control of Transportation Systems, Institute of Transportation Studies, University of California, Berkeley, 1983.

8. J. T. Sanderson and M. H. Cameron,"Identification of Hazardous Road Locations," Australian Road Rese[illegible]ch Board Journal, 13th ARRB, Vol.-13, Part 9, Safety, pp-133-147, 1986.

9. John D. Leonard, Thomas F. Golob, Wilfred W. Recker," An Analysis of the Severity and Incident Duration of Truck-involved Freeway Accidents." Accident Analvsis and Prevention, Vol.-19, No.-5, pp-375395, 1987.

10. John W. Davis, Adaptina Radar to the Automotive Environment, Paper presented at the Eleventh International Technical Conference on Experimental Safety Vehicles, Washington D. C., 1987.

11. Julia L. Higle, James M. Witkowski, Bay[illegible] Identification of Hazardous Locations, Paper presented at the 1988 Annual Meeting of the Transportation Research Board, 1988.

12. King K. Mak, Barbara H. DeLucia, T. Chira-Chavala, and R. Quinn Brackett, Accident Analvsis for Urban Freewavs. Volume I. Technical Report, Texas Transportation Institute, College Station, Texas, 1988.

13. Rebecca Yette, Don Young, David Provines, Accident Analvsis for Urban Freeways, Volume II, MAAP User Manual, Texas Transportation Institute, College Station, Texas, 1988.

14. Robert D. Ervin, Kan Chen, “Towards Motoring Smart.” Issues in Science and Technology, pp-92-97, Winter 1988-89.

15. Robert L. French, Road Transport Informatics: The Next 20 Years, SAE Technical Paper Series, Future Transportation Technology Conference and Exposition, San Francisco, August 1988.

16. Steven E. Shladover, Roadwav Automation Technoloav-- Research Needs, 68th Annual Meeting Transportation Research Board, Washington D. C., 1989.

17. Tan Hee Wee and K. W. Ogden,"Truck Involvement in Fatal Road Accidents,” Australian Road Research Board Journal, 14th ARRB, Part 4, pp-64-77, 1988.

18. Thomas D. Wickens, Multiway Contingency Tables Analysis for the Social Sciences, Lawrence Erlbaum Associates, Publishers, Hillsdale, New Jersey, 1989.

19. Thomas F. Gold,, Wilfred W. Recker," An Analysis of the Salient Characteristics of Truck-involved Freeway Accidents using the Method of Log-linear Modelling." Journal of Safety Research, Vol.-18, No.-3 pp. 121-136, 1987.

APPENDICES

A. DATA BASE DESCRIPTION

Accident Characteristics File

FIELD DESCRIPTION AND CONTENT

BYTE POS. IN RECORD	FIELD NAME	FIELD VALUE/ NOTES
1-2	Request District	
3-4	Year Request Made	
5-8	Request Number	
9	Print Number	
lo-12	Route	
13	Route Suffii	
14-20	Route Sequence #	
21	Postmile Prefii	
22-27	Postmile	Format 999v999
28	Record Type	0 = Title 4 = Accident 1,5 = Highway
29-34	Date of Accident	yrmodd
35-38	Time of Accident	hh mm
39	Record Number	1 = Parties 1, 2, 3 2 = Parties 4, 5, 6 3 = Parties 7, 8, 9.
40-41	District	
42-44	Route	
45	Route Suffii	
46-47	County	See County Table
48	Postmile Prefii	
49-54	Hwy Database PM	Format 999v999
55	Highway Group	R=Independent Alignment Right L=Independent Alignment Left Z=Divided or Undivided
56	Filetype	H, I, or R

Table A.1 Characteristic File of Individual Accidents

Accident Characteristics File

FIELD DESCRIPTION AND CONTENT

BYTE 'OS. IN ıECORD	FIELD NAME	FIELD VALUE/ NOTES
57-62	Date of Accident	Yr Mo Dd
6366	Time of Accident	Hh Mm
67	Record Number	1 = Parties 1, 2, 3 2 = Parties 4, 5, 6 3 = Parties 7, 8, 9.
68-73	Postmile	Format 999v999
74	Postmile Suffix	E = Equation Blank = None
75	Side of Highway	N = Northbound S = Southbound W = WestBound E = EastBound
76	Intersection/ Ramp Accident Location	1 = Ramp intersection (exit) 2 = Ramp 3 = Ramp entry - = Does not apply
77	CHP Acc. indicator	Blank = Processed by CHP
78-86	Common Acc. Number	Digits I-4 source of Acc. Report Digits 5-9 Officer's Badge Number
87	Reporting Level	1 = Below Reporting Level 2 = Above Reporting Level < = Not Stated or Undetermined
88	Primary Collision Factor	See Primary Collision Factor Tables
89	Day of Week	1 = Sunday, Etc.
90	Weather	See Collision Factor Tables
91	Lighting	,,
92	Road Surface	,,
93	Road Condition	,,
94	Right of Way Control	,,
95	Type of Collision	,,

Table A.1 Characteristic File of Individual Accidents

Accident Characteristics File

FIELD DESCRIPTION AND CONTENT

BYTE POS. IN RECORD	FIELD NAME	FIELD VALUE/ NOTES
96-97	Number of Veh. Involved	1 thru 9
98	Number of Parties Involved	1 thru 9
99	Party Type	See Party Type Table
100	Direction of Travel	N = North, NE or NW Bound S = South, SE or SW Bound E = Eastbound W = Westbound
101	Veh. Highway Indicator	1 = On State Route 2 = Not on State Route 3 = Intersecting State Route < = Not Stated
102	Special Information	A = Hazardous Material B = Fire Involved C = Tire Defect/ Failure < = Not Stated
103-104	Persons Killed	For Party 1, Total in Accident Party 2-9, Total in that Party
105-106	Persons Injured	For Party 1, Total in Accident Party 2-9, Total in that Party
107-108	Object Struck - 1st	See Object Struck Table
109	Collision Location - 1 st	See Collision Location Table
110-111	Object Struck - 2nd	See Table
112	Collision Location -2nd	,,
113-114	Object Struck - 3rd	,,
115	Collision Location - 3rd	,,
116-117	Object Struck - 4th	,,
118	Collision Location - 4th	,,
119	Other Asso. Factor	See Other Asso. Factor Table
120	Other Asso. Factor -2nd	,,
121	Movement Preceding Coll.	See Movement Prec. Coll. Table
122	Sobriety /Drug /Physical	See Table
123	Sobriety/drg/physical 2nd	See Table
124-323	Parties 2 to 9	Each Party add 25 Bytes same as Col 99-123

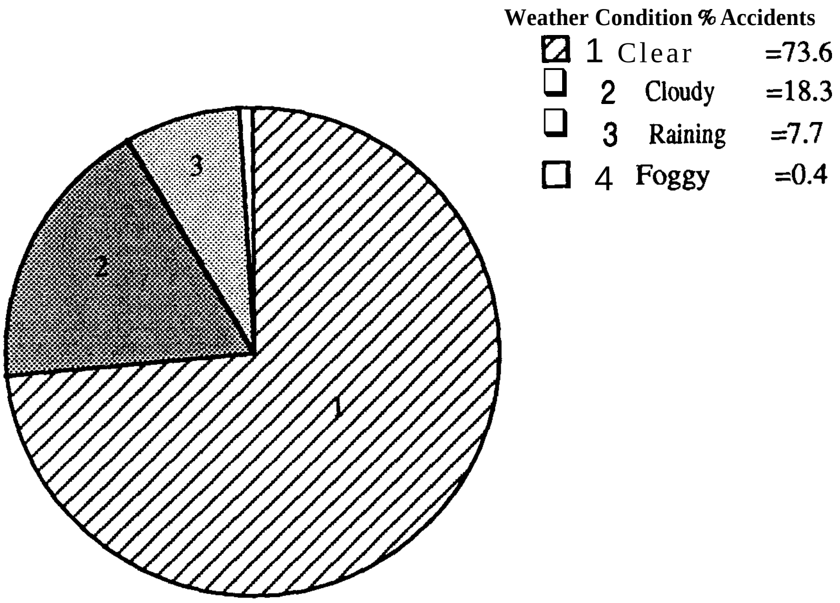
Table A.1 Characteristic File of Individual Accidents

B. RELEVANT TABLES AND FIGURES

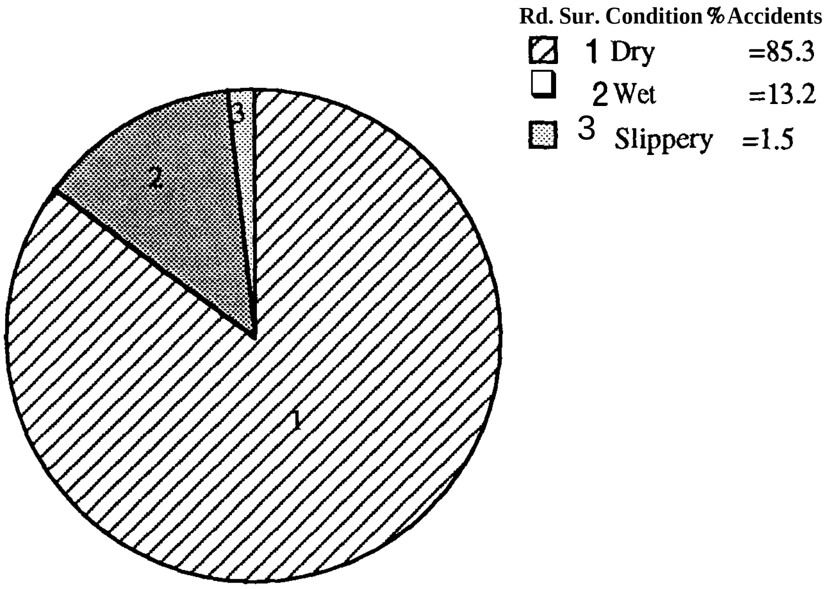
Accident Status X Month

Month	%age Accidents		
	Other	Relevant	Total
Jan	6.4	10.3	6.9
Feb	7.5	7.3	7.4
Mar	7.2	8.4	7.3
Apr	9.1	8.8	9
May	8.1	6.6	7.9
Jun	8.6	7.7	8.5
Jul	8.6	10.3	8.8
Aug	8.9	8.1	8.8
Sep	9.7	9.9	9.8
Oct	9	8.4	8.9
Nov	8.5	7	8.3
Dec	8.5	7.3	8.3
Total	**100**	**100**	**100**

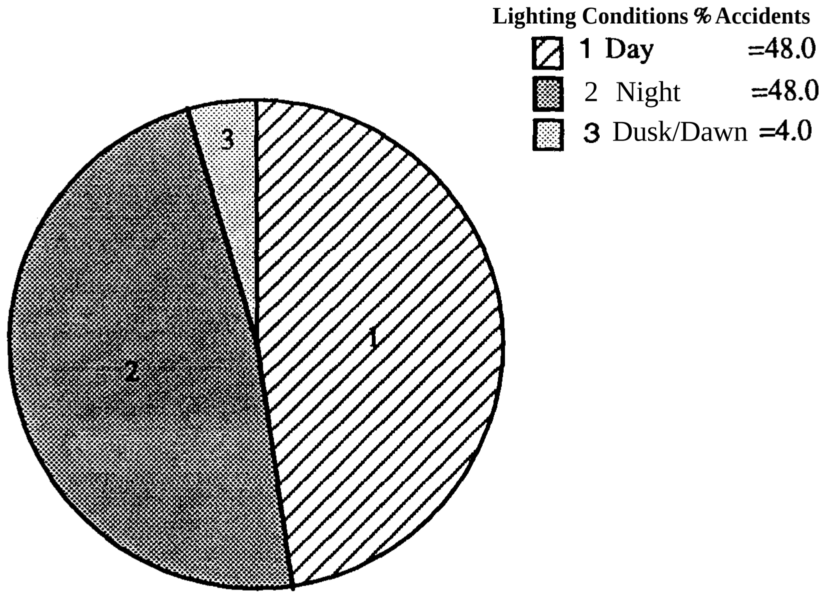
TABLE B.l



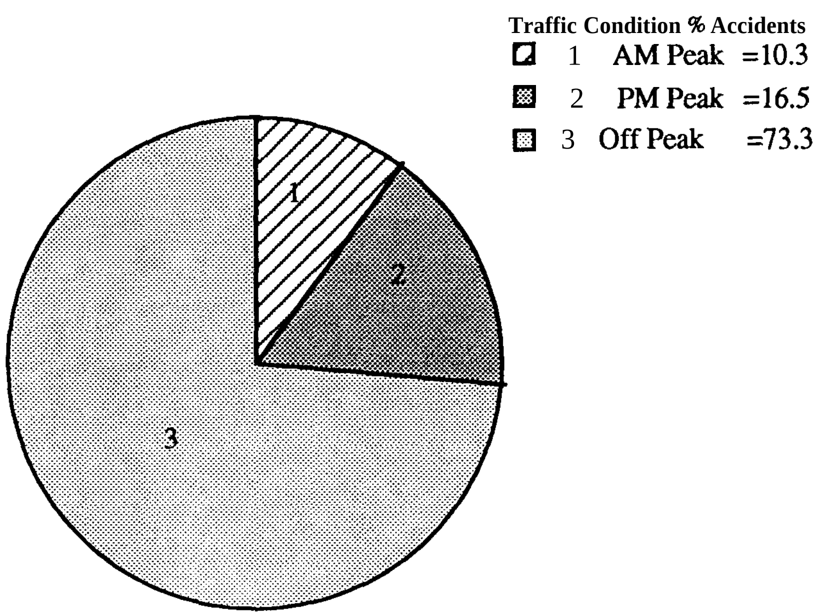
Accidents by Weather Conditions
Figure B.1



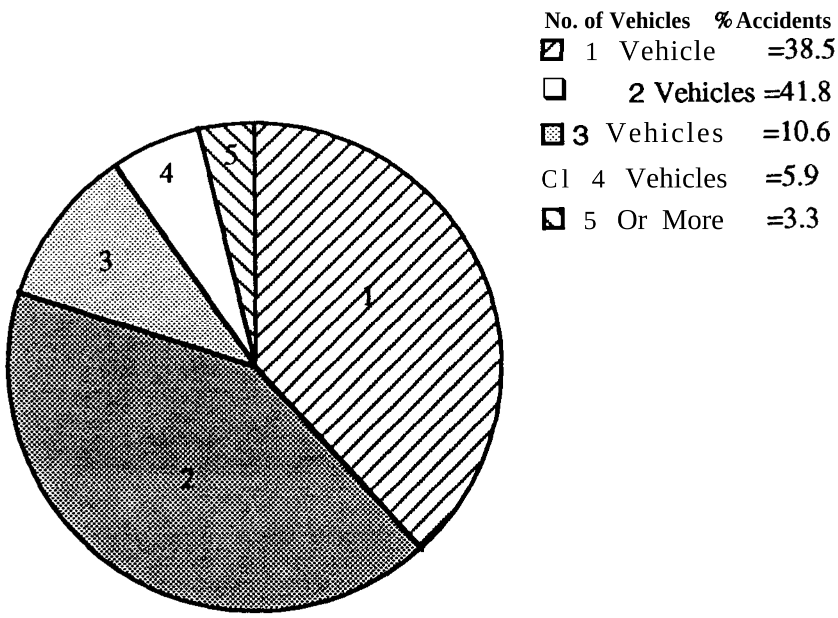
Accidents by Road Surface Condition
Figure B.2



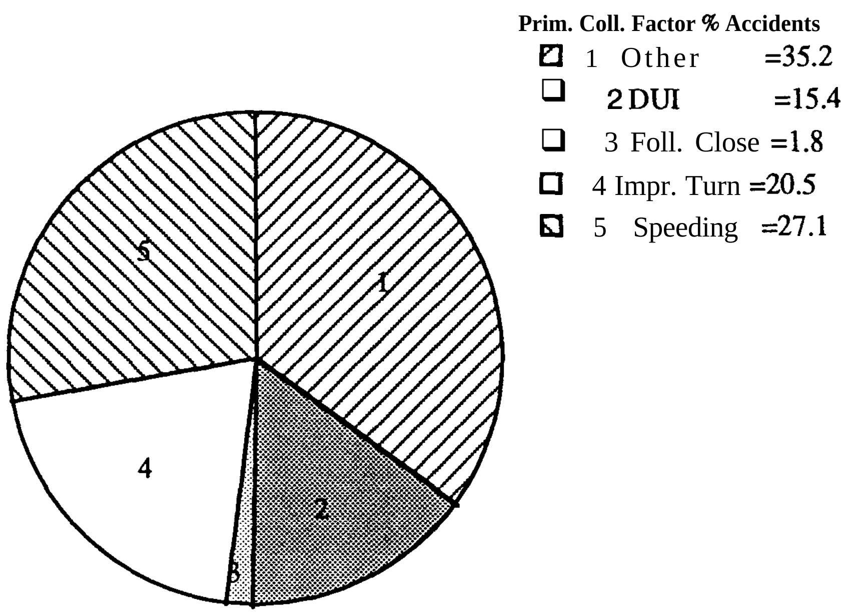
Relevant Accidents by Lighting
Figure 8.3



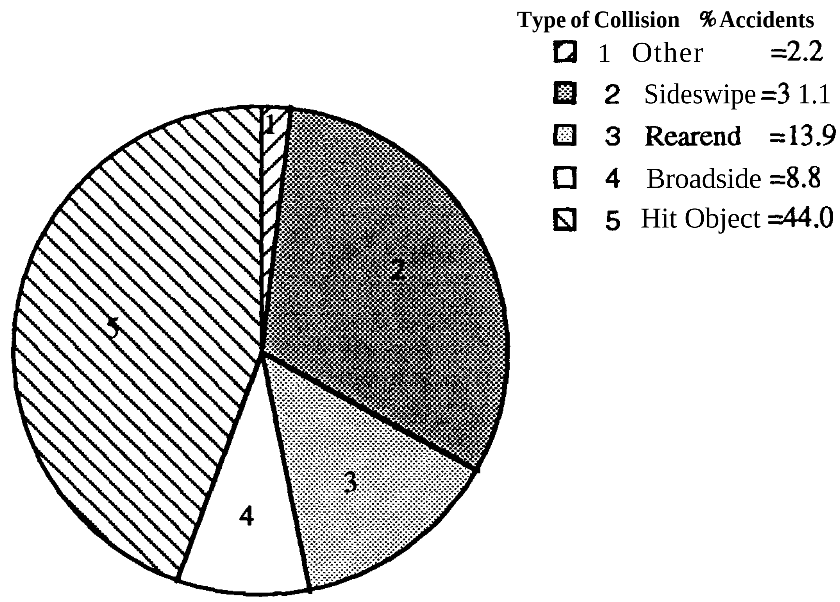
Accidents by Traffic Conditions
Figure B.4



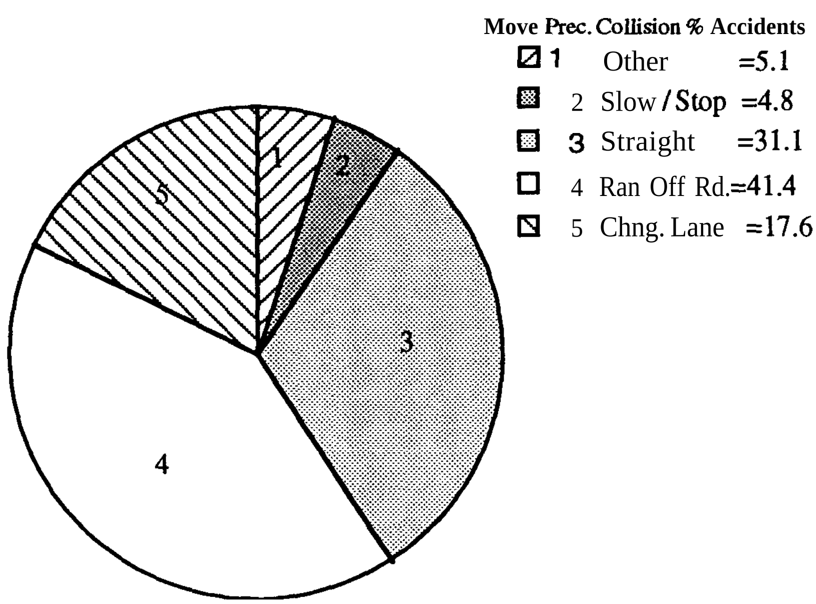
Accidents by No. of Vehicles Involved
Figure B.5



Accidents by Primary Collision Factors
Figure B.6



Accidents by Type of Collision
Figure B.7



Accidents by Moue Preceding Collisi on
Figure B.8

C. PROGRAM TO IDENTIFY RELEVANT ACCIDENTS FROM DATA

```
C     ONLY RELEVANT DATA FOR EACH ACCIDENT IS SAVED
      CHARACTER *1 A(400),C(25)
      INTEGER B(50) OPEN(UNIT=12,FILE='TR1616.DAT',STATUS='OLD')
      OPEN(UNIT=13,FILE='CLASSOUT',STATUS='NEW')
         DO 100 I=1,2411
            READ(12,15) A
 15         FORMAT(80A1)
                IF( A(28).EQ.'1') GO TO 100
                IF( A(28).EQ.'5') GO TO 100
C     TYPE 1 ACCIDENTS
                IF (A(109).EQ.'E') GO TO 21
                IF (A(109).EQ.'F') GO TO 21
                IF (A(109).EQ.'G') GO TO 21
                IF (A(109).EQ.'H') GO TO 21
                IF (A(109).EQ.'I') GO TO 21
                IF (A(109).EQ.'J') GO TO 21
            GO TO 28
 21      DO 30 J=112,312,25
                IF (A(J).EQ.'A') GO TO 123
                IF (A(J).EQ.'B') GO TO 123
                IF (A(J).EQ.'C') GO TO 123
                IF (A(J).EQ.'D') GO TO 123
 30         CONTINUE
         DO 31 J=115,315,25
                IF (A(J).EQ.'A') GO TO 123
                IF (A(J).EQ.'B') GO TO 123
                IF (A(J).EQ.'C') GO TO 123
                IF (A(J).EQ.'D') GO TO 123
 31         CONTINUE
         DO 32 J=118,318,25
                IF (A(J).EQ.'A') GO TO 123
```

```
      IF (A(J).EQ.'B') GO TO 123
      IF (A(J).EQ.'C') GO TO 123
      IF (A(J).EQ.'D') GO TO 123
32    CONTINUE
C     TYPE 2 ACCIDENTS
28    IF (A(109).EQ.'C') GO TO 29
      IF (A(109).EQ.'D') GO TO 29
      GO TO 60
29    IF (A(95).EQ.'B') GO TO 40
      IF (A(95).EQ.'D') GO TO 40
      IF (A(95).EQ.'E') GO TO 40
      GO TO 60
40    IF (A(121).NE.'J') GO TO 41
      GO TO 60
41    IF (A(102).NE.'C') GO TO 223
C
C     TYPE 3 ACCIDENTS
60    IF (A(109).EQ.'A') GO TO 61
      IF (A(109).EQ.'B') GO TO 61
      GO TO 70
61    IF (A(121).EQ.'C') GO TO 62
      GO TO 70
62    IF (A(102).NE.'C') GO TO 323
C     TYPE 4 ACCIDENTS
70    IF (A(109).EQ.'A') GO TO 71
      IF (A(109).EQ.'B') GO TO 71
      IF (A(109).EQ.'C') GO TO 71
      IF (A(109).EQ.'D') GO TO 71
```

```
      GO TO 26
71          IF (A(102).EQ.'C') GO TO 423
      GO TO 26
26          B(1)=1
      GO TO 300
223         I2=I2+1
      GOT0 23
123         I1=I1+1
      GOT0 23
323         I3=I3+1
      GOT0 23
423         I4=I4+1
23          B( 1)=2
300         C( 12)=A(31)
            C( 13)=A(32)
            C( 14)=A(29)
            C( 15)=A(30)
            C( 16)=A(33)
            C( 17)=A(34)
            C( 1 )=A(35)
            C(2)=A(36)
            C(3)=A(37)
            C(4)=A(38)
C     PRIMARY  COLLISION  FACTOR
            IF  (A(88).EQ.'1') B(6)=2
            IF  (A(88).EQ.'2') B(6)=3
            IF  (A(88).EQ.'3') B(6)=1
```

```
                  IF (A(88).EQ.'4') B(6)=4
                  IF (A(88).EQ.'5') B(6)=5
                  IF (A(88).EQ.'6') B(6)=1
                  IF (A(88).EQ.'B') B(6)=1
                  IF (A(88).EQ.'C') B(6)=1
                  IF (A(88).EQ.'D') B(6)=1
                  IF (A(88).EQ.'E') B(6)=1
                  IF (A(88).EQ.'<') B(6)=1
C     WEATHER
                  IF (A(90).EQ.'A') B(7)=1
                  IF (A(90).EQ.'B') B(7)=2
                  IF (A(90).EQ.'C') B(7)=3
                  IF (A(90).EQ.'E') B(7)=4
C     LIGHTING
                  IF (A(91).EQ.'A') B(8)=1
                  IF (A(91).EQ.'B') B(8)=3
                  IF (A(91).EQ.'C') B(8)=2
                  IF (A(91).EQ.'D') B(8)=2
                  IF (A(91).EQ.'E') B(8)=2
                  IF (A(91).EQ.'F') B(8)=2
C     ROAD SURFACE CONDITION
                  IF (A(92).EQ.'A') B(9)=1
                  IF (A(92).EQ.'B') B(9)=2
                  IF (A(92).EQ.'C') B(9)=4
                  IF (A(92).EQ.'D') B(9)=3
                  IF (A(92).EQ.'<') B(9)=4
C     TYPE OF COLLISION
```

```
          IF (A(95).EQ.'A') B( 10)=1
          IF (A(95).EQ.'B') B( 10)=2
          IF (A(95).EQ.'C') B( 10)=3
          IF (A(95).EQ.'D') B( 10)=4
          IF (A(95).EQ.'E') B( 10)=5
          IF (A(95).EQ.'F') B( 10)=1
          IF (A(95).EQ.'G') B( 10)=1
          IF (A(95).EQ.'H') B( 10)=1
          IF (A(95).EQ.'<')  B(IO)=I
C    NO. OF VEHICLES
          C(5)=A(97)
          IF  (A(97).EQ.'6') C(5)='5'
          IF  (A(97).EQ.'7') C(5)='5'
          IF  (A(97).EQ.'8') C(5)='5'
          IF  (A(97).EQ.'9') C(5)='5'
C    PARTY
          L=12
      DO 200 K=99,299,25
          B( L)=O
          IF  (A(K).EQ.'A') B(L)=1
          IF (A(K).EQ.'C') B(L)=2
          IF (A(K).EQ.'D') B(L)=3
          IF (A(K).EQ.'F') B(L)=4
          IF (A(K).EQ.'4') B(L)=5
          IF (A(K).EQ.'H') B(L)=6
          IF (A(K).EQ.'I') B(L)=6
          IF (A(K).EQ.'S') B(L)=7
```

```
      L=L+1
200   CONTINUE
C     MOVE PRECEEDING COLLISION
      IF (A(121).EQ.'A') B(21)=2
      IF (A(121).EQ.'B') B(21)=3
      IF (A(121).EQ.'C') B(21)=4
      IF (A(121).EQ.'H') B(21)=2
      IF (A(121).EQ.'J') B(21)=5
      IF (A(121).EQ.'L') B(21)=1
      IF (A(121).EQ.'P') B(21)=1
      IF (A(121).EQ.'D') B(21)=1
      IF (A(121).EQ.'E') B(21)=1
      IF (A(121).EQ.'F') B(21)=1
      IF (A(121).EQ.'G') B(21)=1
      IF (A(121).EQ.'I') B(21)=1
      IF (A(121).EQ.'K') B(21)=1
      IF (A(121).EQ.'Q') B(21)=1
      IF (A(121).EQ.'M') B(21)=1
      IF (A(121).EQ.'N') B(21)=1
      IF (A(121).EQ.'O') B(21)=1
      IF (A(121).EQ.'R') B(21)=1
      IF (A(121).EQ.'<') B(21)=1
      C(6)=A(49)
      C(7)=A(50)
      C(8)=A(51)
      C(9)=A(52)
      C(10)=A(53)
```

```
          C( 11)=A(54)

C   SOBRIETY/DRUG/PHYSICAL
          IF (A(122).EQ.'A') B(22)=2
          IF (A(122).EQ.'B') B(22)=3
          IF (A(1 22).EQ.'C') B(22)=1
          IF (A( 122).EQ.'D') B(22)=1
          IF (A(122).EQ.'E') B(22)=4
          IF (A( 122).EQ.'F') B(22)=1
          IF (A( 122).EQ.'G') B(22)=1
          IF (A( 122).EQ.'H') B(22)=1
          IF (A(122).EQ.'I') B(22)=5
          IF (A(122).EQ.'<') B(22)=1
          IF (A(122).EQ.'-') B(22)=1
          IF (A(75).EQ.'E') B(23)=1
          IF (A(75).EQ.'W') B(23)=2
      WRITE (13,150) B(l), B(23), C(1), C(2), C(3), C(4), B(6), 1 B(7),
    B(8), B(9), B(10), C(5), B(12), B(13), B(14), B(15), 1 B(16),
    B(17), B(18), B(19), B(20), B(21), C(6), C(7), C(8), 1 C(9),
    C(10), C(11), B(22), C(12), C(13), C(14), C(15), 1 C(16),
    C(17).
150   FORMAT (211, 4A1, 5I1, Al, 1011, 6A1, I1, 2A1, 2A1, 2A1)
100   CONTINUE
      STOP
      END
```

D. Annotations of Literature Related to Accident Analysis

Safety is a very important aspect that has to be considered in any highway project undertaken to solve the existing transportation problems. Accidents relevant to any study and the factors contributing to these accidents are details that have to be identified so that necessary changes could be accommodated for a better and safer highway system. The literature search revealed a number of ways to analyze accidents. Some of the literature that was used in this study is documented below. The principle objectives were to identify the relevant accidents and analyze these accidents to find the contributing factors.

Edward C. Sullivan and Chang-Ing Hsu. "Accident Rates alona Conaested Freewavs."Research Report. California Department of Transportation. California. March 1988.

The report presented the results of a study to quantify the relationship between accident rates and congestion on the San Francisco Bay Area freeways in California. The authors developed several regression and cross-classification models which related to accident rates, to levels of congestion (represented by queuing) and to several other variables which characterized the prevailing physical and traffic flow conditions. The regression model revealed that the expected number of accidents in the freeway section considered were a function of the section lane-miles. The number of accidents not only increased with increase in flow, but also for an increasing number of ramps per mile and decreased with the presence of auxiliary lanes and percentage of the peak period during which queuing does not occur.

The disaggregate analysis revealed that the accident rate in the presence of a queue was two to three times that of the rate when there is no queuing. The cross classification models are considered to have the most general mathematical structure and to be inherently transferable to other locations throughout the state. The study was helpful in getting an insight into the effect of congestion on the accident rate. The study also revealed that recent advances in microcomputers and analytical tools have made it possible to extensively analyze accident data. This study showed that congestion increases accidents.

Anthony Hitchcock. "Intelliaent Vehicle / Hiahwav Svstem Safetv : Problems of Reauirement Specification and Hazard Analysis." Transportation Research Board, 70th Annual Meeting, January 1991.

The paper attempts to demonstrate by examples some methods of requirement specification and hazard analysis. The study considers only one lane of the freeway to be automated with the automated part of the freeway sharing the on and off-ramps with the other non-automated part. The accidents that are related to this study are vehicle failure (flat tire, etc.), which leads to a vehicle under automatic control to be separated only by a short distance from a stationary / slow moving vehicle or debris in its path (due to vehicle failure), which is potentially hazardous. To minimize hazards, a slow moving object must not be allowed to enter the automated lane. So the author suggests that the automated lane should be separated from the non-automated lane by a physical barrier with some openings so as to enable vehicles to enter and leave the automated lane. These physical barriers may themselves be a hazard to the highway system as the vehicles trying to enter or leave the automated lane could crash into them. The author concludes that the operations would be very complex and that it is not possible to propose a simple, hazard free system.

. T.Sanderson and M. H. Cameron. "Identification of Hazardous Road Locations." Australian Road Research Board.13th ARRB. Vol-13. Part 9. Safety. pp-133-147. 1986.

The study included a review of procedures for identifying and improving hazardous locations taking into account research and current practices, both in Australia and overseas. Statewide accident data was used to compare accident experience of the individual intersections. The average number of accidents and accident rates per intersection were categorized by the intersection geometry and traffic control and then these were compared. They concluded that the hazardous locations could be identified either by using accident number related to distance or accident rate methods. The study provides a good example of how to identify and rank hazardous locations. This study is very relevant and useful to the spatial analysis performed on accidents in this study.

Tan Hee Wee and K. W. Ogden. "Truck Involvement in Fatal Road Accidents." Proceedings 14th ARRB Conference. Part 4. pp-64-77.1988.

This study used the Australian Fatal File as the accident data base to present the truck accident situation in terms of accident types, causal factors, and accident rates. The significance of location factors, road geometry, environmental factors, vehicle factors and driver factors in truck accidents were studied. The study used two-way contingency tables to determine the number of accidents in each category (like vehicle type by number of fatal accidents, vehicle type by area of operation etc.).

Multi-way contingency tables were also used in the analysis of accidents (for example, area of operation and vehicle type by the type of accidents etc.). The results indicated that the trucks were overrepresented in fatal accidents. 10% of all fatal accidents involved trucks in Australia. One of the other noticeable features was that single vehicle, rural, articulated truck accidents, with the trucks striking a fixed object were mainly associated with curves, unlit roads at night and vertical alignment. Truck accidents mostly involved more than one vehicle. In urban areas, a high proportion of truck accidents were found to occur near or at intersections. The study also suggests possible cost-effective accident counter measures related to truck accidents. The percentage of accidents in each cell of the contingency tables indicated the causal factors of accidents involving trucks. The study gave an insight into the use of contingency tables for the identification of contributing factors.

Thomas F. Golob, Wilfred W. Recker, and John D. Leonard. "An Analysis of the Severity and Incident Duration of Truck-Involved Freeway Accidents." Accident Analysis and Prevention, Vol-19. No. 5. pp-375-395. 1987.

This paper analyzes accident data on trucks from the TASAS data base. The accident data were analyzed relative to collision factors, accident severity, and incident duration and lane closures. Log-linear modeling was used to establish relationships between type of collision and accident characteristics. The characteristics of truck involved accidents on the freeway was found to be a function of the type of collision. The collision type and primary collision factors were inter-related. Most severe accidents (fatalities) were found to be hit-object collisions followed by rear end collisions. The injury rate for these types of collisions was twice as large as that for all the other accidents.

The duration of accident for homogeneous groups of accidents was found to be log normally distributed. The study also indicated that certain freeway segments were prone to certain types of accidents. The overall traffic levels were found to explain the patterns in the freeway segment results. This study presents how log-linear modeling can be a useful in uncovering the underlying patterns in accident characteristics. Lane traversing accidents are a critical issue that was not discussed in all the previous studies.

King K. Mak, Barbara H. DeLucia, T. Chira-Chavala, and R. Quinn Brackett, "Accident Analysis for Urban Freeways, Volume 1-Technical Report", Texas Transportation Institute, Texas, 1988.

The study involved the development of a process to identify high accident locations on urban interstate freeways. The accidents were also analyzed to obtain the causative factors associated with these high accident sites. A computer program was written that utilizes a 'window' which is a highway segment of 2 miles, This is then moved along a freeway network in 0.1 mile increments and the accident rate calculated for each increment. The accidents in the sites of interest were then analyzed using an algorithm based on the discrete multivariate approach.

The variables that were significantly overrepresented were identified using a program written for the purpose and a model was developed. The expected accident frequency and the actual frequency were compared for each cell of the different contingency tables. Various high accident sites were located using the 'window'. The results indicated that multi-vehicle accidents (36.5%) during weekday afternoon rush hour during June and on Tuesdays and Fridays from 5:00 and 6:00 pm were overrepresented in the data. Male drivers under 21 and female drivers over 55 were overrepresented in the accident data for Site No. 1. This study provides a good example of the use of microcomputers for the identification of relevant accident sites and the analysis of the accidents at these sites.