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DEVELOPMENT OF A HIGHWAY SAFETY IMPROVEMENT PROGRAM FOR THE RURAL ENVIRONS OF PAKISTAN

By

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ABSTRACT

DEVELOPMENT OF A HIGHWAY SAFETY IMPROVEMENT PROGRAM FOR THE RURAL ENVIRONS OF PAKISTAN

By

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A Highway Safety Improvement Program (HSIP) was suggested for alleviating rural trunkline accident problems in Pakistan. The HSIP is a contemporary term for a sequential plan of implementing highway related safety improvements. However, the principal restraining factor anticipated in the transfer of HSIP technology was the absence of an adequate and accessible accident data base in the country. This research was, therefore, conducted to develop accident prediction models using various highway and traffic hazards as the surrogate measures of safety.

The independent variables developed for this study represented the hazards in terms of inadequate access control, deficient pavement and shoulder width, deficient pavement markings, guardrail deficiencies, potential intersection conflict points, low pavement serviceability and roadside obstructions. The ambient hazardousness was quantified using three types of procedure: use of design standard deficiencies as a measure of hazard; use of erratic maneuvers and traffic conflicts as a measure of hazard; and use of an expert team for subjective rating of hazardousness. Consequently, three types of data sets were generated: measurements; counts; and ratings.

A three-year period (January 1988 to December 1990) accident data were retrieved from police records to be used as the dependent variable in the study. The experimental site was comprised of 86 kilometers of rural two-lane, two-way and four-lane divided sections of the National Highway (N-5) in the District Rawalpindi, Pakistan.

Multivariate linear regression analyses were performed to investigate the statistical significance of the hypothesized relationship between the hazards and accidents. The analyses indicate existence of a statistical relationship between the hazards and the accidents, and show that inadequate control of access and operational friction are significantly correlated with accidents. These findings are substantiated by the results of previous studies made in the United States and other countries.

The results of this research provide a means to implement a HSIP in Pakistan even when archival accident records may not be available. The research findings also expose vital issues for the planners and policy makers that would arise from the incorporation of preventative safety measures in future highway transportation facilities. The most significant impact of implementing these measures would be on the land-use pattern of the country.

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LIST OF ABBREVIATIONS

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ADT	Annual Daily Traffic
EOS	End of Shoulder
FHWA	Federal Highway Administration (USA)
GNP	Gross National Product
HI	Hazard Index
HSIP	Highway Safety Improvement Program
JICA	Japan International Cooperation Agency
Km	Kilometer
Kmph	Kilometer per Hour
MOE	Measure of Effectiveness
MOH	Measure of Hazard
MVKm	Million Vehicle Kilometers
MVM	Million Vehicle Miles
NHA	National Highway Authority (Pakistan)
NHSB	National Highway Safety Board (USA)
NHTSA	National Highway Traffic Safety Administration (USA)
NTRC	National Transport Research Centre (Pakistan)
OECD	Organization for Economic Cooperation and Development
PDO	Property Damage Only
PHD	Punjab Highway Department (Pakistan)
RRR	Resurfacing, Restoration and Rehabilitation
TOPICS	Traffic Operations for Increased Capacity and safety
TRRL	Transport and Road Research Laboratory (UK)
TRB	Transportation Research Board (USA)
USAID	United States Agency for International Development
USDOT	United States Department of Transportation
VMT	Vehicle Miles of Travel

CHAPTER 1

INTRODUCTION AND RESEARCH BACKGROUND

1.1 THE THRESHOLD

Human knowledge on the subject of highway traffic safety is beyond infancy and, at present, relatively improved explanatory axioms are employed for having a refined comprehension about the crash mechanism. Over the past three decades the rate of motorization and highway network expansion has increased worldwide. This growth, particularly in the developed countries, has acted as a strong stimulus for attaining the present extent of behavioral and technological research concerning highway transportation. Over a period of time, this scholastic enterprise has induced some fundamental conceptual shifts and contributed many innovative notions to the transportation knowledge-base.

One such development is perceived in observing that the word *cause* has largely disappeared from the technical literature on highway safety, since the term conveyed the notion of a single responsible factor in the deterministic sense in which it was used in the physical sciences and engineering literature [1]. In fact, the results of the state of the art review indicates that current research no longer supports the classical single-liability-assignment model of accident causation based on the typical taxonomy of a "vehicle-road-user" system. The current research rather looks at the interactive and multiple level role of these three basic factors in each traffic crash [2].

A crash is certainly initiated by a set of circumstances that usually include these three factors. However, it would seldom result from an unambiguous single cause [3]. Quite often a single cause is associated with a crash occurrence because accident reports may ask explicitly for one, and to probe for the intricate and interactive reasons may not be easy. In fact, modeling a highway traffic safety system is very complex because of the high degree of interrelation among the system variables. This approach requires the modeler to predict and compare the individual and interactive effectiveness of changes in various parameters in increasing overall safety benefits. For these reasons of complexity, even the highly motorized and developed societies lack a composite safety system model and their present highway safety practices reveal a quasi-integrated but simultaneous effort to improve each prominent component.

One of these practices, with engineering orientation and proven effectiveness for safety improvement, is the identification and correction of hazardous highway locations. There is increasing evidence from the developed countries, and also with particular relevance to the Third World, that relatively detailed spot investigations combined with low cost remedial measures can be highly cost effective and impose a very marked effect on road safety [4,5,38]. The practice of identifying and correcting hazardous highway locations evolved in the early forties as the road mileage and use of automobiles increased dramatically in the United States. Through persistence, the practice and the techniques have attained a high degree of sophistication. At present in the United States, a vast knowledge base exists on this discipline, and the implementation strategy (usually a multiple step sequential model) is referred to as a Highway Safety Improvement Program (HSIP).

It follows (from the details given elsewhere in this dissertation) that implementing a HSIP would be the ultimate desirable option for Pakistan for alleviating the country's highway safety problems. However, initiation of a formal HSIP in a developing country like Pakistan is associated with many limitations stemming from various financial, technical and administrative constraints. These impediments, in conjunction with a preponderance for correcting the most critical individual factor first, has resulted in polarized priorities targeted to enhance highway safety. As such, there is an absence of a definite national policy on highway safety in the country. In spite of the public desire, media campaigns and government efforts, no strategy so far has been effective in alleviating the problem of increasing highway traffic crashes.

1.2 HIGHWAY SAFETY ADMINISTRATION IN PAKISTAN

The public sector highway administration in Pakistan operates at two levels of government: i) Provincial, and ii) Federal. Most of the important inter-provincial trunk lines and major highways of the country are controlled by the federal government through an administering agency referred to as the National Highways Authority (NHA) while the primary (i.e., inter-district) and the secondary (i.e., intra-district and agricultural roads) networks are administered by the provincial highway departments and local bodies.

Traditionally these agencies are only regarded as "highway construction and maintenance organizations" rather than the potential saviors of trauma and perpetual misery in human life. Their functional charter does not necessarily include participation in a formal HSIP. At present these highway organizations have practically no formal procedure for identifying hazardous elements, though they are frequently seen and often reported by the maintenance workers, police and inspecting officials. As a result, casual attempts at improving highway safety for isolated locations are practiced. However, due to the absence of a well structured and integrated program the selection of suspect sites and countermeasures is not based on sound statistical procedures.

The motorization rate in Pakistan during the past few years has been increasing. The motor vehicle population of the country reached 1,220,145 by the end of 1986 as compared to 191,851 in 1970 [6]. This annual growth rate of 13% includes a higher proportion of trucks and buses resulting from the deregulation of trucking in 1960 and a partial deregulation of buses in 1970. The increasing traffic volume and axle-load has consistently resulted in expansion and rehabilitation of the highway network. For example, in the province of Punjab about 250 kilometers of the National Highway (N-5), the country's most important strategic and trade route, have been upgraded to a four-lane divided highway and almost an equal length is currently undergoing such improvement. Besides, during the decades of 1970 and 1980, some busy segments of provincial highways were upgraded as dual carriageway sections and many by-passes were provided to avoid interaction of urban traffic with the main-stream flow.

Pakistan is committed to an ambitious new highway construction program. Many prioritized highway rehabilitation and construction programs have been completed and some are under implementation with the assistance of various cooperating agencies for international development; like the World Bank, the Asian Development Bank, USAID and JICA. However, these programs clearly address the issues of access, capacity and structural adequacy with little emphasis on safety, and regretfully reveal that no important lessons have been learned from the highway loss experience. These improvement programs are appallingly replicating the safety deficiencies and persistently adding to the size of problem.

1.3 MOTIVATION

Unfortunately Pakistan continues to be among the developing nations of the third world having a consistently high road crash and fatality rate. During the period from 1971 to 1989, the number of total road crashes in Pakistan increased from 5,892 to 11,238 per year, and fatal crashes from 1,793 to 4,371 per year [6,7]. Although the statistics for the year 1988 indicate a very slight drop in crash and fatality rate per ten-thousand vehicles (which may be attributed to the relatively higher rate of motorization than in the previous years), the fact remains unchanged that the increasing trend of road crashes has not declined, and the status of highway safety in Pakistan remains much lower than the developed countries of the world. For example, the present road fatality rate per ten thousand licensed vehicles in Pakistan is estimated about 10 to 12 times higher than USA and UK respectively [38].

In the early 1980's, a program for the removal of highway blackspots was initiated in the Province of Punjab and sizeable funds were allocated by the government to meet the prospective expenditure. Unfortunately this vital program, instead of gaining significance, tapered off and was eventually discontinued after 1987 because its effectiveness was neither measurable nor perceived by the public. As an example, a financial statement for the removal of highway blackspots in Rawalpindi Division is presented in Appendix A. The obvious cause of this unimpressive performance was the execution of safety programs without following a prescribed and systematic procedure.

It is quite apparent that identification of hazardous locations is the basic step in order to embark on a formal process of highway safety improvement. Traffic crashes are believed to be the most direct measure of safety of a highway location. However, attempts to estimate the relative safety of a highway location using this approach are fraught with the problems of unreliable accident records and the time required to wait for adequate sample sizes. In Pakistan, three research studies [9-11] were conducted for the identification of black-spots which used traffic accident data to accomplish the task. While one of these studies [9] concluded that due to fragmentary accident data, identification of black-spots at reasonably exact positions was not possible, the other two [10,11] categorically enunciated that these spots could not be identified due to incomplete police reporting regarding accident location.

Herein lies the fiber of motivation for the conclusion that surrogate measures of highway safety need to be investigated to develop accident prediction models for the identification of hazardous locations, so that a HSIP could be formally initiated and practiced in Pakistan.

1.4 OBJECTIVE

The primary objective of this research is to develop a logical procedure to identify hazardous locations by employing surrogate measures of highway safety as predictors of accidents. This would provide the vital missing link required for initiating a formal HSIP in Pakistan in the absence of a reliable and accessible accident data base.

1.5 RESEARCH APPROACH

To determine the course of research and to pinpoint the crucial variables, a backward screening process was employed at four distinctive levels, constituting the essence of the research approach. Briefly, this screening process was employed to achieve the following objectives.

1) To rationalize the road as the principal factor of interest in the "road-vehicle-user" classification of accident causation. A review of relevant literature [2-5,38,39,68,71] provides the necessary back-up to this rationale.
2) To select a method of identifying hazardous locations.
3) To screen out ambient highway hazards from an inventoried template and identify their presence. This operation resulted in developing the

experimental design for determining a relationship between hazards and accidents.

4) To distinguish significant independent variables for utilization in predictive modeling.

This screening operation provided an instrument by which all the prominent safety aspects and technical options were considered prior to fine-tuning the research approach and selecting the variables of interest. A detailed description of the four levels of elimination is presented in Chapter three.

The experimental design is based on the outcome of this screening. The research data is comprised of information on ambient highway hazards and accident history of highway sections. These data were collected in Pakistan in early 1991 [12] and correspond to the time period of January 1988 to December 1990. The experimental site was comprised of 86 kilometers of the National Highway (N-5) passing through the rural areas of District Rawalpindi. Of these, 52 kilometers were 2-lane, 2-way, and 34 kilometers were 4-lane divided highway sections.

Finally, computer routines for multivariate regression analysis were employed to investigate statistical relationships between the two entities. Accident prediction models were then developed using this information with annual accident frequency per kilometer as the dependent variable. The feasibility of aggregating the data in terms of a hazard index to determine the accident potential of a highway section was also examined.

1.6 ORDER OF PRESENTATION

This dissertation is organized in six main chapters followed by appendices A to E. Following this chapter, a literature review based on global research experiences in a chronological order is presented in Chapter Two. Since literature from the USA and UK is frequently referred for prospective application in a developing country, a critical assessment of specific literary material in terms of its applicability and transferability is included.

Chapter three presents the details of the research approach and the specifications of the experimental design.

Chapter four concerns statistical analysis and accident prediction modeling. The development of a hazard index based on an adequacy rating of a highway section to determine its accident potential forms a part of this chapter.

Chapter five offers a thorough discussion on various inputs, the implementation processes and the results of the research. This includes an evaluation of the independent variables; data type; predictive models; hazard index; and accident data.

Chapter six presents the research limitations, inferences and conclusions, and the suggested research. The chapter also covers the remaining steps of the HSIP.

The research data, some selected photographs of the experimental site, and the SPSS program for data analyses are presented as the relevant appendices.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORICAL PERSPECTIVE

Intellectual concerns about the public health problems inflicted by automobiles and highway-travel started surfacing in the motorizing societies of the world in the early 1940's. As the level of motorization gradually increased during the 1960's, accompanied by an upward trend in traffic crash frequency, the issue of resulting property damage, injury and pre-retirement of life became a matter of wide public concern. Although the time frame in which various countries attained a certain level of motorization differs, they had a common viewpoint on road safety which included a high degree of national concern for research and improvement programs. However, it was not until the late 1960's and early 1970's that the global importance of highway safety was further emphasized through legislation and research in many countries. The United States, Canada, Australia, and various other countries of Western Europe (e.g., Great Britain, France, Belgium and Sweden), having the highest rates of motorization, were the pioneers to assign a national importance to the subject of highway safety.

Besides assignment of national importance, the topic of highway safety was intensively discussed at an international level. For example, Organization for Economic Cooperation and Development (OECD), and Commission of the European Community (CEC) were particularly active in Western Europe in road safety research and dissemination of results. The efforts of these organizations in transportation research mostly converged to one common objective: to ameliorate road crashes. It was anticipated that the wisdom of the Western European nations would be able to frame effective international regulations before automobiles confirmed their increasing reputation as "the plague of the 20th century". The Overseas Unit of the Transport and Road Research Laboratory (TRRL), U.K., performed numerous studies to investigate the highway safety problems in many developing countries.

Extensive efforts were made in the motorizing countries to find a plausible explanation of the traffic crash phenomenon in terms of its rationale and apparent attributes. These studies were the genesis of many theories and macro models of highway safety relating accidents, fatalities or injuries with a myriad of independent variables. These variables represented a broad spectrum of technological, social, economic, demographic, biographic, psychological and even the religious aspects of driver and road system [14-23]. Since a discussion about the macro models is not the main scope of this work, only the findings of some of the selected references is summarized in Table 2.1 to maintain continuity.

Table 2.1 Summary of Socio-Economic Macro Models of Highway Safety.

REF No.	RESEARCH PARTICULARS	VARIABLES OF INTEREST				TYPE* OF ANALYSIS
		Dependent Variable(s)	Independent Variable(s)			
			Significant 80% + level		Non Significant	
			(+) Coeff.	(-) Coeff.		
14	Peltzman (1975)	1,2	Average speed Driver age Income	Alcohol-consumption (AC) Cost/accident		CS
15	Eshler (1977)	1	VMT, GNP Vehicle population	Unemployment		TS
16	Sivak (1983)	1	Young drivers Murder rate		Suicide rate	CS
17	Zlatoper (1984)	5,6,7	VMT Average speed Rural/Urban travel	Vehicle length	Cost /accident Income	TS
18	Hautzinger (1986)	2	Vehicle population			CS, TS
19	Gaudry (1987)	2,3,4	Young drivers Seat belt, AC	Cost/accident Unemployment		TS
20	Loeb (1987)	3	Rural/Urban travel Average speed, AC	Length of arterial roads		CS

* CS = Cross-sectional
TS = Time Series

<u>Listed Dependent Variables</u>:

1. Fatalities in road accidents per vehicle miles travelled (VMT).
2. Injury accidents per capita or per VMT.
3. Fatality road accidents per capita or per VMT.
4. Fatalities at night.
5. Total number of road fatalities or injuries.
6. Number of motor-vehicle-occupants fatalities.
7. Number of pedestrian fatalities or injuries.

The technological aspects of highway safety were further segregated into two distinct areas of interest: the automobiles and the highways. In this dissertation, only the highway-related safety aspects are considered, being the specific orientation of the work. A chronological overview of the evolution of this subject in the motorizing countries is presented in the following pages.

During the decade of the 1950's a large number of studies were carried out in the USA on the relationship between the highway geometric design elements and traffic flow characteristics, and road safety. In 1954, the AASHO published design guidelines [24] which reflected the major findings of these studies. The main theme of these guidelines was to classify a road hierarchy, and to assign different standards to different types of road. In this hierarchy, access-controlled and divided highways were categorized as a relatively safer class of highways. In 1965, AASHO issued the next edition of these guidelines [25] placing greater emphasis on the complexity of road accidents and the role of the human element. However, the prime importance continued on highway geometrics including topics on crash barriers, road side obstacles, and specific criteria for climbing lanes. (These guidelines were further revised and expanded by AASHTO in 1984 and 1990).

In 1963, the Automotive Safety Foundation and the US Bureau of Public Roads published a major study [26] on highway safety considering the relationship of traffic control and roadway elements with traffic crashes. In this study traffic volumes, access control, cross-section, alignment, intersections and interchanges, at-grade railroad crossings, driveways, speed, pavement surfaces, one-way streets, illumination and parking were thoroughly investigated for their relationship with highway safety. In 1966, the AASHO special Traffic Safety Committee undertook a critical survey of the safety characteristic of the interstate and other highway system and recommended improvements [27] applicable to two distinct areas: roadside design and appurtenances, and traffic operations.

The increasing frequency of highway fatalities during the mid 1960's drew the attention of the US Congress to the need for an expanded federal role in Highway Safety. In 1965, the rigorous lobbying of Ralph Nader and his distinguished publication [28] raised public consciousness of the issue of highway safety and stimulated national concerns for reducing traffic accidents and fatalities. Numerous Congressional hearings were held and these resulted in enactment of two important pieces of legislation concerning highway safety, i.e., The National Traffic and Motor Vehicle Safety Act, and The National Highway Safety Act, of 1966. These legislative actions significantly expanded the federal role in highway safety by creating NHSB (the predecessor of the present NHTSA), and by bringing new focus to research for the advancement of the knowledge-base in highway safety [29]. The Highway Safety Program Manual was accordingly developed by the USDOT which included the Standards for various specialties, as shown in Table 2.2.

Table 2.2 Standards for Highway Safety Programs.

STANDARD NO	GENERAL DESCRIPTION
1	Periodic Motor Vehicle Inspection
2	Motor Vehicle Registration
3	Motorcycle Safety
4	Driver Education
5	Driver Licensing
6	Codes and Laws
7	Traffic Courts
8	Alcohol in Relation to Highway Safety
9	Identification and Surveillance of Accident Locations
10	Traffic Records
11	Emergency Medical Services
12	Highway Design, Construction and Maintenance
13	Traffic Engineering Services (Traffic Control Devices)
14	Pedestrian Safety
15	Police Traffic Services
16	Debris Hazard Control and Cleanup
17	Pupil Transportation Safety
18	Accident Reporting and Investigation

These standards covered 18 program areas which are now administered by NHTSA and FHWA. While efforts in the United States featured a coordinated approach to improve multiple aspects of highway safety at all levels of government, two major European publications in the mid 1960's represented the state of the art in other knowledge areas.

In Sweden, a strategy based on the relationship between urban planning and road safety emerged for alleviating problems of traffic accidents. The Swedish National Board of Urban Planning issued guidelines in 1968 [30] giving more attention to hierarchy and strict design standards with more conservative speeds applicable to urban and rural environments.

In Great Britain, the TRRL in 1963 presented the combined results of studies on pedestrians, drivers, vehicles and road design [31]. This study presented, for the first time, a coherent compilation of research findings on the interaction among road users, vehicle characteristics and highway design as integrated components of the highway transportation system.

The evolved phrase of "vehicle-highway-user" system forthwith became a popular entity and generated areas of interest for further research and development during the 1970's and early 1980's. However, attempts to assign liability and to concentrate efforts on the correction of a specific component was a major pitfall, soon discovered by the developed world. Unfortunately this was not realized by most developing countries.

2.2 THE CONCEPT OF LIABILITY-ASSIGNMENT IN ACCIDENT CAUSATION

In the era after the mid 1960's, the three basic components of the highway transportation system, i.e., the vehicle; the roadway; and the user were thoroughly critiqued for malfunctioning. Their individual responsibility toward highway safety in terms of perpetrating serious social problems were assessed. The classical literature indicated a minor contribution from the roadway and the vehicle as compared to the driver in accident causation. Following is a brief component-wise overview of these findings from various countries of the world.

Vehicle: Typically vehicle failures were found not to have a major (i.e., not more than 10%) contribution in causing traffic accidents in the developed countries. In the USA, Hoback [32] reported that only 9.3% of the accidents on Oklahoma Turnpikes resulted from adverse causes related to vehicles. In the UK, Sabey and Staughton [33] found an overall contribution of 8% due to vehicle failures. In Germany, Bitzl [34] reported 6.9% of accidents on the Autobahnen as being due to tire failure and defective vehicle mechanism.

Roadway: The roadway, quite similar to vehicles, was shown to have a relatively small causal relationship to traffic accident. Michaels [35] reported that highway characteristics played a significant role in only 5% of the accidents. In analyzing the role of roadway elements in Pennsylvania Turnpike accidents, Eckhardt et al. [36] concluded that considering the three main components of driving operation, the roadway design was well ahead of the driver and his vehicle. Treat [37] reported a contribution factor of 3% for the USA, while Sabey and Staughton [33] attributed the road environment to cause only 2% of the accidents.

Driver: Historically, the driver has been identified as the most significant single component of accident causation in context of the vehicle-roadway-driver system. In the USA, Treat [37], utilizing data from Indiana, found that the driver was the exclusive factor in 57% of total accidents. In the UK, Sabey and Staughton [33] found that driver errors alone were the causative factor for 65% of the accidents.

2.2.1 Liability Studies in Developing Countries

Various studies [38,39,40], made in the developing countries during the period 1970-85 to analyze the causes of accidents, revealed similar results and showed a low contribution of the roadway and the vehicle, as compared to a very significant role of the user. The Overseas Unit of the TRRL collected annual police reports from a number of developing countries which provided a basic summary of the road accident situation and the major "cause" of the accident. Though the police had ascribed a "single cause" to each accident rather than listing the "factors involved", this information was nevertheless considered to provide an insight to the police viewpoint of major factors involved in road accidents. The results of the study based on the police data of 5 developing countries are reproduced in Table 2.3. Road user error was identified as the main cause in 71-95% of the road accidents [38].

Table 2.3 Causes of Road Accidents in 5 Developing Countries [38].

COUNTRY	JAMAICA 1977	GHANA 1974	BOTSWANA 1976	MALAYSIA 1976	HONG-KONG 1977
MAIN CAUSE OF ACCIDENT	+P	±P	+P	+P	+I
Road-user Error	95	77	71	87	92
Vehicle Defect	1	16	12	1	*
Adverse Road Conditions	1	5	2	8	*
Other	3	2	15	4	8
TOTAL	100	100	100	100	100

+P = PDO included ±P = PDO inclusion not known +I = Injury accident only

Ergun [39] found similar ordered figures for Turkey, as summarized in Table 2.4.

Table 2.4 Traffic Accident Causes in Turkey [39].

CAUSE	PERCENT CONTRIBUTION*
Road User Error	94
Vehicle Defect	5
Road and Environment	1
Others	-

*** Total accidents considered.**

Swati and Downing [40] also reported the road-user as the single major cause of accidents in Pakistan. The percentage contribution of each cause/factor is reproduced in Table 2.5.

Table 2.5 Traffic Accident Causes in Pakistan [40].

CAUSE/FACTOR	PERCENT CONTRIBUTION*
Road User	90
Road and Environment	6
Vehicle	4

*** Percentage of accidents in which cause/factor was identified.**

2.2.2 The Theology of Single-Liability-Assignment

The above cited factor-contribution studies mostly used police accident reports. Their results merely indicate that driver errors, often accompanied by law violation, are in the chain of events leading to 70 to 90% of all highway accidents. Commenting on this situation, Oglesby [41] observed that single minded proponents of driver education or strict enforcement sometimes distort this statement by saying that driver errors cause 90% of accidents.

In many developing countries, highway safety efforts are extremely influenced by the single liability approach and consequently their primary focus is on driver correction. For example, Al-Isa [42] reported that in Saudi Arabia highway safety authorities held the traditional "violation-error" attitude toward accidents. Therefore, the safety programs in that country were directed toward changing the behavior of violator drivers by imprisonment or fines.

The recommendations of Somnemitr [43], for traffic accident prevention in Thailand, indicated the need for road user education and traffic law enforcement because of unlicensed drivers, disobedience of traffic laws, and use of amphetamine and other stimulants while driving. In Pakistan, Swati [44] stressed prioritized safety measures oriented toward improving the road user's knowledge of traffic rules, enforcement, and updating laws for alleviating highway safety problems.

In the United States as well, most early highway safety initiatives were focused on the driver being the major contributor to motor vehicle crashes. These efforts included safety campaigns, driver education, training and testing programs, and use of punishment as a deterrent to violations. However, the jeopardy of isolating the human component for its prioritized correction was timely detected in the motorized countries. To them, it became obvious beyond doubt that the importance of vehicle and highway related safety programs could not be ignored at the cost of improving human traits. For example, in the USA, due to a dominant focus on the driver as the primary cause of crashes, vehicle crashworthiness research remained a largely undeveloped area until the mid 1960's. Significant advancement and application of knowledge in this area was noticed after the mid 1960's. Similarly, highway-related programs, having indirect and direct bearing on safety, like TOPICS, RRR, and HSIP were launched after the mid 1960's, which later on demonstrated a definite achievement of objectives.

It was shown by Koshi [45] that accident reduction in Japan in the 1970's was largely attributable to improvement of the environments of road users rather than improvement of the road users themselves.

2.2.3 The Interactive Role of Accident Causative Factors

In the 1970's two major studies [37,33] were carried out in the USA and the UK to investigate the independent and the interactive role of factors associated with large samples of crash data. The US study was performed at the Indiana

University by Treat [37] while the British study was performed at the TRRL by Sabey and Staughton [33]. In both the studies a multi-disciplinary accident investigation team was employed to find the accident causes. This approach had been previously employed with reasonable accuracy to determine accident causes in other man-machine systems such as, aviation, railroads, and shipping. This approach was supported by other techniques like experimental analysis and incidence reporting.

Rumar [46] summarized the results from both studies in an interesting pattern as shown in Figure 2.1 with the following interpretation:

1) The vehicle is identified as the sole factor in 2% of the crashes;
2) the interaction between vehicle and road user is identified as a factor in 6% of the crashes;
3) the interaction between vehicle, road user and environment is identified as a factor in 3% of the crashes; and
4) the interaction between vehicle and road environment is identified as a factor in 1% of the crashes.

The corresponding values for the UK study are 2%; 4%; 1%; and 1% respectively.

The analysis of the US study [34] were further extended by classifying the type of human errors involved and are reproduced in Figure 2.2. It can be seen from Figure 2.2 that recognition and decision error predominate. These type of

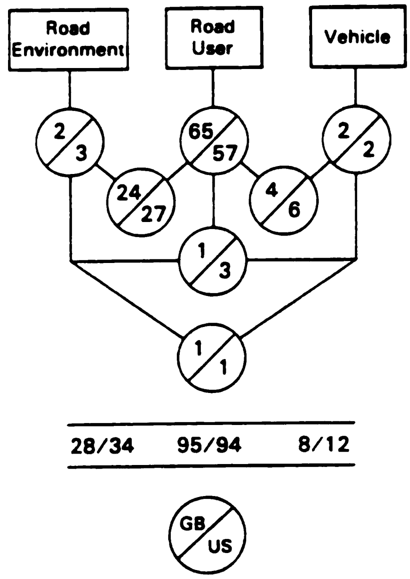


Figure 2.1 Percentage Contributions to Road Accidents as Obtained in a British and US Accident Study [46].

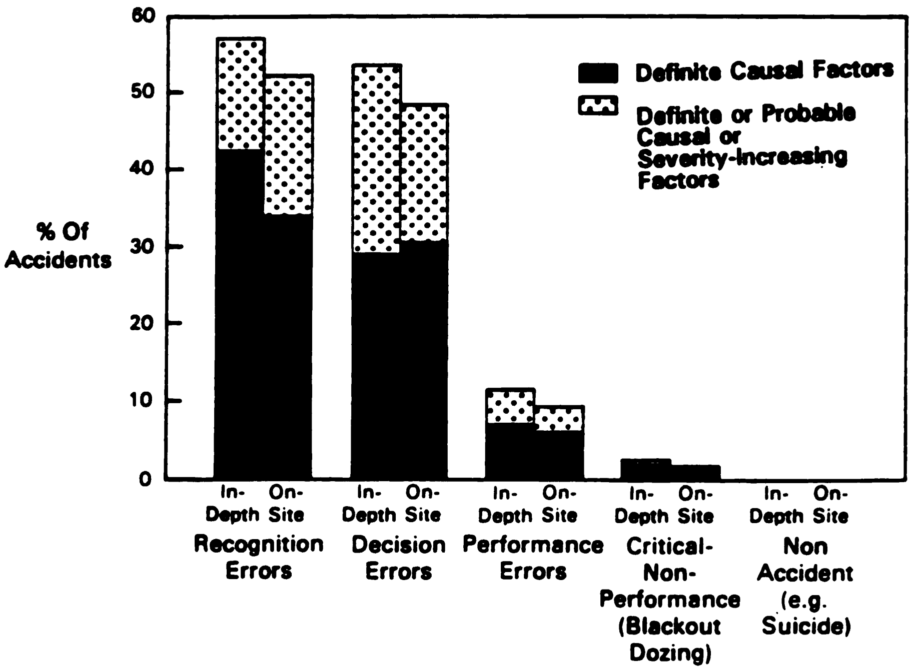


Figure 2.2 Percentages of Accidents in which Human Factors were Identified as Definite or Probable Causal Factors [37].

errors are obviously caused by "inappropriate information acquisition and processing." This study further specified human errors in the decreasing order of frequency of occurrence revealing the following hierarchy of errors:

1. Improper lookout.
2. Excessive speed.
3. Inattention.
4. False assumption.
5. Improper maneuver.
6. Internal distraction.

Investigating the interactive role of these factors in Jordan, Balbissi [47] also found results quite similar to the US and British studies. His results are shown in Table 2.6.

Table 2.6 Traffic Accident Causes in Jordan [47].

REASONS OF ACCIDENT	PERCENT CONTRIBUTION*
Human Errors	65.00
Combined Human and Road Elements	24.00
Combined Human and Vehicle Elements	04.50
Combined Human, Road and Vehicle Elements	01.25
Road Elements	02.50
Road and Vehicle Elements	00.25
Vehicle Elements	02.50

* Averaged over 5 years (1979 through 1983).

These three completely separate and large studies [33, 37,47] of several thousand accident records, and corresponding to different geographical locations, were almost unanimous in assigning the road user as the dominating cause of highway traffic accidents.

However, many words of caution have been offered by researchers such as Klien and Waller [48], Shinar [49], Campbell [50], Blatnik [51], Jacobs and Sayer [38], and Rumar [46] about drawing instantaneous and raw inference from the results of such studies and interpreting their findings. The reasons for citing such cautions by these researchers are many and diverse.

Klien and Waller [48] maintained that data collected through police investigation or through self reporting were:

1) Incomplete (in terms of the relevant observations that were to be recorded).
2) Unreliable (in terms of the citizen's or the police interpretation of the observation that were recorded).
3) Unrepresentative (in terms of crash investigations that did not represent a cross-section of all crashes that occurred).

Overall, they concluded:

> -"a number of carefully designed research studies have attempted to identify causal factors, and most of these have developed conclusions that differ markedly from those reached from the use of police data or common sense".

Campbell [50], referring to the results of the State Road Commission's research on two-lane rural highways in West Virginia, observed that roadway features were associated with the driver in accident involvement. He further commented that technological innovations for highway improvement could substantially help protect the vehicle and occupants after the accident dynamic was activated.

Blatnik [51], as the chairman of the special sub-committee on the Federal-Aid Highway Program categorically emphasized highway-related safety improvements. He rejected the approach ascribing the majority of accidents to "driver failure" because of human limitations (e.g., imperfect sight and hearing, limited intelligence etc.), and a complex of emotions that no one fully understood. His deposition stated:

- " when a driver falls victim to an accident despite his best efforts, it may not be the driver who has failed".

Jacobs and Sayer [38], commenting upon the use of police accident records to analyze causes of accidents in various developing countries, concluded that it could be dangerous to draw conclusions about variations between the countries as there were likely to be differences in the types of accidents reported to the police, and in the way in which the police analyzed the accidents for causes. Even for a single case, their observations were:

- " Also it is likely that the percentages are under estimates of the true contribution of these factors because in many of these accidents there are probably several factors involved and not just one. Thus the percentage of accidents due to adverse road conditions and environments may in reality be much higher because many of the road use errors could have been due to inadequate road signing or marking".

Rumar [46] observed that the weakness of the liability assignment approach was evident because these studies lacked an explicit theoretical basis, their results were hard to relate to other types of data, and they tend to use the human factor as a scrap box. Referring to Haight's article [52], he quoted the example of the Japanese White Paper of 1982 which listed " failure to drive safely" as the major cause of accidents. He concluded that typical human errors contributing to accidents were both perpetual and decisional, and were related with information acquisition and processing.

Evans [1] commented on the high rate of driver's involvement in traffic crashes and discredited existence of a relationship between driver performance and characteristics by citing young drivers record in the USA. His observations were:

> - "While various aspects of driver performance are related to safety, there is not a coherent pattern. The findings of no effect from driver education and knowledge, and that younger drivers, with the best visual acuity and shortest reaction times, have the highest crash rates, suggest that driver performance is not the driver characteristic which has the largest influence on traffic safety".

Numerous studies have attempted to identify human traits that were common in individuals involved in traffic crashes. Due to a variety of psychological traits apparent in chronic traffic violators and accident repeaters, such as aggressiveness, intolerance, and resentment of authority, it was concluded by Goldstein [53] that it would be difficult if not impossible to use human characteristics as reliable predictors of accident involvement.

The accumulated main theme of these perspectives implies that the liability approach neither explains the traffic crash phenomenon nor assigns a substantial importance to highway-related safety improvement programs concurrent to efforts aimed at promoting driver's performance.

2.3 THE CONCEPT OF EXPOSURE

The concept of exposure takes into account the amount of opportunity for accidents which the driver of the traffic system experiences. Quite in contrast to the liability concept, many studies showed that exposure was the most convincing explanatory approach to the interpretation of traffic crash situations. Blunden [54] categorically pointed out that there had been too much concentration of effort in the past on the liability factor, and urged that more emphasis be placed on the study of exposure. Commenting upon the explanatory potential of the exposure approach, Chapman [55] observed that:

> - "If the number of accidents is found to be closely related to the amount of travel, the amount of the traffic can be regarded as a measure of exposure. If no relation is found, does this invalidate the use of traffic as such measure? The answer to this is negative; the variation which has not been explained by travel may be due to something which has not been measured. This problem is faulty experimental design, with no control of variables other than those under study".

In this study, Chapman [55] has presented a fairly complete review of the exposure literature describing the concept and application of exposure, and various terms and extensions associated with it. In a different comparative study of exposure measures at intersections, Chapman [56] found that the accident rate at cross roads were significantly higher than at T- or Y-junctions; twice higher in urban areas; and five times in rural area, irrespective of many variants of accident measures.

Erlander et. al [57], showed that significant variation in the daily accidents in rural areas could be explained by the amount of traffic. Baker [58] further commented on these results that correlated exposure with accidents. He enunciated:

> - " The absolute number of fatalities and injuries has steadily increased, but so has the population and amount of travel. As the population increases, the number of travellers and vehicle-miles of travel will increase for the same level of mobility for individuals. As a result, the degree of "exposure" to accidents is increased, and a greater number of accidents would be expected if no improvements were made in the highway transportation system".

In a study by Operation Research Inc. [59], strong attention was paid to exposure, viewing it as a systematic process affecting the crash system, which was an outcome of the continual interaction of driving behavior with the ever changing environment. The study considered that three basic elements of exposure were important:

1) Characteristics of drivers and vehicles;
2) Characteristics of the road system and intensity of system use; and
3) Environmental conditions (weather, day/night etc.).

2.3.1 Induced Exposure

Literature showed that it was not always possible to obtain an appropriate estimate of the exposure in terms of the above mentioned elements. Thrope [60], first of all, proposed a method which did not require directly measured exposure (i.e., in terms of traffic and roadway characteristics) but which induced exposure from the accident data. Subsequently many other researchers, e.g., Carr [61] and Haight [62], also followed this approach to develop various mathematical models pertaining to highway safety. Their fundamental concept presumed that the population of innocent accident involvement could be taken as the representative of the entire population at risk. A comprehensive validation of this concept was made by Taylor and DeLong [63] employing more sophisticated asymmetrical models.

An extensive review of the literature on exposure, and affiliated material, is beyond the scope of this dissertation. The objective of briefly citing exposure literature was to demonstrate its potential and applicability toward explaining the traffic crash phenomenon, which was something beyond the concept of simple liability assignment.

2.4 THE CONCEPT OF RISK-HOMEOSTASIS AND RISK-COMPENSATION

The theory of risk-homeostasis was first presented by Wilde [64] in the early 1980's. According to this theory, risk taking behavior involves an attempt to balance perceived risk and desired risk, and people adjust their behavior in response to changes in perceived risk. A concurrent theory, presenting a more acceptable view of the effects of safety measures on driver behavior, concerns offsetting driver behavior or risk compensation. According to this theory road users adapt to conditions and regulations in a way that alter their level of risk, and in some cases even negate their original desired intent. The findings by Crandall [65] partially discredited this theory by showing that the National Traffic and Motor Vehicle Safety Act was effective in significantly reducing the car-occupant fatality rate.

The concept of utility maximization, quite analogous to these theories, has specific application in many areas of transportation engineering including planning and policy decision making. In the context of safety, this concept would imply that an individual driver will choose between safety and his other activity options (i.e., work, recreation etc.), and then will weigh the benefits and cost of safety features with the set of anticipated driving conditions. Literature's [66,67] distinct indication of practical application choice models in travel demand analysis which were based on the principle of utility maximization, seem to substantiate applicability of the risk compensation theory in highway safety modeling. From this analogy, it may be presumed that properly designed HSIP are most likely to modify driver behavior for safer driving.

2.4.1 The Role of Highway Engineering in Risk Compensation

Highway Engineering can play a dominant role in driver's behavior of risk-compensation if it can be demonstrated that traffic crashes are most frequent in those circumstances where relatively higher demand is placed on the drivers ability to perceive and cope with the situation. A study by Vercase [68] provided important information on this aspect. He studied fourteen highway variables in which factor analysis techniques were applied to roadway and accident data. He concluded:

> -"only one single factor emerged from the vast amount of the data in this analysis which explained where accidents occurred. Although only highway variables were included in the analysis, this one factor conveys a psychological meaning: There are more accidents at those places where situation places greater demands on the momentary perceptual-decision-motor capacities of the driver. The drivers basic psychological capacities are heavily exercised when he must deal with a situation around him that is changing rapidly."

This implies that traffic crashes are most frequent in those circumstances where traffic friction or conflict is greater i.e., where one encounters more cars and where there is traffic flow interference from intersections and driveways. In this study it was clearly found that accident frequency was proportional to the load or rate of demand placed on the drivers basic ability to perceive and cope with the situation.

A synthesis of the Vercase findings with the results of Treat's study [37] (that stratified human recognition and decision errors, and showed that "inappropriate information acquisition and processing" were the obvious causal factors), imparts the real significance of highway engineering in risk-compensation. The specific discipline which takes an account of human limitations in the driving task, when considering improvement in the highway transportation system, is referred to as the human engineering approach.

2.5 HUMAN ENGINEERING APPROACH

The highway features and the physical changes which require the driver to make a decision in an extremely short period of time while driving, may be termed as failure of a highway system. The driver has to perform three sequential operations in this short span of time while driving: 1) detect hazards or potential dangers; 2) evaluate the overall situation and decide the ideal action; and 3) take the final action. It is evident that highway engineering and technology is directly related to the first two items of the driving task. The design and signing system alone could avert an impending accident situation at three levels of technology:

1) Primarily, by providing a relatively hazard free designed highway;
2) Auxiliarily, by providing appropriate information about highway hazards if present; and
3) Over and above, by allowing the highway system to forgive the driver even if he misjudged the ambient conditions at certain points.

The vehicle driver is the most important single component of the driving process and the overall highway transportation and safety system, and is the most difficult to understand and control. The human engineering approach attempts to detect human performance limitations in the complexity of the entire driving task and uses these findings to redesign or improve the system to make it compatible with the needs and capabilities of the road users. For example, Evans [1] suggested that, since drivers were poor judges of speed of oncoming cars, technological innovations providing such information could increase traffic efficiency and safety in overtaking maneuvers.

To sum up, it may be concluded that there is a growing body of literature denoting that highway-related engineering measures can drastically reduce accident potential of a highway location or a section. Claes [69] estimated that proper engineering could reduce the accident rate by 70%.

2.5.1 Functionalization of Human Engineering Approach in the Developing Countries Through HSIP

Some important lessons learned in the area of highway safety by the motorized societies, through extensive research and persistent sufferings, could be of significant benefit to the developing nations of the world. The review of the cited literature explicitly showed that in the developed countries, an integrated and simultaneous approach toward the highway safety problems is the crux of state of the art practices. It may be, therefore, inferred that highway-related safety improvement strategies in the developing countries can not be ignored or delayed at the cost of another causal factor deemed to be improved first.

In this context, Ergun [39] pointed out that without the provision of a bare minimum in engineering and safety standards, efforts directed toward improvement of driver behavior in the developing countries might result in a total waste of resources. He further suggested that the safety concepts represented by terminologies like, "design for safety"; "forgiving highways"; "driver expectancy"; and "design consistency" should be incorporated in highway design policies of the developing countries. He enunciated:

> - "Since developing countries are still in their "infancy" of motorization and their highway network expansion, it is very important for them to incorporate safety concepts in highway design as it will become more difficult and costlier to correct such design errors later".

Jacobs and Sayer [38] asserted that for developing countries, safety features such as those involving geometry, signing and delineation, should be introduced at the design stage rather than added later (almost as an "after-thought") for the reasons of increased costs and relocation of at-ground services.

To incorporate safety concepts at a post-design level, a systematic approach is essentially required on account of three basic reasons: 1) For identification of hazardous locations; 2) For selection of appropriate corrective measures to replenish chronic mistakes; and 3) For evaluation of effectiveness of such incorporation.

The pragmatic response to this important technical requirement is offered by the HSIP as described in the following section.

2.6 THE HIGHWAY SAFETY IMPROVEMENT PROGRAM (HSIP)

The Highway Safety Improvement Program (HSIP) is a contemporary US terminology [71] representing a sequential plan for highway-related safety improvements structured in terms of various components, processes, sub-processes, and procedures. These terms are briefly described as follows:

Components: These are the three basic phases of the HSIP, i.e., Planning; Implementation; and Evaluation (also see Tables 2.9-2.11, pages 61-62).

Processes: These are the sequential subsets within each component. For example, there are four processes in the Planning Component.

Sub-processes: Each process is often divided into subprocesses, which are the categorized technical operations.

Procedures: These are the suggested specific methods to perform the technical operations. For example, in the process of identifying hazardous location, there are seven procedures listed to perform this operation.

2.6.1 Framework and Overview of HSIP

A flow-chart presentation of the overview of HSIP is given in Figure 2.3. The magnifications of the chart at the process level and at subprocess level are presented in Figure 2.4 and Figure 2.5 respectively.

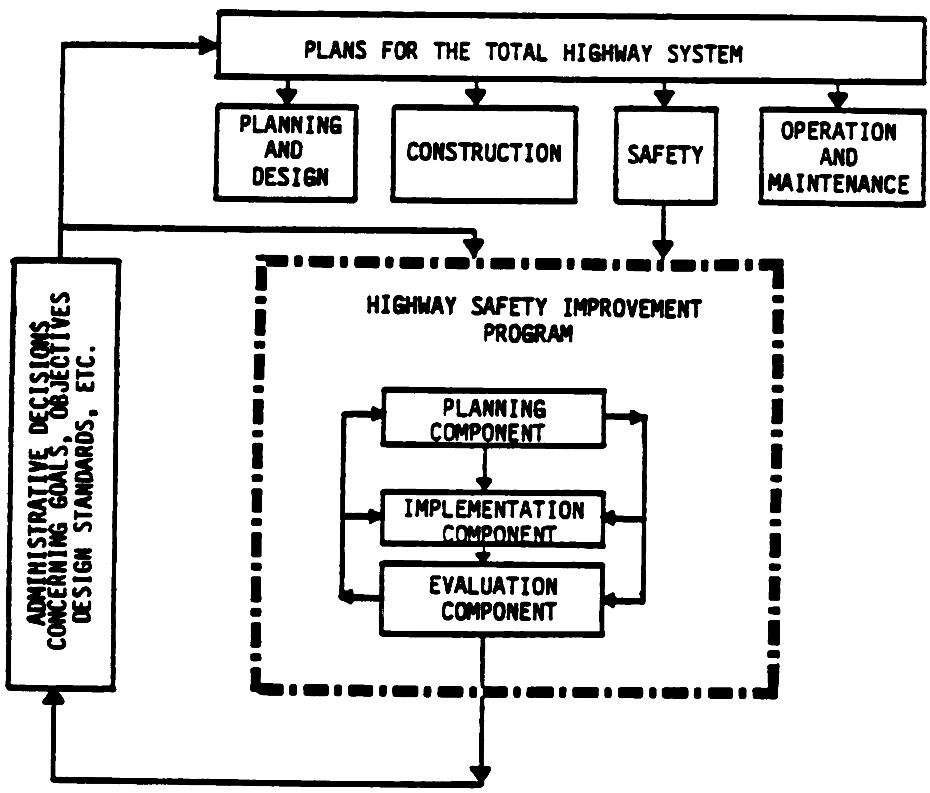


Figure 2.3 Overview of the Highway Safety Improvement Program [71].

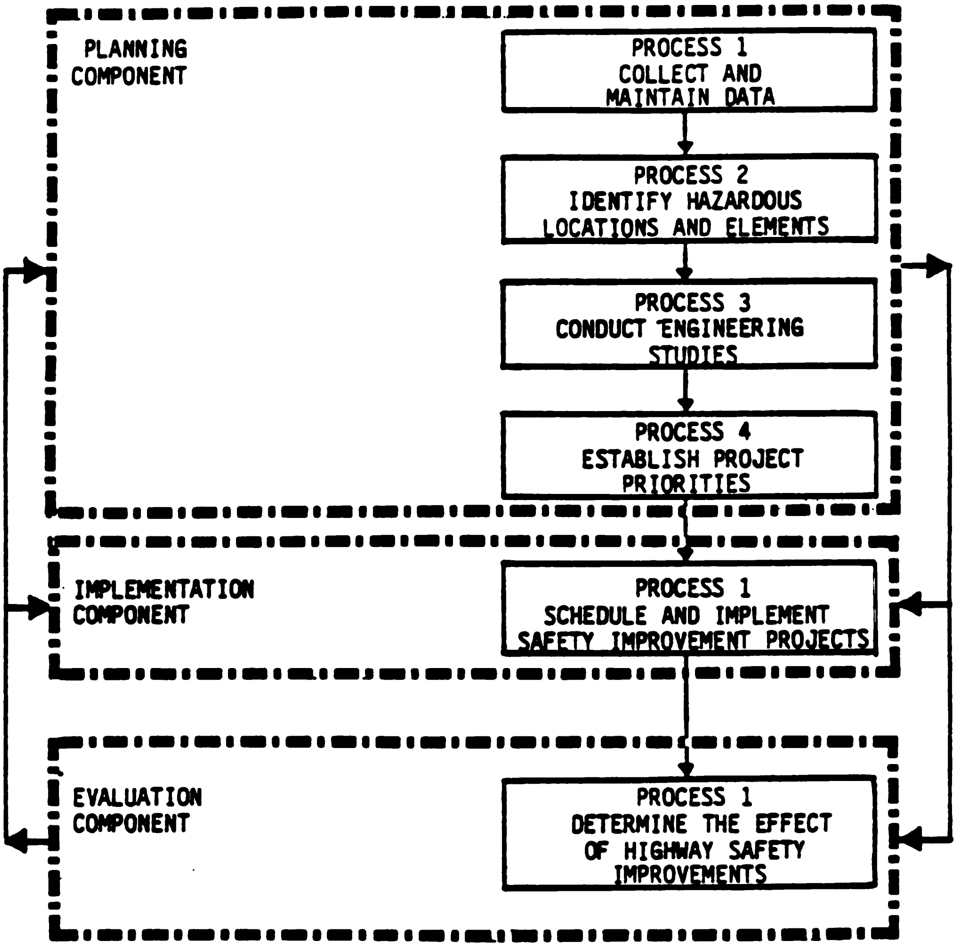


Figure 2.4 Highway Safety Improvement Program at the Process Level [71].

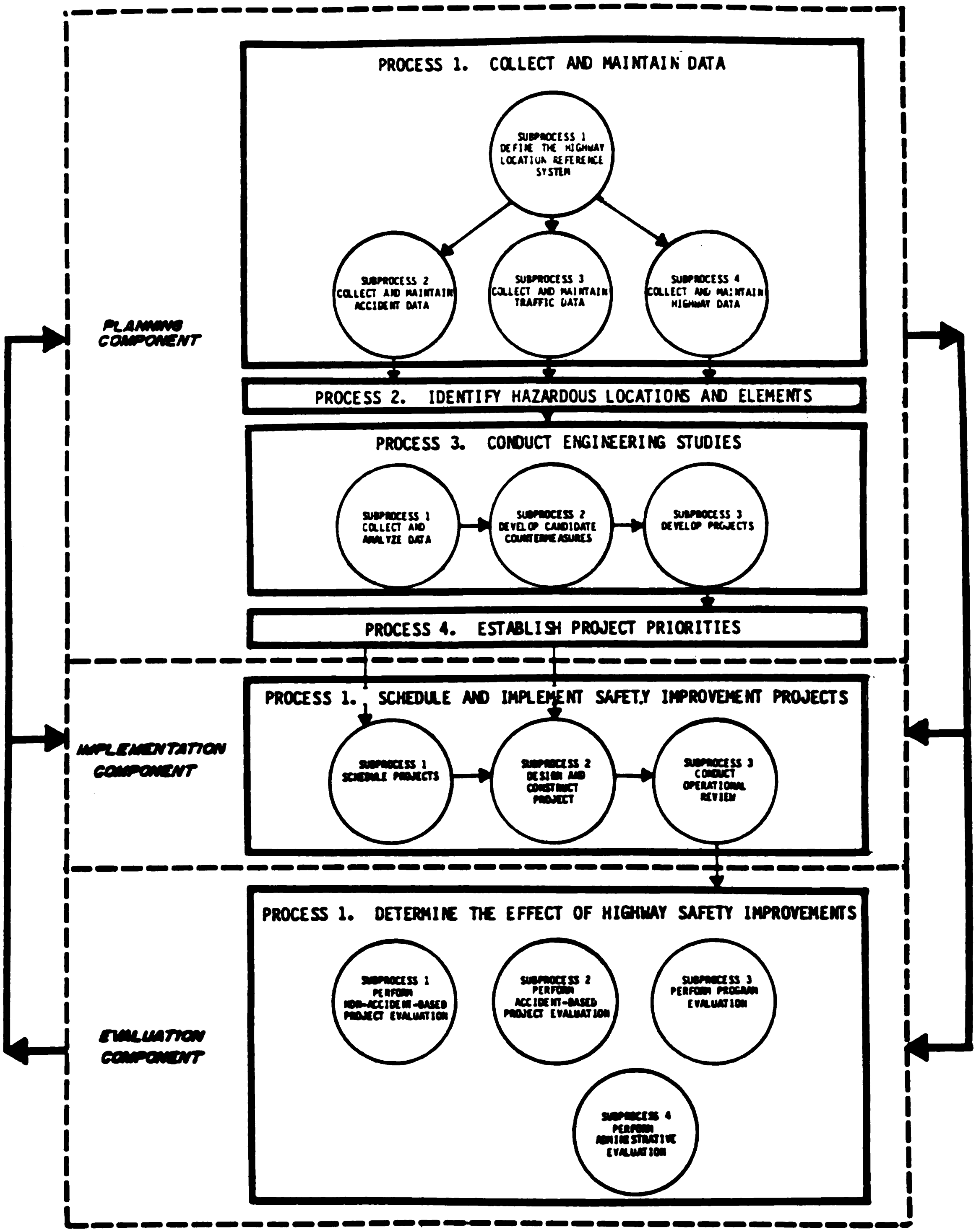


Figure 2.5 Highway Safety Improvement Program at the Sub-Process Level [71].

2.6.2 Implementation of HSIP

Identification of hazardous locations is one of the most fundamental process, and requires collection and recording of accident data to perform this task. However, a substitute strategy will be employed in this dissertation since the objective of the current research is to develop a HSIP practicable in conditions where accidents records are not reliable or readily available.

The following two sections of this chapter precisely cover the literature on the utility of roadway features and traffic characteristics as a surrogate measure of highway safety, and their use in accident prediction.

2.7 SURROGATE MEASURES OF HIGHWAY SAFETY

By convention, traffic crashes are the most direct determinants of hazardous locations. However, some critiques seriously opposed this perception. For example, Hauer and Persaud [72] suggested that there were serious problems of identifying hazardous locations using accident data, and showed that in two cases a significant proportion of deviant accident sites remained unidentified while many sites which were subjected to countermeasures were not deviant at all. Hauer [73] showed that there would be a reduction in the number of accidents at sites identified by a high number of traffic crashes even if the countermeasures were ineffective.

An explanation to this type of phenomenon was offered by Griffin et al. [74] in terms of a mathematical expression referred to as "regression to the mean". In simple words, it means that since sites selected for treatment generally had much higher than average crash rates, these rates would tend to be lower in subsequent years regardless of treatment. Various studies [e.g., 75-77], therefore, developed algorithms for the identification of hazardous locations to reduce the statistical bias caused by accident over-representation from the average. However, these arguments were presented from a purely scholastic standpoint, and were case-specific.

Perkins and Harris [78] had a different reservation in using accident records for identifying hazardous locations, especially for intersections. They suggested that the accident potential of a location should be objectively measured without waiting for an accident history to evolve - an approach which they referred to as "dynamic evaluation of an intersection". They used traffic conflict characteristics as measures of accident potential, and observed that, in three 12-hour observation sessions, it was possible to completely evaluate an intersection using the obtained information, which was more comprehensive than that normally available from accident records. Their studies showed a high level of association between traffic conflicts and the reported accident frequencies.

A comparison of direct and indirect methods for determining accident potential was made by Pahl [79]. He concluded that the outstanding problem in using accident records was the moral issue of having to wait a certain number of accidents before any statistically reliable results could be obtained. He asserted that, in principle, the correlation between a direct candidate measure and the accident potential of a highway site appeared to be feasible. Pahl's findings supported the use of indirect measures and pointed out that the indirect candidate measure needs to be correlated with accident data.

However, concurrent with these findings, the use of accident records is still the state of the practice for diagnosis of deficiencies and application of corrective countermeasures. At present, practically every highway agency having access to a comprehensive accident data base, uses some variant of the rate or number method to identify hazardous locations, for discharging its obligation toward highway safety.

The specific literature on HSIP indicated several methods for identifying hazardous highway locations utilizing accident histories (see Table 2.9, Page 61). However, in circumstances where accident records are not available, adverse highway features and geometrics, and operating traffic characteristics which deviate from the norm, may act as the surrogate determinants of safety. A few examples of adverse highway features are: deficient geometric design, roadside obstacles, slippery pavement surface conditions, and lack of access control. Likewise, the examples of deviant traffic characteristics are: traffic conflicts, erratic maneuvers, short headways, extreme lateral placements, and digressing speed distributions. For a detailed description of the use of such surrogate measure of highway safety, some selected studies [80 to 85] are included in the list of references.

2.7.1 Application of Surrogate Measures in Present Research

Based on the above cited examples, various highway features and traffic characteristics were selected for this dissertation, as representative surrogate measures. To evaluate the prospective hazardousness of a highway section, as represented by these surrogate measures, the following three types of hazard-quantification procedures were employed.

1) Direct physical measurements,
2) Unobtrusive observations, and
3) Subjective ratings by an expert team.

Accordingly, these procedures resulted in the generation of three types of corresponding data sets representing ambient hazardousness of highway locations. A detailed description of the data collection process is given in Chapter three.

2.8 USE OF TRAFFIC CHARACTERISTICS AND HIGHWAY DESIGN FEATURES FOR ACCIDENT PREDICTION MODELING

The classical literature on highway safety revealed many studies on the relationship between various highway features and accident rates. These studies mostly examined the effect of one or more highway element or design aspect on traffic accidents. For example, pavement and shoulder width were traditionally investigated for their effect on accident rates by various researchers.

Blensly et al. [86] studied the relationship between accident data and gravel shoulder widths in Oregon and found insignificant effects at lower volumes. However, for volumes between 3600 to 5500 ADT, there was a significant relationship between accidents (total and PDO) and shoulder width. Stohner [87], considering the entire system of rural two-lane roads in New York state, found that there existed a measurable relationship between shoulder width and accidents rates, which was especially true for property damage accidents. His finding showed that the wider shoulder, within reasonable limits, were associated with a lower accident rate.

Raff [88] studied the effect of a number of design features on accident rates on rural highways. The factors of interest included number of lanes, ADT, degree of curvature, sight distance restrictions and traffic flow characteristics at intersections. He concluded that traffic volumes and sharp curves caused accidents and wide pavements and shoulders increased safety on two lane curves. This finding substantiated the causal relationship, reported by Blensly et al. [86], between personal injury accident frequency and paved shoulder width for specific volumes.

Belmont [89] investigated the effect of shoulder width on accidents on two lane tangents, using 1333 accident records for 533 miles of roads in California, and obtained the following regression equations:

$$\sqrt{A}=0.4766+0.2202\sqrt{vm}$$

(With no restrain on S) (2.1)

$$\sqrt{A}=0.1018+0.01971\sqrt{vm}+0.4514\sqrt{m}$$

(For S < 6 ft.) (2.2)

$$\sqrt{A}=0.1018+0.005485\sqrt{vm}+0.4514\sqrt{m}$$

(For S > 6 ft., and v > 5000) (2.3)

where,

A = Number of accidents;
v = Average daily traffic volume;
m = Length of the road section; and
S = Shoulder width.

Musick [90] investigated the effect of pavement edge marking on two lane rural state highways in Ohio. His findings showed that pavement edge markings resulted in a significant reduction (i.e., a net decrease of 37% at 0.02 level) in fatality and injury causing accidents. This was specially true for intersections, alleys and driveways whereas accidents between access points showed no significant change. In the context of pavement edge marking, Williston [91] studied various locations in Connecticut and found that on 2-lane and 4-lane divided highways, the presence of a painted line along the outer edge of pavement effected the lateral position of vehicles and the most significant change in position occurred during darkness.

Taylor et al. [92] analyzed Ohio's curve delineation program and tested the effectiveness of roadside delineators in the presence of pavement edge lines. Their before-and-after study, using 557 test and 357 control sections, showed that Ohio's delineation program provided significant reduction in accidents. However, the use of additional parameters was suggested to increase program efficiency.

Agent et al. [93] studied the relationship between roadway geometrics and accidents for various types of highways in Kentucky. Information on accident severity, road surface conditions, light conditions, road characteristics, and type of traffic control were included in the study. Their findings showed that four-lane undivided highways had the highest average accident rate, while parkways (toll roads) had the lowest rate. Single vehicle accidents, those involving pedestrians, and accidents which occurred on curves had the highest severity index.

The effects of gradient and curvature on accidents on the London-Birmingham motorway were studied by Hillier et al. [94]. They reported evidence of a definite trend in accident rate with gradient on straight three-lane sections. On the steeper up-gradients, the accident rate was found to be higher.

Apart from finding the significance of effects and relationship between the highway features and accidents, the literature offered a multitude of approaches to develop mathematical equations that can be used to predict accidents from such features. In this context, Schoppert [95] represented equations, developed by the Oregon State Highway Department, that could be used to predict accidents on rural two-lane highways employing roadway elements such as ADT, lane width, shoulder width, sight distance restrictions, driveways and intersections. Based on a sample of 1400 miles of 2-lane, 2-way highways and three years of accident records in Oregon, the following set of equations for western regions were generated:

For ADT 3000 - 3999:

$$A = 7.69 - 0.21\ SH + 0.10\ CDW + 0.030\ SDR - 0.41\ LA \quad (2.4)$$

For ADT 4000 - 4999:

$$A = 8.51 - 0.58\ SH + 0.23\ CDW + 0.004\ RDW \quad (2.5)$$

For ADT 5000 - 6999:

$$A = 4.84 - 0.12\ SH + 0.19\ CDW + 0.310\ RDW \quad (2.6)$$

For ADT Over 7000:

$$A = 3.75 - 0.24\ SH + 0.26\ RDW + 0.160\ ADT \quad (2.7)$$

For highways in Eastern Oregon and for ADT 3000 and over the forecasting equation was:

$$A = 1.04 + 0.23\ CDW + 0.11\ RDW + 0.08\ INT + 0.12\ SH \quad (2.8)$$

Where,

A = Total non-intersectional accident experience for a one-mile section during one-year period;
ADT = Average Daily Traffic divided by 100;.
CDW = Number of commercial driveways per mile;
INT = Number of intersections per mile;
LA = Lane width in feet;
RDW = Number of residential driveways per mile;
SDR = Percent of the one-mile section where sight distance was restricted expressed as a whole number, (i.e., 10% = 10.0); and
SH = Shoulder width in feet.

Dart and Mann [96] investigated the relationship of rural highway geometry to accident rates in Louisiana. They developed mathematical models for total accidents per 100 MVM and used traffic volume and mix proportion, pavement and shoulder width, cross-slope, alignment, and roadside friction as independent variables. Regression analysis technique revealed the following relationship with R^2= 0.46 and F-ratios significant at the 0.05 level.

$$y = 41.32 - 1.23X_1 - 0.54X_2 - 0.67X_6 + 0.03X_1X_2 + 0.03X_2X_6 - 0.0009X_2X_9 + 0.026X_2X_{11} - 0.12X_4X_{11} + 0.009X_5X_9 \quad (2.9)$$

where,

y = Total Accidents per 100-MVM,
X_1 = Percentage of trucks,
X_2 = Traffic volume ratios,
X_4 = Lane width,
X_5 = Shoulder width.
X_6 = Cross slope
X_9 = Horizontal alignment, and
X_{11} = Traffic conflicts.

Sparks [97] used ten independent variables representing various highway geometrics and use characteristics and developed the following equation correlating accident rates.

$$AR = 2.57 + .0607x1 - 0.397x2 - 0.111x3 -0.425x4 -0.475x5 - 0.119x6 + 0.335x7 -0.295x8 \quad (2.10)$$

where,

AR = Accident Rate
x1 = Surface type index
x2 = Curvature index
x3 = Gradient index
x4 = Stopping sight distance index
x5 = Passing sight distance index
x6 = Hazard index
x7 = Surface condition index
x8 = Shoulder condition

The other two variables contributed nothing statistically and were not included in the final equation. Since the standard error of the equation was in excess of 5.00, it was considered practically worthless for predicting accident rates. However, to provide better correlation with accident rates, another approach was employed by aggregating the data into a cumulative index. The revised relationship in terms of the cumulative index yielded an improved significance and statistical methods showed that 45% of the variance that occurred in accident rates was attributable to the magnitude of the adequacy index. This relationship was shown graphically, as reproduced in Figure 2.6, and was represented by the following equation:

$$Y = 1.604 - 0.0483\ (X) \qquad (2.11)$$

where,

Y = Cumulative Adequacy Index, and
X = Accident Rate (MVM)

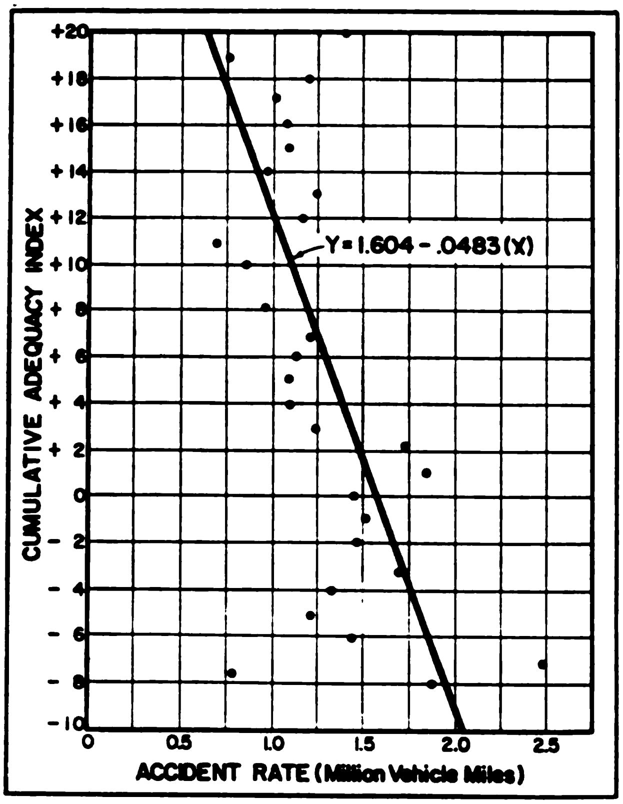


Figure 2.6 Cumulative Adequacy Index vs. Accident Rate [97].

Kihlberg and Tharp [98] investigated the effects of specific geometric features on accident rates. The studied geometric features included number of lanes, access control, median presence, curvature, gradient, ADT, and the presence of intersections and structures. Accident prediction monographs relating traffic volumes with accidents for various geometric conditions were developed. Though the data explicitly represented Florida, Connecticut and Ohio, the results may be generalized, based on reasonably acceptable R^2 values, for similar ambient conditions elsewhere. Their principal findings showed that:

1) Access control had the most significant accident reducing effect;
2) The multi-vehicle accident rate increased with ADT, and single-vehicle accident rate decreased.
3) The presence of gradients, curves, intersections, and structures increased accident rates.

2.8.1 Accident Prediction Modeling in Developing Countries

The relationship between accident rates and geometric design standards in two developing countries (Kenya and Jamaica) was investigated by Jacobs [99]. He developed mathematical equations predicting the accident rate in terms of several independent variables representing various highway and traffic features. Stepwise multiple regression analysis produced the following set of equations.

For Kenya:

$y = 1.45 + 1.02X5 + 0.017X3$ (at 5% level). (2.12)
$y = 1.09 + 0.62X5 + 0.031X3 + 0.0003X4 + 0.062X2$ (at 10% level). (2.13)

For Jamaica:

$y = 5.77 - 0.755\ X1 + 0.275\ X5$ (at 5% level). (2.14)
No further factor was reported to enter at 10% level.

where,

y = Accident Rate per MVkm,
x1 = Road width (m),
X2 = Vertical curvature (m/km),
X3 = Horizontal curvature (degrees/km),
X4 = Surface irregularity (mm/km), and
x5 = Junctions per km.

In Greece, Frantzeskakis [100] studied the relationship of traffic accidents to traffic characteristics (e.g., volume and Level of Service), on two non-controlled access National Highways. The accident analysis which were carried out per kilometer resulted in the following equation.

$$R_n = \frac{A_n \times 10^6}{F_n\ (v/c)_n} \qquad (2.15)$$

Where,

R_n = Accident Rate for a LOS n.
A_n = Number of accidents occurring under LOS n.,
F_n = Number of hours each section examined operates under LOS n.
$(v/c)_n$ = Average ratio of volume to capacity for the LOS n for all one kilometer sections examined.

The analysis of accident rates for each kilometer of the two sections was used to identify hazardous locations. The study concluded that the operational characteristics created by a certain volume of traffic significantly affected the accident rates.

2.8.2 The Indexation Approach for the Identification of Hazardous Locations

The literature indicated several examples [101-104] of employing indexed values for the identification of hazardous locations. These indices were, in some manner, related to the ambient hazardousness and addressed the safety issue both at micro and macro levels. For example, at the micro level, Hazard Indices (HI) were developed for the identification and ranking of hazardous highway locations by Taylor and Thompson [101] in USA, by Gharaybeh [102] in Jordan, and by Al-Isa et al. [103] in Saudi Arabia. At a macro level, an Accident Hazard Index (AHI) was developed by Shen [104] to measure relative safety of 46 counties in South Carolina. These index development studies employed one of the following three types of hazard indicators: 1) purely accident based factors; 2) a combination of accident and non- accident based factors; and 3) purely non-accident based safety surrogate factors.

The effectiveness of the Hazard Index (HI) approach is supported by both theoretical and practical considerations. In the HI approach, a sufficiency (or deficiency) evaluation criteria is employed to rate the composite hazardousness of a highway location. From a theoretical standpoint, this composite hazardousness rating provides a reasonably accurate prediction of future accident experience. On the contrary, any single hazard might not possess such predictive characteristics. This point is further elaborated in a review of the study by Taylor and Thompson [101], presented in the following pages.

The practical advantage of the HI approach lies in the simplicity of computations as compared to the more complex approach of accident modeling and forecasting. These studies found that HI approach could be used to measure the relative highway safety so that proper countermeasures could be developed accordingly.

Taylor and Thompson [101] developed a hazardousness rating formula (HRF) which provided a means for arriving at a hazardous index for any suspect site. The formula incorporated data inputs for both accident and non-accident based nine indicators as listed below.

Accident Based Indicators

1. Number of Accidents per Year
2. Accident Rate
3. Accident Severity

Non-Accident Based Indicators

4. Volume/Capacity Ratio
5. Sight Distance
6. Traffic Conflicts
7. Erratic Maneuvers
8. Driver Expectancy
9. Information System Deficiency

The general form of the HRF was as following

$$HI = \frac{[W_i \ (IV)_i]}{W_i} \qquad (2.16)$$

Where,

HI = Hazardousness Index for the site under study
W_i = Weighing factor for indicator i.
IV = Indicator Value (subjectively scaled values from 0 to 100) for indicator i.

Each indicator was a measure of hazardousness. Some indicators were considered more powerful than others and this was reflected in the differing weights assigned to the individual indicators. An example of determination of HI employing their formula is presented in Table 2.7.

Taylor and Thompson established that the composite hazardousness rating provided a reasonably accurate prediction of future accident experience, as compared to any single hazard that might not possess such predictive characteristics. In this context, they reported that restricted sight distance was a definite factor in hazardousness at a given location but analysis of sight distance restrictions in themselves did not provide good estimates of future accident experience.

Table 2.7 Computation of Hazardousness Index [101].

Type: Rural Intersection

Indicator	Data Value	Units	Indicator Value	Weight	Part H.I.
1. Number of Accidents	7.67	acc/year	59	.145	8.6
2. Accident Rate	2.47	acc/MEV	49	.199	9.8
3. Accident Severity	12850	dollars	70	.169	11.8
4. Volume/Capacity Ratio	0.17	unitless	22	.073	1.6
5. Sight Distance Ratio	2.00	wt. avg	0	.066	0
6. Traffic Conflict	--	conf/hr	--	.053	0
7. Erratic Maneuvers	--	E.M./hr	--	.061	0
8. Driver Expectancy	2.19	wt. avg	37	.132	4.9
9. Info. System Deficiency	2.79	wt. avg	47	.102	4.8
				1.000	41.5

Sum of Applicable Weights = 0.886 [*]
* (Do not include weights for indicators not used at this site).
H.I. = Sum of Partial H.I.s/Sum of Applicable Weights = 41.5/0.886 = 47
Relative Strength of Evaluation = 0.886 x 100 = 89%

Gharaybeh [102] developed a danger index (DI), by aggregating four types of hazard indicators, for the identification of accident-prone locations in Greater Amman, Jordan. These four indicators were: accident frequency; accident rate; a danger factor (DF), computed as a ratio of accident rate to critical rate; and an equivalent total accident number (ETAN), expressed by the following equation.

$$ETAN = aF + bJ + TAN \tag{2.17}$$

in which,

F = Number of persons who died in at the site;
J = Number of persons injured at the site;
TAN = Total number of accidents at the site; and
"a" and "b" are the calibration factors.

Al-Isa et al [103] developed a hazardousness index for determining accident potential of urban intersections in Saudi Arabia. Their models expressed various traffic conflicts as a function of geometric and traffic variables, as represented in Table 2.8.

Table 2.8 Regression Models of Traffic Safety Study in Saudi Arabia [103].

Variable	Indicator/Transformation of	Coefficient Estimates: Rear End and Side Swipe Conf.	Coefficient Estimates: Right angled Conflicts
I. Uncontrolled Approaches			
Intercept		-0.243	-0.8323
NPSRD	Perception Reaction Sight Distance	1.712	-
PRSD11	1/PRSD	-	0.2231
AA1	Approach Volume	-	4.531
LEFRIG	Left and Right-Turns in intersection	0.00231	55.06
DTYPE	Type of Intersection	0.346	0.959
Overall Test Statistics			
R^2		0.422	0.451
F(signif)		24.86	20.74
II. Stop-controlled Approaches			
Intercept		1.555	-0.4256
NEWCRSD	Crossing Sight Distance	2.279	4.2395
AA	Approach Volume	-	47.679
CC	Crossing Volume	9.11	10.297
SPEED	Average Speed	0.0391	-
APPWIDTH4	Approach Width	-	78.98
Overall Test Statistics			
R^2		0.56	0.88
F(signif)		11.91	47.88

Shen [104] developed an Accident Hazard Index (AHI) for 46 counties in South Carolina. The AHI was computed by determining the arithmetic average of three accident rate indices, assigning equal weights to each, as expressed by the following formula.

$$(AHI)_i = \left\{ \frac{PAI + VAI + MAI}{3} \right\}_i \qquad (2.18)$$

where,

PAI = Population-based accident rate index;
VAI = Vehicle-based accident rate index; and
MAI = Mileage-based accident rate index.

The validity of the constructed indices was tested by using a correlation analysis in which per capita economic loss (PEL) resulting from accidents was used to determine the adequacy of AHI. The per capita loss was defined as following.

$$(PEL)_i = \frac{C_1 X_{i1} + C_2 X_{i2} + C_3 X_{i3}}{P_i} \qquad (2.19)$$

in which,

$(PEL)_i$ = Per capita economic loss in County i;
C_1 = Estimated average cost per fatal accident;
C_2 = Estimated average cost per injury accident;
C_3 = Estimated average cost per PDO accident; and
P_i = Population of county *i*.
The terms X_{i1} ; X_{i2} ; and X_{i3} represented the average number of corresponding type of accidents per year in the county *i*.

2.9 RELEVANCE OF LITERATURE REVIEW TO CURRENT RESEARCH

The current research has its primary prospective applicability in Pakistan, a country placed in the category of infancy of motorization [39]. The nation's highway safety problems are not necessarily the same as those faced by the developed countries today. As such, the state-of-the-art in certain areas of technology may not be applicable to the conditions in Pakistan. Therefore the material selected for review, primarily, represented the era of early motorization of the present developed countries.

Specifically, frequent citations were made to literature from the USA and the UK reflecting the state of the art of 1960's and 70's. A synthesis was made with the results of research work pertinent to developing countries, like Saudi Arabia, Jordan, Turkey, Greece, Thailand, and Pakistan. Material from the Overseas Unit of the TRRL has been of particular utility in exposing safety problems in countries like Jamaica, Ghana, Botswana, Malaysia and Hong-Kong. More sophisticated safety analysis in terms of accident prediction modeling were cited for Jamaica and Kenya.

The literature review identified three important considerations in highway safety that have a direct bearing on the present research.

1) Assignment of liability on any single causative factor does not necessarily explain the traffic crash phenomenon. Hence, resources should not be

concentrated on isolated correction of a single cause, which traditionally has been found to be the driver.

2) There are many other theories, in contrast to the single liability approach, which offer a more refined explanation of accident occurrence, and theoretical models based on such postulates have been validated by empirical estimation.

3) The importance of highway-related safety improvement is consistently augmented, whether inferences are made based on a crude liability approach, or a refined conceptual framework including exposure and risk-compensation is employed.

As such, participation in a systematic program, oriented toward highway-related safety improvements, was indicated as a valid strategy for alleviating traffic accident problems in Pakistan.

The literature review also revealed that a systematic program, such as the system referred to as HSIP, could be made functional in Pakistan. Specific references to literature were made to identify various surrogate measures of highway safety, and their use in accident prediction. In addition to accident forecasting, the development and use of a hazard index in terms of a composite hazardousness for identification of hazardous locations was demonstrated. This information provided important guidelines for the experimental design, and is extensively used in this research.

2.9.1 Transferability of the HSIP Technology

Over the past four decades, the motorized countries have gradually attained considerable experience in administering highway-related safety improvement programs. These programs are the outcome of extensive research spanning several years and stand tested for their technical soundness and economic viability. This knowledge-cum-experience base could be of immense benefit for the developing nations in evaluating their highway safety needs, provided a compatibility of critical parameters and transferability of relevant technical procedures could be established.

To be specific, the US model of HSIP [71] is examined in this dissertation for application in Pakistan. A detailed overview of this strategy are described in Sections 2.6 and 2.7. Since the HSIP is purely a technical oriented approach, a comparison of social, economic or demographic parameters between US and Pakistan is not required. However, it will be necessary to look into the technical aspects.

The contents of the three main components of the HSIP are tabulated in Tables 2.9, 2.10, and 2.11. A cursory glance at these tables reveals that "procedure" is the basic unit of the program. Therefore, to qualify for technology transfer, it is essential that, from all technical and administrative standpoints, at least one procedure should be accomplishable in Pakistan. The transferability status of the HSIP procedures is indicated in column 2 of these tables.

Table 2.9 Procedures of Planning Component [71].

PLANNING COMPONENT	TRANSFERABILITY STATUS
• Process 1 - COLLECT AND MAINTAIN DATA	
> Subprocess 1 - Define the Highway Location Reference System	
Procedure 1 - Milepost Method	+
Procedure 2 - Reference Point Method	+
Procedure 3 - Link Node Method	+(-)
Procedure 4 - Coordinate Method	-
Procedure 5 - LORAN-C Method	-
> Subprocess 2 - Collect and Maintain Accident Data	
Procedure 1 - File of Accident Reports by Location	+(-)
Procedure 2 - Spot Maps	-
Procedure 3 - Systemwide Computerization of Accident Data	-
> Subprocess 3 - Collect and Maintain Traffic Data	
Procedure 1 - Routine Manual Traffic Counts	+
Procedure 2 - Use of Mechanical/Electronic Traffic Count Devices	+
Procedure 3 - Permanent Count Stations	+
Procedure 4 - Maintenance of Traffic Data on Maps of Files	+
Procedure 5 - Systemwide Computerization of Traffic Data	-
> Subprocess 4 - Collect and Maintain Highway Data	
Procedure 1 - Systemwide Manual Collection of Highway Data	+
Procedure 2 - Photologging and Videologging	-
Procedure 3 - Maintenance of Highway Data on Maps of Files	+
Procedure 4 - Systemwide Computerization of Highway Data	-
• Process 2 - IDENTIFY HAZARDOUS LOCATIONS AND ELEMENTS	
Procedure 1 - Frequency Method	-
Procedure 2 - Accident Rate Method	-
Procedure 3 - Frequency Rate Method	-
Procedure 4 - Rate Quality Control Method	-
Procedure 5 - Accident Severity Method	-
Procedure 6 - Hazard Index Method	-(+)
Procedure 7 - Hazardous Roadway Features Inventory	+
• Process 3 - CONDUCT ENGINEERING STUDIES	
> Subprocess 1 - Collect and Analyze Data at Identified Hazardous Locations	
Procedure 01-05 - Accident Studies	-
Procedure 06-14 - Traffic Studies	+
Procedure 15-20 - Environmental Studies	+
Procedure 21-24 - Special Studies	+
> Subprocess 2 - Develop Candidate Countermeasure(s)	
Procedure 1 - Accident Pattern Tables	-
Procedure 2 - Fault Tree Analysis	+(-)
Procedure 3 - Multi-disciplinary Investigation Team	+
> Subprocess 2 - Develop Project(s)	
Procedure 1 - Cost Effectiveness method	+
Procedure 2 - Benefit to Cost Ratio Method	+
Procedure 3 - Rate-of-Return Method	+
Procedure 4 - Time-of-Return Method	+
Procedure 5 - Net Benefit Method	+
• Process 4 - ESTABLISH PROJECT PRIORITIES	
Procedure 1 - Project Development Ranking	+
Procedure 2 - Incremental Benefit to Cost Ratio	+
Procedure 3 - Dynamic Programming	+
Procedure 4 - Integer Programming	+

+ = Transferable.
- = Not Transferable.
+(-) = Transferable with certain limitations.
-(+) = Not Transferable without modifications.

Table 2.10 Procedures of Implementation Component [71].

IMPLEMENTATION COMPONENT	TRANSFERABILITY STATUS
• Process 1 - SCHEDULE AND IMPLEMENT SAFETY IMPROVEMENT PROJECTS	----------------------
> Subprocess 1 - Schedule Projects	
Procedure 1 - Gantt Charts	+
Procedure 2 - Program Evaluation and Review Technique (PERT)	+
Procedure 3 - Critical Path Method (CPM)	+
Procedure 4 - Multiproject Scheduling System	+
> Subprocess 2 - Design and Construct Projects	+
> Subprocess 3 - Conduct Operational Review	+

Table 2.11 Procedures of Evaluation Component [71].

EVALUATION COMPONENT	TRANSFERABILITY STATUS
• Process 1 - DETERMINE THE EFFECT OF HIGHWAY SAFETY IMPROVEMENTS	----------------------
Procedure 1 - Perform Accident Based Evaluations	-
Procedure 2 - Perform Non-Accident Based Evaluations	+
Procedure 3 - Perform Program Evaluation	+
Procedure 4 - Perform Administrative Evaluation	+

+ = Transferable.
- = Not Transferable.

2.9.2 Technical Gap in Transferability

The information displayed in Tables 2.9 through 2.11 reveal that "identification of hazardous location using accident data" (i.e., Process 2 of the Planning Component) is the only process which lacks transferability in the entire HSIP. The hazardous roadway features inventories could be used as an alternative to serve the purpose. However, it would be implicitly desirable to validate the technical soundness of this alternate approach.

2.9.3 Suggested Method to Bridge the Transferability Gap

As mentioned above, the proposed alternative method of identification of hazardous location needs to be validated prior to its application. This could be accomplished by quantifying the hazardousness represented by the hazardous roadway features inventories, and then correlating it with accident records. The specifications of the procedures devised for quantification of ambient hazardousness are specified in the Experimental Design (Chapter 3).

Since a reliable accident data base is not likely to be readily available, this may be developed from police records. In case a significant correlation is indicated between the two entities (i.e., hazardousness and accidents), the former may be adopted as a surrogate in identical environmental situations.

In this dissertation this course is specifically adopted to bridge the transferability gap and constitutes the basis of the research. In the experimental design, the hazardous roadway features are identified using an inventoried checklist developed on the basis of information available in the literature and in synthesis with indigenous hazard conditions. The ambient hazards include detrimental highway elements, adverse geometric design and pavement deficiencies, and inadequate control of access.

In the perspective of technology transfer, it also became apparent that accident files need to be constructed for testing the highway hazard data against the accident records. This was accomplished by retrieving accident reports for selected highway segments from police records. The retrieved information was further authenticated using linear plans to cross check the police narrative or sketched description of the accident location.

2.10 FORMULATION OF HYPOTHESIS

The mathematical models reviewed in Section 2.8 demonstrated a high degree of correlation between the accidents and the explanatory variables as indicated by the various determinants of statistical significance (i.e., R^2, F-ratios and probability levels). This significance led to the practical application of these models for the prediction of accidents.

For example, Schoppert [95] asserted that the equations presented by him could be used to predict total accidents on one-mile sections of rural two lane highways with similar characteristics in Oregon. Kihlberg and Tharp [98] explicitly demonstrated the application of their developed monographs to predict accidents for various geometric conditions. As a corollary to this, they also demonstrated how various geometric designs could be evaluated for safety.

As an analogy to these findings, it may be postulated that the accident potential of a highway location in Pakistan may be assessed using appropriate surrogate measures of hazardousness. It is, therefore, hypothesized that the tangible hazardousness of a rural highway section in Pakistan is representative of its accidents potential. The precise specification of the null hypothesis is as following:

" There is no relationship between the ambient hazards and the accident potential of a rural highway section in Pakistan."

To test this hypothesis, an experimental design is presented in the following chapter.

CHAPTER 3

RESEARCH METHODOLOGY AND EXPERIMENTAL DESIGN

3.1 THE VARIABLES OF INTEREST

The topic of highway safety may be viewed from a variety of perspectives representing several aspects of individual and communal interests. In this dissertation, this topic is purely dealt with from an engineering standpoint, and in specific, the technological aspect of highway-related safety improvements are addressed.

To rationalize the course of research, and to select the crucial variables, a four-level screening procedure was employed. At each level, a group of entities relevant to highway safety were screened by backward elimination. This means that all the group-components were considered for their appropriateness prior to retaining the pivotal ones. A detailed description of the four levels of elimination is presented in the following pages.

First Order Elimination

In the first level of elimination, the three conventional accident-causal factors (i.e., road, user, and vehicle) were considered. The objective was to validate the relevancy of highway-related safety improvement programs in the given situation.

The improvements aimed at the vehicle and the user were filtered on three important considerations. First, the country's indigenous industrial research and production base was not likely to effect automotive safety improvements in the near-future. Second, the literature indicated that there was a low probability of a change in user behavior in a short time period, even by education or enforcement. Third, any strategy oriented toward the correction of the highway system would interactively address the other two factors in achieving safety.

Second Order Elimination

In the second level of elimination, various procedures for identifying hazardous locations were reviewed, since this operation is the foremost step in the design and implementation of a highway related safety improvement program. The specific literature on implementation of a HSIP [71] suggested seven methods of identifying hazardous locations as listed in Table 3.1.

The first six methods require application of accident data in some form. The last method was considered most appropriate for use in Pakistan. The choice was based on the

Table 3.1 Second Order Elimination - Procedures for Identifying Hazardous Locations.

No.	PROCEDURES	SELECTION STATUS
1	Frequency Method	0
2	Accident Rate Method	0
3	Frequency Rate Method	0
4	Rate Quality Control Method	0
5	Accident Severity Method	0
6	Hazard Index Method	0-1
7	Hazardous Roadway Inventory Method	1

0 = Can not be selected due to technological limitations.
0-1 = Can be selected with certain limitations.
1 = Can be selected without any limitation.

fact that a reliable and accessible highway accident data base was not likely to be available in the country. However, preceding any generalization, this approach needs to be further authenticated with the help of selected accident data.

Third Order Elimination

In the third level of elimination, various highway hazards were examined to select those to be used in this study. Literature [105] indicated that there was no universally accepted definition of a hazardous location or an element. In fact, highway safety personnel recognize various types of highway locations and features which, if not corrected, are likely to be associated with high accident frequency or severity. For example, roadway sections with closely located fixed obstacles and with low skid resistance properties are considered to have an increased potential for accidents. Similarly, a drop-off of several inches from pavement-edge to shoulder is considered a potential hazard. The AASHTO [106] established a generally accepted group of hazardous road elements identifying specific types of hazards. The FHWA [107] also developed a similar classification of hazardous elements. The aggregated hazardous situations, based on the cited literature and those commonly found on rural trunk lines in Pakistan, are summarized in Table 3.2.

This table eventually served as a checklist to determine the number of hazards and to spot their physical location on the ground. According to this checklist, 22 types of hazards were found to be present in the experimental site, that are marked either as "P" or "PNC" in the table. However, only 19 (out of the 22 present) hazards were considered, that are marked as "P" in the table. The three hazards which were present but not considered are marked as "PNC". These included inconsistent use of signs and traffic control devices, and poor illumination conditions.

The experimental design is based on the outcome of this screening process. Twelve Measures of Hazard (MOH) were developed for the quantification of hazardousness. A detailed description of these MOH and the results of their operation is given in Sections 3.2.2 and 3.2.3.

Table 3.2 Third Order Elimination - Inventory of Hazardous Highway Features.

No.	HAZARDOUS HIGHWAY FEATURES	PRESENCE STATUS
1	Narrow bridges, abutments, piers and bridge approaches	P
2	Guardrail deficiencies	P
3	Sharp curves (poor vertical and/or horizontal alignment)	A
4	Fixed objects (roadside obstacles), trees etc.	P
5	Sight distance restrictions (e.g., vegetation)	P
6	Utility and signal poles	P
7	Poor, inadequate or non-uniform signing	PNC
8	Animal and pedestrian crossing	P
9	Narrow shoulders and shoulder drop-offs	P
10	Smooth, slippery pavements	P
11	Culverts, headwalls, drainage facilities	P
12	Steep side slopes, high fills, ditches	P
13	Substandard railroad crossings (e.g., no protection)	A
14	Deficient intersections (e.g., blind approaches)	P
15	Inadequate or worn pavement markings or delineation	P
16	Substandard geometric	P
17	Deficient bridge rail and connecting guardrail	P
18	Substandard traffic signals or signal timing	A
19	Rough pavement surface (e.g., potholes etc.)	P
20	Lane drops and pavement discontinuities	A
21	Narrow lane and pavement	P
22	Rocks	A
23	Barriers, fences and stone walls	P
24	Obsolete geometric design	P
25	Poor super-elevation	A
26	Non-uniform traffic control devices	PNC
27	Gore areas	A
28	Buildings	P
29	Lack of storage lanes	A
30	Traffic circles	A
31	Poor illumination	PNC
32	Dumpster boxes	A
33	Abandoned autos	A
34	Hydrants	A
35	Short tapers	A

P = Present
A = Absent
PNC = Present (but Not Considered)

Fourth Order Elimination

The fourth, and final, level of elimination constitutes the principal part of this research. In this process the independent variables, representing the quantified hazardousness, are tested for their correlation with accident data extracted from the police records. This operation results in the development of accident prediction models. The entire process is presented in Chapter 4 which deals with the analysis of the research data.

3.2 THE DESIGN OF EXPERIMENTS

Chapter 2 concluded with the formulation of a hypothesis that there are no identifiable hazards on rural highway sections in Pakistan which are the determinants of accident potential. To test this hypothesis, it was intended to examine the statistical significance of any relationship between the quantified hazardousness and the accident data. Multivariate regression analysis were performed to test correlations with a control on multicollinearity, since the hazard data was represented by multiple descriptors. The details of the proposed analysis are covered in Section 3.2.4. The experimental plan essentially requires information on two types of data: 1) The Hazard Data, quantified from hazardous highway features and adverse operating traffic characteristics; and 2) The Accident Data, extracted from archival accident records.

The primary objective of the experiment was to determine if accident surrogates could be confidently used as a substitute for actual accident histories which are unavailable or deemed unreliable. This substitution is a requirement to bridge an obvious gap in transferability of HSIP technology for implementation in Pakistan. The following pages describe the salient features of the experimental plan.

3.2.1 The Ambient Highway Hazards

As a result of third order elimination (see page 68), the following 19 types of hazards present on the experimental site were considered for this study.

1) Narrow bridges, and bridge approaches.
2) Guardrail deficiencies.
3) Fixed objects (roadside obstacles), trees etc.
4) Sight distance restrictions (e.g., vegetation).
5) Utility and signal poles.
6) Animal and pedestrian crossing.
7) Narrow shoulders and shoulder drop-offs.
8) Smooth, slippery pavements.
9) Culverts, headwalls, drainage facilities.
10) Steep side slopes, high fills, ditches.
11) Deficient intersections (e.g., blind approaches).
12) Inadequate or worn pavement markings or delineation.
13) Substandard geometry.
14) Deficient bridge rail and connecting guardrail.
15) Rough pavement surface (e.g., potholes etc.).

16) Narrow lane and pavement.

17) Barriers, fences and stone walls.

18) Obsolete geometric design.

19) Buildings.

Some photographs of locations within the experimental site showing the ambient highway hazards are presented in Appendix B.

The next logical step in the experimental design was to develop some appropriate techniques to quantify these hazards. As such, the following three types of procedures were employed for the quantification of hazardousness: 1) Use of design standard deficiencies as a measure of the hazard; 2) Use of drivers erratic maneuvers and traffic conflicts as a measure of the hazard; and 3) Use of an expert team for subjective rating of the hazard.

Application of these quantification procedures resulted in three type of corresponding data sets: on-ground measurements; unobtrusive observational counts; and 3) scaler rating numbers.

3.2.2 Development of Measures of Hazard (MOH)

Twelve MOH were carefully developed to measure the 19 types of hazards utilizing one (of the three) quantifying techniques. These MOH depicted the typical features of a rural trunk line highway and operating traffic characteristics in Pakistan, and ultimately acted as the independent variables for mathematical modeling. These MOH and their intended use are presented in Table 3.3.

Table 3.3 The MOH Development Plan and their Use Characteristics.

No.	MOH	Quantification Technique	Location-wise Use
1.	MOH [ACCESS]		
2.	MOH [GDRAIL]		
3.	MOH [PWIDTH]	Measurement	Non-intersection
4.	MOH [SWIDTH]		
5.	MOH [PMARKS]		
6.	MOH [INTENT]		
7.	MOH [INTSPD]		Intersection
8.	MOH [INTCOL]	Observation	
9.	MOH [SPDCHG]		
10.	MOH [LANCHG]		Non-intersection
11.	MOH [PVCOND]	Rating	
12.	MOH [SIDEOB]		

3.2.3 MOH Specifications and On-Ground Application

The application of these MOH resulted in generation of both continuous and discrete numbers, depending upon the nature of the hazard, and provided a numerical basis for the descriptive statistics of the composite hazardousness of a location. The specifications of the developed MOH and their application method for hazard quantification are described in the following pages.

1. MOH [ACCESS]: This MOH was employed to evaluate the hazardousness due to inappropriate access control. This deficiency not only causes intrusion of pedestrian and animals on the road, but also encourages bus drivers to off-load passengers upon demanded. Any section of road naturally or otherwise unprotected against such accessibility was measured.

Three types of lateral access conditions were included in the study: 1) linear ribbon development **[RIBBON]**; 2) specific lateral paths **[SPATHS]**; and 3) median openings **[MEDOPN]** in the case of 4-lane sections. A presence of any of these condition was assumed a potential hazard and was measured in meters per kilometer.

2. MOH [GDRAIL]: Installation of guardrail often has a contradictory effect on overall safety i.e., it reduces the number of fatalities but increases the number of injuries and accidents [108, 109]. Though guardrail by itself may not precisely avert an impending accident situation, the evaluation of hazardousness due to the absence of guardrail on warranted highway sections was considered appropriate for this study. Accordingly, this MOH was used to evaluate the hazardousness due to the absence of guardrail at bridge approaches and embankments of three meters or higher. This hazard was measured in meters per kilometer.

3. MOH [PWIDTH]: For evaluating the prospective hazardousness caused by deficient pavement width and narrow bridges, sections having a lateral width below 3.65 meters (12 ft.) per lane were included in the analysis. It is pertinent to point out here that some sections of two-lane, two-way highway and either carriageway of a 4-lane divided highway had pavement widths more than 7.30 meter (24 ft.) because of stage construction or intermittent road widening programs. Though not deficient in width, these sections were considered to pose an increased threat to highway safety by causing non-channelization and overtaking potential due to the available extra width. Such hazardous sections were also covered by this MOH and included in the study. The variation of width from the specified was taken as a hyperbolic (second degree) function to incorporate the effect of negative deviations and to ignore minor deviations in evaluating hazardousness as shown in Figure 3.1.

4. **MOH [SWIDTH]:** This MOH was used to determine prospective hazardousness due to the shoulder deficiency. The standard shoulder width for various types of roads are specified by AASHTO [25] depending upon the traffic volumes and the type of road. For the purpose of this study, a shoulder width less than 3.0 meter was counted as deficient. This deficiency, on the average, was considered a measure of hazard and was recorded in meters per kilometer.

5. **MOH [PMARKS]:** Absence of longitudinal pavement markings poses a hazard in terms of non channelization, improper overtaking and off-tracking of vehicles. Evaluation of this hazard was an important factor because dangerous

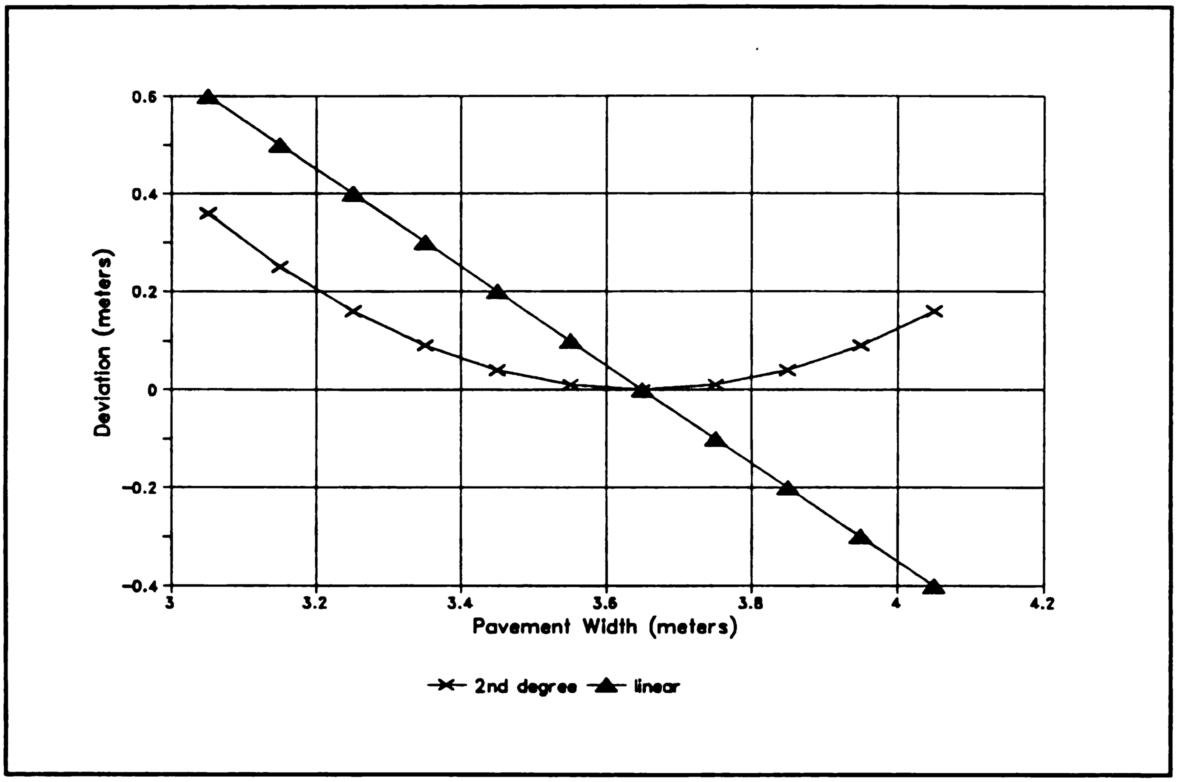


Figure 3.1 [PWIDTH] - A Hyperbolic Function of Pavement Width Variation from the Standard.

overtaking was earlier identified as a principal cause of fatal accidents in Pakistan [40]. The hazardousness was measured in kilometers per kilometer both for the longitudinal sections and intersection areas.

6. MOH [INTENT]: This MOH, along with the next two i.e., MOH [INTSPD] and MOH [INTCOL] were simultaneously used to evaluate hazardousness at an intersection with permanent obstructed visibility and adverse geometry. The hazardousness was evaluated by unobtrusively recording the number of non stopping vehicle entries in the intersection per unit time and in proportion to the operating volume. Thus the devised unit for the measure of hazard was a ratio of vehicles per hour.

7. **MOH [INTSPD]:** This MOH was conceived as an indicator of the hazardousness due to adverse geometry of the intersection area and approaches. In developing this measure it was assumed that the vehicle driver who entered an intersection area without stopping would either try to quickly stop or clear off the intersection in haste, to avoid an impending collision. A change in speed exceeding 15 Kmph after a vehicle's entry in the intersection area was defined as an "abrupt change" for this study. The number of such speed changes per unit time, and in proportion to operating traffic volume, were unobtrusively recorded and used as a measure of hazard.

8. **MOH [INTCOL]:** This MOH is an indicator of the degree of adverse intersection geometry as evidenced by a near collision. The evidence of having two or more vehicles reasonably close (defined as one meter or less for this study) and trying to avoid a collision were unobtrusively recorded per unit time and used as a measure of hazard.

The MOH [INTENT], MOH [INTSPD], and MOH [INTCOL] were specific to intersections. Based on the values of these three MOH, an aggregated variable **[INTSEC]** was employed in the analyses to represent the composite intersection hazardousness. Besides evaluating the independent effect of these MOH, their interdependent effect were also included in the analysis.

9. MOH [SPDCHG]: This MOH was a measure of roadway hazard in terms of spatially located skid-zones, corrugations, humps, ditches and pot-holes. The number of abrupt speed reduction events to avoid such roadway hazards (in a distance of 30 meters or less) were recorded by a front-seat passenger using the following rated weights.

1 = Low hazard (for speed reduction up to 15 kmph).

2 = Medium hazard (for speed reduction up to 30 kmph).

3 = High hazard (for speed reduction more than 30 kmph).

10. MOH [LANCHG]: This MOH was used as a conjugate to the previous one and was devised with the assumption that, when confronted with an impending accident situation due to adverse lane conditions, a driver may suddenly change his lane. Only road hazard based incidents were recorded. The number of such actions were recorded by a front-seat passenger who observed lane changes in a distance of 30 meters or less. The following weights were used for hazard evaluation.

1 = Low hazard (1/4 lane change).

2 = Medium hazard (1/2 lane change).

3 = High hazard (full lane change).

The MOH [SPDCHG] and MOH [LANCHG] were specific to isolated lane hazards. By aggregating the values of these two MOH, a variable **[ISLAND]** was employed in the analyses to represent the total hazardousness caused by isolated lane defects like corrugations, humps, and pot-holes.

11. MOH [PVCOND]: This MOH represented the road surface and riding-quality hazards. The recommended procedures [110] were adopted for pavement condition rating in terms of surface cracking, rutting, roughness and edge drop-offs. Each kilometer of the test section was rated on a scale of 0 (least hazardous) to 100 by a two member expert team comprised of experienced highway engineers.

12. MOH [SIDEOB]: Utilizing this MOH, the road-side obstruction caused by fixed objects which were liable to impose increased accident severity (e.g. road-side trees, poles etc.) were measured in number of their occurrence. The employed MOH provided a relatively simple approach to evaluate the road-side obstructions by the observers of an expert team. The distance of the road-side obstacle from the pavement was not prefixed and the rating-judgement alone was the sole criterion to determine the hazardousness caused by such obstructions.

The employed MOH and their measurement attributes are summarized in Table 3.4.

Table 3.4 The Hazard Measurement System.

No.		MOH	UNIT	MODE	TECHNIQUE
Use of Design Standard Deficiency as a Measure of Hazard					
1		MOH [ACCESS]	meters/km	linear measurement	taping
2		MOH [GDRAIL]	meters/km	linear measurement	taping
3		MOH [PWIDTH]	meters/km	linear measurement	taping
4		MOH [SWIDTH]	meters/km	linear measurement	taping
5		MOH [PMARKS]	kms/km	linear measurement	taping
Use of Traffic Conflicts and Erratic Maneuvers as a Measure of Hazard					
6	Inter-section situation	MOH [INTENT]	#/hr.	counting	unobtrusive field observations
7		MOH [INTSPD]	#/hr.	counting	unobtrusive field observations
8		MOH [INTCOL]	#/hr.	counting	unobtrusive field observations
9		MOH [SPDCHG]	#/km.	counting	co-driver's observations
10		MOH [LANCHG]	#/km.	counting	co-driver's observations
Use of an Expert Team's Subjective Rating as a Measure of Hazard					
11		MOH [PVCOND]	#/km.	subjective rating	expert team's judgement
12		MOH [SIDEOB]	#/km.	subjective counting	expert team's judgement

The printouts of the hazard data and the numerical values for the quantified hazardousness employing the above described MOH are presented as Appendix C.

3.2.4 The Applied Procedures for Data Analysis

Multivariate linear regression analyses were performed to test the null hypothesis of no relationship between the hazardousness and accidents. This is one of the most versatile data analysis techniques available for model building, and has a demonstrated applicability [17-18, 96-97, 111-115] in safety research. The proposed accident prediction model can be expressed as:

$$A_f = B_0 + B_1.X_{1i} + B_2.X_{2i} + ... + B_p.X_{pi} + e_i$$

Where, A_f is the accident frequency on a particular kilometer of the highway section, expressed in #/year. X_{pi} represents the value of the *p*th independent variable for the kilometer i. The B coefficients are the unknown parameters and were determined as the result of regression analysis. The e_i terms are assumed as independent random variables that are normally distributed with mean 0 and constant variance σ^2. It is also assumed that in the proposed model, the dependent variable (accident frequency) has a normal distribution for every combination of the values of the MOH (independent variables). The following statistic was used to test the hypotheses.

$$t = \frac{B_1}{S_{B1}}$$

where, B_1 is the slope of the regression line, and S is the standard error of B1. The distribution of the statistic when the hypothesis of no relationship is true would be the *Student's-t* distribution with N-2 degrees of freedom.

These analyses were made using a commercial software package, Statistical Package for Social Sciences (SPSS). The t statistic and their two-tailed observed significance levels are displayed in the standard output results of SPSS regression routines.

Multicollinearity Diagnostics: Since the hazard data is represented by a variety of descriptor independent variables (i.e., MOH), the regression analyses were performed with a control on multicollinearity. This terminology refers to a situation in which there is a likelihood of high correlation between the independent variables. The problem with such a situation is that the different MOH would provide similar or interrelated information about the hazardousness of a location. A check on this phenomenon enables the analyst to retain the pivotal MOH. Any decision on the retention of the pivotal MOH was further subjected to practical considerations of variable acquisition. Two measures of collinearity, Tolerance of Variable (TOL), and Variance Inflation Factor (VIF) were employed as diagnostic tools.

The extended capabilities of the SPSS regression routine includes computations for the TOL and VIF values. In addition to these statistics, eigenvalues and condition indexes are also useful tools to examine collinearity of a data matrix. A specific application of these proposed statistical procedures is made in Chapter 4 which deals with the analysis of data.

3.3 THE RESEARCH DATA

The research data is distinctively divided in two categories: 1) The hazard data (independent variables); and

2) The accident data (dependent variable). In developing the experimental design, it was planned that the MOH should act as the independent variables. The accident data were primarily used in frequency version rather than rate format. The details of these data are presented in the following subsections.

3.3.1 The Hazard Data

The requisite data on highway hazards were collected according to the experimental plan as described in Section 3.2.3. The following information, inventories and data were initially required for the study.

1) Information on district boundary, kilometer posts, and topographical plans of the sample sites.
2) Inventories of intersections, curves, and bridges with their geometric details.
3) Information on control of access, ribbon development, and median openings.
4) Embankment height data.
5) Pavement width data.
6) Shoulder width data.
7) Pavement marking details.
8) Pavement condition rating data.
9) Road-side obstructions data.
10) Traffic volume counts.

These initial data on physical roadway features and the topographical site plans were furnished by the National Highway Authority, Ministry of Communications, Islamabad; and their Consultants, M/S Kampsax International A/S. The furnished information and plans were further checked at site to incorporate any changes due to construction and land-use development.

3.3.2 The Accident Data

The accident data were not readily accessible in terms of a computerized data base. Therefore accident data files were created by retrieving information from the police records which were mostly in narrative form, occasionally formatted or sketched. The following eight police stations (PS) provided accident data for the three year period January 1988 through December 1990.

	Police Station	Jurisdiction (Km)
1)	PS Gujar Khan.	1481 - 1496
2)	PS Mandra.	1497 - 1510
3)	PS Riwat.	1511 - 1520
4)	PS Sehala.	1521 - 1530
5)	PS Rawalpindi (CL).	1531 - 1546
6)	PS Tarnol.	1547 - 1564
7)	PS Taxila.	1565 - 1570
8)	PS Wah.	1571 - 1583

The accident locations as described in the police records were cross-checked with the help of linear highway plans to authenticate the narrative report, and to identify their correct position. The printouts of the accident data files are presented as Appendix D.

3.4 EXPERIMENTAL SITE

The National Highway (N-5) in the Rawalpindi District, excluding the municipal limits of urbanized areas, was selected as the experimental site for collecting the required road hazard data. The sample site constituted a rural stretch of 86 kilometers, beginning from Kilometer 1481 and ending at Kilometer 1583. This site excluded the 17 kilometers of the urbanized sections of highway passing though the cities of Gujar Khan and Rawalpindi. The first 52 kilometers of the site were two-lane, two-way, while the remaining 34 kilometers were four-lane divided highway. The geographical location of the experimental site, and its diagrammatic magnification are shown in Figure 3.2 and Figure 3.3 respectively.

The selected site had the following intrinsic qualities to the advantage of the experimental plan.

- **Effective Highway Patrol**. The Rawalpindi District includes the city of Rawalpindi - a Divisional Headquarter, and the territories of the Federal Capital, Islamabad. The national importance of Rawalpindi together with the diplomatic significance of Islamabad, has resulted in a reasonably efficient highway patrol system in the District and especially

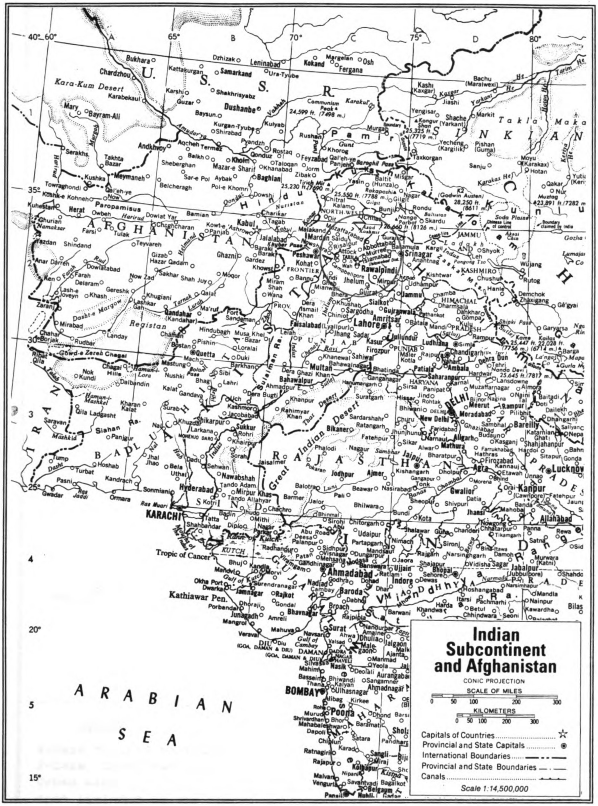
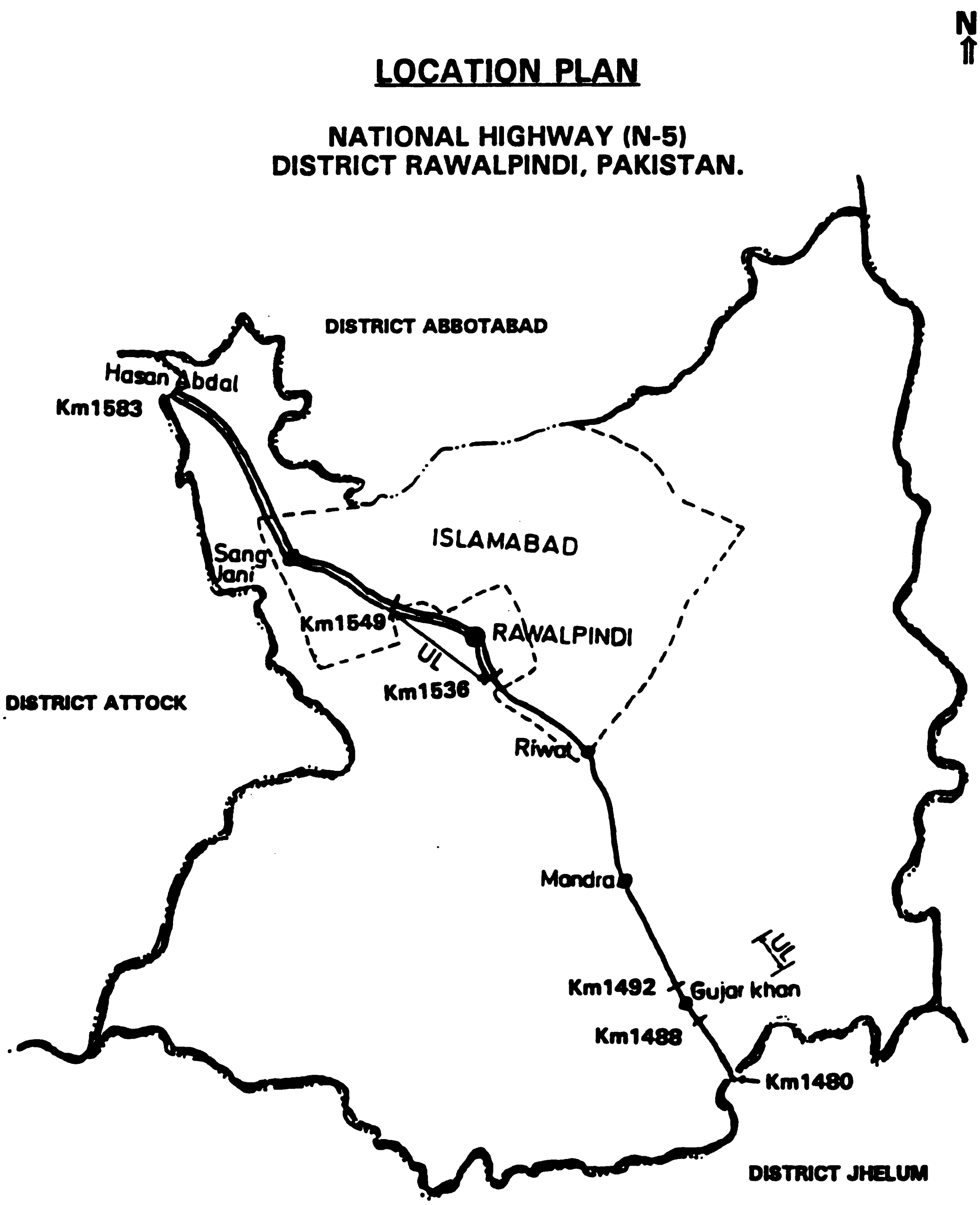


Figure 3.2 The Geographical Location of the Experimental Site (Map Source [70]).



LEGEND

4-Lane Divided Sections	(thick line)
2-Lane, 2-Way Sections	(thin line)
Urban Limits	|<— UL —>|
(not included in the study)	

Figure 3.3 The Magnified Diagram of the Experimental Site.

on N-5. As a result of this proficiency, the accident reporting rate for the test site was more consistent and comprehensive than for less significant areas of the country.

- **Availability of Two Types of Highway Sections**. As mentioned above, the experimental section of N-5 is comprised of both 2-lane and 4-lane divided highways. This distinctive situation provided a site to investigate the hazard-accident relationship characteristics for two basic categories of highway system.

- **Representation of Traffic Mix**. The N-5 is the most important trade and passenger route in the country, and therefore operates a traffic mix representative of both private and commercial vehicles. The study was, therefore, not specific to any single important mode of highway transportation system.

- **Representation of Topography**. The terrain of the experimental site ranged from flat to mild-rolling, and was therefore considered a reasonable representative of the topographic features of many other sections of N-5 and other important arterials in the country.

3.5 EXECUTION OF THE EXPERIMENT

The highway hazard data were collected on the experimental site using the twelve MOH developed for this study. These data were collected during January to March 1990 under the supervision of the author by the technical staff of the National Transport Research Centre (NTRC), Islamabad. The data collection procedures, applicable to the experimental design, were explained to the staff and were demonstrated on site before the start of a particular operation.

A part of the experimental plan also required use of a front seat passenger for recording observations on driving maneuvers to collect data concerning MOH [SPDCHG] and MOH [LANCHG]. A Ford Transit 1989 van with necessary equipment was provided by the NTRC to accomplish the task. The component of subjective rating in the experimental plan was covered by an expert team of two civil engineers having their Masters degree earned in the United States. Both the team-members were the employees of the Centre and had their professional expertise in highway engineering.

A technical report was published by the NTRC based on the data collected on highway hazards [12]. This report only dealt with the description of the hazards that were physically observed at the experimental site (i.e., in terms of their magnitude and frequency of occurrence), and did not address the location's relationship with accidents. Subsequently accident data were extracted from the police records in the required format and are now being used in this dissertation to achieve the objective of the present research.

CHAPTER 4

DATA ANALYSIS

4.1 THE ANALYTICAL APPROACH AND PRESENTATION

The foremost objective of this data analysis was to determine the statistical significance of the presumed relationship between the ambient hazards and accident history of a highway section as represented by the following model.

$$A_f = B_0 + B_1.X_{1i} + B_2.X_{2i} + \ldots\ldots + B_p.X_{pi} + e_i \qquad (4.1)$$

Where,

A_f = Accident frequency on a particular kilometer *i* of the highway section, expressed in #/year.

X_{pi} = The value of the *p*th hazard for the kilometer *i*.

B = Unknown coefficients (parameters) to be determined as the result of regression analysis.

e_i = Independent random variables that were assumed normally distributed with mean 0 and constant variance σ^2.

The proposed model had its genesis in the theoretical perception of accidents as a function of adverse highway features, expressed as following.

$$Accidents = f(adverse\ highway\ features) \tag{4.2}$$

For the present research, a null hypothesis of no relationship was assumed. Primarily, multivariate linear regression analyses were performed to test the hypothesis. Since it was assumed that the adverse highway features would have a direct causal relationship with accidents, the variables having a negative correlation with accidents were considered to violate this assumption and were controlled. Besides negativity, the regression analyses were performed controlling for multi-collinearity since the hazardousness was represented by a variety of independent variables.

The regression analyses, performed with these specifications, resulted in the formulation of mathematical models predicting the accident potential of a highway section in terms of crucial non-accident based variables. These sections (analytical units) had a uniform length of one kilometer each and included the intersections. The analytical unit was not further segregated by the type of location since accident records did not furnish information in terms of intersection and non-intersection accidents that was required for such discrimination. These analyses were primarily made using the Statistical Package for Social Sciences (SPSS), with other supporting software packages used for graphics and spreadsheet computations.

An analytical approach based on the following described eight tasks was developed to accomplish the overall objectives of data analysis. The results of implementing these tasks are contained in Sections 4.2 (page 99) and 4.3 (page 124) for the 2-lane, 2-way and the 4-lane sections respectively.

- **Task 1. Compute Descriptive Statistics**

The descriptive statistics of the variables was comprised of the mean, standard deviation, and minimum and maximum values. This procedure was important in three ways: First, it provided the basic information on the limits and variation of the variables. Second, it served as a confirmatory tool to ascertain flawless transfer of research data brought from Pakistan on micro computer disks to the local operating system. Third, it established the accuracy of the created SPSS system-files in responding to data files.

- **Task 2. Determine Frequency Distribution**

The frequency distribution histograms were displayed to examine the nature of occurrence of hazards and accidents on the experimental site. Though not an ultimate measure, the frequency distributions furnished important logical checks and were one of the criteria used for variable selection in model building.

- **Task 3. Determine Simple Correlations**

These analyses were made to examine the type and the order of any relationship between the dependent and the independent variables. A significant and non-negative relationship provided the necessary rationale to proceed further with the analysis and test the postulate of a hazard-accident relationship. The insignificant and inverse relationships were noted as a point of concern to be considered when selecting the final variables for model building.

Moreover, the correlations also provided information on the inter-relationship between the various independent variables. The prominent interrelated independent variables were further examined with multicollinearity diagnostic tests to decide their importance in model building. The term multicollinearity refers to a situation in which the independent variables are correlated and tend to provide similar or interrelated information. A check on this phenomenon resulted in identifying the statistical appropriateness of candidate variables. The two diagnostic techniques employed were: 1) the eigenvalues analysis; and 2) the variance inflation factor (VIF) method [116]. Their description is covered in the following two tasks.

- **Task 4. Compute Eigenvalues and Condition Indices**

To examine the collinearity between the independent variables, the eigenvalues of the scaled uncentered cross-products matrix, and decomposition of regression variance corresponding to these eigenvalues were computed. There is an evidence of near dependency of variables when there is a high proportion of the variance of two or more coefficients associated with the same eigenvalue [116,117]. The condition index is defined as:

$$\text{Cond. Index}_i = [\text{eigenvalue}_{max} \,/\, \text{eigenvalue}_i]^{0.5} \qquad (4.3)$$

The presence of near-linear dependencies results in small eigenvalues and, consequently, larger condition indices. In these computations, the number of large condition indices is the determinant of the near-dependent number of cases.

- **Task 5. Compute Variable Tolerance and Variance Inflation Factor (VIF)**

The literature [116] indicated that the tolerance of a variable was another commonly used measure of collinearity. The tolerance of a variable is defined as:

$$\text{Tolerance (TOL)} = (1-R_i^2) \qquad (4.4)$$

where R_i is the multiple correlation coefficient of the *i*th independent variable when it is predicted from other independent variables. The variance inflation factor (VIF) is the reciprocal of the tolerance and, therefore, for the *i*th independent variable, it can be expressed as:

$$VIF = [1 / (1-R_i^2)] \quad (4.5)$$

The extended capabilities of SPSS regression routine produced computations for the eigenvalues, condition indices, TOL and VIF values. These computations displayed the required statistical characteristics of the variables and provided a logical check on their appropriateness for model building.

- **Task 6. <u>Perform Regression Analysis and Select Crucial Variables</u>**

The process of BACKWARD ELIMINATION in the SPSS regression analysis routine was used for retaining the significant variables. This process starts with all the entered variables of the prospective multivariate model and sequentially removes them. Two removal criteria are employed: 1) the minimum F value (FOUT) that a variable must have in order to remain in the equation; and 2) the maximum F value (POUT) a variable can have.

All the independent variables were initially entered into this process for the final selection. The system default values of 2.71 for (FOUT), and 0.10 for (POUT) respectively, were adopted in the analysis for the two removal criteria.

Besides the BACKWARD ELIMINATION, the other two available procedure: the FORWARD and the STEPWISE, were additionally employed to authenticate the entire process of regression analysis. The former procedure employed entry of one variable at a time, while the later examined each variable for entry or removal at each step.

- **Task 7. Compare Accident Frequency Versus Rate as the Dependent Variable**

The accident data were primarily used as frequencies. However, a noticeable variation in traffic volume was reported [118] for different sections of the experimental site. As such, accident rates were taken into account and the effect of operating volume on the hazard-accident relationship was investigated in developing the final predictive models.

- **Task 8. Construct the Final Accident Prediction Models and Test the Hypotheses**

This task was comprised of constructing two separate multivariate models for predicting the accident potential of a highway section, corresponding to the two types of highway section studied. The choice of variables was essentially based on the outcome of the first seven tasks, which provided a logical check for variable selection. In this final task, the null hypotheses of no relationship between the quantified hazardousness and the accident history of highway sections were tested. Explicit inferences about the acceptance or rejection of hypothesis were made employing the statistics of the final accident prediction models. The analysis of residuals and comparison of predicted accidents to actual were covered in this task.

In addition to accident modeling using regression analysis techniques, a hazard index (HI) was also developed for the identification and ranking of hazardous locations. The developed HI, based on an adequacy rating concept, represented the composite hazardousness of an analytical unit. The competence of HI approach was shown by the studies [101-104] indicating that composite hazardousness rating could provide a reasonably accurate prediction of future accident experience. A detailed description of the HI approach is covered in the literature review, and its application in the development of indices for this study is presented in Section 4.5. The SPSS program to accomplish the entire analytical approach is presented in Appendix E.

The data analysis and the results, based on the above described eight tasks, are separately presented for the two types of highway sections studied: two-lane, two-way; and four-lane divided highway sections. In the following pages, this analytical approach is virtually replicated for the two highway types.

4.2 DATA ANALYSIS FOR TWO-LANE, TWO-WAY SECTIONS

4.2.1 Descriptive Statistics

The descriptive statistics of variables indicated that data for the entire 52 kilometers were processed and there were no missing values. A summary of the descriptive statistics of the variables employed in the study is presented in Table 4.1.

A list of 13 variables is exhibited in Table 4.1. The first ten are the independent variables developed for accident modeling. The details of development of these variables are presented in Section 3.2.2 (page 73). These candidate variables were further screened based on the criteria of variability; non-negativity; independency; and repressibility for employment in the model.

Item 11 in Table 4.1, the [ACCFRQ], represents the three year period accident data. The [ANACFQ], i.e., item 12, is the average annual accident frequency based on [ACCFRQ]. Primarily, the [ANACFQ] was used as the dependent variable in predictive modeling. Item 13, the [ANACRT], represents the annual accident rate, computed to account for the reported variation of traffic volume in different segments of the experimental site. A detailed description of the effect of traffic volume variation on accidents, and using [ANACRT] as the dependent variable, is presented in Section 4.2.7 (page 114).

Table 4.1 Descriptive Statistics of Variables.

No.	Variable	Mean	Std Dev	Min	Max	N	Label
1.	[RIBBON]	490.79	466.33	0.00	1622.00	52	RIBBON DEVELOPMENT
2.	[SPATHS]	15.79	8.87	0.00	39.00	52	SPECIFIC LATERAL PATHS
3.	[GDRAIL]	246.60	260.85	0.00	1092.00	52	DEFICIENT GUARDRAIL SECTIONS
4.	[PWIDTH]	0.27	0.74	0.00	4.84	52	DEFICIENT PAVEMENT WIDTH
5.	[SWIDTH]	0.84	0.82	0.00	3.00	52	DEFICIENT SHOULDER WIDTH
6.	[PMARKS]	2.05	.14	2.00	2.62	52	DEFICIENT PAVEMENT MARKINGS
7.	[INTSEC]	2.00	6.27	0.00	26.14	52	INTERSECTION DEFICIENCIES
8.	[ISLAND]	0.52	1.20	0.00	7.00	52	ISOLATED LANE DEFICIENCIES
9.	[PVCOND]	44.43	9.01	23.50	62.00	52	PAVEMENT CONDITION RATING
10.	[SIDEOB]	14.52	11.92	0.00	46.50	52	ROADSIDE OBSTRUCTIONS
11.	[ACCFRQ]	5.29	5.00	0.00	21.00	52	ACCIDENT FREQUENCY
12.	[ANACFQ]	1.76	1.67	0.00	7.00	52	ANNUAL ACCIDENT FREQUENCY
13.	[ANACRT]	1.51	1.43	0.00	5.72	52	ANNUAL ACCIDENT RATE

4.2.2 Frequency Distribution

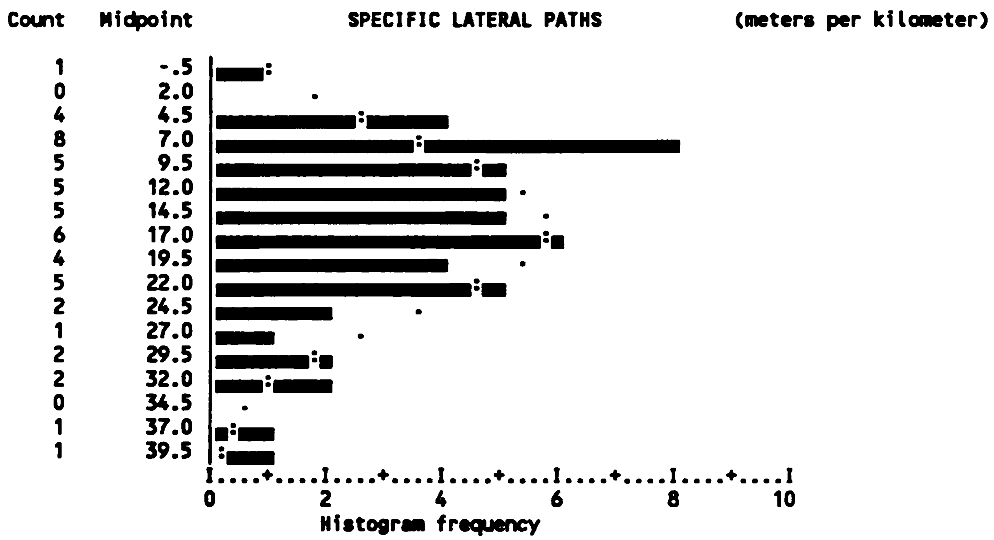
An investigation of the frequency distribution of the studied hazards and accidents was considered important to gain some insight on their characteristics. The frequency distribution histograms of the hazards and accidents are presented in Figures 4.1 through 4.11.

Percentile : Value = 15.0 : 0.00, 85.0 : 992.10

Figure 4.1
Frequency Distribution of Variable [RIBBON] - RIBBON DEVELOPMENT.

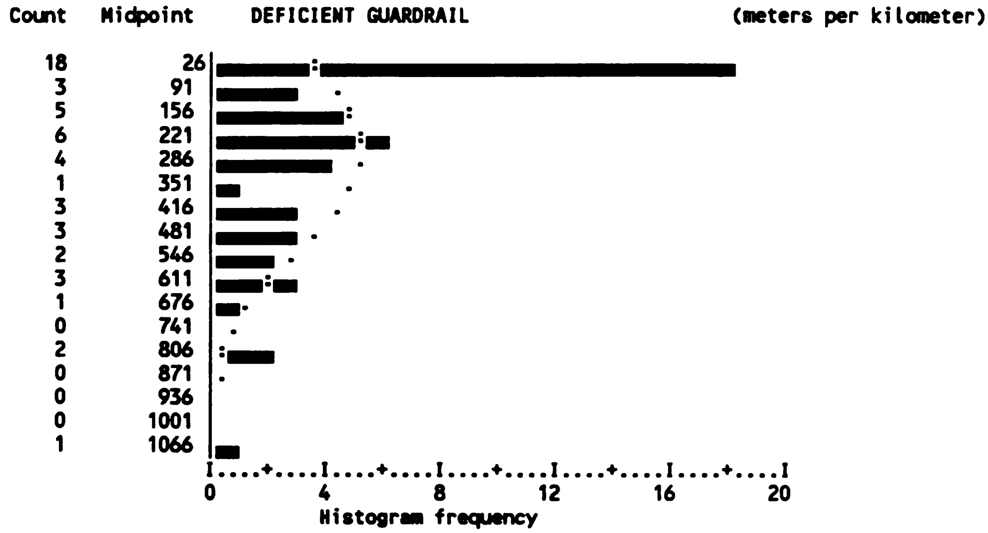
In these frequency histograms, the "count" column represents the number of kilometers. Their sum always equals 52, representing the total length of the 2-lane, 2-way test section. The "midpoint" column represents a scaled axis for the histograms, and is divided into equidistant intercepts based on the minimum and the maximum value of the variable.

For example, in Figure 4.1 for variable [RIBBON], the first reading (14) in the "count" column signifies the number of kilometers having a midpoint value of the hazard as 43 units per kilometer. This vertical axis is divided into equidistant intercepts of 96 units each to cover the minimum-maximum range of 0 to 1622 of the variable value.



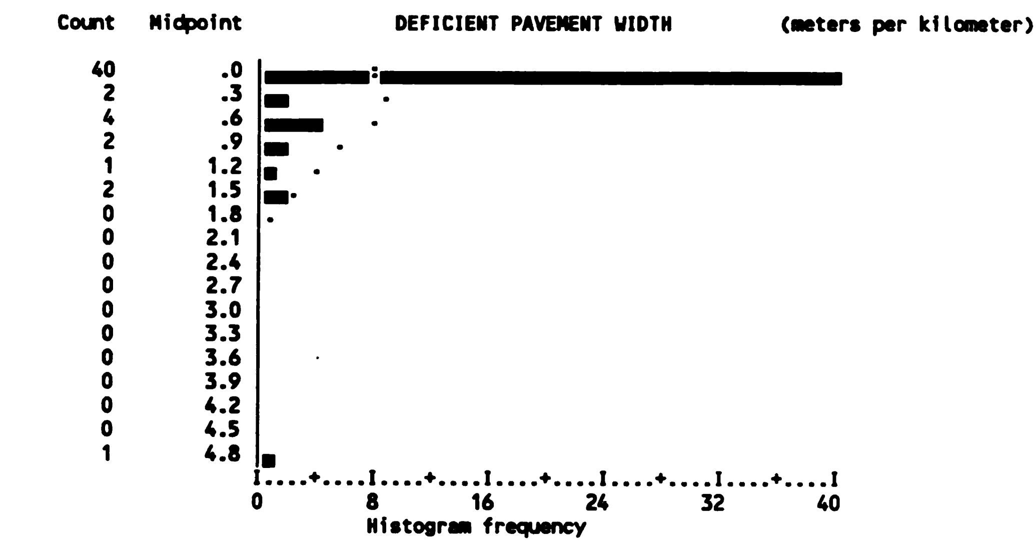
Percentile : Value = 15.0 : 7.00, 85.0 : 25.10

Figure 4.2
Frequency Distribution of Variable [SPATHS] - SPECIFIC LATERAL PATHS.



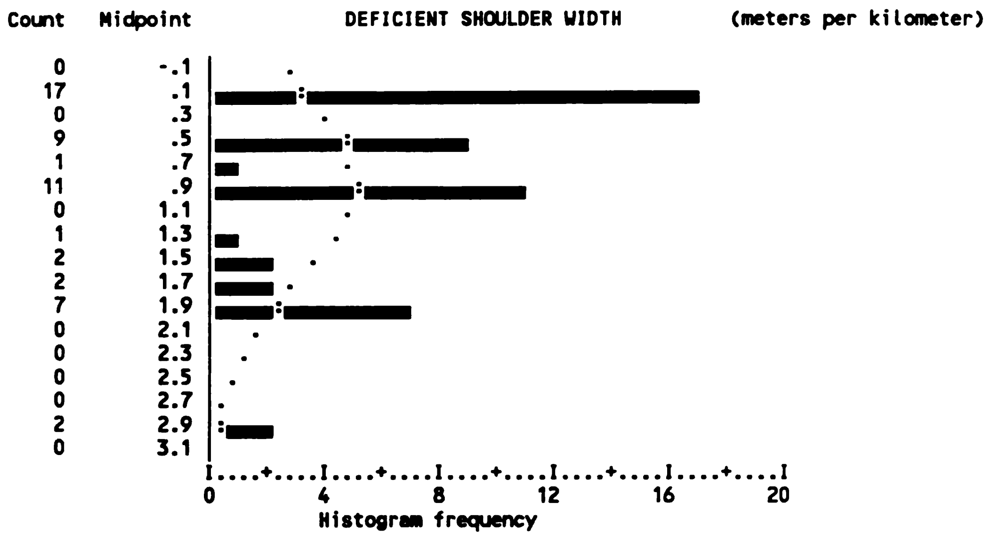
Percentile : Value = 15.0 : 0.00, 85.0 : 546.85

Figure 4.3
Frequency Distribution of Variable [GDRAIL] - DEFICIENT GUARDRAIL.



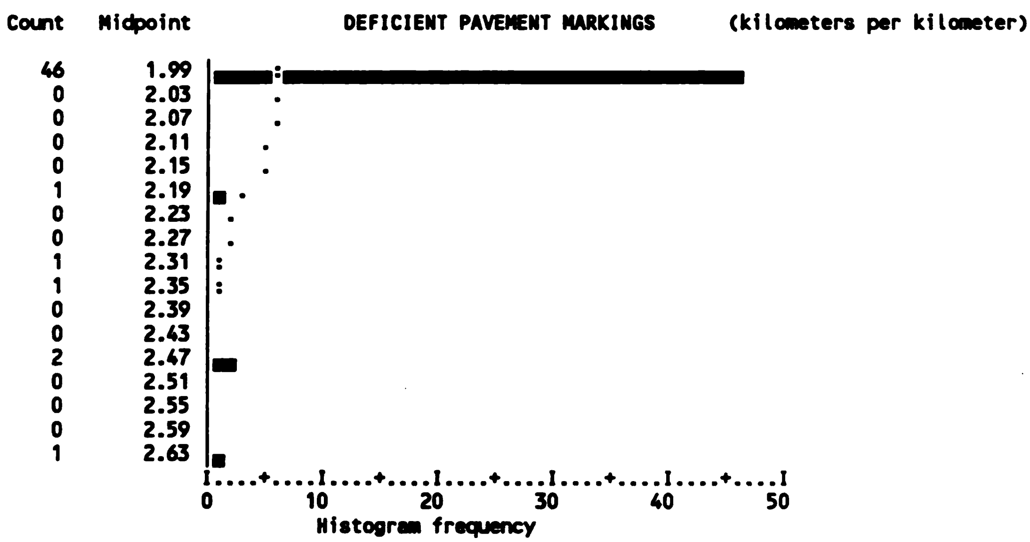
Percentile : Value = 15.00 : 0.00, 85.00 : 0.49

Figure 4.4
Frequency Distribution of Variable [PWIDTH] - DEFICIENT PAVEMENT WIDTH.



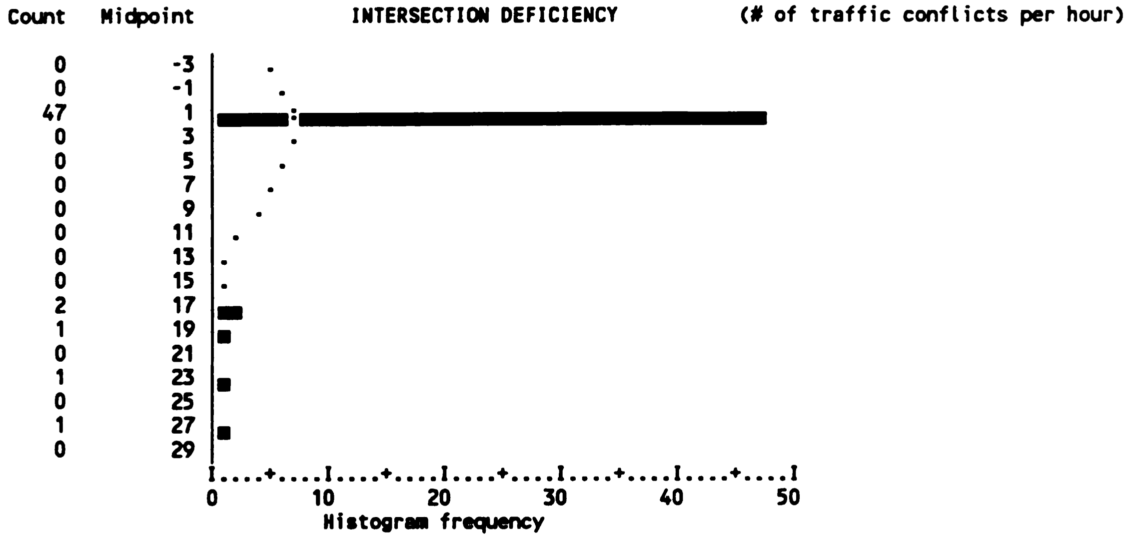
Percentile : Value = 15.00 : 0.00, 85.00 : 2.00

Figure 4.5
Frequency Distribution of Variable [SWIDTH] - DEFICIENT SHOULDER WIDTH.



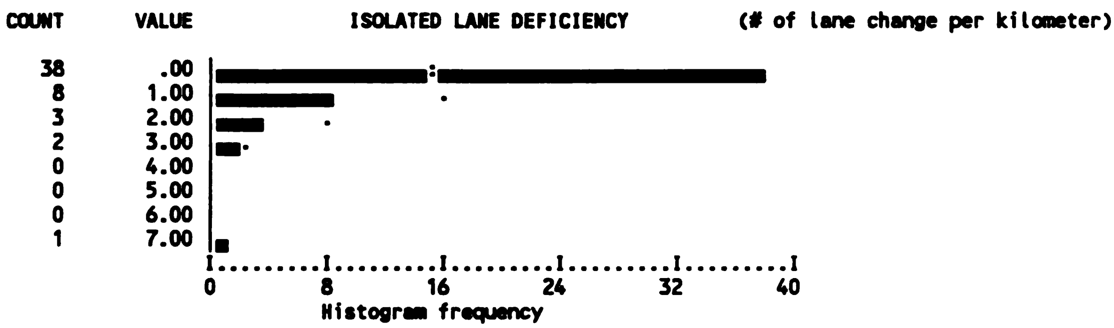
Percentile : Value = 15.00 : 2.00, 85.00 : 2.00

Figure 4.6
Frequency Distribution of Variable [PMARKS] - DEFICIENT PAVEMENT MARKINGS.



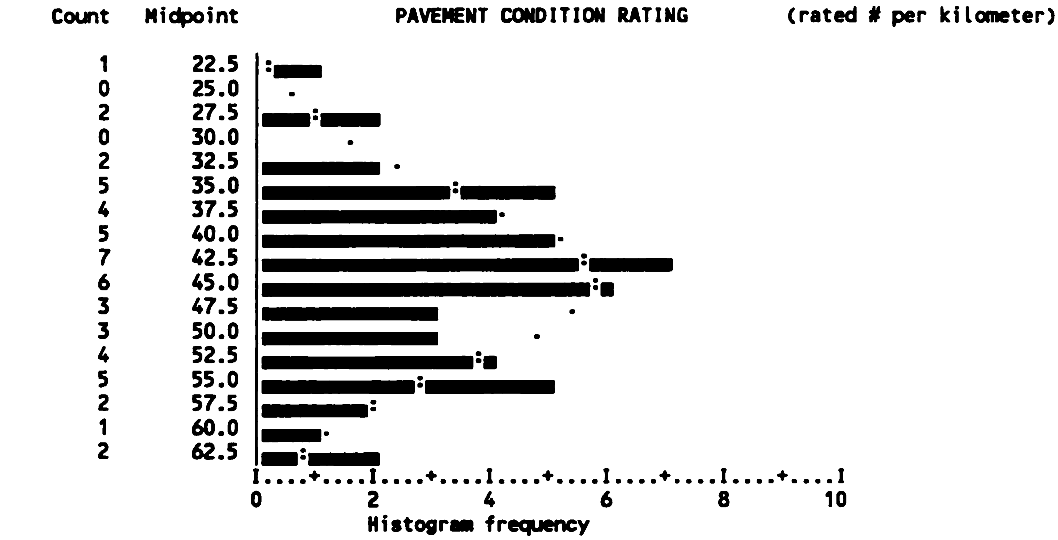
Percentile : Value = 15.00 : 0.00, 85.00 = 0.00

Figure 4.7
Frequency Distribution of Variable [INTSEC] - INTERSECTION DEFICIENCY.



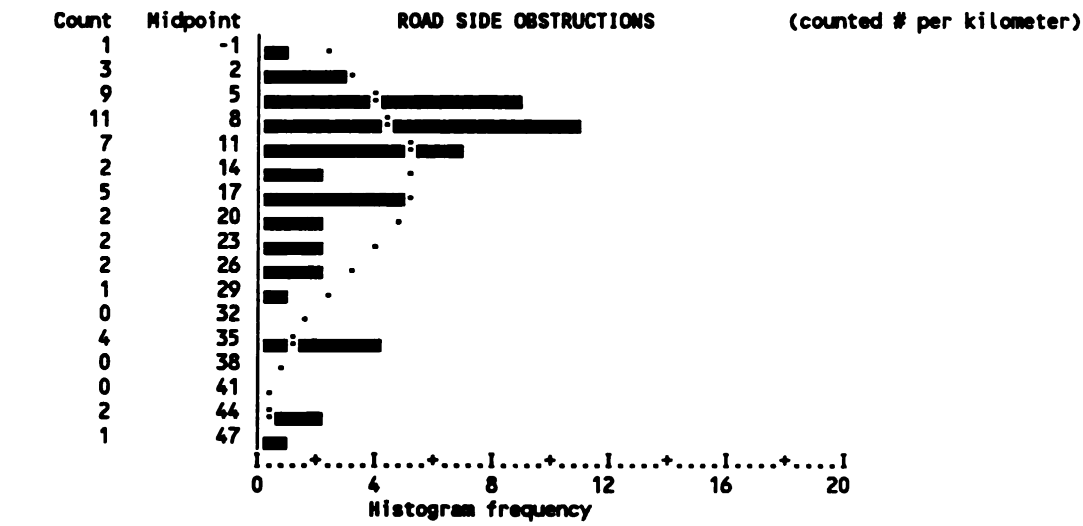
Percentile : Value = 15.00 : 0.00, 85.00 : 1.00

Figure 4.8
Frequency Distribution of Variable [ISLAND] - ISOLATED LANE DEFICIENCY.



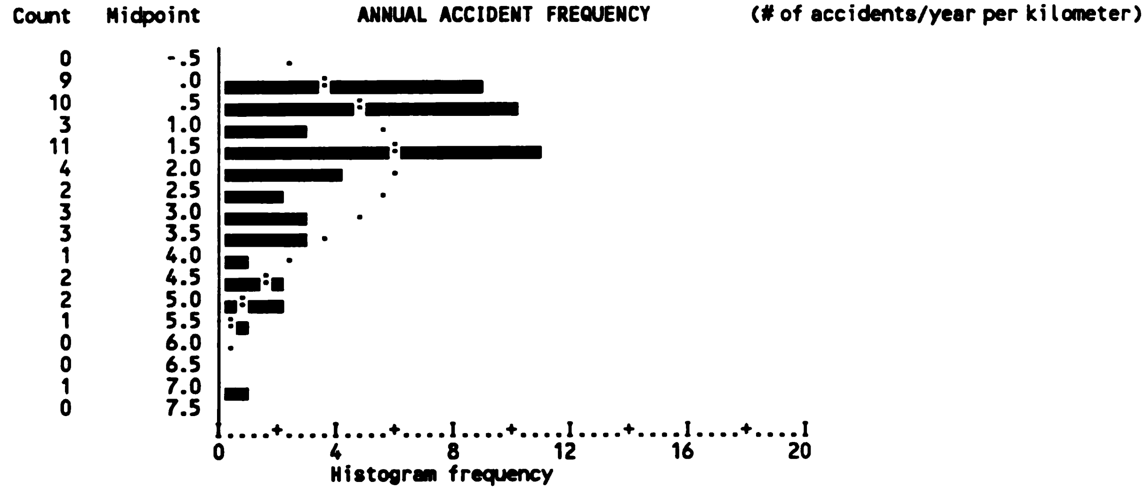
Percentile : Value = 15.00 : 34.950, 85.00 : 54.50

Figure 4.9
Frequency Distribution of Variable [PVCOND] - PAVEMENT CONDITION RATING.



Percentile : Value = 15.00 : 4.975, 85.00 : 30.175

Figure 4.10
Frequency Distribution of Variable [SIDEOB] - ROAD SIDE OBSTRUCTIONS.



Percentile : Value = 15.00 : 0.00, 85.00 : 3.683.

Figure 4.11
Frequency Distribution of [ANACFQ] - ANNUAL ACCIDENT FREQUENCY.

The frequency distribution of the independent variables, [PWIDTH], [PMARKS] and [ISLAND] showed that the hazards represented by them were neither very frequently occurring nor had a noticeable variance. This point, though not totally decisive, was of interest for variable retention in the final predictive model. The interpretation of the frequency distribution histogram for variable [INTSEC] required caution in the sense that the output was only for the five intersections of the experimental site. These were isolated spots and were not distributed in 52 kilometers of the test section like the other hazards.

4.2.3 Simple Correlations

The correlation matrix showing the characteristics of the relationship between the variables is presented in Table 4.2.

Table 4.2 The Correlation Matrix.

	[RIBBON]	[SPATHS]	[GDRAIL]	[PWIDTH]	[SWIDTH]	[PMARKS]	[INTSEC]	[ISLAND]	[PVCOND]	[SIDEOB]	[ANACFQ]
[RIBBON]	1.0000**										
[SPATHS]	.1879	1.0000**									
[GDRAIL]	-.2842	.1984	1.0000**								
[PWIDTH]	-.0163	-.2245	-.0011	1.0000**							
[SWIDTH]	.2000	-.2463	-.1291	.4111*	1.0000**						
[PMARKS]	.1373	.0202	-.1775	.0912	.2829	1.0000**					
[INTSEC]	.1352	-.0442	-.2027	.0141	.1342	.8443**	1.0000**				
[ISLAND]	-.1780	.0438	-.2375	-.0510	-.1551	-.1255	-.0897	1.0000**			
[PVCOND]	-.0638	-.2432	-.0240	-.1335	-.2328	-.2235	-.1329	.1024	1.0000**		
[SIDEOB]	.1355	-.1557	-.0977	-.0202	.0604	.0883	.0362	.2729	-.0461	1.0000**	
[ANACFQ]	.4365**	.2398	.2682	-.1080	-.0379	-.0959	-.0718	-.1501	.0997	.0669	1.0000**

N of cases: 52 1-tailed Signif: * - .01 ** - .001

The correlation matrix indicated the variables [PWIDTH], [SWIDTH], [PMARKS], [INTSEC] and [ISLAND] had a negative relationship with accidents. This counter-intuitive effect was noted as a point of concern while selecting final variables for model building. The decision about the retention of these variables was further subjected to various diagnostic tests for checking multicollinearity, and multiple procedures for performing regression analysis.

4.2.4 Eigenvalues and Condition Indices

The computed eigenvalues and the condition indices are shown in Table 4.3. Each column of the table, after the condition index, indicates the proportion of the variance of each of the coefficients associated with each of the eigenvalues. For example, for the [RIBBON] coefficient, 0.464% of the variance of the coefficient is attributable to the first eigenvalue.

In this table, the variables with high proportions of variance for the smallest eigenvalue are highly dependent. The number of suspect collinear variables is indicated by the number of higher-valued condition indices. In other words, there are as many near dependencies among the variables as there are large condition indices [116].

Referring to Table 4.3, the last eigenvalue i.e., 0.00052 (at serial number 11) is the smallest, and accounts for 98.553%

Table 4.3 Collinearity Diagnostics: Eigenvalues and Condition Indices.

Number	Eigen-values	Condition Index	Variance Proportions										
			Constant	RIBBON	SPATHS	GDRAIL	PWIDTH	SWIDTH	PMARKS	INTSEC	ISLAND	PVCOND	SIDEOB
1	6.45264	1.000	.00002	.00464	.00269	.00425	.00279	.00434	.00002	.00071	.00254	.00068	.00508
2	1.10599	2.415	.00000	.00444	.00403	.00486	.18144	.03520	.00000	.04275	.15133	.00027	.00563
3	.95685	2.597	.00000	.01001	.00001	.05904	.15681	.00333	.00000	.13141	.02212	.00002	.00365
4	.90277	2.674	.00000	.00604	.00699	.06482	.19651	.00739	.00000	.00041	.30271	.00011	.00943
5	.57616	3.347	.00000	.22213	.00011	.16467	.03266	.02466	.00000	.08814	.02943	.00002	.00790
6	.35721	4.250	.00000	.06678	.08772	.02190	.12005	.08461	.00000	.00038	.05049	.00013	.42984
7	.29889	4.646	.00002	.08314	.00000	.00524	.27775	.51823	.00002	.00202	.04143	.00047	.25769
8	.19812	5.707	.00060	.22376	.01684	.43375	.00472	.10208	.00052	.00870	.22161	.03734	.00101
9	.13385	6.943	.00003	.34312	.57808	.23149	.00839	.03217	.00001	.00209	.14480	.02302	.19338
10	.01700	19.484	.01360	.01964	.27532	.00039	.01738	.12457	.01389	.02877	.01660	.91232	.06607
11	.00052	111.186	.98571	.01631	.02821	.00958	.00152	.06343	.98553	.69461	.01693	.02561	.02031

and 69.461% of the variance of [PMARKS] and [INTSEC]. This implies that these two variables are inter-dependent. Since other independent variables have small variance proportions for the 11th eigenvalue, they do not seem to have multicollinearity. There are two condition indices (at serial 10 and 11) with magnitude (19.484 and 111.186) significantly higher than the rest. This indicates two suspect cases of collinear variables. Both [PMARKS] and [INTSEC] were also indicated for filtering out of the equation, based on non-negativity of the simple correlation criteria.

4.2.5 Variable Tolerance (TOL) and Variance Inflation Factor (VIF)

The second diagnostic test of multicollinearity involved computing variable tolerance and variance inflation factors. These statistics are produced in Table 4.4.

Table 4.4 Collinearity Diagnostics: TOL and VIF.

Variable	Tolerance	VIF
[SIDEOB]	.787332	1.270
[PWIDTH]	.790045	1.266
[INTSEC]	.256323	3.901>>
[RIBBON]	.675306	1.481
[PVCOND]	.799510	1.251
[GDRAIL]	.705304	1.418
[ISLAND]	.702357	1.424
[SWIDTH]	.627266	1.594
[SPATHS]	.613606	1.630
[PMARKS]	.234617	4.262>>

>> High VIF.

In Table 4.4, high VIF values for [INTSEC] and [PMARKS] indicate that the two independent variables are collinear, and substantiate the previous findings based on the eigensystem diagnostic test.

4.2.6 Regression Analysis and the Crucial Variables

All the ten variables were entered in to the process of BACKWARD ELIMINATION for regression analysis. This process was employed to observe the removal order of variables. The observed elimination sequence (in the order of variable significance based on a POUT = 0.100 criteria) is summarized in Table 4.5.

Table 4.5 The Variable Removal Order by Backward Elimination.

Step #	Variable Removed	T	Sig T
1.	[SWIDTH]	-.842	.4040
2.	[ISLAND]	.467	.6427
3.	[INTSEC]	-.540	.5920
4.	[PWIDTH]	-.858	.3953
5.	[SIDEOB]	.289	.7741
6.	[PMARKS]	-.860	.3938
7.	[SPATHS]	.461	.6467
8.	[PVCOND]	1.283	.2056

Consequently, [RIBBON] and [GDRAIL] were retained as the two most significant variables. The FORWARD and the STEPWISE methods also indicated [RIBBON] and [GDRAIL] as the two most significant variables for equation building. The significance of T-statistics of the filtered out variables indicated that any additional variable could not be selected even by relaxing the adopted limit of POUT. The output results of the regression analysis are presented in Table 4.6.

Table 4.6 The Statistical Results of Regression Analysis.

Multiple R	.59827
R Square	.35792
Adjusted R Square	.33172
Standard Error	1.36230

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	50.69269	25.34635
Residual	49	90.93765	1.85587

F = 13.65739 Signif F = .0000

Dependent Variable. [ANACFQ] ANNUAL ACCIDENT FREQUENCY

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
RIBBON	.001993	4.26663E-04	.557777	4.672	.0000
GDRAIL	.002726	7.62760E-04	.426730	3.574	.0008
(Constant)	.112287	.370548		.303	.7631

The indicated appropriateness of selecting independent variables, based on the different criteria employed in the study, is summarized in Table 4.7.

Table 4.7 Indicated Appropriateness of Independent Variables.

No.	Variable	VARIABLE SELECTION CRITERIA			
		FD	NN	MC	RG
1.	[RIBBON]	+	+	+	+
2.	[SPATHS]	+	+	+	-
3.	[GDRAIL]	+	+	+	+
4.	[PWIDTH]	-	-	+	-
5.	[SWIDTH]	+	-	+	-
6.	[PMARKS]	-	-	-	-
7.	[INTSEC]	+	-	-	-
8.	[ISLAND]	-	-	+	-
9.	[PVCOND]	+	+	+	-
10.	[SIDEOB]	+	+	+	-

Symbols
\+ = Variable indicated for inclusion in the predictive model.
\- = Variable not indicated for inclusion in the predictive model.

Abbreviations
FD = Frequency distribution.
NN = Non-negativity.
MC = Multicollinearity.
RG = Regression.

Table 4.7 shows that, based on all four criteria of variable selection, the most appropriate indicated variables for employing in the model were [RIBBON] and [GDRAIL].

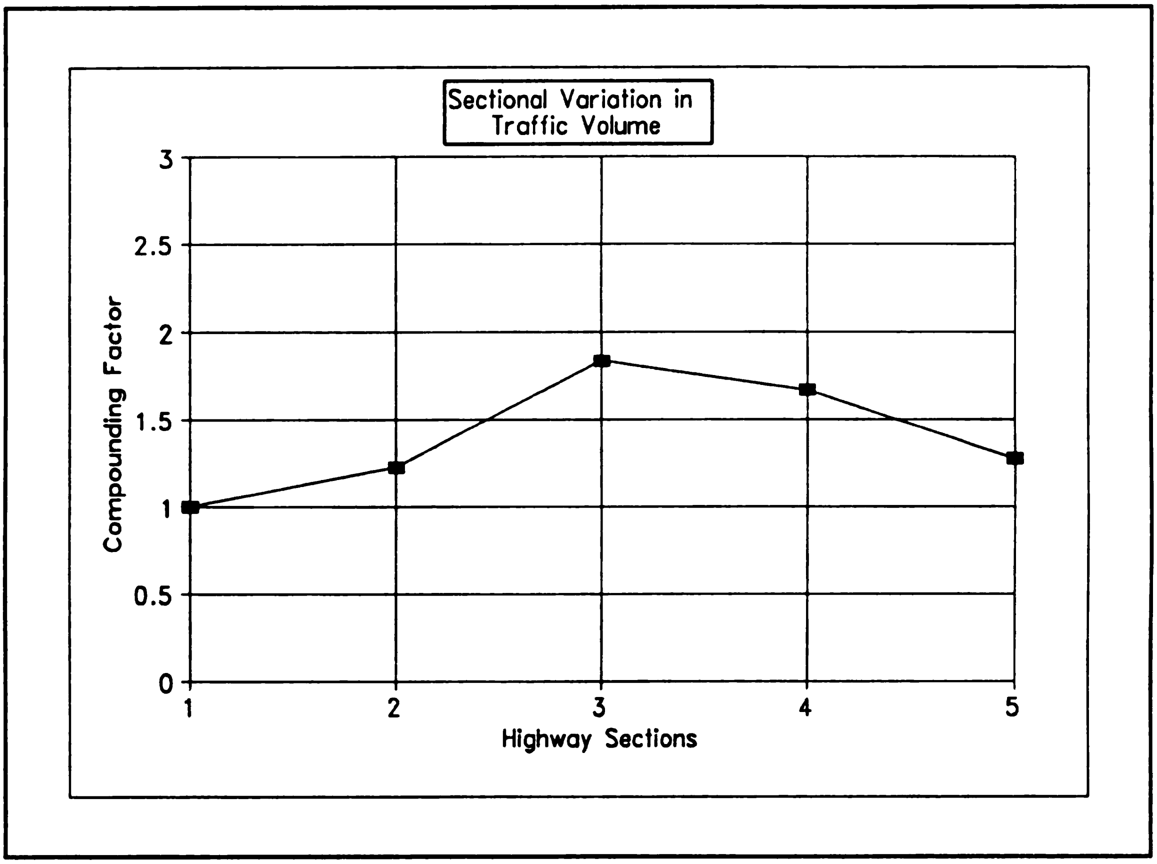
4.2.7 Accident Frequency Versus Rate as the Dependent Variable

A noticeable variation in the operating traffic volumes was reported [118] for the experimental sites. To incorporate the effect of traffic volume variation, accident rates for the various sections of the experimental sites were calculated. The average annual traffic volume for the entry section (i.e., Gujar Khan - Mandra section, Kilometer (1480 - 1502) was taken as the base value to discount the remaining sections. The reported variation and the calculated discounting factors are shown in Table 4.8.

Table 4.8 Reported Variation in Traffic Volumes.

No.	Section	Year 1988	1989	1990	Mean	Discounting Factor (mean/8656)
		<-----	ADT	----->		
1.	Gujar Khan - Mandra	8146	8739	9083	8656	1.00
2.	Mandra - Rawalpindi	9470	10332	11982	10595	1.22
3.	Rawalpindi - Tarnol	15654	15882	16103	15880	1.83
4.	Tarnol - Taxila	12366	15355	15616	14446	1.67
5.	Taxila - Wah	10635	11072	11415	11041	1.27

The compounding effect of the traffic volume variation on the experimental site is shown in Figure 4.12. The peak represents the increased traffic flow in the suburbs of Rawalpindi and Islamabad.



2-Lane, 2-Way Highway
Section 1 = Gujar Khan - Mandra.
Section 2 = Mandra - Rawalpindi.

4-Lane Divided Highway
Section 3 = Rawalpindi - Tarnol.
Section 4 = Tarnol - Taxila.
Section 5 = Taxila - Wah.

Figure 4.12
The Compounding Effect of Traffic Volume Variation.

The correlation of the variables with the two versions of accident data (i.e., frequency and rate), was also examined. This exercise was considered appropriate to explore the possibility of having an incremental gain in the predictive model's statistics by incorporating the reported variation in traffic volume.

For this purpose, Annual Accident Frequency [ANACFQ] and Annual Accident Rate [ANACRT] were used as the two dependent variables. The correlation between the two versions of accident data and the variables indicated a nominal difference in the coefficients as shown in Table 4.9.

Table 4.9 Correlation of Indicated Variables with Accident Frequency and Rates.

Variables	[ANACFQ]	[ANACRT]
[RIBBON]	.4365**	.4144*
[SPATHS]	.2398	.2451
[GDRAIL]	.2682	.3151
[PWIDTH]	-.1080	-.0982
[SWIDTH]	-.0379	-.0535
[PMARKS]	-.0959	-.1086
[INTSEC]	-.0718	-.0846
[ISLAND]	-.1501	-.1421
[PVCOND]	.0997	.0816
[SIDEOB]	.0669	.0705

1-tailed Signif: * - .01 ** - .001

The comparison presented in Table 4.9 indicates a very nominal difference between the coefficients of correlation of the variables. Moreover, model development using [ANACFQ] and [ANACRT] as two separate dependent variables showed a gain of only 1.77% in the value of R^2 for the "rate" format as compared to "frequency" (i.e., R^2 for [ANACFQ] was 0.35792 versus 0.37564 for [ANACRT]). Since there were no strong reasons to switch, the [ANACFQ] was retained as the dependent variable of the predictive model. This selection also seemed justified from a practical standpoint considering that computation of accident rate required additional information on traffic counts.

4.2.8 Final Accident Prediction Model and Test of Hypotheses

The equation which finally emerged from the regression analysis for predicting accident potential of a 2-lane, 2-way section provided the following relationship between the accident frequency and the hazardousness.

$$Y_{(f)} = 0.112287 + 0.001993\ x_1 + 0.002726\ x_2 \qquad (4.6)$$

where,

$Y_{(f)}$ = Accident frequency per year per kilometer.
x_1 = Length of ribbon development on both sides (meters).
x_2 = Length of highway section with deficient guardrail (meters).

The presence of variable [RIBBON] (i.e., x_1) in the equation indicates that deficient control of access is related to accidents in Pakistan. This finding is supported by the results of many studies [e.g.,95,98,99] reporting that control of access was a significant factor associated with accidents, both in the motorized and motorizing countries.

Based on the following statistics of the predictive model

R	=	0.59827
R^2	=	0.35792
$R^2_{(Adj)}$	=	0.33172
F	=	13.65739
$F_{(Sig)}$	=	0.0000

Variable	T	Sig T
x1	4.672	0.0000
x2	3.574	0.0008

the null hypothesis of no linear relationship between the ambient hazardousness and accidents was rejected, and it was concluded that at a probability of F=0.00, 35.79% of the variation in accidents was explained by two types of identified hazards:

1) Deficient control of access; and

2) Deficient provision of guardrail.

4.2.8.1 Analysis of Residual and Predicted Values

The following four statistics for examining the residuals and predicted values were calculated.

1. PRED Unstandardized predicted values.
2. RESID Unstandardized residuals.
3. ZPRED Standardized predicted values.
4. ZRESID Standardized residuals.

These statistics are presented in Table 4.10.

Table 4.10 Statistics for the Residuals and Predicted Values.

	Min	Max	Mean	Std Dev	N
*PRED	.1123	3.7719	1.7628	.9970	52
*RESID	-2.8610	3.2281	.0000	1.3353	52
*ZPRED	-1.6555	2.0152	.0000	1.0000	52
*ZRESID	-2.1001	2.3696	.0000	.9802	52

Durbin-Watson Test = 1.92816

The Durbin-Watson statistic is a measure of auto-correlation in the residuals. Regression analysis assumes that the residuals are not auto-correlated, in which case the Durbin-Watson test should have a value near 2.00 [116]. The indicated value of 1.92816 for the constructed model signifies a satisfactory non auto-correlation between the residuals.

Residual Outliers

The SPSS system default produces the ten worst outlier cases based on absolute values of the residuals and the standardized residuals. The information on outliers presented in Table 4.11 reveal that the model is good enough to predict accidents by a maximum error of $\pm$ 2 (taken as a discrete rounded value for accidents), with two exceptions.

Table 4.11 Outlier - Standardized Residual.

Case #	Km	*RESID	*ZRESID
22	1506	3.22809	2.36958
52	1536	-2.86098	-2.10010
7	1487	-2.39181	-1.75571
25	1509	2.22977	1.63677
26	1510	2.16272	1.58755
20	1504	2.14652	1.57566
51	1535	-2.10017	-1.54163
47	1531	1.98800	1.45929
21	1505	-1.96217	-1.44034
4	1484	-1.91629	-1.40666

Residual Normality

The histogram for the standardized residuals is presented in Figure 4.13. This histogram depicts the observed number of residuals (labeled "N"), and the number expected (labeled "Exp N") in each interval. The extreme intervals (labeled "Out") contain more than 3.16 standard deviations from the mean. The expected frequencies and the overlap between expected and observed are indicated by a period and a colon respectively. In the histogram presented in Figure 4.13, the distribution seems to be fairly normal except for a mild clustering of residuals at the center.

```
 N Exp N       (* = 1 Cases,     . : = Normal Curve)

 0   .04   Out
 0   .08  3.00
 0   .20  2.67
 1   .46  2.33 *
 0   .95  2.00 .
 3  1.74  1.67 *:*
 5  2.85  1.33 **:**
 2  4.19  1.00 ** .
 3  5.52   .67 ***  .
 8  6.51   .33 ******:*
 4  6.88   .00 ****  .
10  6.51  -.33 ******:***
 6  5.52  -.67 *****:
 5  4.19 -1.00 ***:*
 2  2.85 -1.33 **.
 2  1.74 -1.67 *:
 1   .95 -2.00 :
 0   .46 -2.33
 0   .20 -2.67
 0   .08 -3.00
 0   .04   Out
```

Figure 4.13
Histogram - Standardized Residual.

Predicted Values

The normal probability plot in Figure 4.14 presents a comparison of the probability of the observed and the predicted values. The cumulative distributions of the two entities were plotted against each other and examined for deviation from the expected straight line. If the two distributions are identical (the zero-error case), a straight line should result. By observing the scatter of the predicted points about the expected straight line, it may be inferred that the probability of having the predicted values from the developed model will be reasonably close to the actual values.

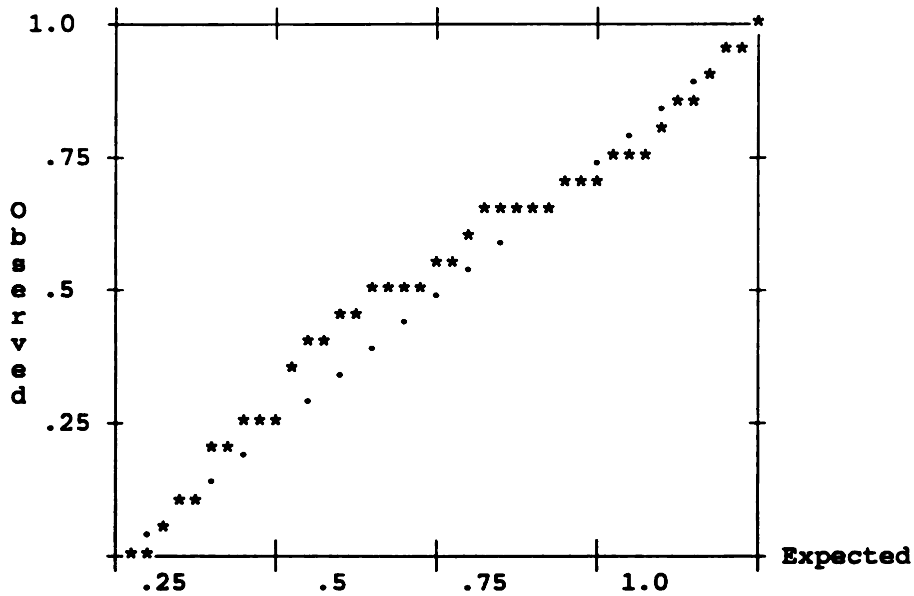


Figure 4.14
Normal Probability (P-P) Plot - Predicted Values.

For a kilometer-wise prediction evaluation, a spreadsheet implementation of the model is presented in Table 4.12. The resulting deviations of the predicted accidents from the actual are shown in Figure 4.15.

Table 4.12 Spreadsheet Implementation of Accident Predictive Model (2-Lane, 2-Way Section).

Km.#	Variables x_1	x_2	Acc Frequency 3-Yrs	Annual	Constant	x_1* (0.001993)	x_2* (0.002726)	Predicted Accidents	Difference
1481	901	545	6	2.00	.112287	1.795693	1.48567	3.39	-1.39365
1482	0	180	1	.33	.112287	0	.49068	.60	-.269634
1483	0	500	0	.00	.112287	0	1.363	1.48	-1.47529
1484	0	784	1	.33	.112287	0	2.137184	2.25	-1.91614
1485	0	412	1	.33	.112287	0	1.123112	1.24	-.902066
1486	570	670	13	4.33	.112287	1.13601	1.82642	3.07	1.258616
1487	319	1092	4	1.33	.112287	.635767	2.976792	3.72	-2.39151
1488	980	150	10	3.33	.112287	1.95314	.4089	2.47	.8590063
1493	142	822	13	4.33	.112287	.283006	2.240772	2.64	1.697268
1494	214	602	5	1.67	.112287	.426502	1.641052	2.18	-.513174
1495	0	0	2	.67	.112287	0	0	.11	.5543797
1496	310	50	4	1.33	.112287	.61783	.1363	.87	.4669163
1497	100	328	9	3.00	.112287	.1993	.894128	1.21	1.794285
1498	50	188	0	.00	.112287	.09965	.512488	.72	-.724425
1499	50	630	6	2.00	.112287	.09965	1.71738	1.93	.070683
1500	810	0	4	1.33	.112287	1.61433	0	1.73	-.393284
1501	98	0	2	.67	.112287	.195314	0	.31	.3590657
1502	0	399	1	.33	.112287	0	1.087674	1.20	-.866628
1503	305	150	4	1.33	.112287	.607865	.4089	1.13	.2042813
1504	600	200	12	4.00	.112287	1.1958	.5452	1.85	2.146713
1505	1597	0	4	1.33	.112287	3.182821	0	3.30	-1.96177
1506	1040	582	21	7.00	.112287	2.07272	1.586532	3.77	3.228461
1507	396	301	5	1.67	.112287	.789228	.820526	1.72	-.055374
1508	1032	284	8	2.67	.112287	2.056776	.774184	2.94	-.276580
1509	718	450	15	5.00	.112287	1.430974	1.2267	2.77	2.230039
1510	660	517	15	5.00	.112287	1.31538	1.409342	2.84	2.162991
1511	990	0	2	.67	.112287	1.97307	0	2.09	-1.41869
1512	629	0	5	1.67	.112287	1.253597	0	1.37	.3007827
1513	610	0	3	1.00	.112287	1.21573	0	1.33	-.328017
1514	821	423	11	3.67	.112287	1.636253	1.153098	2.90	.7650287
1515	534	195	6	2.00	.112287	1.064262	.53157	1.71	.291881
1516	409	50	4	1.33	.112287	.815137	.1363	1.06	.2696093
1517	710	142	10	3.33	.112287	1.41503	.387092	1.91	1.418924
1518	0	200	0	.00	.112287	0	.5452	.66	-.657487
1519	0	200	2	.67	.112287	0	.5452	.66	.0091797
1520	523	488	6	2.00	.112287	1.042339	1.330288	2.48	-.484914
1521	518	0	9	3.00	.112287	1.032374	0	1.14	1.855339
1522	0	88	0	.00	.112287	0	.239888	.35	-.352175
1523	913	0	3	1.00	.112287	1.819609	0	1.93	-.931896
1524	400	0	4	1.33	.112287	.7972	0	.91	.4238463
1525	222	266	0	.00	.112287	.442446	.725116	1.28	-1.27985
1526	0	285	0	.00	.112287	0	.77691	.89	-.889197
1527	0	200	0	.00	.112287	0	.5452	.66	-.657487
1528	755	0	8	2.67	.112287	1.504715	0	1.62	1.049665
1529	0	88	2	.67	.112287	0	.239888	.35	.3144917
1530	170	50	1	.33	.112287	.33881	.1363	.59	-.254064
1531	1622	0	16	5.33	.112287	3.232646	0	3.34	1.988400
1532	356	100	9	3.00	.112287	.709508	.2726	1.09	1.905605
1533	229	212	0	.00	.112287	.456397	.577912	1.15	-1.14660
1534	1340	0	5	1.67	.112287	2.67062	0	2.78	-1.11624
1535	1499	0	3	1.00	.112287	2.987507	0	3.10	-2.09979
1536	1379	0	0	.00	.112287	2.748347	0	2.86	-2.86063
Total			275	91.67				91.66	.0088917

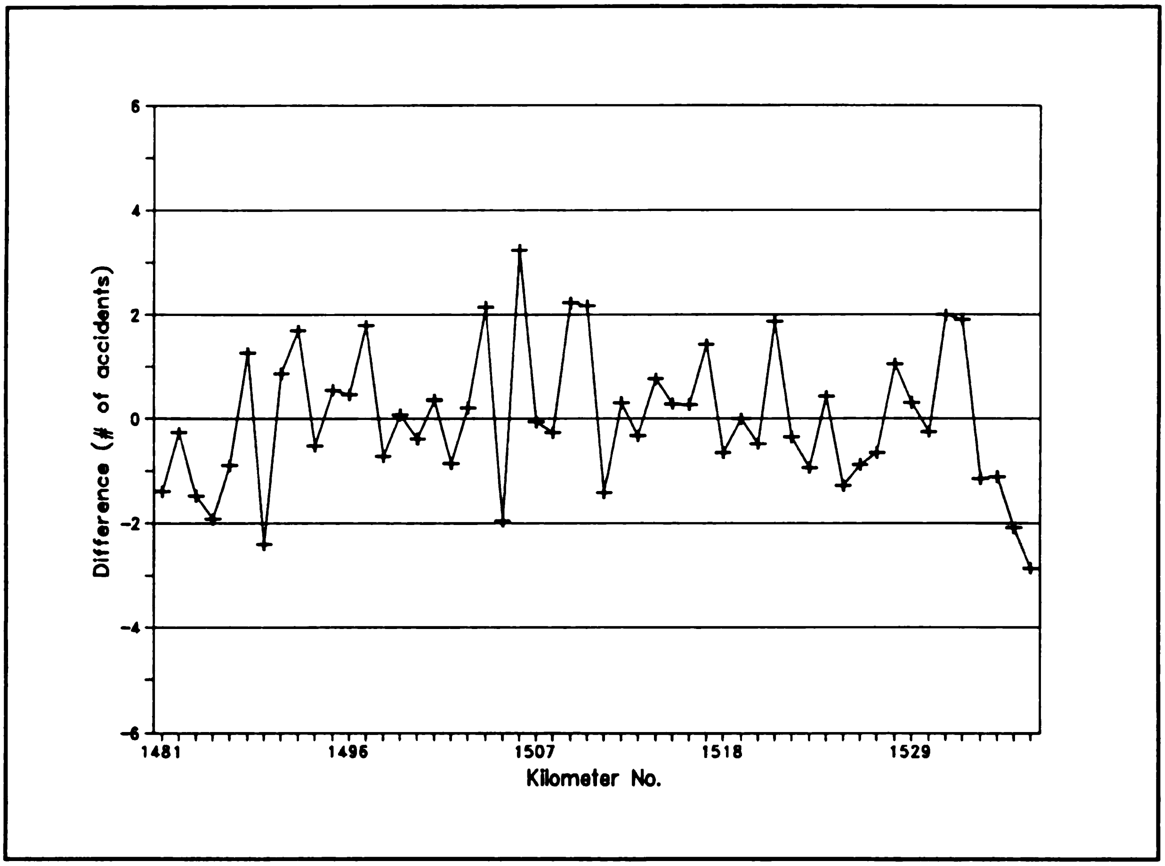


Figure 4.15
Difference between Actual and Predicted Accidents
2-Lane 2-Way Section (N-5), Kilometer 1481 - 1536.

4.3 DATA ANALYSIS FOR FOUR-LANE DIVIDED HIGHWAY SECTIONS

The analyses for the four lane divided highway section (kilometer 1550 - 1583) are presented in the following pages. Since the analytical approach, in essence, is the same as that followed for the two lane analysis, any repetitive description of the statistical procedures and terminologies is avoided.

4.3.1 Descriptive Statistics

The descriptive statistics of variables indicated that data for the entire 34 kilometers were processed and there were no missing values. A summary of the descriptive statistics of the variables employed in the study is presented in Table 4.13.

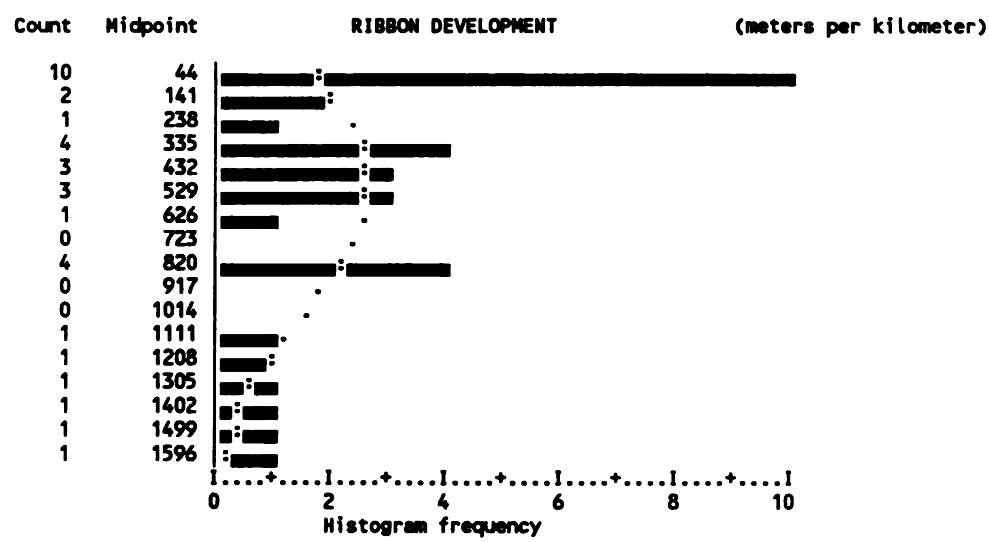
A list of 14 variables is exhibited in Table 4.13. The first 11, are the independent variables, developed for the quantification of hazard and use in modeling, as described in Section 3.2.2 (page 73). As before, the [ACCFRQ] represents accident data for a period of three years; [ANACFQ] is the average annual accident frequency; and [ANACRT] represents the annual accident rate. Primarily, [ANACFQ] was used as the dependent variable in predictive modeling. However, the effect of traffic volume variation on accidents, using [ANACRT] as the dependent variable, was also examined and is presented in Section 4.3.7 (page 139).

Table 4.13 Descriptive Statistics of Variables.

No.	Variable	Mean	Std Dev	Min	Max	N	Label
1.	[RIBBON]	490.65	493.06	0.00	1639.00	34	RIBBON DEVELOPMENT
2.	[SPATHS]	21.21	9.37	1.00	41.00	34	SPECIFIC LATERAL PAT
3.	[MEDOPN]	37.65	54.37	3.00	318.00	34	MEDIAN OPENINGS
4.	[GDRAIL]	158.62	286.07	0.00	1490.00	34	DEFICIENT GUARDRAIL
5.	[PWIDTH]	.55	.96	.00	3.25	34	DEFICIENT PAVEMENT WIDTH
6.	[SWIDTH]	2.24	1.20	.00	5.50	34	DEFICIENT SHOULDER WIDTH
7.	[PMARKS]	1.99	1.01	.00	4.24	34	DEFICIENT PAVEMENT MARKINGS
8.	[INTSEC]	0.97	3.26	0.00	16.31	34	INTERSECTION DEFICIENCIES
9.	[ISLAND]	2.71	2.33	0.00	8.00	34	ISOLATED LANE DEFICIENCIES
10.	[PVCOND]	44.16	7.69	28.50	53.25	34	PAVEMENT CONDITION RATING
11.	[SIDEOB]	11.22	6.35	4.50	31.00	34	ROADSIDE OBSTRUCTION
12.	[ACCFRQ]	4.38	5.12	0.00	21.00	34	ACCIDENT FREQUENCY
13.	[ANACFQ]	1.46	1.71	0.00	7.00	34	ANNUAL ACCIDENT FREQUENCY
14.	[ANACRT]	0.96	1.20	0.00	5.40	34	ANNUAL ACCIDENT RATE

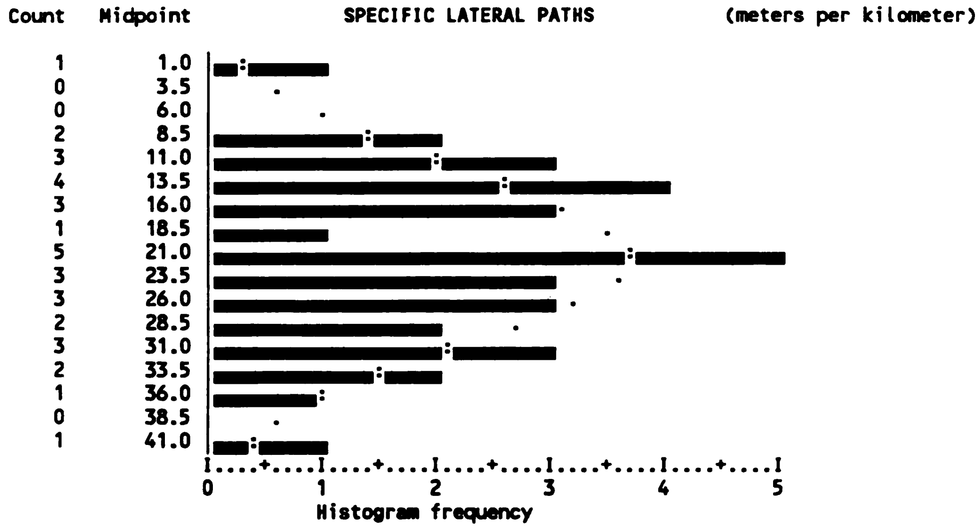
4.3.2 Frequency Distribution

An investigation into the frequency distribution of the studied hazards and accidents was considered important to gain some insight into their characteristics. The frequency distribution histograms of the hazards and accidents are presented in Figures 4.16 through 4.27.



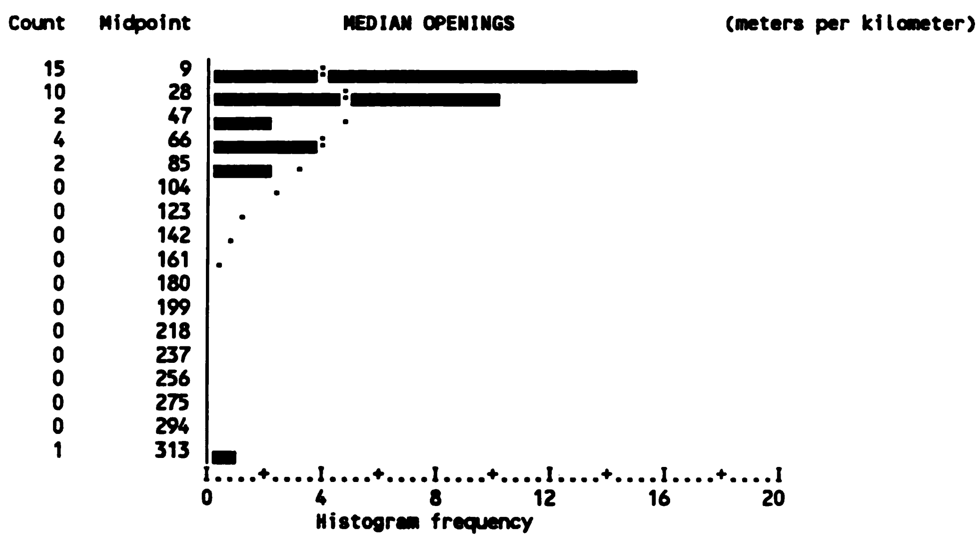
Percentile : Value = 15.00 : 0.00, 85.00 : 1189.50

Figure 4.16
Frequency Distribution of Variable [RIBBON] - RIBBON DEVELOPMENT.



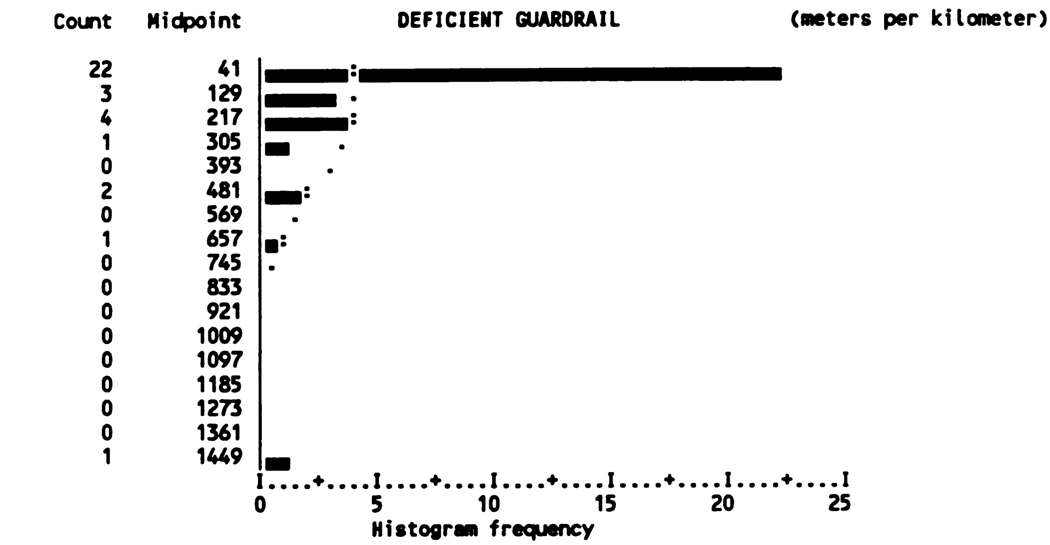
Percentile : Value = 15.00 : 12.00, 85.00 : 32.00

Figure 4.17
Frequency Distribution of Variable [SPATHS] - SPECIFIC LATERAL PATHS.



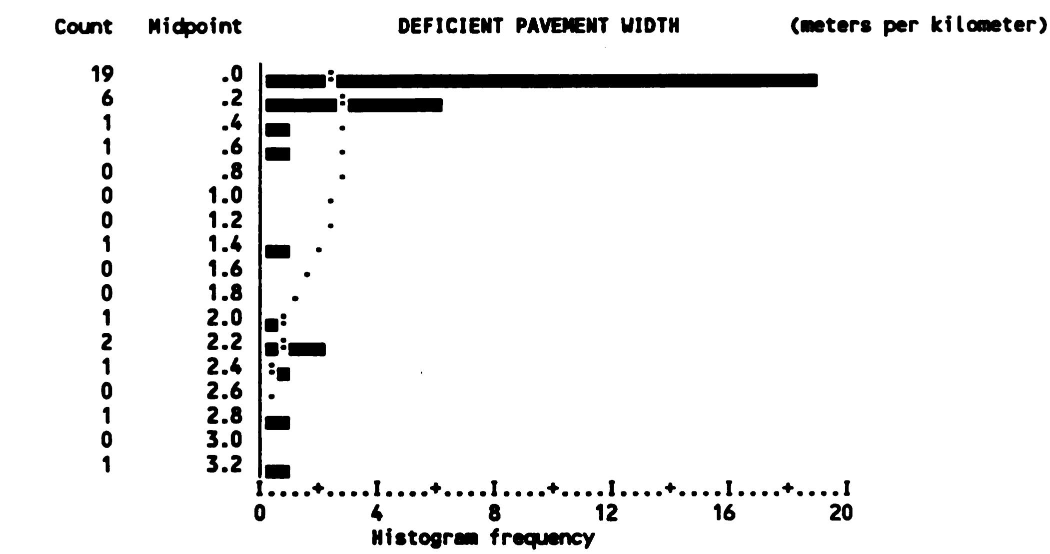
Percentile : Value = 15.00 : 6.50, 85.00 : 65.75

Figure 4.18
Frequency Distribution of Variable [MEDOPN] - MEDIAN OPENINGS.



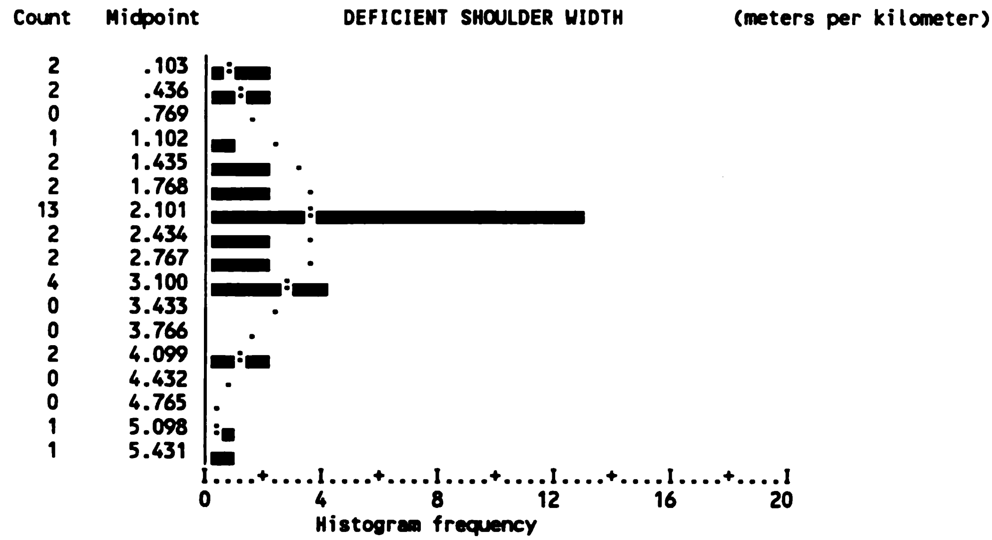
Percentile : Value = 15.00 : 0.00, 85.00 : 313.00

Figure 4.19
Frequency Distribution of Variable [GDRAIL] - DEFICIENT GUARDRAIL.



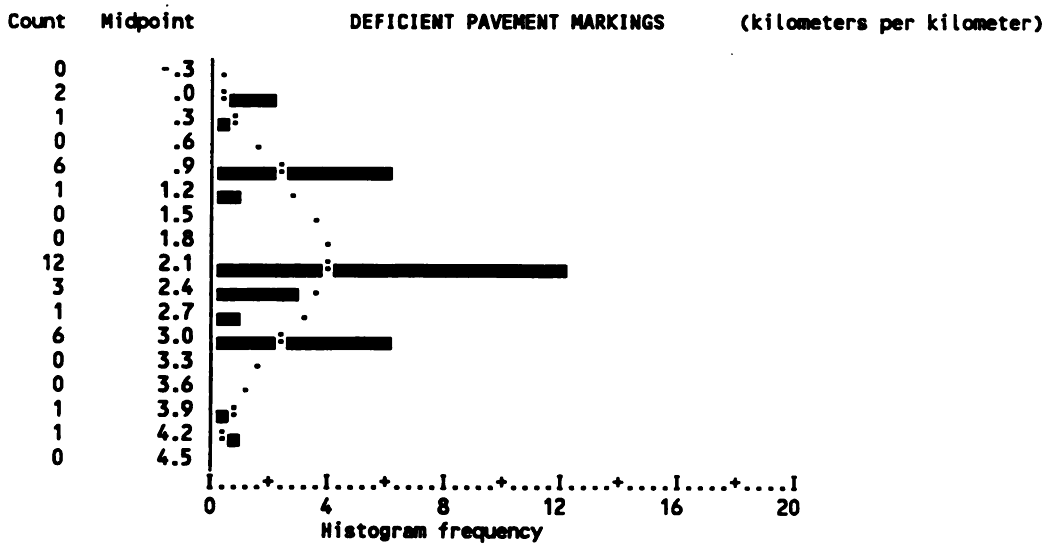
Percentile Value = 15.00 : 0.00, 85.00 : 2.185

Figure 4.20
Frequency Distribution of Variable [PWIDTH] - DEFICIENT PAVEMENT WIDTH.



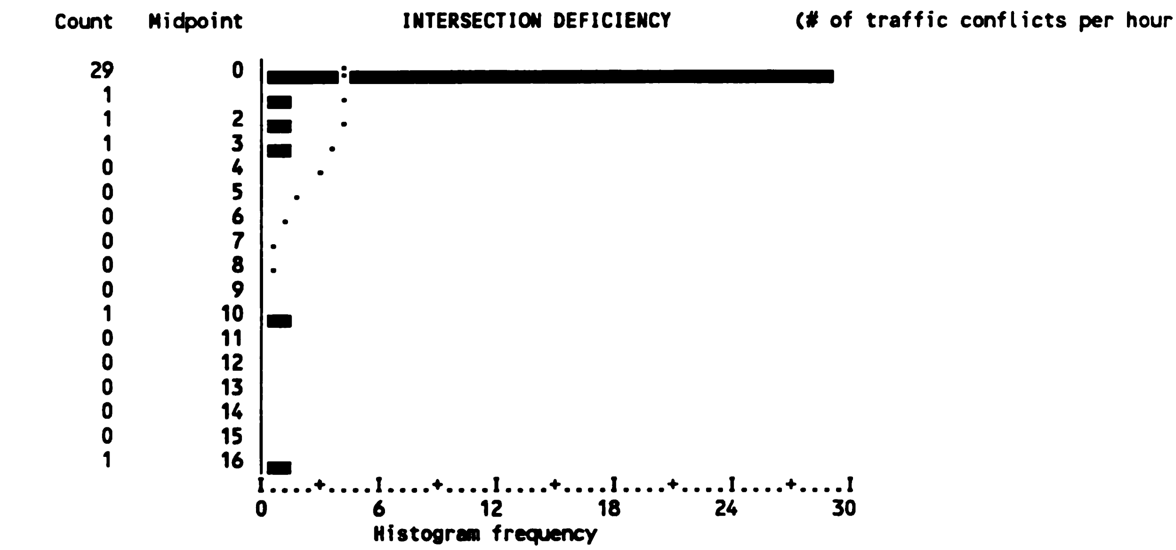
Percentile : Value = 15.00 : 1.075, 85.00 : 3.000

Figure 4.21
Frequency Distribution of Variable [SWIDTH] - DEFICIENT SHOULDER WIDTH.



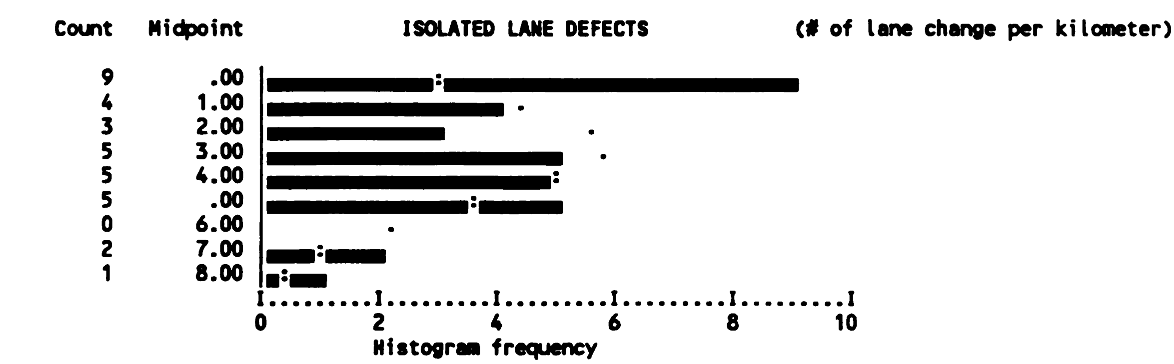
Percentile : Value = 15.00 : 1.00, 85.00 : 3.00

Figure 4.22
Frequency Distribution of Variable [PMARKS] - DEFICIENT PAVEMENT MARKINGS.



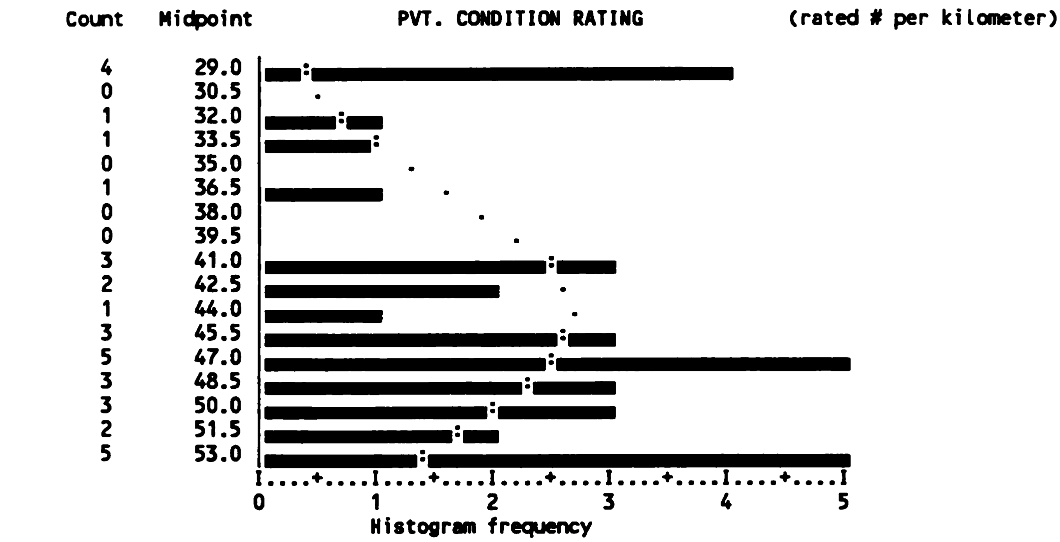
Percentile : Value = 15.00 : 0.00, 85.00 : 0.556

Figure 4.23
Frequency Distribution of Variable [INTSEC] - INTERSECTION DEFICIENCY.



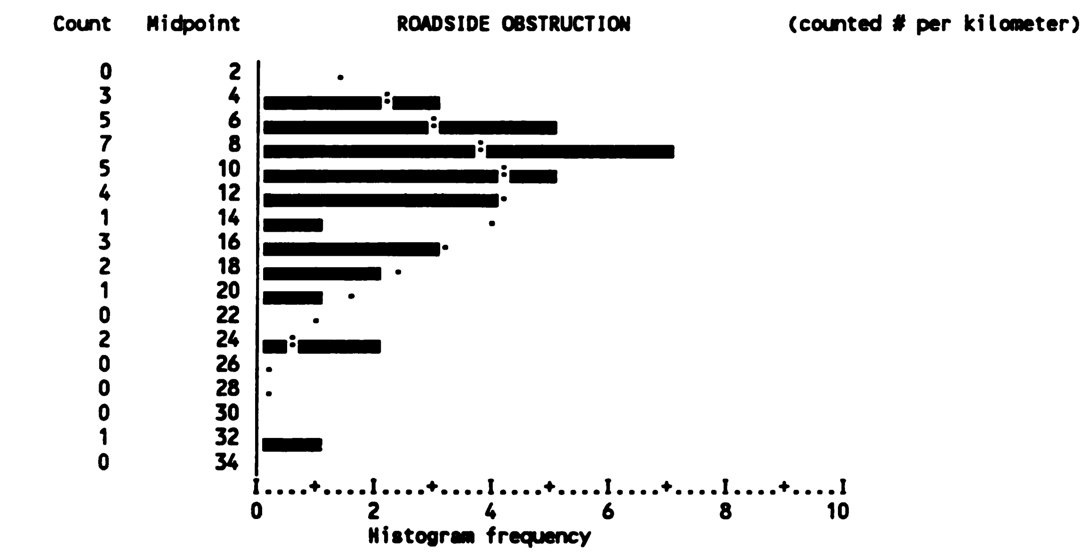
Percentile : Value = 15.00 : 0.00, 85.00 : 5.00

Figure 4.24
Frequency Distribution of Variable [ISLAND] - ISOLATED LANE DEFICIENCY.



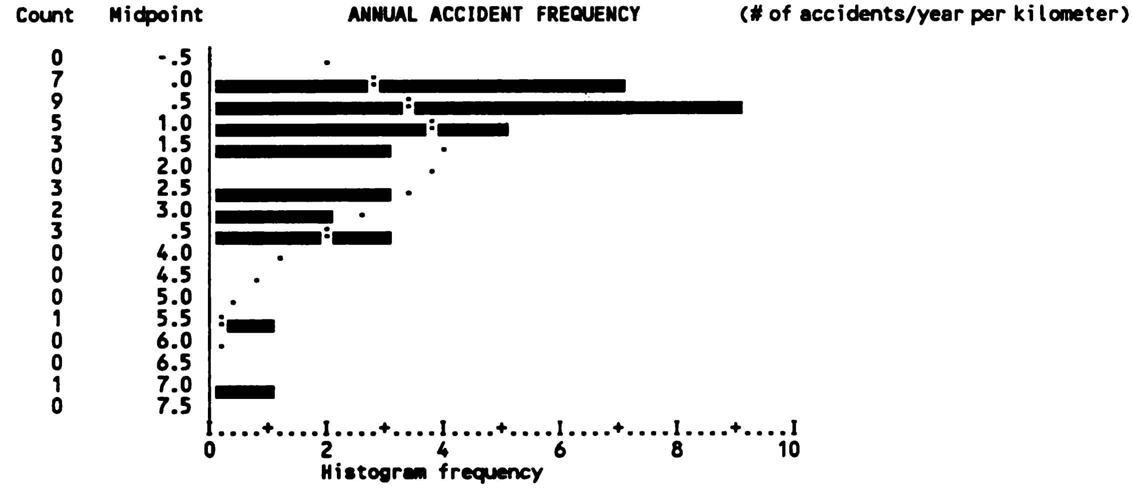
Percentile : Value = 15.00 : 32.875, 85.00 : 52.063

Figure 4.25
Frequency Distribution of Variable [PVCOND] - PAVEMENT CONDITION RATING.



Percentile : Value = 15.00 : 5.00, 85.00 : 18.50

Figure 4.26
Frequency Distribution of Variable [SIDEOB] - ROAD SIDE OBSTRUCTIONS.



Percentile : Value = 15.00 : 0.00, 85.00 : 3.50

Figure 4.27
Frequency Distribution of [ANACFQ] - ANNUAL ACCIDENT FREQUENCY.

The frequency distribution of the independent variable [PWIDTH], much like the 2-lane case, showed that deficient pavement width neither occurred very frequently nor had a noticeable variance. The non-variability reflected that [PWIDTH] was not a robust candidate for modeling. The interpretation of the frequency distribution histogram for variable [INTSEC] required caution in the sense that the output was only for the six intersections in the experimental site. These were isolated spots and were not distributed in the 34 kilometers of the test section like the other hazards.

4.3.3 Simple Correlations

The correlation matrix showing the nature and the order of the relationship between the variables is presented in Table 4.14

Table 4.14 The Correlation Matrix.

	[RIBBON]	[SPATHS]	[MEDOPN]	[GDRAIL]	[PWIDTH]	[SWIDTH]	[PMARKS]	[INTSEC]	[ISLAND]	[PVCOND]	[SIDEOB]	[ANACFQ]
[RIBBON]	1.0000**											
[SPATHS]	.0982	1.0000**										
[MEDOPN]	-.1004	.0734	1.0000**									
[GDRAIL]	.0305	.1398	-.1486	1.0000**								
[PWIDTH]	-.2486	.1041	-.1853	.2309	1.0000**							
[SWIDTH]	.2609	.4019*	-.0187	-.0091	-.1371	1.0000**						
[PMARKS]	.1965	.2244	-.2493	.0431	.2040	-.1472	1.0000**					
[INTSEC]	.2350	.1918	-.0512	.1347	.2816	.2324	.4094*	1.0000**				
[ISLAND]	.0358	-.1277	-.1399	-.2498	-.1705	-.2202	.0073	-.3221	1.0000**			
[PVCOND]	.1599	-.1481	-.1030	.1899	.2813	.1679	-.1448	.2061	-.2657	1.0000**		
[SIDEOB]	.2796	.2384	.4020*	-.0763	-.3159	.1471	.0658	.0117	-.3294	-.2583	1.0000**	
[ANACFQ]	.6403**	.1486	-.0921	.4245*	.0743	.0813	.3421	.4838*	.0122	.2648	-.1079	1.0000**

N of cases: 34 1-tailed Signif: * - .01 ** - .001

The correlation matrix indicated all variables, except [MEDOPN] and [SIDEOB], had a positive relationship with accidents. This effect was noted as a point of concern while selecting final variables for model building. The decision about the retention of the variables was further subjected to various diagnostic tests for checking multicollinearity, and multiple procedures of performing regression analysis.

4.3.4 Eigenvalues and Condition Indices

The computed eigenvalues and the condition indices are produced in Table 4.15. (A detailed description of the statistical terminologies and interpretation of this type of table is given in Section 4.2.4, page 109).

The last eigenvalue in Table 4.15 (i.e., 0.00658 at serial number 12) is the smallest and accounts for 21.173, 88.776, and 18.922 of the variance of [ISLAND], [PVCOND], and [SIDEOB] respectively. This implies that these three variables are susceptible to near dependency. Since other independent variables have small variance proportions for the 12th eigenvalue, they do not seem to have multicollinearity. However, the collinear variables are not sharply distinguished as there are only two condition indices (at serial 11 and 12) having their magnitude 12.000, and 33.664 respectively, higher than the rest. This indicates that there are two suspect cases of collinear variables.

Table 4.15 Collinearity Diagnostics: Eigenvalues and Condition Indices.

Number	Eigen-value	Condition Index	Variance Proportions											
			Constant	RIBBON	SPATHS	MEDOPN	GDRAIL	PWIDTH	SWIDTH	PMARKS	INTSEC	ISLAND	PVCOND	SIDEOB
1	7.45901	1.000	.00017	.00323	.00160	.00284	.00329	.00230	.00184	.00172	.00151	.00223	.00029	.00160
2	1.26300	2.430	.00005	.00103	.00002	.04016	.07008	.09553	.00022	.00061	.14375	.01565	.00001	.00314
3	.83762	2.984	.00012	.02363	.00010	.05174	.08221	.07839	.00137	.00007	.25350	.03464	.00019	.00410
4	.72060	3.217	.00000	.08100	.00025	.32105	.04304	.04092	.00077	.00401	.00996	.03759	.00000	.00274
5	.65858	3.365	.00004	.03247	.00002	.00484	.54512	.15654	.00053	.00292	.01952	.02183	.00004	.00204
6	.31953	4.832	.00004	.00136	.01055	.17070	.15287	.04736	.05668	.00171	.19136	.28083	.00028	.02822
7	.26483	5.307	.00040	.53376	.02590	.05292	.00576	.27076	.08569	.00002	.09048	.00886	.00013	.00566
8	.21950	5.829	.00008	.09097	.00115	.04992	.00002	.05943	.14058	.21455	.00192	.02142	.00095	.09246
9	.11263	8.138	.01171	.04055	.46236	.01552	.00109	.02992	.00021	.00010	.01103	.02795	.04587	.00311
10	.08632	9.296	.00026	.05014	.01334	.19467	.01311	.08233	.00314	.33564	.18965	.28045	.00562	.64670
11	.05179	12.000	.01444	.00692	.44816	.09563	.08266	.11247	.70800	.35055	.08206	.05682	.05885	.02102
12	.00658	33.664	.97269	.13495	.03655	.00000	.00075	.02406	.00097	.08811	.00526	.21173	.88776	.18922

4.3.5 Variable Tolerance (TOL) and Variance Inflation Factor (VIF)

The second diagnostic test of multicollinearity was comprised of computing variable tolerance and VIF. These statistics are produced in Table 4.16.

Table 4.16 Collinearity Diagnostics: TOL and VIF.

Variable	Tolerance	VIF
[SIDEOB]	.472085	2.118>>
[INTSEC]	.580699	1.722
[GDRAIL]	.826755	1.210
[SWIDTH]	.571155	1.751
[PVCOND]	.602800	1.659
[MEDOPN]	.676510	1.478
[RIBBON]	.599652	1.668
[SPATHS]	.624303	1.602
[PWIDTH]	.605702	1.651
[PMARKS]	.567050	1.764
[ISLAND]	.562582	1.778

>> Highest VIF.

In Table 4.16, [SIDEOB] is the only variable having a clearly higher VIF value than the rest indicating one suspect case of dependency. The VIF analysis did not clearly show other dependencies, and only partially supported the findings based on the eigensystem diagnostic test which indicated [ISLAND], [PVCOND], and [SIDEOB] having interdependency. The cumulative conclusion drawn from the two diagnostic tests for multicollinearity (i.e., eigenvalues and the VIF tests) is that only one variable, [SIDEOB] failed both tests whereas [ISLAND] and [PVCOND] were not clearly indicated for interdependency.

4.3.6 Regression Analysis and the Crucial Variables

To explore the most significant variables, all the eleven independent variables were entered to the process of BACKWARD ELIMINATION for regression analysis. The observed elimination sequence (in the order of variable significance based on a POUT = 0.100 criteria) is summarized in Table 4.17.

Table 4.17 The Variable Removal Order by Backward Elimination.

Step #	Variable Removed	T	Sig T
1.	[PWIDTH]	-.251	.8035
2.	[PVCOND]	-.036	.9716
3.	[SPATHS]	.220	.8274
4.	[SWIDTH]	-.630	.5340
5.	[ISLAND]	.777	.4440

As a result of this operation [RIBBON], [MEDOPN], [GDRAIL], [PMARKS], [INTSEC] and [SIDEOB] were retained as the six most significant variables. However, a negative coefficient was indicated for [SIDEOB] (as was expected due to negative correlation). Besides, the FORWARD and STEPWISE methods excluded [MEDOPN] and [PMARKS] based on a PIN = 0.050 criteria. Thus [RIBBON], [GDRAIL] and [INTSEC] were selected as the three most relevant significant variables for model building. The results of various iterative runs of regression analysis indicated these three variables as the most appropriate regressors. However, it is important to note that [MEDOPN] would have been the next most significant variable for modeling if the selection criteria were relaxed.

The output results of the final regression analysis are presented in Table 4.18.

Table 4.18 Statistical Results of Regression Analysis.

Multiple R	.81211
R Square	.65952
Adjusted R Square	.62547
Standard Error	1.04503

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	3	63.46281	21.15427
Residual	30	32.76268	1.09209

F = 19.37046 Signif F = .0000

Dependent Variable. [ANACFQ] ANNUAL ACCIDENT FREQUENCY

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
RIBBON	.001932	3.79586E-04	.557823	5.089	.0000
GDRAIL	.002189	6.41767E-04	.366633	3.410	.0019
INTSEC	.158703	.057857	.303268	2.743	.0102
(Constant)	.012487	.272011		.046	.9637

The indicated appropriateness of selecting independent variables, based on the different criteria employed in the study, is summarized in Table 4.19.

Table 4.19 Indicated Appropriateness of Independent Variables.

No.	Variable	VARIABLE SELECTION CRITERIA			
		FD	NN	MC	RG
1.	[RIBBON]	+	+	+	+
2.	[SPATHS]	+	+	+	-
3.	[MEDOPN]	+	-	+	-
4.	[GDRAIL]	+	+	+	+
5.	[PWIDTH]	-	+	+	-
6.	[SWIDTH]	+	+	+	-
7.	[PMARKS]	+	+	+	-
8.	[INTSEC]	+	+	+	+
9.	[ISLAND]	+	+	-	-
10.	[PVCOND]	+	+	-	-
11.	[SIDEOB]	+	-	-	-

Symbols
\+ = Variable indicated for inclusion in the predictive model.
\- = Variable not indicated for inclusion in the predictive model.

Abbreviations
FD = Frequency distribution.
NN = Non-negativity.
MC = Multicollinearity.
RG = Regression.

Table 4.19 shows that, based on all four criteria of variable selection, the most appropriate variables indicated were [RIBBON], [GDRAIL] and [INTSEC].

4.3.7 Accident Frequency Versus Rate as the Dependent Variable

To incorporate the effect of traffic volume variation, accident rates for the various sections of the experimental site were calculated as explained in Section 4.2.7 (page 114). The correlation of the indicated variables with the two versions of accident data: 1) Annual Accident Frequency [ANACFQ]; and 2) Annual Accident Rate [ANACRT] were examined. A comparison of the two showed a nominal difference in the coefficients of correlation as shown in Table 4.20.

Table 4.20 Correlation of Indicated Variables with Accident Frequency and Rates.

Variables	[ANACFQ]	[ANACRT]
[RIBBON]	.6403**	.6969**
[SPATHS]	.1486	.1260
[MEDOPN]	-.0921	-.1226
[GDRAIL]	.4245*	.3537
[PWIDTH]	.0743	.0148
[SWIDTH]	.0813	.0875
[PMARKS]	.3421	.2873
[INTSEC]	.4838*	.3750
[ISLAND]	.0122	.1065
[PVCOND]	.2648	.2377
[SIDEOB]	-.1079	-.1203

1-tailed Significance: * - .01 ** - .001

The model development using [ANACFQ] and [ANACRT] as two separate dependent variables showed better statistical results for the "frequency" format as compared to "rate" (e.g., R^2 for

[ANACFQ] was 0.65952 versus 0.62698 for [ANACRT]). Therefore, the [ANACFQ] was adopted as the dependent variable of the predictive model. Much like the 2-lane case, this selection was justified from a practical standpoint as well, considering that the computation of accident rate required additional information on traffic counts.

4.3.8 Final Accident Prediction Model and Test of Hypotheses

It was concluded in Section 4.3.6 that [RIBBON], [GDRAIL] and [INTSEC] were the most appropriate independent variables for model building. The equation which finally emerged for predicting the accident potential of a 4-lane divided highway section provided the following relationship between the accident frequency and the hazardousness.

$$Y_{(f)} = 0.012487 + 0.001932\ x_1 + 0.002189\ x_2 + 0.158703\ x_3 \quad (4.7)$$

where,

$Y_{(f)}$ = Accident frequency per year per kilometer.
x_1 = Length of ribbon development on both carriageways (meters).
x_2 = Length of highway section with deficient guardrail (meters).
x_3 = The aggregated ratio of traffic conflicts to the operating volume in an intersection expressed as percent.

The presence of [RIBBON] and [INTSEC] (i.e., x_1 and x_3) reveal that deficient control of access and lateral entrance conditions were predominantly associated with accidents in Pakistan. These findings are upheld by many studies made in the developed countries, and by the TRRL, U.K., for some third world countries [e.g., 95,98,99].

Based on the following statistics of the predictive model

R	=	0.81211
R^2	=	0.65952
$R^2_{(Adj)}$	=	0.62547
F	=	19.37046
$F_{(Sig)}$	=	0.0000

Variable	T	Sig T
x_1	5.089	0.0000
x_2	3.410	0.0019
x_3	2.743	0.0102

the null hypothesis of no linear relationship between the ambient hazardousness and accidents was rejected, and it was concluded that at probability of F=0.000, 62.55% of the variation in accidents was explained by three types of identified hazards.

1) Deficient control of access;
2) Deficient provision of guardrail on warranted sections; and
3) Intersection deficiencies.

4.3.8.1 Analysis of Residual and Predicted Values

The following four statistics for examining the residuals and predicted values were calculated.

1. PRED Unstandardized predicted values.
2. RESID Unstandardized residuals.
3. ZPRED Standardized predicted values.
4. ZRESID Standardized residuals.

These statistics are presented in Table 4.21.

Table 4.21 Statistics for the Residuals and Predicted Values.

	Min	Max	Mean	Std Dev	N
*PRED	.0125	5.5138	1.4608	1.3868	34
*RESID	-2.0442	3.7555	.0000	.9964	34
*ZPRED	-1.0444	2.9226	.0000	1.0000	34
*ZRESID	-1.9561	3.5937	.0000	.9535	34

Durbin-Watson Test = 2.09919

The Durbin-Watson statistic is a measure of auto-correlation in the residuals. Regression analysis assumes that the residuals are not auto-correlated, in which case the Durbin-Watson test should have a value near 2.00 [116]. The indicated value of 2.09919 for the constructed model signifies satisfactory non auto-correlation between the residuals.

Residual Outliers

The SPSS system default produced the ten worst outlier cases based on absolute values of standardized residuals. The information furnished on outliers is presented in Table 4.22 which reveals that the model was good enough to predict accidents by a maximum error of ± 2 (taken as a discrete rounded value for # of accidents), with one exception.

Table 4.22 Outliers - Standardized Residual.

Case #	Km	*RESID	*ZRESID
23	1572	3.75548	3.59366
30	1579	-2.04417	-1.95609
5	1554	-1.87951	-1.79852
22	1571	-1.56187	-1.49456
34	1583	-1.30388	-1.24769
11	1560	1.17303	1.12248
8	1557	.87809	.84025
6	1555	-.87478	-.83708
15	1564	.84745	.81093
12	1561	.83011	.79434

Residual Normality

The histogram for the standardized residuals is presented in Figure 4.28 (the interpretation of the histogram is given at page 119). Here the distribution does not seems to be normal due to clustering of residuals at the center and a steep tail toward negative values. The statistical literature [116] indicated the following supporting remarks:

> *"it would unreasonable to expect the observed residuals to be exactly normal - some deviation is expected because of sampling error. Even if the errors are normally distributed in the population, sample residuals are only approximately normal".*

```
 N Exp N       (* = 1 Cases,     . : = Normal Curve)
 1   .03   Out *
 0   .05  3.00
 0   .13  2.67
 0   .30  2.33
 0   .62  2.00 .
 0  1.14  1.67 .
 0  1.87  1.33  .
 2  2.74  1.00 **.
 3  3.61   .67 ***.
 5  4.26   .33 ***:*
12  4.50   .00 ****:*******
 5  4.26  -.33 ***:*
 1  3.61  -.67 *  .
 1  2.74 -1.00 * .
 2  1.87 -1.33 *:
 1  1.14 -1.67 :
 1   .62 -2.00 :
 0   .30 -2.33
 0   .13 -2.67
 0   .05 -3.00
 0   .03   Out
```

Figure 4.28
Histogram - Standardized Residual.

Predicted Values

The comparison of the probability of the observed and the predicted values is presented by the normal probability plot in Figure 4.29. The cumulative distributions of the two entities were plotted against each other and examined for deviation from the expected straight line. By observing the scatter of the predicted points about the expected straight line, it was inferred that with the exception of a few data points, the probability of having the predicted values from the developed model will be reasonably close to the actual values.

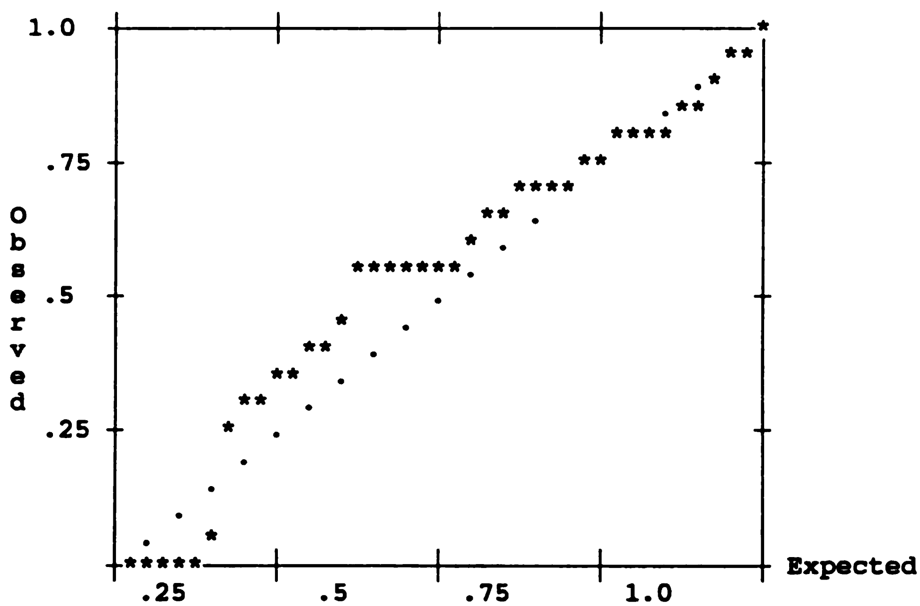


Figure 4.29
Normal Probability (P-P) Plot - Predicted Values.

A spreadsheet implementation of the predictive model is presented in Table 4.23, and the resulting deviations of the predicted accidents from the actual are shown in Figure 4.30.

Table 4.23 Spreadsheet Implementation of Accident Predictive Model (4-Lane Divided Section).

	--- Variables ---			Accident Freq		Constant	x_1*	x_2*	x_3*	Predicted	Diff-
Km.#	x_1	x_2	x_3	3Yrs	Annual		(.001932)	(.002189)	(.158703)	Accidents	erence
1550	517	332	10.07	11	3.67	.012487	.998844	.726748	1.598139	3.34	.3304485
1551	121	30	.00	1	.33	.012487	.233772	.06567	0	.31	.0214043
1552	0	50	.00	0	.00	.012487	0	.10945	0	.12	-.121937
1553	0	25	.00	2	.67	.012487	0	.054725	0	.07	.5994547
1554	818	60	3.08	1	.33	.012487	1.580376	.13134	.4888052	2.21	-1.87967
1555	324	108	.00	0	.00	.012487	.625968	.236412	0	.87	-.874867
1556	0	0	.00	1	.33	.012487	0	0	0	.01	.3208463
1557	0	50	.00	3	1.00	.012487	0	.10945	0	.12	.878063
1558	0	77	.00	1	.33	.012487	0	.168553	0	.18	.1522933
1559	0	0	.00	1	.33	.012487	0	0	0	.01	.3208463
1560	400	476	.00	9	3.00	.012487	.7728	1.041964	0	1.83	1.172749
1561	50	0	.38	3	1.00	.012487	.0966	0	.0603071	.17	.8306059
1562	0	44	.00	0	.00	.012487	0	.096316	0	.11	-.108803
1563	0	45	.00	0	.00	.012487	0	.098505	0	.11	-.110992
1564	0	64	.00	3	1.00	.012487	0	.140096	0	.15	.847417
1565	300	1490	.00	11	3.67	.012487	.5796	3.26161	0	3.85	-.187030
1566	300	695	2.38	7	2.33	.012487	.5796	1.521355	.3777131	2.49	-.157822
1567	1104	62	.00	7	2.33	.012487	2.132928	.135718	0	2.28	.0522003
1568	799	128	.00	7	2.33	.012487	1.543668	.280192	0	1.84	.4969863
1569	1218	256	16.31	17	5.67	.012487	2.353176	.560384	2.588446	5.51	.1521737
1570	439	0	.00	4	1.33	.012487	.848148	0	0	.86	.4726983
1571	802	0	.00	0	.00	.012487	1.549464	0	0	1.56	-1.56195
1572	1639	30	.00	21	7.00	.012487	3.166548	.06567	0	3.24	3.755295
1573	590	230	.00	5	1.67	.012487	1.13988	.50347	0	1.66	.0108297
1574	1344	468	.00	11	3.67	.012487	2.596608	1.024452	0	3.63	.0331197
1575	500	0	.00	2	.67	.012487	.966	0	0	.98	-.311820
1576	437	0	.61	3	1.00	.012487	.844284	0	.0968088	.95	.0464202
1577	198	50	.00	0	.00	.012487	.382536	.10945	0	.50	-.504473
1578	330	20	.00	0	.00	.012487	.63756	.04378	0	.69	-.693827
1579	1456	100	.00	3	1.00	.012487	2.812992	.2189	0	3.04	-2.04438
1580	1424	40	.00	9	3.00	.012487	2.751168	.08756	0	2.85	.148785
1581	566	227	.00	4	1.33	.012487	1.093512	.496903	0	1.60	-.269569
1582	165	236	.00	1	.33	.012487	.31878	.516604	0	.85	-.514538
1583	841	0	.00	1	.33	.012487	1.624812	0	0	1.64	-1.30397
Total				149	49.67					49.67	-.003012

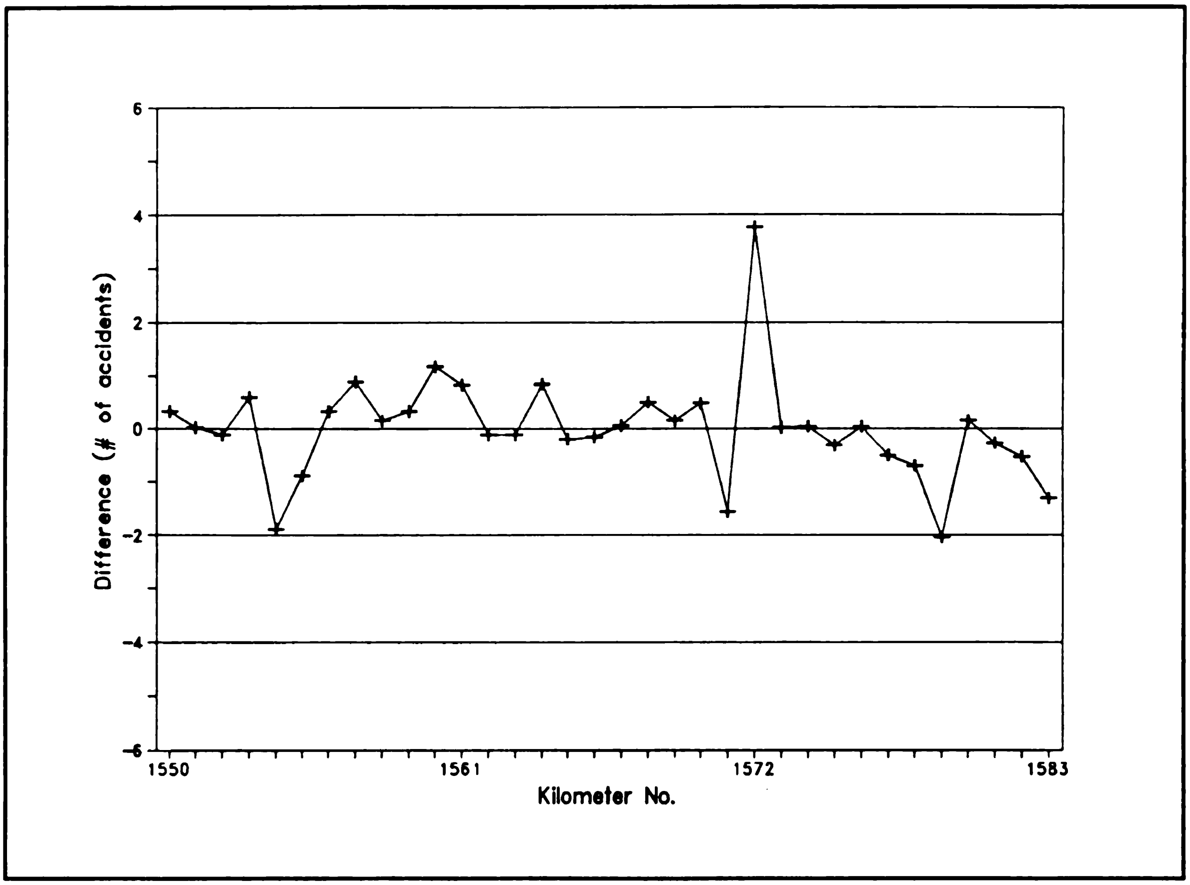


Figure 4.30
Difference between Actual and Predicted Accidents
4-Lane Divided Section (N-5), Kilometer 1550-1583.

4.4 AN EVALUATION OF THE DATA TYPE

As the result of modeling the hazard-accidents relationship by regression analyses, equations 4.6 and 4.7 (page 117, 140) were developed for 2-lane, and 4-lane sections respectively. The significant variables common to both the equations, were [RIBBON] AND [GDRAIL], both of which are measures of design deficiencies. Additionally, in the case of the 4-lane model, the variable [INTSEC] was also significant. This measure is comprised of the conflict (observational) data set. However, neither of the models included a measure from the expert team data set among the explanatory variables.

One of the objectives of this study was to test association of each data set separately with the dependent variable. This operation was important to determine which type of data set would be the most appropriate for measuring the ambient hazardousness so that the findings could be applied to an experimental design for optimizing resources in the data collection.

To achieve this objective, the three type of data: geometric data; observational data; and subjective data were independently used in regression analyses. The categorization of the variables according to type of data is indicated as following.

	Type of Data	Variables
1)	GEOMETRIC:	[RIBBON] [SPATHS] [MEDOPN][1] [GDRAIL] [PWIDTH] [SWIDTH] [PMARKS]
2)	OBSERVATIONAL:	[INTSEC] [ISLAND]
3)	SUBJECTIVE:	[PVCOND] [SIDEOB]

[1] Applicable to 4-lane sections only.

As before, the three methods of model building BACKWARD, FORWARD and STEPWISE were employed. The results of this investigation for both type of highway sections are presented in Table 4.24.

Table 4.24 Regression Analysis Results from One Type of Data.

DATA TYPE	STATISTICAL SIGNIFICANCE		
	R^2	F	Fsignif
2-LANE SECTIONS			
GEOMETRIC	0.37809	4.55971	0.0011
OBSERVATIONAL	0.02988	0.75449	0.4756
SUBJECTIVE	0.01505	0.37431	0.6897
4-LANE SECTIONS			
GEOMETRIC	0.63591	6.48740	0.0002
OBSERVATIONAL	0.26555	5.60420	0.0084
SUBJECTIVE	0.07181	1.19922	0.3150

The determinants of statistical significance in Table 4.24 clearly indicate a hierarchy of data type and show that geometric data are much better predictors of accidents in the traffic and environmental conditions in Pakistan.

4.5 HAZARD INDEXATION

Several studies [101-104] employing the hazard index (HI) approach for the identification and ranking of hazardous locations were reviewed in Chapter 2. In these studies, the HI was developed using any one of three type of indicators: 1) purely accident based factors; 2) a combination of accident and non-accident based factors; and 3) purely non-accident based safety surrogate factors.

It was shown in these studies [i.e., 101-104] that the composite hazardousness rating of a highway location provided a more accurate prediction of future accident experience than any single type of indicator. For example, Taylor and Thompson [101] established that restricted sight distance was a definite factor in hazardousness at a given location but analysis of sight distance restrictions in themselves did not provide good estimates of future accident experience.

The practical advantage of the HI approach lies in the simplicity of computations as compared to the more complex approach of accident modeling and forecasting. The above cited, and many other, studies have found that the HI approach can be used for measuring relative highway safety so that proper countermeasures could be developed accordingly.

4.5.1 Development of HI for the Present Research

The feasibility of developing hazard indices from the present data was examined and it was found that an aggregation of the three types of data (as described on pages 73 and 159) would produce better indices than employing a single type of data set. A detailed description of the development of hazard indices for the two types of highway sections is presented in the following pages.

4.5.1.1 HI for 2-Lane, 2-Way Sections

The HI were developed for each kilometer of the test section by computing the arithmetic sum of the hazard data values and are presented in Table 4.25.

Table 4.25 Hazard Index: 2-Lane 2-Way Sections.

Km #	RIBBON	SPATHS	GDRAIL	PWIDTH	SWIDTH	PMARKS	INTSEC	ISLAND	PVCOND	SIDEOB	HZINDX	ACCFRQ
1481	901.00	39.00	545.00	.00	.00	2.00	.00	.00	34.00	11.00	1532.00	2.00
1482	.00	5.00	180.00	.00	.00	2.00	.00	1.00	34.00	12.00	234.00	.33
1483	.00	17.00	500.00	.36	.00	2.00	.00	.00	35.00	7.50	561.86	.00
1484	.00	15.00	784.00	.00	.00	2.00	.00	.00	37.50	4.50	843.00	.33
1485	.00	7.00	412.00	.00	.70	2.00	.00	.00	40.00	45.00	506.70	.33
1486	570.00	16.00	670.00	.00	.00	2.00	.00	.00	42.00	23.00	1323.00	4.33
1487	319.00	24.00	1092.00	.00	.00	2.00	.00	.00	45.00	9.00	1491.00	1.33
1488	980.00	21.00	150.00	.01	.00	2.00	.00	.00	46.50	12.50	1212.01	3.33
1493	142.00	10.00	822.00	1.44	2.00	2.00	.00	.00	38.00	11.00	1028.44	4.33
1494	214.00	23.00	602.00	.00	1.00	2.00	.00	.00	42.00	7.00	891.00	1.67
1495	.00	10.00	.00	.00	1.00	2.00	.00	2.00	54.50	7.00	76.50	.67
1496	310.00	19.00	50.00	.49	.00	2.00	.00	7.00	50.00	46.50	484.99	1.33
1497	100.00	14.00	328.00	.09	.00	2.00	.00	1.00	45.50	44.50	535.09	3.00
1498	50.00	6.00	188.00	.00	1.00	2.00	.00	.00	47.50	4.50	299.00	.00
1499	50.00	7.00	630.00	.49	2.00	2.00	.00	.00	40.00	5.00	736.49	2.00
1500	810.00	23.00	.00	.04	1.00	2.00	.00	1.00	50.50	9.00	896.54	1.33
1501	98.00	9.00	.00	.49	.50	2.00	.00	.00	53.00	8.00	170.99	.67
1502	.00	31.00	399.00	.09	.00	2.00	.00	1.00	58.00	5.00	496.09	.33
1503	305.00	.00	150.00	.00	.00	2.00	.00	.00	61.00	6.50	524.50	1.33
1504	600.00	11.00	200.00	.00	1.00	2.45	17.69	.00	57.00	15.50	904.64	4.00
1505	1597.00	29.00	.00	.04	.50	2.00	.00	.00	43.00	21.50	1693.04	1.33
1506	1040.00	30.00	582.00	.01	1.00	2.00	.00	.00	49.00	5.00	1709.01	7.00
1507	396.00	13.00	301.00	.01	1.00	2.00	.00	1.00	54.50	10.00	778.51	1.67
1508	1032.00	9.00	284.00	.09	2.00	2.00	.00	1.00	62.00	24.50	1416.59	2.67
1509	718.00	16.00	450.00	.01	1.40	2.00	.00	.00	54.50	19.00	1260.91	5.00
1510	660.00	19.00	517.00	.09	.00	2.00	.00	.00	55.00	33.50	1286.59	5.00
1511	990.00	5.00	.00	.09	.00	2.00	.00	.00	61.50	30.00	1088.59	.67
1512	629.00	17.00	.00	.09	1.00	2.00	.00	.00	54.00	17.00	720.09	1.67
1513	610.00	8.00	.00	.00	.50	2.00	.00	2.00	51.50	8.00	682.00	1.00
1514	821.00	15.00	423.00	.09	.00	2.00	.00	.00	39.00	7.00	1307.09	3.67
1515	534.00	17.00	195.00	.09	.50	2.00	.00	3.00	45.50	2.00	799.09	2.00
1516	409.00	12.00	50.00	.09	.00	2.00	.00	.00	45.50	16.50	535.09	1.33
1517	710.00	13.00	142.00	.09	1.70	2.00	.00	.00	45.50	6.00	920.29	3.33
1518	.00	5.00	200.00	.00	1.60	2.00	.00	.00	45.50	33.50	287.60	.00
1519	.00	23.00	200.00	.00	1.00	2.32	17.07	.00	42.50	7.50	293.39	.67
1520	523.00	32.00	488.00	.00	1.50	2.00	.00	.00	42.50	14.50	1103.50	2.00
1521	518.00	21.00	.00	.49	.50	2.00	.00	1.00	36.00	19.00	597.99	3.00
1522	.00	8.00	88.00	.16	1.50	2.00	.00	3.00	36.50	25.50	164.66	.00
1523	913.00	19.00	.00	.00	.00	2.35	23.32	.00	36.00	.50	994.17	1.00
1524	400.00	14.00	.00	.04	1.00	2.00	.00	.00	43.00	8.50	468.54	1.33
1525	222.00	4.00	266.00	4.84	2.00	2.00	.00	.00	51.50	.00	552.34	.00
1526	.00	16.00	285.00	.00	.00	2.00	.00	.00	51.50	1.00	355.50	.00
1527	.00	7.00	200.00	.04	1.00	2.00	.00	.00	48.50	5.50	264.04	.00
1528	755.00	13.00	.00	.00	.50	2.00	.00	.00	43.50	4.50	818.50	2.67
1529	.00	14.00	88.00	.00	.50	2.20	19.55	1.00	40.50	17.50	183.25	.67
1530	170.00	38.00	50.00	.04	.50	2.00	.00	2.00	33.50	5.50	301.54	.33
1531	1622.00	25.00	.00	.01	.50	2.00	.00	.00	38.50	9.50	1697.51	5.33
1532	356.00	19.00	100.00	.81	2.00	2.00	.00	.00	27.50	11.50	518.81	3.00
1533	229.00	27.00	212.00	.81	2.00	2.46	.00	.00	26.50	17.50	517.27	.00
1534	1340.00	10.00	.00	1.44	2.00	2.00	.00	.00	23.50	36.00	1414.94	1.67
1535	1499.00	8.00	.00	1.21	3.00	2.62	26.14	.00	33.00	34.00	1606.97	1.00
1536	1379.00	8.00	.00	.00	3.00	2.00	.00	.00	39.00	9.50	1440.50	.00

A simple correlation of the individual "hazard" value of the independent variables; and the composite hazardousness [HZINDX] (evaluated by aggregating the data) with annual accident frequency [ANACFQ] is presented in Table 4.26.

Table 4.26 Correlation of Individual Variables and HI with Accidents (2-Lane Sections).

Variables	[ANACFQ]
[RIBBON]	.4365**
[SPATHS]	.2398
[GDRAIL]	.2682
[PWIDTH]	-.1080
[SWIDTH]	-.0379
[PMARKS]	-.0959
[INTSEC]	-.0718
[ISLAND]	-.1501
[PVCOND]	.0997
[SIDEOB]	.0669
[HZINDX]	.5907**

N of cases: 52
1-tailed Signif: * - .01 ** - .001

The results presented in Table 4.26 are the same as those displayed in the correlation matrix (Table 4.2, page 108) except that the new variable [HZINDX] is introduced here. The magnitude and the sign of the correlation coefficient of [HZINDX] clearly indicates a substantial improvement in the relationship by combining all types of data rather than using them in a segregated form. This finding is distinctively supported by the results reported by Spark [97] who found that aggregating the data into a cumulative index significantly increased (to the extent of 45%) the correlation of explanatory variables with accidents. A detailed review of this study is included in the literature review (Chapter 2).

However, the vital issue that needs to be addressed here is to assign appropriate weights to the individual hazard indicators (independent variables). In most of the above quoted studies of hazard index development, the variables were assigned weights by subjective rating of a hazard according to its importance based on engineering and professional judgement. In the present research, this question is partially answered in the sense that significant hazard indicators were identified in accident modeling by regression analysis.

Figure 4.31 is a graphical representation of the developed HI with the annual accident frequency.

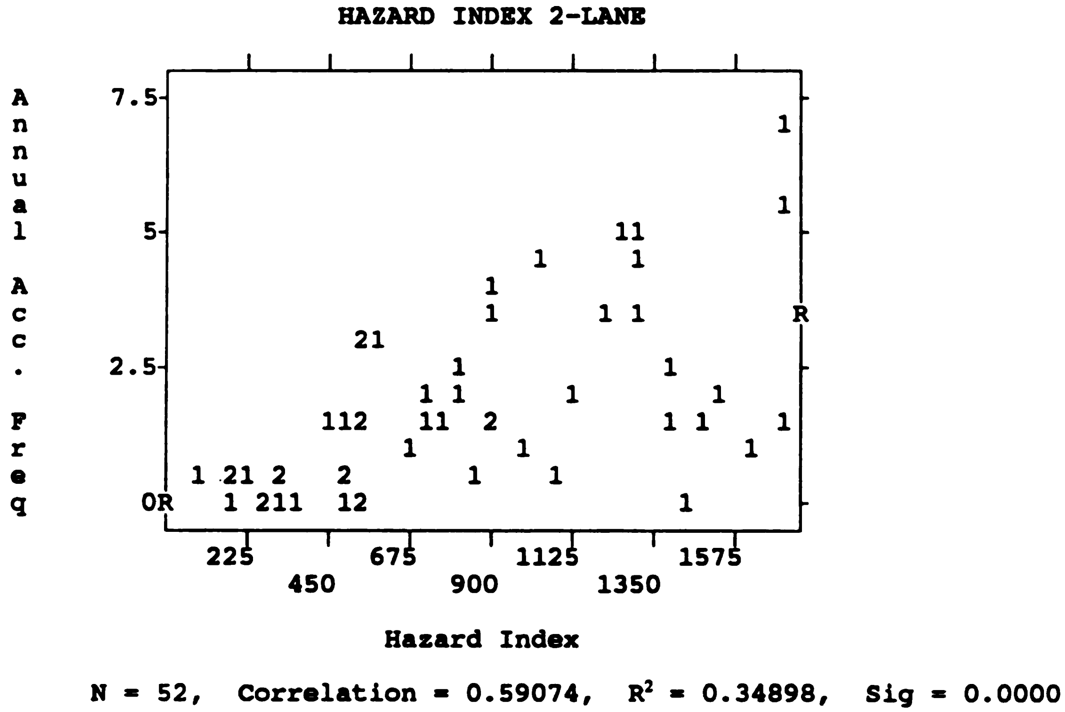


Figure 4.31
A Graphical Representation of hazard Index Vs. Accidents.

4.5.1.2 HI for 4-Lane Divided Sections

The 34 indices for each kilometer were developed as before by computing the arithmetic sum of the hazard data, and are presented in Table 4.27.

Table 4.27 Hazard Index: 4-Lane Divided Highway Sections.

Km #	RIBBON	SPATHS	MEDOPN	GDRAIL	PWIDTH	SWIDTH	PMARKS	INTSEC	ISLAND	PVCOND	SIDEOB	HZINDX	ANACFQ
1550	517.00	34.00	60.00	332.00	.08	5.00	2.50	10.07	.00	53.00	10.50	1024.15	3.67
1551	121.00	41.00	80.00	30.00	.01	3.00	3.00	.00	2.00	29.25	23.50	332.76	.33
1552	.00	13.00	21.00	50.00	.01	2.00	3.00	.00	2.00	28.75	5.00	124.76	.00
1553	.00	12.00	45.00	25.00	.00	2.00	2.00	.00	5.00	28.50	9.50	129.00	.67
1554	818.00	32.00	80.00	60.00	.00	2.00	2.83	3.08	1.00	29.50	31.00	1059.41	.33
1555	324.00	20.00	66.00	108.00	.13	.00	2.00	.00	8.00	34.00	15.00	577.13	.00
1556	.00	29.00	18.00	.00	.01	2.00	2.00	.00	5.00	32.50	7.00	95.51	.33
1557	.00	12.00	24.00	50.00	.04	.00	3.00	.00	5.00	40.25	5.50	139.79	1.00
1558	.00	15.00	16.00	77.00	1.48	.50	2.00	.00	3.00	43.50	4.50	162.98	.33
1559	.00	37.00	15.00	.00	2.26	2.50	2.00	.00	.00	45.25	7.50	111.51	.33
1560	400.00	21.00	40.00	476.00	.58	1.00	2.00	.00	1.00	36.50	12.50	990.58	3.00
1561	50.00	29.00	37.00	.00	2.34	1.30	2.30	.38	2.00	45.50	7.50	177.32	1.00
1562	.00	14.00	20.00	44.00	3.25	2.00	2.00	.00	5.00	48.50	4.50	143.25	.00
1563	.00	8.00	32.00	45.00	1.96	2.20	2.00	.00	4.00	53.25	4.50	152.91	.00
1564	.00	13.00	65.00	64.00	.01	4.00	.00	.00	4.00	49.00	9.50	208.51	1.00
1565	300.00	32.00	13.00	1490.00	2.29	1.90	2.00	.00	.00	50.00	12.50	1903.69	3.67
1566	300.00	13.00	8.00	695.00	.26	1.90	2.30	2.38	1.00	53.25	5.00	1082.09	2.33
1567	1104.00	10.00	33.00	62.00	.08	.50	3.00	.00	1.00	50.75	11.00	1275.33	2.33
1568	799.00	25.00	70.00	128.00	.05	2.20	4.00	.00	5.00	50.75	18.50	1102.50	2.33
1569	1218.00	24.00	3.00	256.00	2.74	2.50	4.24	16.31	.00	50.25	9.50	1586.54	5.67
1570	439.00	22.00	318.00	.00	.04	2.10	.20	.00	.00	47.00	18.50	846.84	1.33
1571	802.00	20.00	9.00	.00	.04	2.80	3.00	.00	.00	48.75	19.00	904.59	.00
1572	1639.00	23.00	11.00	30.00	.00	2.00	3.00	.00	7.00	47.00	7.00	1769.00	7.00
1573	590.00	17.00	6.00	230.00	.01	3.00	2.00	.00	3.00	47.00	11.50	909.51	1.67
1574	1344.00	27.00	15.00	468.00	.10	2.80	1.00	.00	4.00	42.25	7.50	1911.65	3.67
1575	500.00	22.00	3.00	.00	.09	1.40	1.00	.00	4.00	52.50	5.00	588.99	.67
1576	437.00	25.00	6.00	.00	.18	2.00	1.00	.61	3.00	53.00	9.00	536.79	1.00
1577	198.00	23.00	16.00	50.00	.34	3.00	1.32	.00	.00	49.25	16.50	357.41	.00
1578	330.00	32.00	30.00	20.00	.18	4.00	1.00	.00	3.00	45.25	8.00	473.43	.00
1579	1456.00	33.00	5.00	100.00	.13	5.50	2.00	.00	3.00	42.75	13.00	1660.38	1.00
1580	1424.00	16.00	18.00	40.00	.00	3.00	2.00	.00	4.00	40.25	15.00	1562.25	3.00
1581	566.00	18.00	33.00	227.00	.00	2.00	1.00	.00	7.00	40.25	6.00	900.25	1.33
1582	165.00	8.00	29.00	236.00	.00	2.00	1.00	.00	.00	47.00	8.50	496.50	.33
1583	841.00	1.00	35.00	.00	.00	2.00	.00	.00	.00	47.00	23.00	949.00	.33

Table 4.28 presents a simple correlation of the individual "hazard" value of the independent variables; and the composite hazardousness [HZINDX] with annual accident frequency [ANACFQ].

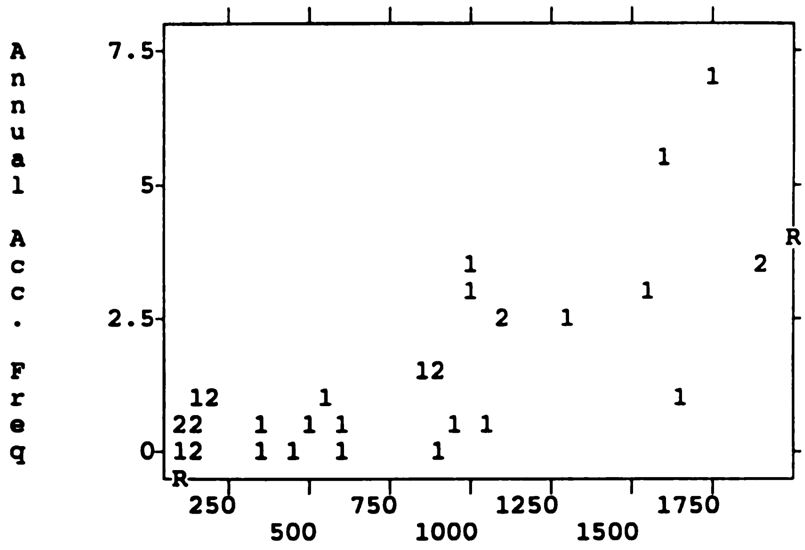
Table 4.28 Correlation of Individual Variables and HI with Accidents (4-Lane Sections).

Variables	[ANACFQ]
[RIBBON]	.6403**
[SPATHS]	.1486
[MEDOPN]	-.0921
[GDRAIL]	.4245*
[PWIDTH]	.0743
[SWIDTH]	.0813
[PMARKS]	.3421
[INTSEC]	.4838*
[ISLAND]	.0122
[PVCOND]	.2648
[SIDEOB]	-.1079
[HZINDX]	.7570**

N of cases: 34
1-tailed Signif: * - .01 ** - .001

Much like the 2-lane case for HI development, it is observed from the contents of Table 4.28 that for the 4-lane sections [HZINDX] has a substantially improved relationship with [ANACFQ] as compared to each of the independent variable individually. However, the question of assigning appropriate weights to the individual hazard indicators (i.e, the independent variables) still remains to be addressed. The graphical representation of the developed HI with the annual accident frequency for the 4-lane sections is presented in Figure 4.32.

HAZARD INDEX 4-LANE



N = 34, Correlation = 0.75703, R^2 = 0.57310, Sig = 0.0000

Figure 4.32
A Graphical Representation of hazard Index Vs. Accidents.

A comparison of the various determinants of statistical significance for the predictive models and hazard indices is presented in Table 4.29 which shows the ascendancy of the predictive modeling using regression analysis over the HI approach.

Table 4.29 A Comparison of the Predictive Modeling and HI Approach.

	Predictive Model			HI Approach		
	R	R^2	Sig	R	R^2	Sig
2-Lane	0.59827	0.35792	0.000	0.59074	0.34898	0.000
4-Lane	0.81211	0.65952	0.000	0.75703	0.57310	0.000

CHAPTER 5

DISCUSSION OF RESULTS

5.1 PERFORMANCE EVALUATION OF RESEARCH INPUTS AND RESULTS

To embark on a research program concerning highway safety in Pakistan was challenging in many ways. First and foremost, there was a lack of an acceptable theoretical foundation on which the design of a research program could be based. Efforts were made to bridge the theoretical gaps with proven postulates in highway safety as evidenced by the literature, especially from the United States and United Kingdom. In doing so, several variables evolved as candidates for explaining and predicting traffic accidents in Pakistan.

Second, there was a lack of coherent empirical studies on the subject of accident prediction modeling. Therefore, the experimental design was framed ab-initio with some insight on the topic furnished by Taylor and Thompson's work [101]. Subsequently, Schoppert's study [95] on accident prediction from roadway elements, and the TRRL studies [99] relating accidents with roadway characteristics in various developing countries, provided basic guidelines for designing the analytical framework. As a result, multivariate regressions were chosen as the predictive modeling technique.

Third, variable acquisition according to an ideal scholastic design was not always possible. For example, in the case of independent variables, the intersection hazardousness was evaluated in terms of conflicts rather than sight distance deficiencies. In the case of the dependent variable, accident records did not furnish information on accident type that was required for certain in-depth analysis.

Fourth, the assumption of design deficiency as an indicator of hazard was seriously violated in some cases due to absence of an uniform standard. This was particularly true in the case of traffic signs. Their absence (or presence) made no meaningful difference since there were no standards to quantify the deficiency. This was the basic reason that signs were included in the "PNC" category in the experimental design and were disregarded in the present study (see pages 69-70).

Since this study was an innovative effort for accident prediction modeling in Pakistan, and there was no defined entry point, it was considered appropriate to expose several procedure for variable acquisition. The intent here was to acquire data on a number of potential determinants of accidents to begin with, and use a stochastic approach rather than following a deterministic approach for variable selection. Later, the influential variables were identified employing a series of screening processes.

Prior to drawing any conclusion from the analysis, an evaluation of the performance of the following research inputs and results is presented in the subsequent pages.

- Evaluation of Independent Variables
- Evaluation of Data Type
- Evaluation of Prediction Models
- Evaluation of Hazard Index
- Evaluation of Accident Data

5.1.1 Evaluation of Independent Variables

The literature [116,117] cautioned that including a large number of independent variables in a regression model was never a good strategy unless there were strong, previous reasons to suggest that they all should be involved. Accordingly, it was never intended that all the postulated determinants of accidents would be used as the independent variables in model building. It was expected that only appropriate variables (in terms of independency, randomness and variability) would be retained.

The following three types of procedures were employed for the quantification of ambient hazardousness:

1) Use of design standard deficiencies as a measure of hazard;
2) Use of drivers erratic maneuvers and traffic conflicts to evaluate hazard; and
3) Use of an expert team for subjective rating of ambient hazardousness.

Correspondingly, the following three types of data sets were generated by employing the above mentioned procedures of hazardousness quantification:

1) Measurements: evaluating a potential hazard in linear dimensions (e.g., lack of access control was measured in meters/kilometer).
2) Counts: evaluating a potential hazard in number of events signifying its presence (e.g., number of conflicts in an intersection in proportion to traffic volume, were counted in #/unit time).
3) Numbers: evaluating a potential hazard by a subjective rating using a scale of 0 to 100 (e.g., each kilometer was rated on this scale, zero signifying the least hazardous).

The analysis showed that the first two procedures (i.e., use of design standard deficiencies; and use of drivers erratic maneuvers and traffic conflicts), produced the best predictive variables. The use of subjective rating did not yield appropriate variables for modeling.

5.1.2 Evaluation of Data Type

Three type of research data: geometric; observational; and subjective data, were used independently in regression analyses. The results of this investigation, for both type of highway sections, were presented in Table 4.24 (page 148) which clearly indicated that geometric data were much better predictors of accidents in the traffic and environmental conditions in Pakistan.

In the experimental design, the rationale of using a particular measuring system to quantify a hazard was based on the applicability of the techniques and available resources. For example, traffic conflicts were employed to evaluate intersections hazardousness because frequent illustrations of such cases were found in the literature [78,119]. As another example, pavement condition was evaluated using subjective rating techniques because the determination of Pavement Serviceability Rating (PSR) by this approach was found an established engineering practice [110].

As a result of this study, it is suggested that the hazardousness evaluated in terms of observational or subjective data should be measured in the form of geometrical dimensions. For example, the intersection deficiencies should be measured using sight distance data rather than employing the traffic conflict approach as incorporated in this study. As another example, roadside obstruction should be measured in terms of lateral placement from the EOS line rather than subjectively rating their prospective hazardousness.

5.1.3 Evaluation of Predictive models

The predictive models, for both 2-lane, 2-way, and 4-lane divided sections, indicated control of access as a significant factor explaining the accident variance. This finding is quite understandable intuitively, and supported by the results of many studies.

Referring back to the equations 2.4 - 2.8 (page 48) developed by Schoppert [95], it may be seen that the following variables (highway elements) were significantly associated with accidents:

1) "CDW", number of commercial driveways per mile;
2) "INT, number of intersections per mile; and
3) "RDW", number of residential driveways per mile;

Similarly, equations 2.12 - 2.14 (page 52) were developed by Jacobs [99] representing the relationship between accident rates and geometric design standards in two developing countries, Kenya and Jamaica. It may be seen that in both the equations, the accident rate per MVKm was a function of junctions per km. Moreover, the findings of Kihlberg and Tharp

[98] also revealed that access control had the most significant accident reducing effect.

However, contrary to expectations, it was surprising to note that the absence of guardrail on warranted sections emerged as an important factor in the predictive models. This association, *prima-facie*, was not supported by a simple theoretical basis because guardrail by itself may not cause, or avert, an impending accident situation. Its role in reducing severity was quite understandable and substantiated by the literature [108,109].

Accident data were, therefore, examined to find if the association of accidents with the absence of guardrail could be explained by "run-off-the-road" type accidents on high embankments. It was found that the accident data did not provide explicit information on the type of accidents. The only relevant information in this context was in a narrative form (i.e., "the vehicle fell into ditch"), and revealed that these locations were different than the one indicated by the model. The cause of the accidents was mostly described as "due to driver's negligence". It was, however, verified that these accident sites were mostly the high embankment locations. Another possible explanation is that vehicles leave the road at random locations but the only reportable accident were for high embankments, while at other locations the accidents were not reported being less serious.

These findings indicated that driver behavior was, in some manner, related to the absence of guardrail on high embankment sections. It was, therefore, assumed that, on high embankments, drivers preferred to keep the transverse position of their vehicles away from the outer edge of the pavement for safety reasons and got involved in accidents due to improper lateral placement conditions. A plausible support to this assumption was furnished by Taragin's study [120] which reported that transverse positions of vehicles were effected by the presence of objects and barricades on highway shoulders. As a corollary, it was inferred that the drivers on high embankment sections kept the lateral position of their vehicles away from the outer edge of the pavement. However, this premise warrants further research. If a linkage between lateral placement of vehicles and embankment height is evidenced by empirical studies then operational friction may be generalized as the principal factor associated with accidents on high embankments. The analyses also indicated association of intersection deficiencies with accidents for the 4-lane sections. For this study, the intersection deficiencies were quantified in terms of operational hazards (i.e., conflicts). This finding is intuitively understandable and supported by the literature [78,105,119].

The detailed analysis of residual and predicted values for the developed models were presented in Chapter 4. Here, the performance of the models is evaluated from a different angle. The limits of the two models are worked out by plugging in the minimum and the maximum values for the variables (i.e., the values a hazard can possibly have on-ground). The results of this exercise are summarized in Table 5.1.

The annual accident frequency based on the average of three years of accident data (January 1988-December 1990) showed 0 and 7 as the minimum and maximum number of accidents per referenced kilometer. The results shown in Table 5.1 indicate that the predicted accident range practically covers the observed limits.

Table 5.1 Model Limits in Accident Prediction.

2-Lane, 2-Way Section

$Y_{(f)} = 0.112287 + 0.001993\ x_1 + 0.002726\ x_2$

VARIABLE VALUE	Constant	Variable		# of Accidents	
		x1	x2	Predicted	Actual
Minimum	0.112287	0	0	0.11	0
Maximum	0.112287	1500	1500	7.21	5.33

4-Lane Divided Highway Section

$Y_{(f)} = 0.012487 + 0.001932\ x_1 + 0.002189\ x_2 + 0.158703\ x_3$

VARIABLE VALUE	Constant	Variable			# of Accidents	
		x1	x2	x3	Predicted	Actual
Minimum	0.012487	0	0	0	0.01	0
Maximum	0.012487	1300	1300	36.7	11.12	7.00

2-Lane, 2-Way Section.
$Y_{(f)}$ = Accident frequency per year per kilometer.
x_1 = Length of ribbon development on both sides (meters).
x_2 = Length of highway section with deficient guardrail (meters).

4-Lane Divided Highway Section.
$Y_{(f)}$ = Accident frequency per year per kilometer.
x_1 = Length of ribbon development on both carriageways (meters).
x_2 = Length of highway section with deficient guardrail (meters).
x_3 = The aggregated ratio of traffic conflicts to the operating volume in an intersection expressed in percent.

5.1.4 Evaluation of Hazard Index

Concurrent to accident modeling by regression analyses, the feasibility of an aggregated use of the three type of data was also examined. These analyses were aimed at developing hazard indices (HI) for identifying and ranking of hazardous highway sections. The details of this task were presented in Section 4.5.

The development of a hazard index to examine the relationship of composite hazardousness rating of a highway section with accidents indicated a logical feasibility of employing this approach for the identification and ranking purposes for the highway and traffic conditions in Pakistan. The finding that an aggregation of various types of data produce the best indices rather than employing a single type of data is substantiated by the literature [97,102]. However, the shortcomings of the HI approach lie in the arbitrariness in assigning the weights to the individual indicators of hazardousness.

5.1.5 Evaluation of Accident Data

As mentioned in Chapter 3, the accident data were not readily accessible in terms of a computerized data base. The accident files were created by retrieving information from the police records for the three-year period: January 1988 through December 1990.

The three years period was considered adequate because longer period could involve changes in physical, environmental and demographic characteristics, invalidating the results. The adequacy of this time-frame was supported by the studies by Renshaw et al. [122], and by Shen [104] which demonstrated that a three-year accident data base was an appropriate sample for accident analysis. Schoppert [95] also used a three-year accident data in developing predictive models for two-lane highways in the State of Oregon.

However, the details of the accident data were not adequate to conduct certain in-depth analyses. For example, accident data could not be segregated by the type of location (i.e., intersection and non-intersection) and were integrated for use on a one-kilometer section that included both type of locations.

The other example of the accident data inadequacy concerns inability to segregate by the degree of severity (i..e., fatal, injury, and P.D.O). This limitation was primarily due to inadequate sample size for each severity level and did not necessarily concern lack of details.

5.2 ACCIDENT PREDICTION MODELS AND HSIP

The predictive model for 2-lane sections only explained 36% of the variation in accidents. A comparison with the results of the 4-lane analysis, which explained 66% of the variation in accidents, leads to a higher degree of confidence in claiming these models as satisfactory prediction tools for employing in HSIP.

The primary objective of accident prediction modeling was to provide a basis for the transferability of HSIP technology to Pakistan. The results of the present research show that this transfer is accomplishable, and the formal program of applying accident countermeasures may be initiated even in the absence of a reliable accident data base.

5.3 HSIP AND POLICY DECISION MAKING

An important feature of the prediction models is the consistency in indicating deficient control of access as a principal factor associated with accidents for both 2-lane and 4-lane sections of the experimental site. This finding is supported by many highway safety studies for both developed and underdeveloped countries as discussed thoroughly in Section 5.1.3 in the preceding pages.

This is a remarkable point to note in the sense that the HSIP has emerged as an analytical tool for policy making rather than a simple means for identifying hazardous locations on the rural highways in Pakistan. Unlike correcting other hazards, the remedial measures required to improve highway access control involve social implications in addition to technical and financial feasibility.

For example, the issues of the social cost of relocating people, and their properties and businesses to improve the existing network may become a leading policy matter. Similarly, incorporation of preventative safety measures in the future design and construction of new facilities may constitute vital policy issues. This is particularly true because safety measures oriented toward the improvement of highway access control would make a very significant impact on the land-use pattern of the country.

CHAPTER 6

LIMITATIONS, CONCLUSIONS AND SUGGESTED RESEARCH

6.1 RESEARCH LIMITATIONS

A detailed discussion of the data inputs and the attained results was presented in the preceding chapter. As is the case with any other empirical research, the available data placed limitations on the resulting analysis. The following factors should be recognized in extrapolating the results of this study.

1. The three-year accident data base employed in the research was quite sparse. It furnished an average of 5.29 (=275/52) and 4.38 (=149/34) accidents per km for the 2-lane and 4-lane sections respectively (see pages 122 and 145 for details). Out of 86 kms of the experimental site, 16 kms had no accidents; 12 kms had one; and 7 kms had two accidents.

2. The accident data base was comprised of only reportable and retrievable accidents. As such, a bias in terms of accident severity and accident type prevailed that debarred in-depth analysis based on these aspects.

3. The developed hazard measurement system (see page 81), employed a predetermined definition of hazard in certain cases. For example, the absence of guardrail on an embankment height of 10 ft. or more was defined to constitute a hazardous situation. This limitation prevented an analysis of the relationship between the embankment height and accidents.

4. Hazardousness evaluation based on sufficiency criteria provided a sound rationale. However, the consistency in the occurrence of some hazards did not yield good variables for regression analysis. Absence of pavement markings is the most relevant example in this context. This hazard was so consistently present that, in terms of variability, it did not produce an appropriate regressor for accident modeling.

These limitations should be considered in perusing the following prominent findings.

6.2 PROMINENT FINDINGS

The results of the research indicate existence of a statistical relationship between the hazards and accidents, and furnish the necessary basis for initiating a formal HSIP in Pakistan. Based on these results, the null hypothesis negating a relationship between the identifiable hazards on rural highway sections in Pakistan and its accident potential was rejected.

The prominent findings pertain to the following three categories of interest: 1) The identified hazards; 2) Implementation of the HSIP; and 3) Policy issues. These findings, relevant to each category, are summarized in the following pages.

6.2.1 The Identified Hazards

- Inadequate control of access was the most significant identified hazard associated with accidents.
- Both for 2-lane and 4-lane sections, the most adverse condition of control of access was the ribbon development.
- The lateral openings in the form of specific paths did not indicate correlate with accidents.
- Median openings would have been an additional potential indicator of accidents for 4-lane sections, if the criterion of variable entry in model building were to be relaxed.
- Deficient intersection control was a significant factor for 4-lane sections.
- High embankment sections with deficient guardrail system were associated with accidents.
- The absence of pavement marking and roadside obstructions were the two frequently occurring hazards that were not associated with accidents.
- The deficiencies of pavement and shoulder width, and inadequate pavement serviceability were not frequently occurring hazards.

6.2.2 Implementation of the HSIP

- The transferability of HSIP technology to Pakistan is accomplishable, and a formal program of applying accident countermeasures can be initiated on the country's rural trunklines in the absence of a reliable accident data base.
- Countermeasures oriented toward improving the control of highway access should receive priority implementation.

6.2.3 Policy issues

- Inadequate control of access on a rural trunklines, operating at a volume of 10,000-16,000 ADT, warrant prioritized treatment, preferably in the form of full control of access.
- Providing access control would require substantial resources to meet the direct costs and social costs of relocations.
- The general land holding pattern of the country, having integrated interests on both sides of the existing highway, could inflict serious problems in providing an access controlled facility.
- New highway projects / facilities may be appraised based on these findings.

6.3 SUGGESTED RESEARCH

While presenting a discussion of the performance of variables and the predictive models in Section 5.1, it was pointed out that variable acquisition according to an ideal scholastic design was not always possible for the present research. For example, accident records did not furnish information on accident type that was required for in-depth analysis.

It is, therefore, the natural and desirable outcome of this research that accidents may be segregated by the type of location in terms of intersection and non-intersection accidents. This is particularly true because the literature [e.g., 78,101,105] generally describes them as different entities.

In this research, the assumption of one or more design deficiencies as an indicator of hazard was seriously violated in some cases due to the absence of an uniform standard. For example, the absence (or presence) of traffic signs made no meaningful difference since there were no standards to quantify the deficiency. It is suggested that a method to quantify such cases using some appropriate procedures be developed for future research.

Use of different techniques and deployment of different measuring units to quantify ambient hazard is strongly suggested. For example, intersection deficiencies may be quantified in terms of sight distance data rather than in terms of operational maneuvers or conflicts. This strategy would not only provide means to review the present findings but may also suggest a different analytical approach for examining the relationship between hazards and accidents. For example, discriminant analysis might be effectively used for determining the membership of the suspect sites to the most appropriate hazard groups in developing a hazardousness Index.

6.4 REMAINING COMPONENTS OF THE HSIP

Besides the Planning Component which constitutes the major part of the HSIP, the Implementation and Evaluation components are the two remaining parts for completing a HSIP (see Tables 2.9-2.11, pages 61-62). A discussion, specific to the present findings, is presented in the following pages for the accomplishment of these two remaining components.

6.4.1 Implementation Component

The purpose of the Implementation Component is to design, schedule, construct and make necessary final adjustments to the highway safety improvements which were selected in the Planning Component [71]. For the present research, the necessity of the following three types of remedial measures was indicated.

1) Highway access control improvements.

2) Intersection operation improvements.

3) Delineation and channelization improvements on high embankment locations.

The implementation of relevant improvement projects can be carried out in Pakistan by the national or provincial highway agencies. The agencies' managerial capabilities and the knowledge of administrating and monitoring of engineering projects is assumed.

6.4.2 Evaluation Component

The Evaluation Component is the final step of the HSIP which must not be ignored. The purpose of the Evaluation Component is to assess the value of ongoing and completed projects which result from the Planning and Implementation Components [71]. Since surrogate measures of safety were employed in the present research to identify and rank hazardous sections, a discussion on non-accident based project evaluation techniques is warranted.

Non-accident based evaluations refer to methods employing other than frequency or rate of accidents measures to analyze the HSIP effectiveness. Such analyses are conventionally made in terms of various measure of effectiveness (MOE)*. The possible examples of non-accident based MOEs for the evaluation of the countermeasures indicated by the present research are displayed in Table 6.1.

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* *An MOE is a measurable unit or set of units assigned to each evaluation objective. The data collected in the units of the MOE will allow the analyst to determine the degree of achievement for that objective [71].*

Table 6.1 Examples of Non-accident Based MOEs.

No.	Type of Countermeasures	MOEs
1.	Highway Access Control Improvements.	Traffic conflicts, auto-pedestrian conflicts, stopping, loading/offloading maneuvers, traffic control violations.
2.	Intersection Operation Improvements.	Traffic conflicts, erratic vehicle maneuvers, vehicle speeds.
3.	Delineation and Channelization Improvements on High Embankment Locations.	Traffic conflicts, erratic vehicle maneuvers, lateral vehicle placement, vehicle speeds.

The non-accident based evaluations are quasi-robust analyses and should be replaced by accident based evaluations once reliable accident data becomes available. To maintain continuity, it is added that HSIP literature [71] describes four selected plans for evaluating highway safety projects.

1) Before and After Study with Control Sites;

2) Before and After Study;

3) Comparative Parallel Study; and

4) Before, During and After Study.

The cited reference [71] includes a detailed description of each evaluation plan. Additionally, Laughland et al. [123], OECD [124], and Tarrants et al. [125] offer very wide ranging perspectives on safety program evaluations.

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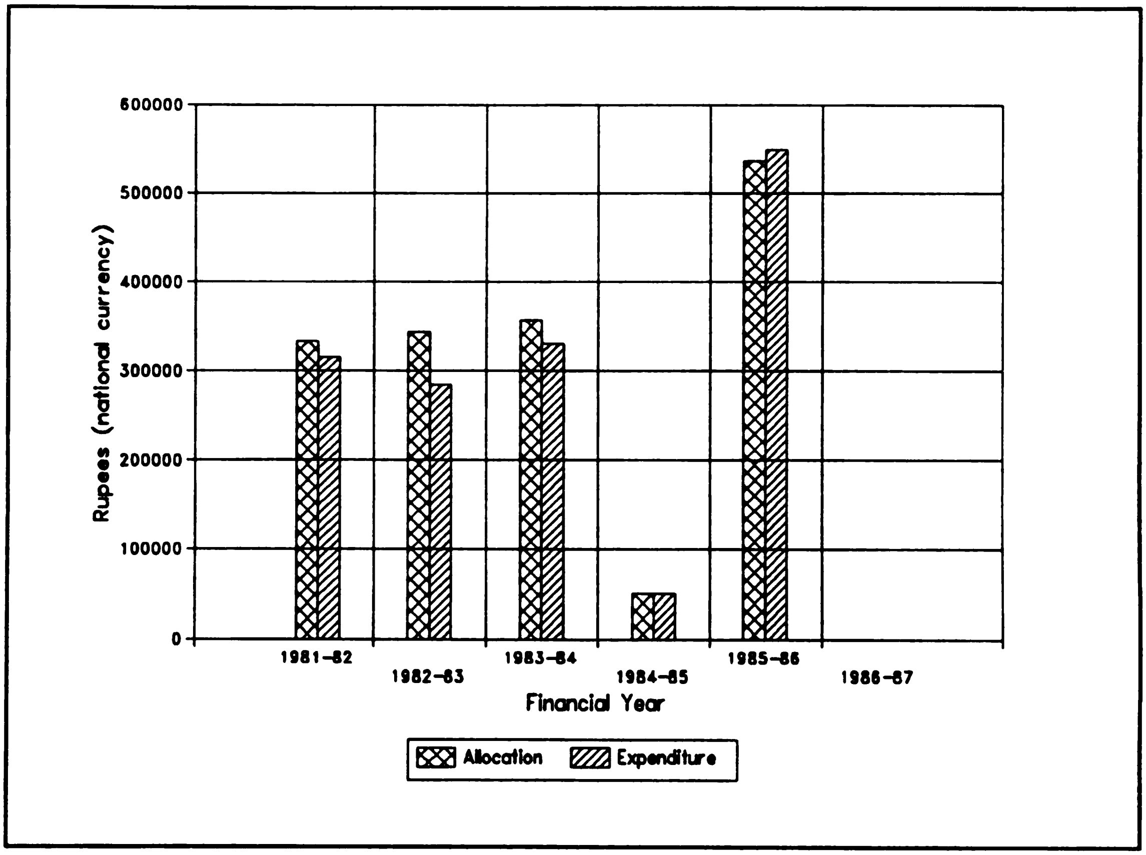
APPENDICES

Appendix A

Financial Statement for the Removal of Blackspots
An Example: Rawalpindi Civil Division, Punjab.
(1980-1987)

Financial Statement for the Removal of Blackspots in Rawalpindi Division. Source: [PHD].

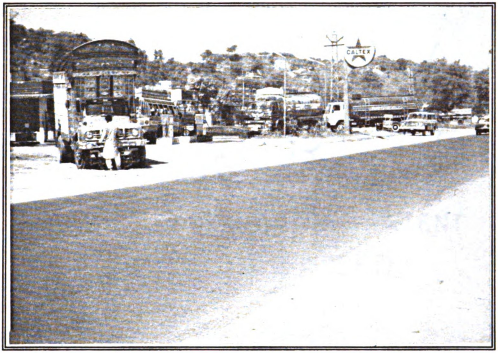
Year	Allocation (Rs)	Expenditure
1981-82	332,660	315,306
1982-83	343,400	283,739
1983-84	356,870	330,679
1984-85	50,000	49,876
1985-86	536,000	549,030
1986-87	Discontinued	--



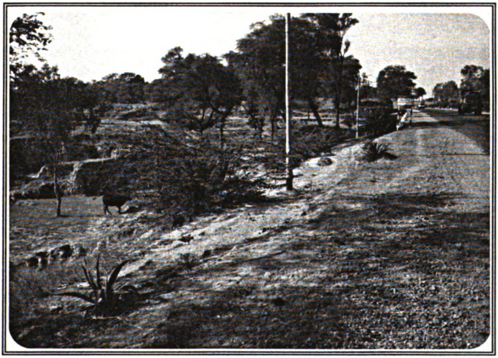
A Graphical Representation of the above Financial Statement.

Appendix B

Some Photographs of the Experimental Site
Showing the Selected Hazards



Deficient Access Control - Ribbon Development: Hazardousness Evaluated by MOH [RIBBON].



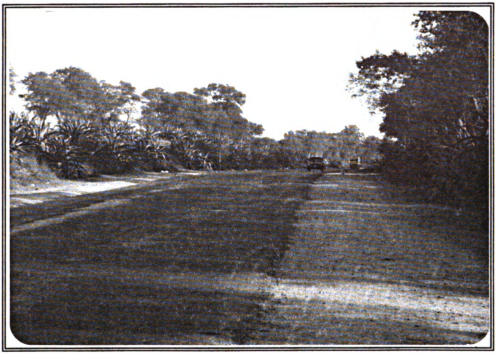
Deficient Access Control - Specific Paths: Hazardousness Evaluated by MOH [SPATHS].

Deficient Access Control - Median Openings: Hazardousness Evaluated by MOH [MEDOPN].

Deficient Guardrail: Hazardousness Evaluated by MOH [GDRAIL].

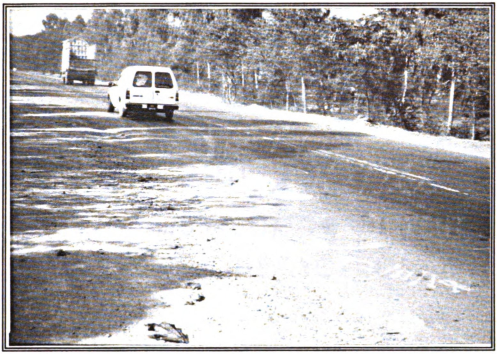
Deficient Pavement Width: Hazardousness Evaluated by MOH [PWIDTH].

Deficient Shoulder Width: Hazardousness Evaluated by MOH [SWIDTH].



Deficient Pavement Markings: Hazardousness Evaluated by MOH [PMARKS].

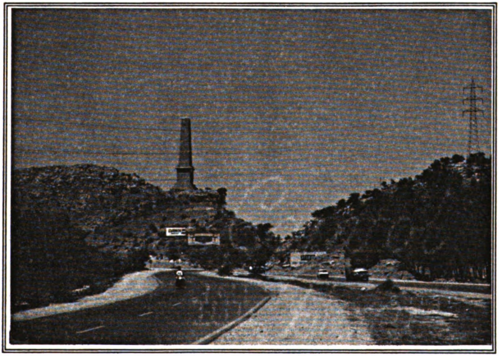
Intersection Deficiencies: Hazardousness Evaluated by MOH [INTSEC].



Isolated Lane Deficiencies: Hazardousness Evaluated by MOH [ISLAND].

Pavement Condition Rating: Hazardousness Evaluated by MOH [PVCOND].

Roadside Obstructions: Hazardousness Evaluated by MOH [SIDEOB].



A Highway Section Having no Hazards that were Included in this Study.

Appendix C

The Hazard Data and the Quantified Hazardousness Using the Developed MOH

NON [ACCESS]: DEFICIENT CONTROL OF ACCESS

Unit of Measurement: meters per kilometer

2-Lane, 2-Way Sections

[RIBBON] = Sum (Ribbon Development)
[SPATHS] = Sum (Specific Paths)

Km.	Ribbon Development (meters)			Specific Paths (meters)		
	Left	Right	[RIBBON]	Left	Right	[SPATHS]
1481	490.00	411.00	901.00	18.00	21.00	39.00
1482	.00	.00	.00	.00	5.00	5.00
1483	.00	.00	.00	4.00	13.00	17.00
1484	.00	.00	.00	7.00	8.00	15.00
1485	.00	.00	.00	7.00	.00	7.00
1486	352.00	218.00	570.00	7.00	9.00	16.00
1487	212.00	107.00	319.00	9.00	15.00	24.00
1488	530.00	450.00	980.00	5.00	16.00	21.00
1493	112.00	30.00	142.00	2.00	8.00	10.00
1494	103.00	111.00	214.00	7.00	16.00	23.00
1495	.00	.00	.00	.00	10.00	10.00
1496	310.00	.00	310.00	19.00	.00	19.00
1497	.00	100.00	100.00	.00	14.00	14.00
1498	.00	50.00	50.00	.00	6.00	6.00
1499	50.00	.00	50.00	5.00	2.00	7.00
1500	510.00	300.00	810.00	14.00	9.00	23.00
1501	98.00	.00	98.00	9.00	.00	9.00
1502	.00	.00	.00	13.00	18.00	31.00
1503	110.00	195.00	305.00	.00	.00	.00
1504	300.00	300.00	600.00	11.00	.00	11.00
1505	782.00	815.00	1,597.00	10.00	19.00	29.00
1506	610.00	430.00	1,040.00	12.00	18.00	30.00
1507	202.00	194.00	396.00	5.00	8.00	13.00
1508	615.00	417.00	1,032.00	6.00	3.00	9.00
1509	430.00	288.00	718.00	16.00	.00	16.00
1510	410.00	250.00	660.00	12.00	7.00	19.00
1511	660.00	330.00	990.00	5.00	.00	5.00
1512	312.00	317.00	629.00	12.00	5.00	17.00
1513	300.00	310.00	610.00	5.00	3.00	8.00
1514	423.00	398.00	821.00	6.00	9.00	15.00
1515	322.00	212.00	534.00	10.00	7.00	17.00
1516	200.00	209.00	409.00	3.00	9.00	12.00
1517	488.00	222.00	710.00	5.00	8.00	13.00
1518	.00	.00	.00	5.00	.00	5.00
1519	.00	.00	.00	10.00	13.00	23.00
1520	296.00	227.00	523.00	12.00	20.00	32.00
1521	310.00	208.00	518.00	9.00	12.00	21.00
1522	.00	.00	.00	8.00	.00	8.00
1523	483.00	430.00	913.00	13.00	6.00	19.00
1524	.00	400.00	400.00	8.00	6.00	14.00
1525	100.00	122.00	222.00	4.00	.00	4.00
1526	.00	.00	.00	10.00	6.00	16.00
1527	.00	.00	.00	7.00	.00	7.00
1528	380.00	375.00	755.00	7.00	6.00	13.00
1529	.00	.00	.00	8.00	6.00	14.00
1530	70.00	100.00	170.00	19.00	19.00	38.00
1531	780.00	842.00	1,622.00	14.00	11.00	25.00
1532	215.00	141.00	356.00	15.00	4.00	19.00
1533	107.00	122.00	229.00	15.00	12.00	27.00
1534	630.00	710.00	1,340.00	4.00	6.00	10.00
1535	777.00	722.00	1,499.00	5.00	3.00	8.00
1536	785.00	594.00	1,379.00	4.00	4.00	8.00

MON [GDRAIL]: DEFICIENT GUARDRAIL SECTIONS

Unit of Measurement: meters per kilometer

2-Lane, 2-Way Sections

[GDRAIL] = SUM [Deficient Guardrail Sections]

Km.	Deficient Guardrail Sections (meters) Left	Right	[GDRAIL]
1481	212.00	333.00	545.00
1482	100.00	80.00	180.00
1483	250.00	250.00	500.00
1484	367.00	417.00	784.00
1485	214.00	198.00	412.00
1486	350.00	320.00	670.00
1487	510.00	582.00	1092.00
1488	110.00	40.00	150.00
1493	396.00	426.00	822.00
1494	328.00	274.00	602.00
1495	.00	.00	.00
1496	.00	50.00	50.00
1497	142.00	186.00	328.00
1498	.00	188.00	188.00
1499	330.00	300.00	630.00
1500	.00	.00	.00
1501	.00	.00	.00
1502	205.00	194.00	399.00
1503	100.00	50.00	150.00
1504	100.00	100.00	200.00
1505	.00	.00	.00
1506	342.00	240.00	582.00
1507	207.00	94.00	301.00
1508	188.00	96.00	284.00
1509	200.00	250.00	450.00
1510	322.00	195.00	517.00
1511	.00	.00	.00
1512	.00	.00	.00
1513	.00	.00	.00
1514	217.00	206.00	423.00
1515	100.00	95.00	195.00
1516	.00	50.00	50.00
1517	50.00	92.00	142.00
1518	100.00	100.00	200.00
1519	100.00	100.00	200.00
1520	280.00	208.00	488.00
1521	.00	.00	.00
1522	.00	88.00	88.00
1523	.00	.00	.00
1524	.00	.00	.00
1525	70.00	196.00	266.00
1526	100.00	185.00	285.00
1527	50.00	150.00	200.00
1528	.00	.00	.00
1529	.00	88.00	88.00
1530	.00	50.00	50.00
1531	.00	.00	.00
1532	100.00	.00	100.00
1533	44.00	168.00	212.00
1534	.00	.00	.00
1535	.00	.00	.00
1536	.00	.00	.00

NON [PWIDTH]: DEFICIENT PAVEMENT WIDTH

Unit of Measurement: meters per kilometer

2-Lane, 2-Way Sections

[PWIDTH] = $(Variation)^2$.
Variation = (3.65 x Number of lanes - Pvt. Width).
A negative variation signifies pavement wider than specified.

Km.	Pvt. Width (meters)	Variation (meters)	[PWIDTH]
1481	7.30	.00	.00
1482	7.30	.00	.00
1483	7.90	-.60	.36
1484	7.30	.00	.00
1485	7.30	.00	.00
1486	7.30	.00	.00
1487	7.30	.00	.00
1488	7.20	.10	.01
1493	8.50	-1.20	1.44
1494	7.30	.00	.00
1495	7.30	.00	.00
1496	8.00	-.70	.49
1497	7.00	.30	.09
1498	7.30	.00	.00
1499	8.00	-.70	.49
1500	7.50	-.20	.04
1501	8.00	-.70	.49
1502	7.00	.30	.09
1503	7.30	.00	.00
1504	7.30	.00	.00
1505	7.10	.20	.04
1506	7.20	.10	.01
1507	7.40	-.10	.01
1508	7.00	.30	.09
1509	7.20	.10	.01
1510	7.00	.30	.09
1511	7.00	.30	.09
1512	7.00	.30	.09
1513	7.30	.00	.00
1514	7.00	.30	.09
1515	7.00	.30	.09
1516	7.00	.30	.09
1517	7.00	.30	.09
1518	7.30	.00	.00
1519	7.30	.00	.00
1520	7.30	.00	.00
1521	8.00	-.70	.49
1522	7.70	-.40	.16
1523	7.30	.00	.00
1524	7.50	-.20	.04
1525	9.50	-2.20	4.84
1526	7.30	.00	.00
1527	7.10	.20	.04
1528	7.30	.00	.00
1529	7.30	.00	.00
1530	7.10	.20	.04
1531	7.20	.10	.01
1532	8.20	-.90	.81
1533	8.20	-.90	.81
1534	8.50	-1.20	1.44
1535	13.50	1.10	1.21
1536	11.00	-.05	.00

MON [SWIDTH]: DEFICIENT SHOULDER WIDTH

Unit of Measurement: meters per kilometer

2-Lane, 2-Way Sections

[SWIDTH] = SUM [Deficiency (+ values only)].
Deficiency = (3.00 - Shoulder Width).
A negative deficiency signifies shoulder wider than specified.

Km.	Shoulder Width (meters)		Deficiency (meters)		
	Left	Right	Left	Right	[SWIDTH]
1481	3.00	3.00	.00	.00	.00
1482	3.00	3.00	.00	.00	.00
1483	3.20	3.20	-.20	-.20	.00
1484	3.00	3.00	.00	.00	.00
1485	2.30	3.20	.70	-.20	.70
1486	3.40	3.40	-.40	-.40	.00
1487	3.00	3.00	.00	.00	.00
1488	3.10	3.00	-.10	.00	.00
1493	2.00	2.00	1.00	1.00	2.00
1494	2.50	2.50	.50	.50	1.00
1495	2.50	2.50	.50	.50	1.00
1496	3.00	3.00	.00	.00	.00
1497	3.00	3.00	.00	.00	.00
1498	2.00	3.00	1.00	.00	1.00
1499	1.50	2.50	1.50	.50	2.00
1500	2.50	2.50	.50	.50	1.00
1501	2.50	3.00	.50	.00	.50
1502	3.00	3.00	.00	.00	.00
1503	3.00	3.00	.00	.00	.00
1504	2.50	2.50	.50	.50	1.00
1505	3.50	2.50	-.50	.50	.50
1506	2.50	2.50	.50	.50	1.00
1507	2.50	2.50	.50	.50	1.00
1508	2.00	2.00	1.00	1.00	2.00
1509	2.30	2.30	.70	.70	1.40
1510	3.00	3.00	.00	.00	.00
1511	3.00	3.00	.00	.00	.00
1512	3.00	2.00	.00	1.00	1.00
1513	2.50	4.00	.50	-1.00	.50
1514	3.00	3.00	.00	.00	.00
1515	3.00	2.50	.00	.50	.50
1516	3.00	3.20	.00	-.20	.00
1517	2.00	2.30	1.00	.70	1.70
1518	2.20	2.20	.80	.80	1.60
1519	3.00	2.00	.00	1.00	1.00
1520	2.50	2.00	.50	1.00	1.50
1521	3.00	2.50	.00	.50	.50
1522	2.50	2.00	.50	1.00	1.50
1523	3.00	3.00	.00	.00	.00
1524	3.00	2.00	.00	1.00	1.00
1525	2.00	2.00	1.00	1.00	2.00
1526	3.00	3.50	.00	-.50	.00
1527	3.00	2.00	.00	1.00	1.00
1528	3.00	2.50	.00	.50	.50
1529	3.00	2.50	.00	.50	.50
1530	3.00	2.50	.00	.50	.50
1531	2.50	3.00	.50	.00	.50
1532	2.00	2.00	1.00	1.00	2.00
1533	2.00	2.00	1.00	1.00	2.00
1534	2.00	2.00	1.00	1.00	2.00
1535	1.50	1.50	1.50	1.50	3.00
1536	1.50	1.50	1.50	1.50	3.00

MON [PMARKS]: DEFICIENT PAVEMENT MARKINGS

Unit of Measurement: Kilometers per kilometer

2-Lane, 2-Way Sections

[PMARKS] = SUM [Deficient Length x Weight] x 1/1000
Weights: 1 = for missing edgeline on one side;
2 = for missing edgeline on both sides; and
3 = for missing centerline and intersection areas.

Km.	Deficient Length (Longitudinal Sections) 1-side	2-sides	C-line	Km.	Deficient Length (Intersection Areas)		Sum	[PMARKS]
1481	.00	1,000.00	1,000.00	1481			5000.00	5.00
1482	.00	1,000.00	1,000.00	1482			5000.00	5.00
1483	.00	1,000.00	1,000.00	1483			5000.00	5.00
1484	.00	1,000.00	1,000.00	1484			5000.00	5.00
1485	.00	1,000.00	1,000.00	1485			5000.00	5.00
1486	.00	1,000.00	1,000.00	1486			5000.00	5.00
1487	.00	1,000.00	1,000.00	1487			5000.00	5.00
1488	.00	1,000.00	1,000.00	1488			5000.00	5.00
1493	.00	1,000.00	1,000.00	1493			5000.00	5.00
1494	.00	1,000.00	1,000.00	1494			5000.00	5.00
1495	.00	1,000.00	1,000.00	1495			5000.00	5.00
1496	.00	1,000.00	1,000.00	1496			5000.00	5.00
1497	.00	1,000.00	1,000.00	1497			5000.00	5.00
1498	.00	1,000.00	1,000.00	1498			5000.00	5.00
1499	.00	1,000.00	1,000.00	1499			5000.00	5.00
1500	.00	1,000.00	1,000.00	1500			5000.00	5.00
1501	.00	1,000.00	1,000.00	1501			5000.00	5.00
1502	.00	1,000.00	1,000.00	1502			5000.00	5.00
1503	.00	1,000.00	1,000.00	1503			5000.00	5.00
1504	.00	1,000.00	1,000.00	1504	Chakwal Y-Junction	450.00	6350.00	6.35
1505	.00	1,000.00	1,000.00	1505			5000.00	5.00
1506	.00	1,000.00	1,000.00	1506			5000.00	5.00
1507	.00	1,000.00	1,000.00	1507			5000.00	5.00
1508	.00	1,000.00	1,000.00	1508			5000.00	5.00
1509	.00	1,000.00	1,000.00	1509			5000.00	5.00
1510	.00	1,000.00	1,000.00	1510			5000.00	5.00
1511	.00	1,000.00	1,000.00	1511			5000.00	5.00
1512	.00	1,000.00	1,000.00	1512			5000.00	5.00
1513	.00	1,000.00	1,000.00	1513			5000.00	5.00
1514	.00	1,000.00	1,000.00	1514			5000.00	5.00
1515	.00	1,000.00	1,000.00	1515			5000.00	5.00
1516	.00	1,000.00	1,000.00	1516			5000.00	5.00
1517	.00	1,000.00	1,000.00	1517			5000.00	5.00
1518	.00	1,000.00	1,000.00	1518			5000.00	5.00
1519	.00	1,000.00	1,000.00	1519	Chack Beli Y-Junction	320.00	5960.00	5.96
1520	.00	1,000.00	1,000.00	1520			5000.00	5.00
1521	.00	1,000.00	1,000.00	1521			5000.00	5.00
1522	.00	1,000.00	1,000.00	1522			5000.00	5.00
1523	.00	1,000.00	1,000.00	1523	Islamabad Y-Junction	350.00	6050.00	6.05
1524	.00	1,000.00	1,000.00	1524			5000.00	5.00
1525	.00	1,000.00	1,000.00	1525			5000.00	5.00
1526	.00	1,000.00	1,000.00	1526			5000.00	5.00
1527	.00	1,000.00	1,000.00	1527			5000.00	5.00
1528	.00	1,000.00	1,000.00	1528			5000.00	5.00
1529	.00	1,000.00	1,000.00	1529	Sihala Y-Junction	200.00	5600.00	5.60
1530	.00	1,000.00	1,000.00	1530			5000.00	5.00
1531	.00	1,000.00	1,000.00	1531			5000.00	5.00
1532	.00	1,000.00	1,000.00	1532			5000.00	5.00
1533	.00	1,000.00	1,000.00	1533	Fauji Fds. Y-Junction	460.00	6380.00	6.38
1534	.00	1,000.00	1,000.00	1534			5000.00	5.00
1535	.00	1,000.00	1,000.00	1535	Ayub Park T-Junction	270.00	5810.00	5.81
1535				1535	Attock Oil T-Junction	350.00	1050.00	1.05
1536	.00	1,000.00	1,000.00	1536			5000.00	5.00

MOH [INTSEC]: INTERSECTION DEFICIENCIES
MOH [INTENT]: ENTRY INTO INTERSECTION WITHOUT STOPPING
MOH [INTSPD]: ABRUPT SPEED CHANGE AFTER ENTRY INTO INTERSECTION
MOH [INTCOL]: NEAR COLLISION SITUATION

Unit of Measurement: # per hour

2-Lane, 2-Way Sections

[INTENT] = NS/TE.
[INTSPD] = EA/TE.
[INTCOL] = NC/TE.
[INTACT] = [(WS-(WS-EA))/TE] + [(WS-(WS-NC))/TE].
for evaluation of interactive effect.
[INTSEC] = [INTENT] + [INTSPD] + [INTCOL] + [INTACT].

Km.	TE (Vph)	NS (Vph)	EA (Vph)	NC (Vph)	Intersection Location	[INTENT]	[INTSPD]	[INTCOL]	[INTACT]	[INTSEC]
1504	1176	72	40	28	Chakwal Y-Junction	.0612	.0340	.0238	.0578	17.69
1519	984	72	28	20	Chack Beli Y-Junction	.0732	.0285	.0203	.0488	17.07
1523	1132	80	56	36	Islamabad Highway Y-Junction	.0707	.0495	.0318	.0813	23.32
1529	880	76	32	16	Sihala Y-Junction	.0864	.0364	.0182	.0545	19.55
1535	1288	28	8	4	Ayub Park T-Junction	.0217	.0062	.0031	.0093	4.04
1535	832	72	32	24	Attock Oil T-Junction	.0865	.0385	.0288	.0673	22.12

TE = Total Entry
NS = No Stopping
EA = Evasive Action
NC = Near Collision
Vph = Vehicles per hour

MOH [ISLAND]: ISOLATED LANE DEFICIENCIES
MOH [SPDCHG]: ABRUPT SPEED CHANGE
MOH [LANCHG]: ABRUPT LANE CHANGE

Unit of Measurement: # per kilometer (weighted)

2-Lane, 2-Way Sections

[ISLAND] = [SPDCHG] + [LANCHG].
[SPDCHG] = (Low ASCx1) + (Medium ASCx2) + (High ASCx3)].
[LANCHG] = (Low ALCx1) + (Medium ALCx2) + (High ALCx3)].

km.	Abrupt Speed Change					Abrupt Lane Change				
	Low	Medium	High	[SPDCHG]		Low	Medium	High	[LANCHG]	[ISLAND]
1481	.00	.00	.00	.00	1481	.00	.00	.00	.00	.00
1482	.00	.00	.00	.00	1482	1.00	.00	.00	1.00	1.00
1483	.00	.00	.00	.00	1483	.00	.00	.00	.00	.00
1484	.00	.00	.00	.00	1484	.00	.00	.00	.00	.00
1485	.00	.00	.00	.00	1485	.00	.00	.00	.00	.00
1486	.00	.00	.00	.00	1486	.00	.00	.00	.00	.00
1487	.00	.00	.00	.00	1487	.00	.00	.00	.00	.00
1488	.00	.00	.00	.00	1488	.00	.00	.00	.00	.00
1493	.00	.00	.00	.00	1493	.00	.00	.00	.00	.00
1494	.00	.00	.00	.00	1494	.00	.00	.00	.00	.00
1495	1.00	.00	.00	1.00	1495	1.00	.00	.00	1.00	2.00
1496	1.00	1.00	.00	3.00	1496	2.00	1.00	.00	4.00	7.00
1497	.00	.00	.00	.00	1497	1.00	.00	.00	1.00	1.00
1498	.00	.00	.00	.00	1498	.00	.00	.00	.00	.00
1499	.00	.00	.00	.00	1499	.00	.00	.00	.00	.00
1500	1.00	.00	.00	1.00	1500	.00	.00	.00	.00	1.00
1501	.00	.00	.00	.00	1501	.00	.00	.00	.00	.00
1502	1.00	.00	.00	1.00	1502	.00	.00	.00	.00	1.00
1503	.00	.00	.00	.00	1503	.00	.00	.00	.00	.00
1504	.00	.00	.00	.00	1504	.00	.00	.00	.00	.00
1505	.00	.00	.00	.00	1505	.00	.00	.00	.00	.00
1506	.00	.00	.00	.00	1506	.00	.00	.00	.00	.00
1507	.00	.00	.00	.00	1507	1.00	.00	.00	1.00	1.00
1508	.00	.00	.00	.00	1508	1.00	.00	.00	1.00	1.00
1509	.00	.00	.00	.00	1509	.00	.00	.00	.00	.00
1510	.00	.00	.00	.00	1510	.00	.00	.00	.00	.00
1511	.00	.00	.00	.00	1511	.00	.00	.00	.00	.00
1512	.00	.00	.00	.00	1512	.00	.00	.00	.00	.00
1513	1.00	.00	.00	1.00	1513	1.00	.00	.00	1.00	2.00
1514	.00	.00	.00	.00	1514	.00	.00	.00	.00	.00
1515	.00	1.00	.00	2.00	1515	1.00	.00	.00	1.00	3.00
1516	.00	.00	.00	.00	1516	.00	.00	.00	.00	.00
1517	.00	.00	.00	.00	1517	.00	.00	.00	.00	.00
1518	.00	.00	.00	.00	1518	.00	.00	.00	.00	.00
1519	.00	.00	.00	.00	1519	.00	.00	.00	.00	.00
1520	.00	.00	.00	.00	1520	.00	.00	.00	.00	.00
1521	1.00	.00	.00	1.00	1521	.00	.00	.00	.00	1.00
1522	1.00	.00	.00	1.00	1522	.00	1.00	.00	2.00	3.00
1523	.00	.00	.00	.00	1523	.00	.00	.00	.00	.00
1524	.00	.00	.00	.00	1524	.00	.00	.00	.00	.00
1525	.00	.00	.00	.00	1525	.00	.00	.00	.00	.00
1526	.00	.00	.00	.00	1526	.00	.00	.00	.00	.00
1527	.00	.00	.00	.00	1527	.00	.00	.00	.00	.00
1528	.00	.00	.00	.00	1528	.00	.00	.00	.00	.00
1529	.00	.00	.00	.00	1529	1.00	.00	.00	1.00	1.00
1530	1.00	.00	.00	1.00	1530	1.00	.00	.00	1.00	2.00
1531	.00	.00	.00	.00	1531	.00	.00	.00	.00	.00
1532	.00	.00	.00	.00	1532	.00	.00	.00	.00	.00
1533	.00	.00	.00	.00	1533	.00	.00	.00	.00	.00
1534	.00	.00	.00	.00	1534	.00	.00	.00	.00	.00
1535	.00	.00	.00	.00	1535	.00	.00	.00	.00	.00
1536	.00	.00	.00	.00	1536	.00	.00	.00	.00	.00

MON [PVCOND]: PAVEMENT CONDITION RATING

Unit of Measurement: number (rated) per kilometer

2-Lane, 2-Way Sections

[PVCOND] = [(Sum Itemized) + (Cumulative Rating)]/2.00
Sum Itemized = SUM [Cracking + Rutting + Roughness + Dropoff].
Cumulative Rating = A composite rating based on above specified distress.

Km.	Subjective Rating Number						
	Itemized Rating					Cumulative Rating	
	Cracking	Rutting	Roughness	Dropoff	Sum Itemized		[PVCOND]
1481	10.00	6.00	7.00	5.00	28.00	40.00	34.00
1482	11.00	5.00	7.00	5.00	28.00	40.00	34.00
1483	13.00	7.00	6.00	4.00	30.00	40.00	35.00
1484	15.00	7.00	6.00	7.00	35.00	40.00	37.50
1485	10.00	6.00	7.00	7.00	30.00	50.00	40.00
1486	15.00	7.00	8.00	4.00	34.00	50.00	42.00
1487	13.00	6.00	7.00	4.00	30.00	60.00	45.00
1488	12.00	7.00	8.00	6.00	33.00	60.00	46.50
1493	15.00	5.00	6.00	5.00	31.00	45.00	38.00
1494	16.00	7.00	8.00	8.00	39.00	45.00	42.00
1495	15.00	9.00	9.00	8.00	41.00	68.00	54.50
1496	14.00	10.00	11.00	7.00	42.00	58.00	50.00
1497	17.00	7.00	8.00	9.00	41.00	50.00	45.50
1498	16.00	8.00	10.00	9.00	43.00	52.00	47.50
1499	15.00	6.00	7.00	10.00	38.00	42.00	40.00
1500	15.00	7.00	8.00	11.00	41.00	60.00	50.50
1501	16.00	7.00	8.00	10.00	41.00	65.00	53.00
1502	20.00	8.00	9.00	11.00	48.00	68.00	58.00
1503	18.00	11.00	10.00	8.00	47.00	75.00	61.00
1504	17.00	10.00	10.00	7.00	44.00	70.00	57.00
1505	15.00	7.00	8.00	4.00	34.00	52.00	43.00
1506	16.00	8.00	9.00	5.00	38.00	60.00	49.00
1507	18.00	10.00	11.00	10.00	49.00	60.00	54.50
1508	21.00	12.00	14.00	12.00	59.00	65.00	62.00
1509	16.00	10.00	11.00	10.00	47.00	62.00	54.50
1510	17.00	10.00	10.00	8.00	45.00	65.00	55.00
1511	16.00	11.00	12.00	9.00	48.00	75.00	61.50
1512	12.00	10.00	11.00	5.00	38.00	70.00	54.00
1513	13.00	11.00	10.00	4.00	38.00	65.00	51.50
1514	12.00	8.00	9.00	4.00	33.00	45.00	39.00
1515	15.00	10.00	9.00	7.00	41.00	50.00	45.50
1516	17.00	8.00	7.00	9.00	41.00	50.00	45.50
1517	18.00	10.00	7.00	8.00	43.00	48.00	45.50
1518	17.00	11.00	6.00	7.00	41.00	50.00	45.50
1519	16.00	10.00	7.00	7.00	40.00	45.00	42.50
1520	15.00	11.00	8.00	6.00	40.00	45.00	42.50
1521	10.00	8.00	9.00	10.00	37.00	35.00	36.00
1522	12.00	10.00	8.00	8.00	38.00	35.00	36.50
1523	11.00	9.00	7.00	5.00	32.00	40.00	36.00
1524	15.00	8.00	7.00	6.00	36.00	50.00	43.00
1525	16.00	10.00	12.00	10.00	48.00	55.00	51.50
1526	13.00	12.00	10.00	10.00	45.00	58.00	51.50
1527	15.00	9.00	8.00	7.00	39.00	58.00	48.50
1528	12.00	8.00	7.00	5.00	32.00	55.00	43.50
1529	7.00	8.00	10.00	6.00	31.00	50.00	40.50
1530	3.00	6.00	8.00	10.00	27.00	40.00	33.50
1531	5.00	8.00	10.00	9.00	32.00	45.00	38.50
1532	3.00	2.00	5.00	5.00	15.00	40.00	27.50
1533	5.00	3.00	6.00	4.00	18.00	35.00	26.50
1534	3.00	3.00	6.00	5.00	17.00	30.00	23.50
1535	10.00	5.00	5.00	6.00	26.00	40.00	33.00
1536	12.00	6.00	5.00	7.00	30.00	48.00	39.00

MON [SIDEOB]: ROADSIDE OBSTRUCTION

Unit of Measurement: number per kilometer

2-Lane, 2-Way Sections

[SIDEOB] = SUM [Count #1 + Count #2]/2.00
Count #1 = Rated counting by member-1.
Count #2 = Rated counting by member-2.

Km.	(Count #1)	(Count #2)	[SIDEOB]
1481	12.00	10.00	11.00
1482	12.00	12.00	12.00
1483	8.00	7.00	7.50
1484	5.00	4.00	4.50
1485	48.00	42.00	45.00
1486	23.00	23.00	23.00
1487	10.00	8.00	9.00
1488	14.00	11.00	12.50
1493	11.00	11.00	11.00
1494	7.00	7.00	7.00
1495	8.00	6.00	7.00
1496	51.00	42.00	46.50
1497	50.00	39.00	44.50
1498	5.00	4.00	4.50
1499	6.00	4.00	5.00
1500	11.00	7.00	9.00
1501	8.00	8.00	8.00
1502	6.00	4.00	5.00
1503	7.00	6.00	6.50
1504	15.00	16.00	15.50
1505	23.00	20.00	21.50
1506	5.00	5.00	5.00
1507	10.00	10.00	10.00
1508	26.00	23.00	24.50
1509	20.00	18.00	19.00
1510	36.00	31.00	33.50
1511	30.00	30.00	30.00
1512	20.00	14.00	17.00
1513	8.00	8.00	8.00
1514	7.00	7.00	7.00
1515	2.00	2.00	2.00
1516	18.00	15.00	16.50
1517	6.00	6.00	6.00
1518	36.00	31.00	33.50
1519	7.00	8.00	7.50
1520	15.00	14.00	14.50
1521	19.00	19.00	19.00
1522	25.00	26.00	25.50
1523	1.00	.00	.50
1524	9.00	8.00	8.50
1525	.00	.00	.00
1526	2.00	.00	1.00
1527	6.00	5.00	5.50
1528	5.00	4.00	4.50
1529	19.00	16.00	17.50
1530	7.00	4.00	5.50
1531	9.00	10.00	9.50
1532	12.00	11.00	11.50
1533	19.00	16.00	17.50
1534	40.00	32.00	36.00
1535	38.00	30.00	34.00
1536	12.00	7.00	9.50

NON [ACCESS]: DEFICIENT CONTROL OF ACCESS

Unit of Measurement: meters per kilometer

(4-Lane Divided Sections)

[RIBBON] = Sum (Ribbon Development).
[SPATHS] = Sum (Specific Paths).
[MEDOPN] = Median Opening.

Km.	Ribbon Development (meters)			Specific Paths (meters)			Median Opening (meters)
	NBC	SBC		NBC	SBC		
			[RIBBON]			[SPATHS]	[MEDOPN]
1550	317.00	200.00	517.00	16.00	18.00	34.00	60.00
1551	121.00	.00	121.00	25.00	16.00	41.00	80.00
1552	.00	.00	.00	10.00	3.00	13.00	21.00
1553	.00	.00	.00	8.00	4.00	12.00	45.00
1554	508.00	310.00	818.00	24.00	8.00	32.00	80.00
1555	224.00	100.00	324.00	8.00	12.00	20.00	66.00
1556	.00	.00	.00	22.00	7.00	29.00	18.00
1557	.00	.00	.00	3.00	9.00	12.00	24.00
1558	.00	.00	.00	15.00	.00	15.00	16.00
1559	.00	.00	.00	22.00	15.00	37.00	15.00
1560	200.00	200.00	400.00	10.00	11.00	21.00	40.00
1561	.00	50.00	50.00	11.00	18.00	29.00	37.00
1562	.00	.00	.00	7.00	7.00	14.00	20.00
1563	.00	.00	.00	4.00	4.00	8.00	32.00
1564	.00	.00	.00	8.00	5.00	13.00	65.00
1565	100.00	200.00	300.00	14.00	18.00	32.00	13.00
1566	100.00	200.00	300.00	8.00	5.00	13.00	8.00
1567	684.00	420.00	1,104.00	10.00	.00	10.00	33.00
1568	315.00	484.00	799.00	17.00	8.00	25.00	70.00
1569	630.00	588.00	1,218.00	.00	24.00	24.00	3.00
1570	322.00	117.00	439.00	9.00	13.00	22.00	318.00
1571	442.00	360.00	802.00	12.00	8.00	20.00	9.00
1572	774.00	865.00	1,639.00	13.00	10.00	23.00	11.00
1573	318.00	272.00	590.00	9.00	8.00	17.00	6.00
1574	660.00	684.00	1,344.00	15.00	12.00	27.00	15.00
1575	214.00	286.00	500.00	10.00	12.00	22.00	3.00
1576	304.00	133.00	437.00	8.00	17.00	25.00	6.00
1577	52.00	146.00	198.00	16.00	7.00	23.00	16.00
1578	230.00	100.00	330.00	24.00	8.00	32.00	30.00
1579	722.00	734.00	1,456.00	21.00	12.00	33.00	5.00
1580	732.00	692.00	1,424.00	16.00	.00	16.00	18.00
1581	482.00	84.00	566.00	15.00	3.00	18.00	33.00
1582	103.00	62.00	165.00	.00	8.00	8.00	29.00
1583	577.00	264.00	841.00	.00	1.00	1.00	35.00

NBC = North Bound Carriageway
SBC = South Bound Carriageway

MON [GDRAIL]: DEFICIENT GUARDRAIL SECTIONS

Unit of Measurement: meters per kilometer

(4-Lane Divided Sections)

[GDRAIL] = SUM [Deficient Guardrail Sections].

Km.	Deficient Guardrail Sections (meters)				
	NBC		SBC		
	Left	Right	Left	Right	[GDRAIL]
1550	222.00	110.00	.00	.00	332.00
1551	30.00	.00	.00	.00	30.00
1552	.00	.00	50.00	.00	50.00
1553	.00	.00	25.00	.00	25.00
1554	60.00	.00	.00	.00	60.00
1555	.00	.00	108.00	.00	108.00
1556	.00	.00	.00	.00	.00
1557	.00	.00	50.00	.00	50.00
1558	.00	.00	77.00	.00	77.00
1559	.00	.00	.00	.00	.00
1560	232.00	244.00	.00	.00	476.00
1561	.00	.00	.00	.00	.00
1562	.00	.00	44.00	.00	44.00
1563	.00	.00	45.00	.00	45.00
1564	.00	.00	64.00	.00	64.00
1565	570.00	460.00	230.00	230.00	1490.00
1566	530.00	.00	165.00	.00	695.00
1567	.00	.00	62.00	.00	62.00
1568	50.00	.00	78.00	.00	128.00
1569	134.00	.00	122.00	.00	256.00
1570	.00	.00	.00	.00	.00
1571	.00	.00	.00	.00	.00
1572	.00	.00	30.00	.00	30.00
1573	112.00	118.00	.00	.00	230.00
1574	250.00	218.00	.00	.00	468.00
1575	.00	.00	.00	.00	.00
1576	.00	.00	.00	.00	.00
1577	50.00	.00	.00	.00	50.00
1578	.00	.00	20.00	.00	20.00
1579	50.00	.00	50.00	.00	100.00
1580	40.00	.00	.00	.00	40.00
1581	85.00	.00	142.00	.00	227.00
1582	118.00	.00	118.00	.00	236.00
1583	.00	.00	.00	.00	.00

NBC = North Bound Carriageway
SBC = South Bound Carriageway

MON [PWIDTH]: DEFICIENT PAVEMENT WIDTH

Unit of Measurement: meters per kilometer

(4-Lane Divided Sections)

[PWIDTH] = SUM [(Variation)^2].
Variation = (3.65 x Number of lanes - Pvt. Width).
A negative variation signifies pavement wider than specified.

Km.	Pavement Width (meters)		Variation (meters)		[PMARKS]
	NBC	SBC	NBC	SBC	
1550	7.10	7.50	.20	-.20	.08
1551	7.40	7.30	-.10	.00	.01
1552	7.40	7.30	-.10	.00	.01
1553	7.30	7.30	.00	.00	.00
1554	7.30	7.30	.00	.00	.00
1555	7.50	7.00	-.20	.30	.13
1556	7.20	7.30	.10	.00	.01
1557	7.50	7.30	-.20	.00	.04
1558	7.50	8.50	-.20	-1.20	1.48
1559	7.40	8.80	-.10	-1.50	2.26
1560	7.00	8.00	.30	-.70	.58
1561	8.80	7.00	-1.50	.30	2.34
1562	9.00	7.90	-1.70	-.60	3.25
1563	8.70	7.30	-1.40	.00	1.96
1564	7.20	7.30	.10	.00	.01
1565	7.50	8.80	-.20	-1.50	2.29
1566	7.80	7.40	-.50	-.10	.26
1567	7.50	7.50	-.20	-.20	.08
1568	7.40	7.50	-.10	-.20	.05
1569	8.80	8.00	-1.50	-.70	2.74
1570	7.30	7.50	.00	-.20	.04
1571	7.50	7.30	-.20	.00	.04
1572	7.30	7.30	.00	.00	.00
1573	7.30	7.20	.00	.10	.01
1574	7.40	7.00	-.10	.30	.10
1575	7.30	7.00	.00	.30	.09
1576	7.00	7.00	.30	.30	.18
1577	6.80	7.00	.50	.30	.34
1578	7.00	7.00	.30	.30	.18
1579	7.50	7.00	-.20	.30	.13
1580	7.30	7.30	.00	.00	.00
1581	7.30	7.30	.00	.00	.00
1582	7.30	7.30	.00	.00	.00
1583	7.30	7.30	.00	.00	.00

NBC = North Bound Carriageway
SBC = South Bound Carriageway

NOM [SWIDTH]: DEFICIENT SHOULDER WIDTH

Unit of Measurement: meters per kilometer

(4-Lane Divided Sections)

[SWIDTH] = SUM [Deficiency (+ values only)].
Deficiency = (3.00 - Shoulder Width).
A negative deficiency signifies shoulder wider than specified.

Km.	Shoulder Width (meters)				Deficiency (meters)				[SWIDTH]
	NBC		SBC		NBC		SBC		
	Left	Right	Left	Right	Left	Right	Left	Right	
1550	1.00	2.00	2.00	2.00	2.00	1.00	1.00	1.00	50.00
1551	2.50	2.50	2.00	2.00	.50	.50	1.00	1.00	30.00
1552	2.50	2.50	2.00	3.00	.50	.50	1.00	.00	20.00
1553	3.00	2.00	2.00	3.00	.00	1.00	1.00	.00	20.00
1554	3.00	2.00	2.00	3.00	.00	1.00	1.00	.00	20.00
1555	3.50	3.20	3.00	3.00	-.50	-.20	.00	.00	.00
1556	2.00	2.00	3.00	3.00	1.00	1.00	.00	.00	20.00
1557	3.00	3.00	3.00	3.00	.00	.00	.00	.00	.00
1558	3.00	3.10	3.00	2.50	.00	-.10	.00	.50	5.00
1559	2.50	2.00	3.00	2.00	.50	1.00	.00	1.00	25.00
1560	3.00	2.00	3.00	3.00	.00	1.00	.00	.00	10.00
1561	2.70	2.00	3.00	3.00	.30	1.00	.00	.00	13.00
1562	2.50	2.00	2.50	3.00	.50	1.00	.50	.00	20.00
1563	3.50	2.30	2.00	2.50	-.50	.70	1.00	.50	22.00
1564	3.20	1.00	2.00	2.00	-.20	2.00	1.00	1.00	40.00
1565	4.60	3.50	2.00	2.10	-1.60	-.50	1.00	.90	19.00
1566	3.00	2.00	2.10	3.00	.00	1.00	.90	.00	19.00
1567	3.90	2.70	2.80	3.00	-.90	.30	.20	.00	5.00
1568	2.00	2.00	2.80	3.00	1.00	1.00	.20	.00	22.00
1569	2.00	3.00	2.00	2.50	1.00	.00	1.00	.50	25.00
1570	3.70	2.70	1.70	2.50	-.70	.30	1.30	.50	21.00
1571	2.50	1.70	2.00	3.00	.50	1.30	1.00	.00	28.00
1572	3.30	2.00	2.00	3.00	-.30	1.00	1.00	.00	20.00
1573	2.00	2.00	2.00	3.00	1.00	1.00	1.00	.00	30.00
1574	2.80	1.40	2.00	3.00	.20	1.60	1.00	.00	28.00
1575	4.00	2.10	2.50	3.00	-1.00	.90	.50	.00	14.00
1576	3.00	2.00	2.00	3.00	.00	1.00	1.00	.00	20.00
1577	3.00	1.00	2.00	3.00	.00	2.00	1.00	.00	30.00
1578	3.00	1.00	1.00	3.00	.00	2.00	2.00	.00	40.00
1579	2.80	1.70	1.00	1.00	.20	1.30	2.00	2.00	55.00
1580	2.00	2.00	2.00	3.00	1.00	1.00	1.00	.00	30.00
1581	3.00	2.00	2.00	3.00	.00	1.00	1.00	.00	20.00
1582	3.00	2.00	2.00	3.00	.00	1.00	1.00	.00	20.00
1583	3.00	2.00	2.00	3.00	.00	1.00	1.00	.00	20.00

NBC = North Bound Carriageway
SBC = South Bound Carriageway

NON [PMARKS]: DEFICIENT PAVEMENT MARKINGS

Unit of Measurement: Kilometers per kilometer.

(4-Lane Divided Sections)

[PMARKS] = SUM [Deficient Length x Weight] x 1/1000
Weights: 1 = for missing edgeline on one side;
2 = for missing edgeline on both sides; and
3 = for missing centerline and intersection areas.

Km.	Deficient Length (meters) (Longitudinal Sections)						Km.	Deficient Length (meters) (Intersection Areas)			
	NBC			SBC							
	1-side	2-sides	C-line	1-side	2-sides	C-line				Sum	[PMARKS]
1550	.00	1,000.00	1,000.00	.00	.00	.00	1550	Kashmir H/W T-Junction	500.00	6500.00	6.50
1551	.00	1,000.00	1,000.00	.00	1,000.00	.00	1551			7000.00	7.00
1552	.00	1,000.00	1,000.00	.00	1,000.00	.00	1552			7000.00	7.00
1553	.00	1,000.00	1,000.00	.00	.00	.00	1553			5000.00	5.00
1554	.00	1,000.00	1,000.00	.00	500.00	.00	1554	Fateh Jang T-Junction	330.00	6990.00	6.99
1555	.00	1,000.00	.00	.00	1,000.00	.00	1555			4000.00	4.00
1556	.00	1,000.00	.00	.00	1,000.00	.00	1556			4000.00	4.00
1557	.00	1,000.00	.00	.00	1,000.00	1,000.00	1557			7000.00	7.00
1558	.00	1,000.00	.00	.00	1,000.00	.00	1558			4000.00	4.00
1559	.00	1,000.00	.00	.00	1,000.00	.00	1559			4000.00	4.00
1560	.00	1,000.00	.00	.00	1,000.00	.00	1560			4000.00	4.00
1561	.00	1,000.00	.00	.00	1,000.00	.00	1561	Sang Jani T-Junction	300.00	4900.00	4.90
1562	.00	1,000.00	.00	.00	1,000.00	.00	1562			4000.00	4.00
1563	.00	1,000.00	.00	.00	1,000.00	.00	1563			4000.00	4.00
1564	.00	.00	.00	.00	.00	.00	1564			.00	.00
1565	.00	1,000.00	1,000.00	.00	.00	.00	1565			5000.00	5.00
1566	.00	1,000.00	1,000.00	.00	.00	.00	1566	Taxila Cantt. T-Junction	300.00	5900.00	5.90
1567	.00	1,000.00	1,000.00	.00	500.00	500.00	1567			7500.00	7.50
1568	.00	1,000.00	1,000.00	.00	1,000.00	1,000.00	1568			10000.00	10.00
1569	.00	1,000.00	1,000.00	.00	1,000.00	1,000.00	1569	HMC T-Junction	240.00	10720.00	10.72
1569							1569	POF Wah Y-Junction	200.00	600.00	.60
1570	.00	1,000.00	1,000.00	.00	1,000.00	.00	1570			7000.00	7.00
1571	.00	1,000.00	1,000.00	.00	1,000.00	.00	1571			7000.00	7.00
1572	.00	1,000.00	1,000.00	.00	.00	.00	1572			5000.00	5.00
1573	.00	1,000.00	.00	.00	.00	.00	1573			2000.00	2.00
1574	1,000.00	.00	.00	.00	.00	.00	1574			1000.00	1.00
1575	1,000.00	.00	.00	.00	.00	.00	1575			1000.00	1.00
1576	.00	1,000.00	.00	.00	.00	.00	1576	Jang Bahter Rd T-Junction	320.00	2960.00	2.96
1577	.00	1,000.00	.00	.00	.00	.00	1577			2000.00	2.00
1578	.00	1,000.00	1,000.00	.00	.00	.00	1578			5000.00	5.00
1579	.00	1,000.00	1,000.00	.00	.00	.00	1579			5000.00	5.00
1580	.00	1,000.00	.00	.00	.00	.00	1580			2000.00	2.00
1581	.00	1,000.00	.00	.00	.00	.00	1581			2000.00	2.00
1582	.00	.00	.00	.00	.00	.00	1582			.00	.00
1583	.00	.00	.00	.00	.00	.00	1583			.00	.00

NBC = North Bound Carriageway
SBC = South Bound Carriageway

MOM [INTSEC]: INTERSECTION DEFICIENCIES
MOM [INTENT]: ENTRY INTO INTERSECTION WITHOUT STOPPING
MOM [INTSPD]: ABRUPT SPEED CHANGE AFTER ENTRY INTO INTERSECTION
MOM [INTCOL]: NEAR COLLISION SITUATION

Unit of Measurement: # per hour

(4-Lane Divided Sections)

[INTENT] = NS/TE.
[INTSPD] = EA/TE.
[INTCOL] = NC/TE.
[INTACT] = [(WS-(WS-EA))/TE] + [(WS-(WS-NC))/TE].
for evaluation of interactive effect.
[INTSEC] = [INTENT] + [INTSPD] + [INTCOL] + [INTACT].

Km.	TE (Vph)	NS (Vph)	EA (Vph)	NC (Vph)	Intersection Location	[INTENT]	[INTSPD]	[INTCOL]	[INTACT]	[INTSEC]
1550	1072	28	24	16	Kashmir H/W T-Junction	.0261	.0224	.0149	.0373	10.07
1554	1104	10	8	4	Fateh Jang T-Junction	.0091	.0072	.0036	.0109	3.08
1561	1044	4	0	0	Sang Jani T-Junction	.0038	.0000	.0000	.0000	.38
1566	1344	16	4	4	Taxila Cantt. T-Junction	.0119	.0030	.0030	.0060	2.38
1569	824	24	12	8	HMC T-Junction	.0291	.0146	.0097	.0243	7.77
1569	796	28	12	8	POF Wah Y-Junction	.0352	.0151	.0101	.0251	8.54
1576	652	4	0	0	Jang Bahter Rd T-Junction	.0061	.0000	.0000	.0000	.61

TE = Total Entry
NS = No Stopping
EA = Evasive Action
NC = Near Collision
Vph = Vehicles per hour

MOH [ISLAND]: ISOLATED LANE DEFICIENCIES
MOH [SPDCHG]: ABRUPT SPEED CHANGE
MOH [SPDCHG]: ABRUPT LANE CHANGE

Unit of Measurement: # per kilometer (weighted)

(4-Lane Divided Sections)

[ISLAND] = [SPDCHG] + [LANCHG].
[SPDCHG] = (Low ASCx1) + (Medium ASCx2) + (High ASCx3)].
[LANCHG] = (Low ALCx1) + (Medium ALCx2) + (High ALCx3)].

Km.	Abrupt Speed Change							Km.	Abrupt Lane Change							[ISLAND]
	NBC			SBC					NBC			SBC				
	Low	Medium	High	Low	Medium	High	[SPDCHG]		Low	Medium	High	Low	Medium	High	[LANCHG]	
1550	.00	.00	.00	.00	.00	.00	.00	1550	.00	.00	.00	.00	.00	.00	.00	.00
1551	.00	1.00	.00	.00	.00	.00	2.00	1551	.00	.00	.00	.00	.00	.00	.00	2.00
1552	.00	1.00	.00	.00	.00	.00	2.00	1552	.00	.00	.00	.00	.00	.00	.00	2.00
1553	.00	2.00	.00	.00	.00	.00	4.00	1553	1.00	.00	.00	.00	.00	.00	1.00	5.00
1554	1.00	.00	.00	.00	.00	.00	1.00	1554	.00	.00	.00	.00	.00	.00	.00	1.00
1555	2.00	1.00	.00	.00	1.00	.00	6.00	1555	1.00	.00	.00	1.00	.00	.00	2.00	8.00
1556	1.00	1.00	.00	.00	1.00	.00	5.00	1556	.00	.00	.00	.00	.00	.00	.00	5.00
1557	2.00	.00	.00	.00	1.00	.00	4.00	1557	1.00	.00	.00	.00	.00	.00	1.00	5.00
1558	2.00	.00	.00	.00	.00	.00	2.00	1558	1.00	.00	.00	.00	.00	.00	1.00	3.00
1559	.00	.00	.00	.00	.00	.00	.00	1559	.00	.00	.00	.00	.00	.00	.00	.00
1560	.00	.00	.00	1.00	.00	.00	1.00	1560	.00	.00	.00	.00	.00	.00	.00	1.00
1561	.00	.00	.00	.00	1.00	.00	2.00	1561	.00	.00	.00	.00	.00	.00	.00	2.00
1562	.00	.00	.00	3.00	.00	.00	3.00	1562	.00	1.00	.00	.00	.00	.00	2.00	5.00
1563	.00	.00	.00	1.00	1.00	.00	3.00	1563	.00	.00	.00	1.00	.00	.00	1.00	4.00
1564	1.00	.00	.00	.00	.00	1.00	4.00	1564	.00	.00	.00	.00	.00	.00	.00	4.00
1565	.00	.00	.00	.00	.00	.00	.00	1565	.00	.00	.00	.00	.00	.00	.00	.00
1566	1.00	.00	.00	.00	.00	.00	1.00	1566	.00	.00	.00	.00	.00	.00	.00	1.00
1567	1.00	.00	.00	.00	.00	.00	1.00	1567	.00	.00	.00	.00	.00	.00	.00	1.00
1568	.00	.00	.00	.00	1.00	1.00	5.00	1568	.00	.00	.00	.00	.00	.00	.00	5.00
1569	.00	.00	.00	.00	.00	.00	.00	1569	.00	.00	.00	.00	.00	.00	.00	.00
1570	.00	.00	.00	.00	.00	.00	.00	1570	.00	.00	.00	.00	.00	.00	.00	.00
1571	.00	.00	.00	.00	.00	.00	.00	1571	.00	.00	.00	.00	.00	.00	.00	.00
1572	1.00	1.00	.00	.00	.00	.00	3.00	1572	.00	1.00	.00	.00	1.00	.00	4.00	7.00
1573	1.00	.00	.00	.00	.00	.00	1.00	1573	.00	1.00	.00	.00	.00	.00	2.00	3.00
1574	.00	.00	.00	.00	.00	.00	.00	1574	.00	1.00	.00	.00	1.00	.00	4.00	4.00
1575	1.00	.00	.00	.00	.00	.00	1.00	1575	1.00	1.00	.00	.00	.00	.00	3.00	4.00
1576	1.00	.00	.00	.00	.00	.00	1.00	1576	1.00	.00	.00	1.00	.00	.00	2.00	3.00
1577	.00	.00	.00	.00	.00	.00	.00	1577	.00	.00	.00	.00	.00	.00	.00	.00
1578	.00	.00	.00	.00	1.00	.00	2.00	1578	.00	.00	.00	1.00	.00	.00	1.00	3.00
1579	1.00	1.00	.00	.00	.00	.00	3.00	1579	.00	.00	.00	.00	.00	.00	.00	3.00
1580	.00	.00	.00	.00	.00	.00	.00	1580	.00	1.00	.00	.00	1.00	.00	4.00	4.00
1581	1.00	.00	1.00	.00	.00	.00	4.00	1581	.00	.00	.00	.00	.00	1.00	3.00	7.00
1582	.00	.00	.00	.00	.00	.00	.00	1582	.00	.00	.00	.00	.00	.00	.00	.00
1583	.00	.00	.00	.00	.00	.00	.00	1583	.00	.00	.00	.00	.00	.00	.00	.00

NBC = North Bound Carriageway
SBC = South Bound Carriageway

MON [PVCOND]: PAVEMENT CONDITION RATING

Unit of Measurement: number (rated) per kilometer
(4-Lane Divided Sections)

[PVCOND] = (Mean Itemized) + (Mean Cumulative)/2.00
Itemized Rating = SUM [Cracking + Rutting + Roughness + Dropoff]$_{NBC,SBC}$.
Cumulative Rating = A composite rating based on above specified distress.

Km.	Subjective Rating Numbers												[PVCOND]
	NBC					SBC							
	Itemized Rating				Cumulative Rating	Itemized Rating				Cumulative Rating			
	Cracking	Rutting	Roughness	Dropoff		Cracking	Rutting	Roughness	Dropoff		Mean Itemized	Mean Cumulative	
1550	22.00	20.00	18.00	.00	65.00	5.00	12.00	10.00	10.00	50.00	48.50	57.50	53.00
1551	4.00	3.00	4.00	8.00	35.00	15.00	13.00	11.00	9.00	15.00	33.50	25.00	29.25
1552	3.00	4.00	2.00	9.00	30.00	12.00	11.00	10.00	9.00	25.00	30.00	27.50	28.75
1553	6.00	2.00	4.00	10.00	30.00	10.00	6.00	9.00	7.00	30.00	27.00	30.00	28.50
1554	5.00	4.00	6.00	8.00	35.00	9.00	2.00	8.00	6.00	35.00	24.00	35.00	29.50
1555	8.00	5.00	4.00	6.00	35.00	10.00	1.00	7.00	5.00	55.00	23.00	45.00	34.00
1556	9.00	6.00	5.00	3.00	35.00	12.00	1.00	8.00	6.00	45.00	25.00	40.00	32.50
1557	15.00	8.00	5.00	8.00	45.00	11.00	3.00	10.00	6.00	50.00	33.00	47.50	40.25
1558	16.00	12.00	4.00	9.00	50.00	10.00	2.00	9.00	7.00	55.00	34.50	52.50	43.50
1559	18.00	10.00	6.00	8.00	50.00	10.00	2.00	9.00	8.00	60.00	35.50	55.00	45.25
1560	16.00	8.00	6.00	5.00	50.00	12.00	2.00	8.00	9.00	30.00	33.00	40.00	36.50
1561	15.00	11.00	9.00	8.00	50.00	9.00	5.00	8.00	7.00	60.00	36.00	55.00	45.50
1562	16.00	12.00	10.00	12.00	65.00	11.00	9.00	8.00	6.00	45.00	42.00	55.00	48.50
1563	20.00	15.00	14.00	12.00	65.00	13.00	10.00	9.00	10.00	45.00	51.50	55.00	53.25
1564	16.00	12.00	15.00	15.00	60.00	12.00	10.00	8.00	8.00	40.00	48.00	50.00	49.00
1565	18.00	10.00	8.00	11.00	60.00	15.00	10.00	9.00	9.00	50.00	45.00	55.00	50.00
1566	16.00	11.00	7.00	10.00	55.00	15.00	11.00	12.00	11.00	65.00	46.50	60.00	53.25
1567	15.00	9.00	7.00	9.00	55.00	14.00	12.00	9.00	8.00	65.00	41.50	60.00	50.75
1568	18.00	12.00	6.00	10.00	55.00	15.00	9.00	8.00	5.00	65.00	41.50	60.00	50.75
1569	15.00	15.00	5.00	9.00	55.00	14.00	9.00	8.00	6.00	65.00	40.50	60.00	50.25
1570	14.00	11.00	8.00	5.00	45.00	13.00	10.00	9.00	8.00	65.00	39.00	55.00	47.00
1571	12.00	10.00	10.00	4.00	45.00	15.00	11.00	10.00	8.00	70.00	40.00	57.50	48.75
1572	10.00	12.00	10.00	6.00	45.00	16.00	15.00	10.00	9.00	55.00	44.00	50.00	47.00
1573	12.00	10.00	8.00	7.00	45.00	15.00	12.00	11.00	13.00	55.00	44.00	50.00	47.00
1574	5.00	6.00	7.00	6.00	30.00	15.00	13.00	12.00	15.00	60.00	39.50	45.00	42.25
1575	8.00	7.00	9.00	10.00	30.00	18.00	17.00	12.00	14.00	85.00	47.50	57.50	52.50
1576	10.00	10.00	9.00	8.00	30.00	18.00	19.00	15.00	13.00	80.00	51.00	55.00	53.00
1577	9.00	8.00	7.00	9.00	25.00	17.00	15.00	10.00	12.00	85.00	43.50	55.00	49.25
1578	6.00	7.00	8.00	8.00	25.00	15.00	12.00	13.00	12.00	75.00	40.50	50.00	45.25
1579	5.00	4.00	8.00	7.00	20.00	16.00	15.00	12.00	14.00	70.00	40.50	45.00	42.75
1580	4.00	6.00	7.00	6.00	30.00	18.00	16.00	10.00	14.00	50.00	40.50	40.00	40.25
1581	6.00	5.00	6.00	5.00	30.00	16.00	14.00	11.00	8.00	60.00	35.50	45.00	40.25
1582	11.00	14.00	7.00	6.00	40.00	15.00	16.00	10.00	9.00	60.00	44.00	50.00	47.00
1583	15.00	13.00	6.00	5.00	45.00	10.00	12.00	8.00	9.00	65.00	39.00	55.00	47.00

NBC = North Bound Carriageway
SBC = South Bound Carriageway

NON [SIDEOB]: ROADSIDE OBSTRUCTION

Unit of Measurement: number per kilometer

(4-Lane Divided Sections)

[SIDEOB] = SUM [Count #1 + Count #2]/2.00.
Count #1 = Rated Counting by member 1.
Count #2 = Rated Counting by member 2.

Km.	Subjective Rating (numbers)				[SIDEOB]
	NBC		SBC		
	(Count #1)	(Count #2)	(Count #1)	(Count #2)	
1550	5.00	5.00	6.00	5.00	10.50
1551	13.00	12.00	11.00	11.00	23.50
1552	3.00	3.00	2.00	2.00	5.00
1553	3.00	3.00	7.00	6.00	9.50
1554	18.00	16.00	17.00	11.00	31.00
1555	8.00	6.00	9.00	7.00	15.00
1556	5.00	5.00	2.00	2.00	7.00
1557	2.00	1.00	5.00	3.00	5.50
1558	5.00	2.00	1.00	1.00	4.50
1559	5.00	2.00	4.00	4.00	7.50
1560	8.00	7.00	6.00	4.00	12.50
1561	3.00	3.00	5.00	4.00	7.50
1562	3.00	3.00	2.00	1.00	4.50
1563	2.00	1.00	3.00	3.00	4.50
1564	4.00	3.00	6.00	6.00	9.50
1565	5.00	5.00	8.00	7.00	12.50
1566	3.00	1.00	3.00	3.00	5.00
1567	8.00	6.00	4.00	4.00	11.00
1568	11.00	8.00	10.00	8.00	18.50
1569	4.00	4.00	6.00	5.00	9.50
1570	14.00	11.00	7.00	5.00	18.50
1571	6.00	5.00	15.00	12.00	19.00
1572	5.00	5.00	3.00	1.00	7.00
1573	7.00	5.00	6.00	5.00	11.50
1574	4.00	5.00	3.00	3.00	7.50
1575	5.00	5.00	.00	.00	5.00
1576	4.00	5.00	5.00	4.00	9.00
1577	14.00	11.00	4.00	4.00	16.50
1578	4.00	3.00	5.00	4.00	8.00
1579	11.00	7.00	4.00	4.00	13.00
1580	10.00	7.00	7.00	6.00	15.00
1581	5.00	2.00	3.00	2.00	6.00
1582	6.00	5.00	4.00	2.00	8.50
1583	7.00	5.00	18.00	16.00	23.00

NBC = North Bound Carriageway
SBC = South Bound Carriageway

Appendix D

The Accident Data

National Highway (N-5), District Rawalpindi, Pakistan.

Traffic Accident Records: Kilometer 1481-1583

January 1988-December 1990.

Police Station Gujar Khan.

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles	Involved	--->	Peds.	Remarks	Km.
1	1481	10/ 4/90	1900	0	1	0	Suzuki	-	-	1	suzuki hit the pedestrian	1481
2	1481	8/14/89	1300	0	2	1	Bus	Tree	-	0	bus hit the tree	1481
3	1481	3/19/89	815	0	0	1	Car	Truck	-	0	car damaged	1481
4	1481	1/18/89	1130	1	2	1	Car	Truck	-	0	truck hit the car from wrong side	1481
5	1481	8/13/90	915	0	0	1	Truck	Wagon	-	0	truck hit the wagon from wrong side	1481
6	1481	8/ 9/00	1800	1	0	2	Truck	Car	-	0	head on collision	1481
7	1482	12/17/88	1850	1	2	2	Truck	Bus	-	0	head on collision	1482
8	1484	4/29/88	1100	0	0	2	Wagon	Suzuki	-	0	both damaged	1484
9	1485	4/ 3/89	1915	0	2	3	Truck	Oil Tanker	Oil Tanker	0	all three vehicles over turned	1485
10	1486	1/29/88	1700	0	1	0	Suzuki	Car	-	0	car damaged	1486
11	1486	5/ 8/89	930	0	1	0	Pickup	-	-	1	pickup hit the pedestrian	1486
12	1486	6/ 8/88	2330	1	0	0	Suzuki	-	-	1	Suzuki hit the pedestrian	1486
13	1486	6/14/88	500	0	5	1	Bus	-	-	0	bus fell into ditch	1486
14	1486	3/11/88	1500	1	3	1	Jeep	Bus	-	0	bus hit the jeep	1486
15	1486	2/22/88	2230	4	9	1	Truck	Wagon	-	0	head on collision	1486
16	1486	9/22/90	330	1	3	1	Truck	Pickup	-	0	truck hit the pickup from back side	1486
17	1486	3/23/89	1100	1	2	1	Truck	-	-	0	truck overturned due to stone on the road	1486
18	1486	4/21/90	1230	1	2	1	Truck	Wagon	-	0	wagon hit the truck from wrong side	1486
19	1486	12/ 1/88	1630	1	1	2	Truck	Truck	-	0	both damaged	1486
20	1486	5/16/88	1350	2	5	2	Wagon	Car	-	0	both vehicles damaged	1486
21	1486	4/23/88	1850	4	9	2	Truck	Wagon	-	0	fast speed	1486
22	1486	2/12/88	2245	1	2	2	Truck	Trailer	-	0	head on collision	1486
23	1487	6/21/90	800	1	0	0	Car	-	-	1	car hit the pedestrian	1487
24	1487	6/12/89	1830	1	0	0	Truck	-	-	1	truck hit the pedestrian	1487
25	1487	9/ 4/89	1145	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1487
26	1487	1/31/88	1400	1	1	2	Wagon	Suzuki	-	0	head on collision	1487
27	1488	1/18/88	1700	0	2	0	Car	Wagon	-	0	car over turned	1488
28	1488	2/19/88	1830	0	0	0	Bus	Suzuki	-	0	Suzuki damaged	1488
29	1488	10/13/89	2100	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1488
30	1488	2/13/90	1515	0	1	1	Bus	Car	-	0	bus hit the car	1488
31	1488	6/ 9/90	1945	0	0	1	Bus	Car	-	0	bus overtook the car wrong side	1488
32	1488	1/ 4/89	1830	0	1	1	Car	Tonga	-	0	car hit the tonga	1488
33	1488	11/19/89	1530	1	2	1	Wagon	Car	-	0	wagon hit the car from wrong side	1488
34	1488	11/26/89	1520	0	2	1	Wagon	Wagon	-	0	wagon hit the wagon	1488
35	1488	1/17/90	1030	0	1	1	Car	Wagon	-	0	wagon overtook the car from wrong side	1488
36	1488	3/18/89	645	0	0	2	Truck	Truck	-	0	head on collision	1488

(continued)

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles	Involved --->		Peds.	Remarks	Km.
37	1489	3/11/88	530	1	0	0	Truck	-	-	1	truck hit the pedestrian	1489
38	1489	1/ 1/89	200	1	0	0	Vehicle	-	-	1	vehicle hit the pedestrian	1489
39	1489	11/22/90	1630	0	1	0	Wagon	-	-	1	wagon crashed the pedestrian	1489
40	1489	2/10/90	900	0	0	1	Car	Truck	-	0	car damaged	1489
41	1489	10/ 9/89	1655	1	0	1	Truck	Car	-	0	truck hit the car at left door of car	1489
42	1489	7/ 8/89	2030	0	0	1	Truck	Truck	-	0	truck hit the truck from back side	1489
43	1489	2/13/88	1730	0	1	1	BC	Wagon	-	0	Wagon hit the BC	1489
44	1489	3/30/89	1300	0	0	2	Bus	Bus	-	0	bus hit the bus	1489
45	1489	1/23/88	1200	0	0	2	Pickup	Car	-	0	damage	1489
46	1489	1/ 8/90	1700	0	1	2	Truck	Car	-	0	head on collision	1489
47	1489	7/ 6/89	1215	0	1	2	Truck	Truck	-	0	side collision	1489
48	1490	1/ 4/88	1300	0	1	0	M.C.	B.C.	-	0	clash between motorcycle & cycle	1490
49	1490	2/ 9/89	1000	1	0	1	Wagon	MC	-	0	wagon hit the MC	1490
50	1490	5/31/90	1200	2	2	2	Truck	Suzuki	-	0	head on collision	1490
51	1490	9/18/90	2100	0	0	2	Pickup	Pickup	-	0	head on collision	1490
52	1491	4/16/88	1630	0	1	0	Bus	-	-	1	bus hit the pedestrian	1491
53	1491	4/17/88	1115	1	0	0	Bus	-	-	1	bus hit the pedestrian	1491
54	1491	11/29/89	1400	1	0	0	Bus	-	-	1	bus hit the pedestrian	1491
55	1491	12/24/89	1900	0	1	0	Bus	-	-	1	bus hit the pedestrian	1491
56	1491	12/11/88	1100	1	0	0	Car	-	-	1	car crashed the pedestrian	1491
57	1491	8/27/88	1230	0	1	0	Car	-	-	1	car hit the pedestrian	1491
58	1491	2/ 8/89	930	1	0	0	Car	-	-	1	car hit the pedestrian	1491
59	1491	11/23/90	1345	1	0	0	Suzuki	-	-	1	suzuki hit the pedestrian	1491
60	1491	6/29/89	200	0	1	0	Truck	-	-	1	truck hit the pedestrian	1491
61	1491	8/ 9/90	800	1	0	0	Truck	-	-	1	truck killed the pedestrian	1491
62	1491	9/22/90	1230	0	1	0	Wagon	-	-	1	wagon crashed the pedestrian	1491
63	1491	5/30/88	2145	2	0	1	Truck	Car	-	0	car fully damaged side collision	1491
64	1491	5/ 2/89	1300	0	0	1	Wagon	MC	-	0	MC damaged	1491
65	1491	5/24/88	1015	1	0	1	BC	Truck	-	0	truck hit the cycle	1491
66	1491	12/18/89	1100	0	1	1	Truck	MC	-	0	truck hit the MC	1491
67	1491	9/20/90	1530	0	2	1	Truck	Suzuki	-	0	truck hit the suzuki	1491
68	1491	8/16/89	230	0	0	1	Truck	Tree	-	0	truck hit the tree	1491
69	1491	5/28/89	1515	0	0	1	Mini Bus	Wagon	-	0	wagon damaged	1491
70	1491	10/11/88	2130	0	1	1	Wagon	BC	-	0	Wagon hit the BC	1491
71	1491	9/ 9/89	700	0	2	1	Wagon	Car	-	0	wagon hit the car wrong side	1491
72	1491	6/ 2/88	1430	0	2	1	Wagon	MC	-	0	Wagon hit the MC	1491
73	1491	5/20/89	1345	0	0	1	Wagon	Suzuki	-	0	wagon hit the suzuki	1491
74	1491	9/29/88	1250	0	2	1	Wagon	Tonga	-	0	wagon hit the tonga	1491
75	1491	9/16/90	1930	0	1	1	Wagon	Tractor	-	0	wagon hit with the tractor	1491
76	1491	1/ 4/89	1740	0	0	2	Oil Tanker	Oil Tanker	-	0	both damaged	1491
77	1491	1/23/88	2115	0	0	2	Wagon	Car	-	0	car damaged from left	1491
78	1491	11/ 6/89	1515	0	12	2	MC	MC	-	0	head on collision	1491
79	1491	8/29/90	200	0	1	2	Truck	Truck	-	0	head on collision	1491
80	1491	9/25/90	1230	0	0	2	Truck	Trailer	-	0	head on collision	1491

(continued)

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of	Vehicles Involved	--->	Peds.	Remarks	Km.
81	1491	12/ 4/88	800	0	0	2	Suzuki	Tonga	-	0	tonga and suzuki damaged	1491
82	1492	2/18/88	1130	0	0	0	Truck	Tractor	-	0	both damaged	1492
83	1492	10/ 8/90	1310	1	0	0	Bus	-	-	1	bus crashed the pedestrian	1492
84	1492	5/31/89	1345	1	0	0	Bus	-	-	1	bus hit the pedestrian	1492
85	1492	6/17/90	2145	0	1	0	Car	-	-	1	car hit the pedestrian	1492
86	1492	2/25/88	2200	0	0	0	Suzuki	Car	-	0	due to not indicating	1492
87	1492	10/30/88	1430	2	1	0	Oil Tanker	-	-	3	oil tanker out of control	1492
88	1492	7/26/89	1630	0	1	0	Bus	-	-	1	passenger fell down from bus	1492
89	1492	10/16/89	515	0	0	0	Truck	-	-	1	truck hit the pedestrian	1492
90	1492	8/13/88	1200	1	0	0	Van	-	-	1	van hit the pedestrian	1492
91	1492	3/17/89	1730	1	0	0	Vehicle	-	-	1	vehicle hit the pedestrian	1492
92	1492	7/23/89	600	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1492
93	1492	3/ 9/90	1715	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1492
94	1492	9/26/89	1330	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1492
95	1492	10/19/88	2000	1	0	1	MC	Bus	-	0	Bus hit the MC	1492
96	1492	6/17/90	2230	0	0	1	Bus	Pole	-	0	bus hit the pole	1492
97	1492	9/25/89	1800	0	3	1	Bus	Wagon	-	0	bus hit the wagon from back side	1492
98	1492	9/23/89	1800	0	2	1	Truck	BC	-	0	truck hit the BC	1492
99	1492	8/20/88	1145	0	1	1	Car	Wagon	-	0	van hit the car	1492
100	1492	7/12/89	1115	1	0	1	Wagon	BC	-	0	wagon hit the BC	1492
101	1492	7/23/90	1615	0	1	1	MC	Wagon	-	0	wagon hit the MC	1492
102	1492	12/ 7/90	400	0	3	1	Wagon	Truck	-	0	wagon hit the standing truck	1492
103	1492	4/ 4/89	940	0	1	1	Wagon	Tonga	-	0	wagon hit the tonga	1492
104	1492	5/25/90	1545	1	1	2	Suzuki	Wagon	-	0	wagon overtook suzuki	1492
105	1492	3/15/90	2040	0	1	1	Car	MC	-	0	car hit the MC	1492
106	1493	5/ 2/90	1100	1	0	0	Bus	-	-	1	bus hit the pedestrian	1493
107	1493	3/19/90	1900	0	1	0	Bus	Trailer	-	0	bus hit the trailer	1493
108	1493	4/ 8/88	1200	2	1	0	Suzuki	Bus	-	0	side collision	1493
109	1493	5/24/90	530	0	1	0	Vehicle	-	-	1	vehicle hit the pedestrian	1493
110	1493	12/ 3/89	1345	0	4	1	Bus	Hill	-	0	bus crashed with the hill	1493
111	1493	4/22/88	700	0	0	1	Car	Bus	-	0	bus hit the car	1493
112	1493	9/19/90	330	0	5	1	Bus	Trailer	-	0	bus hit the standing trailer	1493
113	1493	9/24/89	1915	0	1	1	Truck	Car	-	0	car hit the standing truck	1493
114	1493	9/12/88	2000	0	0	1	Car	Truck	-	0	truck hit the car	1493
115	1493	7/30/89	315	0	3	1	Truck	Car	-	0	truck hit the car	1493
116	1493	8/ 6/89	500	0	2	1	Truck	Suzuki	-	0	truck hit the suzuki	1493
117	1493	5/ 3/88	1715	0	1	1	Wagon	Truck	-	0	wagon damaged	1493
118	1493	4/26/89	1330	0	0	2	Wagon	Wagon	-	0	head on collision	1493
119	1494	5/30/90	1015	0	1	0	Jeep	-	-	1	jeep hit the pedestrian	1494
120	1494	6/19/88	1130	1	0	0	Trailer	-	-	1	trailer hit the pedestrian	1494
121	1494	1/11/89	1500	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1494
122	1494	6/15/88	1915	1	2	2	Bus	Suzuki	-	0	head on collision	1494
123	1494	6/30/88	1815	0	4	2	Car	Wagon	-	0	head on collision	1494
124	1495	7/ 6/89	800	0	1	0	Pickup	-	-	1	pickup hit the pedestrian	1495

(continued)

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of	Vehicles Involved	--->	Peds.	Remarks	Km.
125	1495	12/15/88	1930	1	2	2	Car	Oil Tanker	Jeep	0	car and tanker over turned	1495
126	1496	3/26/88	1430	0	0	0	Car	Bus	-	0	bus hit the car	1496
127	1496	10/ 3/88	1800	0	1	0	MC	-	-	1	MC hit the pedestrian	1496
128	1496	1/28/88	1930	0	0	1	Bus	Car	-	0	car damaged	1496
129	1496	1/28/88	400	0	0	1	Tractor	Pole	-	0	pole damaged	1496
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130	1497	7/ 7/88	1600	0	1	0	Jeep	-	-	1	jeep hit the pedestrian	1497
131	1497	2/23/89	945	0	6	1	Bus	-	-	0	bus fell in the dig	1497
132	1497	12/ 2/89	2100	0	0	1	Oil Tanker	Truck	-	0	oil tanker hit the truck	1497
133	1497	2/26/88	500	1	4	1	Truck	Wagon	-	0	wagon hit the truck	1497
134	1497	10/21/88	2000	0	0	2	Truck	Bus	-	0	Both vehicles damaged	1497
135	1497	12/16/90	1230	0	2	2	Bus	Wagon	-	0	bus hit the wagon from back side	1497
136	1497	11/12/88	2230	1	0	2	Truck	Truck	-	0	head on collision	1497
137	1497	10/27/89	1730	9	9	2	Suzuki	Car	-	0	head on collision	1497
138	1497	11/24/88	200	1	0	2	Wagon	Wagon	-	0	wagon hit the wagon from back side	1497
139	1499	9/ 8/89	1115	0	1	0	Car	Bus	-	0	bus hit the car	1499
140	1499	2/17/90	1100	1	0	0	Car	-	-	1	car hit the pedestrian	1499
141	1499	4/26/89	815	0	2	0	Truck	-	-	2	truck hit the pedestrians	1499
142	1499	6/13/88	1600	0	1	1	Bus	Suzuki	-	0	suzuki hit the bus	1499
143	1499	7/23/90	1900	0	1	1	BC	vehicle	-	0	vehicle hit the MC	1499
144	1499	8/21/89	1745	0	5	2	Wagon	Bus	-	0	head on collision	1499
145	1500	11/19/89	1615	2	0	0	Bus	-	-	2	bus hit the pedestrians	1500
146	1500	10/31/90	1100	0	1	0	Suzuki	-	-	1	suzuki hit the pedestrian	1500
147	1500	8/13/89	100	1	0	0	Truck	-	-	1	truck hit the pedestrian	1500
148	1500	9/ 9/90	1400	0	6	2	Wagon	Car	-	0	wagon hit the car	1500
149	1501	5/30/88	2345	0	0	1	Truck	Car	-	0	car damaged	1501
150	1501	11/ 8/88	0	1	0	2	Bus	-	-	1	bus crashed the pedestrian	1501
151	1502	6/ 8/90	1715	1	2	1	Truck	Ambulance	-	0	Ambulance hit the truck	1502
152	1503	10/22/89	2120	0	1	0	Truck	Truck	-	0	truck hit the truck	1503
153	1503	3/ 2/89	1130	0	1	1	Truck	Car	-	0	truck hit the car	1503
154	1503	5/12/88	1630	0	5	1	Wagon	Tree	-	0	wagon hit the tree	1503
155	1503	10/ 5/89	530	0	1	2	Truck	Truck	-	0	truck hit the truck from side	1503
156	1504	4/17/90	1330	1	0	0	Car	-	-	1	car hit the pedestrian	1504
157	1504	4/10/88	.45	2	0	1	Bus	Pickup	-	0	bus hit the pickup	1504
158	1504	9/25/89	2045	0	4	1	Car	Truck	-	0	car hit the truck	1504
159	1504	1/ 5/89	1900	0	1	1	Car	Wagon	-	0	car over took and hit the wagon	1504
160	1504	9/12/88	1700	0	1	1	Pickup	BC	-	0	pickup hit the BC	1504
161	1504	5/20/88	1330	0	0	1	Truck	Suzuki	-	0	suzuki damaged	1504
162	1504	8/28/90	2030	1	2	1	Truck	Car	-	0	truck hit the car	1504
163	1504	8/13/89	1500	0	2	1	Truck	MC	-	0	truck hit the MC	1504
164	1504	8/ 4/90	2100	0	1	2	Car	Suzuki	-	0	due to not indicating	1504
165	1504	5/12/88	2010	1	0	2	Truck	Truck	-	0	head on collision	1504

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Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles	Involved --->		Peds.	Remarks	Km.
166	1504	6/29/90	1930	0	3	2	Bus	Car	-	0	head on collision	1504
167	1504	9/10/88	1930	0	1	2	Jeep	Wagon	-	0	jeep over took the wagon	1504
168	1505	1/28/90	1330	1	0	0	Bus	-	-	1	bus crashed the pedestrian	1505
169	1505	11/ 8/88	1615	0	1	1	Suzuki	BC	-	0	suzuki hit the BC	1505
170	1505	6/25/90	1830	0	1	1	Truck	Suzuki	-	0	truck hit the suzuki	1505
171	1505	7/27/90	1030	1	0	1	Wagon	MC	-	0	wagon hit the standing MC	1505
172	1506	4/10/89	1030	0	1	0	Bus	-	-	1	bus hit the pedestrian	1506
173	1506	11/15/90	800	0	1	0	Bus	-	-	1	bus hit the pedestrian	1506
174	1506	5/ 5/88	1210	1	0	0	Car	-	-	1	car hit the pedestrian	1506
175	1506	5/ 7/89	1200	0	1	0	Car	-	-	1	car hit the pedestrian	1506
176	1506	11/11/90	615	0	1	0	MC	-	-	1	MC hit the pedestrian	1506
177	1506	11/30/90	1200	0	1	0	Suzuki	-	-	1	suzuki hit the pedestrian	1506
178	1506	8/12/90	1515	1	0	0	Truck	-	-	1	truck hit the pedestrian	1506
179	1506	7/31/88	0	1	0	0	Vehicle	-	-	1	vehicle hit the pedestrian	1506
180	1506	8/21/89	1620	1	0	0	Wagon	-	-	1	wagon crashed the pedestrian	1506
181	1506	5/30/90	1900	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1506
182	1506	9/10/90	1315	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1506
183	1506	10/29/90	1400	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1506
184	1506	7/28/88	1230	1	4	1	Wagon	Truck	-	0	head on collision	1506
185	1506	1/ 6/90	1030	1	4	1	Oil Tanker	Suzuki	-	0	head on collision	1506
186	1506	7/26/88	0	0	1	1	Pickup	BC	-	0	pickup hit the BC	1506
187	1506	3/ 6/88	1000	0	3	1	Suzuki	BC	-	0	suzuki hit the BC	1506
188	1506	7/26/88	1225	0	2	1	BC	Wagon	-	0	wagon hit the BC	1506
189	1506	7/12/88	430	0	1	2	Bus	Truck	-	0	bus overtook truck	1506
190	1506	2/ 9/88	1230	0	0	2	Truck	Truck	-	0	head on collision	1506
191	1506	12/28/89	2030	1	7	2	Truck	Truck	-	0	head on collision	1506
192	1506	2/15/90	930	0	1	2	Wagon	Suzuki	-	0	wagon hit the suzuki	1506
193	1507	1/28/89	1330	1	13	0	Bus	-	-	0	bus turned down	1507
194	1507	11/13/88	2400	1	0	0	Vehicle	-	-	1	vehicle hit the pedestrian	1507
195	1507	3/ 4/90	1245	0	3	1	Bus	Car	-	0	bus hit the car from back side	1507
196	1507	7/25/90	1730	1	0	1	Truck	Car	-	0	head on collision	1507
197	1507	4/ 9/89	100	0	1	1	Truck	Car	-	0	truck hit the car	1507
198	1508	3/27/88	915	1	0	0	Bus	-	-	1	bus hit the pedestrian	1508
199	1508	6/20/88	900	0	1	0	Car	-	-	1	Car hit the pedestrian	1508
200	1508	11/12/90	1700	0	1	0	Jeep	-	-	1	Jeep hit the pedestrian	1508
201	1508	7/29/89	1830	1	0	0	Suzuki	-	-	1	suzuki crashed the pedestrian	1508
202	1508	5/10/89	1800	0	1	1	MC	Bus	-	0	bus hit the BC	1508
203	1508	4/13/88	245	0	7	1	Bus	Tree	-	0	bus hit the tree	1508
204	1508	7/23/88	2000	0	1	1	Tractor	Car	-	0	tractor hit the car	1508
205	1508	4/ 2/89	1830	0	7	2	Suzuki	Car	-	0	head on collision	1508
206	1509	9/10/89	730	0	1	0	Bus	-	-	1	bus hit the pedestrian	1509
207	1509	1/ 3/88	1830	0	1	0	Car	Car	-	0	car hit the car	1509
208	1509	1/ 8/89	1011	0	1	0	Car	-	-	1	Car hit the pedestrian	1509
209	1509	1/25/89	1545	0	1	0	Suzuki	-	-	1	suzuki hit the pedestrian	1509

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Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles	Involved --->		Peds.	Remarks	Km.
210	1509	5/ 1/89	945	0	1	0	Truck	Truck	-	0	truck hit the truck	1509
211	1509	4/29/89	2130	0	1	0	Vehicle	-	-	1	vehicle hit the pedestrian	1509
212	1509	5/14/88	1315	0	1	1	Bus	BC	-	0	bus hit the BC	1509
213	1509	6/26/90	1330	0	1	1	Bus	Wagon	-	0	bus hit the wagon from side	1509
214	1509	8/ 9/88	400	1	1	1	Bus	-	-	0	bus turned down	1509
215	1509	1/11/89	1345	0	2	1	Car	Truck	-	0	Truck hit the car	1509
216	1509	2/19/88	830	0	0	2	Car	Car	-	0	both cars damaged	1509
217	1509	2/28/88	2400	2	9	2	Wagon	Wagon	-	0	head on collision	1509
218	1509	3/ 9/88	1720	0	6	2	Wagon	Suzuki	-	0	head on collision	1509
219	1509	6/11/89	300	1	2	2	Truck	Truck	-	0	head on collision	1509
220	1509	7/31/88	430	0	3	3	Tractor	Bus	Bus	0	bus hit the tractor & tractor hit another bus	1509
221	1510	4/11/89	1600	1	0	0	MC	-	-	1	BC hit the pedestrian	1510
222	1510	10/30/88	400	0	1	0	Car	-	-	1	car crashed the pedestrian	1510
223	1510	7/14/90	1800	1	0	0	Car	-	-	1	car hit the pedestrian	1510
224	1510	4/24/89	0	0	1	0	Car	Pickup	-	0	car hit the pickup	1510
225	1510	2/ 7/89	1430	0	3	0	Car	-	-	3	car hit the three pedestrian	1510
226	1510	6/23/88	1745	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1510
227	1510	12/14/90	1645	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1510
228	1510	12/ 4/88	2300	0	1	1	Oil Tanker	Car	-	0	car hit the oil tanker	1510
229	1510	9/17/89	2320	0	1	1	Truck	Car	-	0	car hit the truck	1510
230	1510	3/18/90	1700	0	2	1	Truck	Car	-	0	car hit the truck from back side	1510
231	1510	10/31/88	1700	1	1	1	Oil Tanker	-	-	0	oil tanker caught fire	1510
232	1510	8/14/88	715	0	1	1	Suzuki	BC	-	0	suzuki hit the BC	1510
233	1510	6/10/89	2015	0	2	2	Bus	Truck	-	0	head on collision	1510
234	1510	4/ 7/90	1100	0	3	2	Bus	Wagon	-	0	head on collision	1510
235	1510	8/ 6/90	30	0	1	2	Oil Tanker	Truck	-	0	truck hit the standing oil tanker	1510

<u>**Police Station Riwat.**</u>

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles	Involved --->		Peds.	Remarks	Km.
236	1511	12/10/88	1830	0	1	1	Bus	Suzuki	-	0	bus hit the suzuki	1511
237	1511	9/21/89	830	5	4	2	Bus	Wagon	-	0	wagon over took the bus	1511
238	1512	11/28/88	1530	0	1	0	Bus	-	-	1	bus hit the pedestrian	1512
239	1512	11/10/88	830	1	0	0	Bus	-	-	0	man fell down from the bus	1512
240	1512	10/12/90	1700	0	2	1	Bus	Car	-	0	bus hit the car	1512
241	1512	10/ 5/89	1530	1	0	1	Tractor	MC	-	0	tractor hit the MC	1512
242	1512	5/25/89	330	1	1	2	Truck	Truck	-	0	truck hit the standing truck	1512
243	1513	5/ 5/88	1530	0	0	1	Oil Tanker	Pickup	-	0	pickup damaged	1513
244	1513	6/21/88	630	0	0	1	Truck	Pickup	-	0	pickup damaged	1513
245	1513	12/13/90	1430	0	6	2	Wagon	Wagon	-	0	head on collision	1513
246	1514	6/11/88	1115	0	1	0	Bus	Bus	-	0	bus hit the bus from side	1514
247	1514	9/ 5/90	1930	0	1	0	Truck	-	-	1	truck hit the pedestrian	1514
248	1514	9/15/89	430	1	0	0	Vehicle	-	-	1	vehicle hit the pedestrian	1514
249	1514	8/20/89	1300	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1514
250	1514	3/11/89	1900	0	1	1	Car	-	-	0	car over turned	1514

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Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles Involved		--->	Peds.	Remarks	Km.
251	1514	12/30/88	2245	1	14	1	Trailer	Wagon	-	0	head on collision	1514
252	1514	11/ 4/90	1130	0	2	1	Wagon	Suzuki	-	0	wagon hit the suzuki	1514
253	1514	10/26/90	1800	0	1	2	Oil tanker	Bus	-	0	bus hit the oil tanker	1514
254	1514	10/21/88	1930	0	5	2	Truck	Car	-	0	head on collision	1514
255	1514	7/ 1/89	1245	10	3	2	Bus	Wagon	-	0	head on collision	1514
256	1514	6/20/88	440	1	2	2	Truck	Bus	-	0	truck hit the bus	1514
257	1515	7/26/89	1600	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1515
258	1515	12/17/89	1230	0	0	2	Oil Tanker	Truck	-	0	both damaged	1515
259	1515	11/ 8/89	235	1	0	2	Bus	Truck	-	0	bus hit the pedestrian	1515
260	1515	11/ 9/89	1100	3	8	2	Wagon	Bus	-	0	head on collision	1515
261	1515	12/28/89	1430	3	3	2	Bus	Wagon	-	0	head on collision	1515
262	1515	6/27/89	1230	0	0	2	Truck	Truck	-	0	truck hit the truck	1515
263	1516	11/10/90	1730	0	1	0	Vehicle	-	-	1	vehicle crashed the pedestrian	1516
264	1516	1/ 8/89	1430	0	2	1	Bus	Car	-	0	but hit the car	1516
265	1516	3/ 8/89	1700	1	6	2	Wagon	Car	-	0	both damaged	1516
266	1516	2/11/89	0	1	0	2	Car	Car	-	0	head on collision	1516
267	1517	5/29/88	200	1	2	0	Truck	Truck	-	0	head on collision	1517
268	1517	8/23/88	445	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1517
269	1517	9/24/88	30	1	1	1	Bus	Car	-	0	bus hit the car	1517
270	1517	3/19/89	1430	0	3	1	Bus	Car	-	0	bus hit the car	1517
271	1517	4/ 9/89	130	0	1	1	Truck	Car	-	0	car hit the truck	1517
272	1517	3/30/89	1200	0	1	1	Jeep	Car	-	0	jeep hit the car	1517
273	1517	9/26/88	1326	1	3	1	Oil tanker	Suzuki	-	0	oil tanker hit the suzuki	1517
274	1517	6/29/89	1800	0	2	1	Pickup	MC	-	0	pickup hit the MC	1517
275	1517	5/ 3/89	1600	0	1	1	Wagon	Wagon	-	0	wagon hit the wagon	1517
276	1517	3/11/88	2230	1	4	2	Bus	Oil Tanker	-	0	head on collision	1517
277	1519	10/17/89	1345	0	1	0	Bus	-	-	1	bus hit the pedestrian	1519
278	1519	11/10/88	1030	0	1	1	Wagon	Jeep	-	0	wagon hit the jeep from back side	1519
279	1520	9/12/90	1530	0	1	0	Tractor	-	-	1	tractor hit the pedestrian	1520
280	1520	5/ 5/88	815	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1520
281	1520	5/17/88	705	0	3	1	Suzuki	-	-	0	suzuki over turned	1520
282	1520	2/17/89	1510	0	0	2	Car	Car	-	0	both cars damaged	1520
283	1520	2/24/89	1900	0	1	2	Bus	Bus	-	0	both damaged	1520
284	1520	3/14/88	945	1	0	2	Truck	Car	-	0	head on collision	1520

<u>**Police Station Sehala.**</u>

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles Involved		--->	Peds.	Remarks	Km.
285	1521	12/20/90	1000	1	0	0	Bus	-	-	1	bus hit the standing pedestrian	1521
286	1521	2/ 3/90	2015	1	0	0	Car	-	-	1	Car hit the pedestrian	1521
287	1521	3/ 4/89	445	1	0	0	Jeep	-	-	1	jeep hit the pedestrian	1521
288	1521	2/27/89	1400	0	1	0	Car	-	-	1	Taxi Car hit the pedestrian	1521
289	1521	8/13/90	2300	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1521
290	1521	12/25/89	1100	0	1	1	Bus	Suzuki	-	0	bus hit the suzuki	1521
291	1521	3/11/90	1515	0	2	1	Pickup	MC	-	0	pickup hit the MC	1521

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Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles	Involved	--->	Peds.	Remarks	Km.
292	1521	10/ 6/89	1330	0	1	2	Car	Car	-	0	car hit the car	1521
293	1521	1/19/89	645	0	2	2	Truck	Truck	-	0	head on collision	1521
294	1523	12/16/90	700	1	1	1	Car	Wall	-	0	car hit the wall of Patrol Pump	1523
295	1523	12/31/90	1645	0	1	1	Car	Wagon	-	0	wagon hit the car	1523
296	1523	7/19/90	1130	0	2	2	Suzuki	Wagon	-	0	wagon hit the suzuki	1523
297	1524	1/24/90	1830	1	0	0	Pickup	-	-	1	pickup hit the pedestrian	1524
298	1524	12/16/89	730	0	4	1	Bus	Tree	-	0	bus hit the tree	1524
299	1524	8/ 4/88	730	1	2	1	MC	Wagon	-	0	wagon hit the MC	1524
300	1524	4/30/90	140	0	1	2	Car	Wagon	-	0	wagon hit the car from back	1524
301	1528	9/ 9/90	1930	1	0	0	Wagon	-	-	1	wagon crashed the pedestrian	1528
302	1528	4/17/88	1800	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1528
303	1528	6/21/89	2130	0	2	0	Wagon	Suzuki	-	0	wagon hit the suzuki	1528
304	1528	9/14/89	1130	2	0	1	Wagon	-	-	0	wagon over turned	1528
305	1528	9/24/89	700	1	0	2	Wagon	Bus	-	0	bus hit the wagon	1528
306	1528	8/27/88	1730	0	2	2	Wagon	Car	-	0	head on collision	1528
307	1528	12/26/90	1715	1	3	2	Wagon	Wagon	-	0	wagon hit the wagon	1528
308	1528	1/ 5/89	800	1	3	2	Jeep	Wagon	-	0	wrong over taking	1528
309	1529	3/ 2/89	900	0	2	1	Truck	Suzuki	-	0	head on collision	1529
310	1529	12/10/89	1430	0	0	2	Wagon	Bus	-	0	head on collision	1529
311	1530	10/22/88	1700	1	0	0	Suzuki	-	-	1	suzuki hit the pedestrian	1530
<u>Police Station Rawalpindi (CL).</u>												
312	1531	9/21/90	100	1	0	0	Car	-	-	1	car hit the pedestrian	1531
313	1531	3/17/90	830	1	0	0	Jeep	-	-	1	jeep hit the pedestrian	1531
314	1531	12/30/88	900	1	0	0	Bus	-	-	0	Passenger fell down from the bus	1531
315	1531	7/23/90	615	1	0	0	Suzuki	-	-	0	passenger fell down from the suzuki	1531
316	1531	2/ 9/89	2115	1	0	0	Vehicle	-	-	1	vehicle hit the pedestrian	1531
317	1531	1/18/89	1630	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1531
318	1531	4/28/90	2115	0	1	1	Suzuki	Bus	-	0	head on collision	1531
319	1531	1/15/89	1130	1	0	1	MC	Tractor	-	0	tractor hit the MC from wrong side	1531
320	1531	12/17/90	1230	0	1	1	Truck	Wagon	-	0	truck hit the wagon wrong side	1531
321	1531	11/10/89	300	1	0	1	Wagon	MC	-	0	wagon hit the MC	1531
322	1531	9/12/90	1225	0	1	1	Wagon	MC	-	0	wagon hit the MC	1531
323	1531	6/12/88	1800	1	0	1	Wagon	Truck	-	0	wagon hit the truck	1531
324	1531	6/23/88	400	0	1	1	Wagon	Truck	-	0	wagon hit the truck	1531
325	1531	1/ 1/90	815	0	5	2	Bus	Wagon	-	0	Bus hit the wagon	1531
326	1531	10/ 5/90	1300	0	1	2	Car	Wagon	-	0	head on collision	1531
327	1531	4/ 4/90	1130	0	1	2	Pickup	MC	-	0	pickup hit the MC	1531
328	1532	5/29/88	0	1	0	0	Car	-	-	1	car hit the pedestrian	1532
329	1532	9/30/89	2230	0	1	0	Pickup	-	-	1	pickup hit the pedestrian	1532
330	1532	12/ 7/89	2205	0	1	0	Suzuki	-	-	1	suzuki carry hit the pedestrian	1532
331	1532	5/20/88	30	1	0	0	Vehicle	-	-	1	vehicle crashed the pedestrian	1532
332	1532	4/21/90	1155	0	1	1	Oil Tanker	Car	-	0	car hit the oil tanker from back side	1532

(continued)

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles Involved		--->	Peds.	Remarks	Km.
333	1532	3/12/90	35	0	0	1	Car	-	-	0	car hit the pole of bridge	1532
334	1532	4/19/90	1820	1	2	1	Suzuki	Truck	-	0	truck hit the suzuki	1532
335	1532	2/15/90	315	0	1	2	Bus	Truck	-	0	bus hit the truck from wrong side	1532
336	1532	10/ 3/88	1100	0	1	2	Truck	Truck	-	0	Truck hit the truck	1532
337	1534	7/17/90	2040	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1534
338	1534	11/16/89	1230	0	0	2	Car	Car	-	0	both damaged	1534
339	1534	4/22/88	1530	0	6	2	Suzuki	Wagon	-	0	head on collision	1534
340	1534	6/11/89	1600	0	2	2	Suzuki	Pickup	-	0	head on collision	1534
341	1534	4/19/88	1300	0	2	2	MC	MC	-	0	MC hit the MC	1534
342	1535	1/10/89	900	1	0	1	Bus	Wagon	BC	0	BC crushed by bus & wagon	1535
343	1535	3/15/90	1100	0	1	1	Wagon	MC	-	0	wagon hit the MC	1535
344	1535	12/16/88	1045	0	0	2	Wagon	Suzuki	-	0	both damaged	1535

<u>Police Station Ternol.</u>

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles Involved		--->	Peds.	Remarks	Km.
345	1547	10/23/89	1100	1	0	0	Bus	-	-	1	bus hit the pedestrian	1547
346	1547	5/26/90	1700	0	2	1	Bus	MC	-	0	MC hit the bus	1547
347	1547	5/ 8/89	1630	1	0	1	Wagon	BC	-	0	wagon hit the BC	1547
348	1548	9/ 7/89	100	1	0	0	Truck	-	-	1	truck hit the pedestrian	1548
349	1548	6/ 1/89	1430	0	3	1	Bus	-	-	1	bus hit the pedestrian & tree	1548
350	1548	1/ 7/88	800	1	0	1	Truck	Suzuki	-	0	truck hit the suzuki	1548
351	1548	11/29/89	1700	0	4	1	Wagon	Truck	-	0	truck hit the wagon	1548
352	1548	1/ 5/90	1200	0	1	2	Wagon	Wagon	-	0	head on collision	1548
353	1548	1/26/90	1615	1	6	2	Wagon	Truck	-	0	truck hit the wagon	1548
354	1548	1/21/90	800	0	0	2	Car	Suzuki	-	0	wrong crossing	1548
355	1549	1/10/90	1215	1	0	0	Truck	-	-	1	truck hit the pedestrian	1549
356	1549	6/ 1/88	930	0	1	1	Bus	Car	-	0	bus hit the car	1549
357	1549	10/26/89	1550	0	2	1	Bus	MC	-	0	bus hit the MC from back	1549
358	1549	8/13/88	1130	1	0	1	Bus	-	-	1	bus hit the pedestrian	1549
359	1549	2/ 9/89	0	5	3	1	Bus	-	-	1	bus hit the pedestrian and fell in the hole	1549
360	1549	12/18/90	800	0	1	1	Tractor	Jeep	-	0	jeep hit the tractor	1549
361	1549	5/ 8/88	1545	1	0	1	Truck	MC	-	0	truck hit the MC	1549
362	1549	4/22/90	1430	1	0	2	Wagon	Car	-	0	head on collision	1549
363	1549	1/24/90	615	0	0	2	Truck	Truck	-	0	wrong crossing	1549
364	1550	2/ 4/88	815	1	0	0	Bus	-	-	1	bus hit the pedestrian	1550
365	1550	11/26/88	1545	0	1	0	Bus	Bus	-	1	bus hit the pedestrian	1550
366	1550	11/18/88	1915	0	1	0	Pickup	-	-	1	pickup hit the pedestrian	1550
367	1550	1/29/89	1045	1	0	1	Bus	BC	-	0	but hit the BC	1550
368	1550	4/21/88	1300	0	0	1	Truck	Car	-	0	car damaged	1550
369	1550	6/11/89	930	1	0	1	Car	BC	-	0	car hit the BC	1550
370	1550	5/11/88	1100	0	2	1	Truck	Bus	-	0	truck hit the bus from side	1550
371	1550	9/ 4/90	1730	1	5	1	Truck	Car	-	0	truck hit the car	1550
372	1550	4/ 8/90	1700	0	0	2	Truck	Truck	-	0	both trucks damaged	1550
373	1550	6/30/90	1145	0	3	2	Bus	Wagon	-	0	bus hit the wagon from back side	1550

(continued)

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles Involved --->			Peds.	Remarks	Km.
374	1550	4/14/88	715	5	1	3	Buses (2)	Wagon	Truck	0	bus hit the wagon, wagon hit the bus & truck	1550
375	1551	9/ 6/89	1130	1	2	1	Bus	-	-	0	Bus fell down in the road side ditch	1551
376	1553	10/17/88	930	0	3	0	Jeep	-	-	3	jeep hit the three standing pedestrians	1553
377	1553	12/ 3/89	1200	0	1	2	Car	Truck	Car	0	head on collision	1553
378	1554	4/27/88	1600	0	2	1	Car	BC	-	0	car hit the pedestrian	1554
379	1556	5/27/88	730	0	1	1	Suzuki	BC	-	0	suzuki hit the BC	1556
380	1557	2/ 9/89	1630	1	0	0	Truck	-	-	1	truck hit the pedestrian	1557
381	1557	1/26/89	1630	1	3	1	Trailer	Car	-	0	Trailer hit the Car	1557
382	1557	7/ 7/90	1830	0	0	1	Truck	Pickup	-	0	truck turned without indicator	1557
383	1558	7/31/88	1730	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1558
384	1559	7/20/89	1415	1	0	1	Car	Tree	-	0	car hit the tree	1559
385	1560	12/13/88	1745	0	2	0	Truck	-	-	2	truck hit the pedestrian	1560
386	1560	4/14/88	1900	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1560
387	1560	3/17/90	1525	6	22	1	Bus	-	-	0	bus fell in the ditch due to over speed	1560
388	1560	7/24/90	930	0	4	1	Bus	Pickup	-	0	bus hit the pickup from back	1560
389	1560	3/29/88	1900	0	1	1	Trailer	Car	-	0	trailer hit the car from back side	1560
390	1560	2/28/88	1000	1	1	1	Wagon	BC	-	0	wagon hit the BC	1560
391	1560	7/ 9/89	300	1	3	2	Truck	Truck	-	0	truck hit the standing truck	1560
392	1560	7/31/88	2300	1	2	2	Truck	Tractor	-	0	truck hit the tractor from back	1560
393	1560	10/13/88	730	0	2	2	Wagon	Truck	-	0	wagon hit the truck from back side	1560
394	1561	6/14/89	1015	1	0	0	Bus	Truck	-	0	bus over took the truck & man fell down	1561
395	1561	9/13/90	1830	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1561
396	1561	5/11/90	2230	0	2	1	Truck	Car	-	0	truck hit the car	1561
397	1564	6/ 8/90	1800	1	0	0	Truck	-	-	1	truck hit the pedestrian	1564
398	1564	7/10/89	800	0	4	1	Truck	Car	-	0	head on collision	1564
399	1564	12/ 1/88	1240	0	3	2	Truck Bus	Car	-	0	bus hit the car	1564

Police Station Taxila.

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles Involved --->			Peds.	Remarks	Km.
400	1565	6/24/90	1100	0	1	0	Suzuki	-	-	1	suzuki hit the pedestrian	1565
401	1565	1/18/90	1630	1	1	0	Trailer	-	-	1	trailer hit the pedestrian	1565
402	1565	1/22/88	1835	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1565
403	1565	3/11/89	1000	0	1	1	Bus	BC	-	0	bus hit the BC	1565
404	1565	5/22/88	630	2	0	1	Truck	-	-	0	truck fell in the road side slope	1565
405	1565	3/26/88	20	0	0	1	Wagon	-	-	0	wagon hit the tree	1565
406	1565	5/17/90	1500	0	1	2	Truck	Car	-	0	car hit the truck	1565
407	1565	4/25/88	1230	0	2	2	Bus	Truck	-	0	due to wrong crossing	1565
408	1565	4/21/90	1810	0	1	2	Car	Wagon	-	0	wagon hit the car	1565
409	1565	8/25/89	1000	0	4	2	Car	Truck	-	0	wrong crossing	1565
410	1565	2/15/90	1045	1	2	2	Car	Car	-	0	wrong crossing	1565
411	1566	3/ 4/90	1515	1	0	0	Bus	-	-	1	bus hit the pedestrian	1566
412	1566	8/26/88	1800	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1566
413	1566	6/10/88	1230	1	0	1	Car	Bus	-	0	car hit the bus	1566
414	1566	6/ 8/89	1700	1	0	1	Suzuki	-	-	0	suzuki fell down in the road side slope	1566

(continued)

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles	Involved --->		Peds.	Remarks	Km.
415	1566	3/24/90	1115	0	4	2	Jeep	Car	-	0	head on collision	1566
416	1566	2/ 2/90	1815	0	2	2	Wagon	Car	-	0	wrong crossing	1566
417	1566	5/14/90	1500	0	2	2	Truck	Bus	-	0	wrong crossing	1566
418	1567	2/10/88	1530	1	0	0	Bus	-	-	1	bus crashed the pedestrian	1567
419	1567	3/19/90	2345	0	1	0	Car	-	-	1	car hit the pedestrian	1567
420	1567	3/10/88	800	0	1	0	Truck	-	-	1	truck hit the pedestrian	1567
421	1567	3/12/90	230	0	1	0	Truck	-	-	1	truck hit the pedestrian	1567
422	1567	1/ 5/89	1300	0	3	1	Bus	-	-	0	bus turned down	1567
423	1567	9/25/88	1200	0	2	1	Truck	Wagon	-	0	wagon hit the standing truck	1567
424	1567	4/18/89	2045	1	2	2	Truck	Truck	-	0	truck hit the truck from back	1567
425	1568	2/22/90	1130	0	1	0	Car	-	-	1	car hit the pedestrian	1568
426	1568	1/10/90	1000	0	1	0	Suzuki	-	-	1	suzuki hit the pedestrian	1568
427	1568	8/13/88	445	1	0	0	Vehicle	-	-	1	vehicle crashed the pedestrian	1568
428	1568	2/29/88	2145	0	2	1	BC	Suzuki	-	0	suzuki hit the MC	1568
429	1568	11/ 2/88	1550	0	1	1	Suzuki	Truck	-	0	suzuki hit the standing truck	1568
430	1568	5/ 6/88	1300	0	2	1	Truck	Car	-	0	truck hit the car	1568
431	1568	12/11/89	1500	2	4	1	Wagon	BC	-	0	wagon hit the BC	1568
432	1569	1/ 6/88	1435	0	1	0	Bus	-	-	1	bus hit the pedestrian	1569
433	1569	9/28/89	830	1	0	0	Bus	-	-	1	bus hit the pedestrian	1569
434	1569	1/27/90	1400	1	0	0	Bus	-	-	1	bus hit the pedestrian	1569
435	1569	7/ 5/90	1315	1	0	0	Bus	-	-	1	bus hit the pedestrian	1569
436	1569	1/26/90	1850	1	0	0	Car	-	-	1	car hit the pedestrian	1569
437	1569	9/13/89	930	0	1	0	MC	-	-	1	MC hit the pedestrian	1569
438	1569	5/10/89	1630	0	1	0	Suzuki	-	-	1	suzuki hit the pedestrian	1569
439	1569	3/ 4/88	1300	1	0	0	Truck	-	-	1	truck hit the pedestrian	1569
440	1569	1/14/89	630	1	0	0	Vehicle	-	-	1	vehicle crashed the pedestrian	1569
441	1569	4/28/88	2315	2	0	0	Vehicle	-	-	1	vehicle crashed the two persons	1569
442	1569	1/20/89	1700	1	0	0	Wagon	-	-	1	wagon crashed the pedestrian	1569
443	1569	12/24/88	830	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1569
444	1569	6/ 5/90	1400	0	1	0	Wagon	-	-	1	wagon hit the pedestrian	1569
445	1569	6/ 1/89	1450	1	1	1	Oil Tanker	Suzuki	-	0	oil tanker hit the suzuki	1569
446	1569	10/ 9/90	1545	1	0	1	Suzuki	BC	-	0	suzuki hit the BC	1569
447	1569	10/ 1/90	1730	0	0	2	Truck	Bus	-	0	head on collision	1569
448	1569	8/21/89	1515	0	0	2	Truck	Wagon	-	0	wrong crossing	1569
449	1570	6/20/88	1600	1	0	0	Jeep	-	-	1	jeep hit the pedestrian	1570
450	1570	7/12/89	1900	0	1	0	Pickup	-	-	1	pickup hit the pedestrian	1570
451	1570	4/ 4/90	1130	0	1	0	Truck	-	-	1	truck hit the pedestrian	1570
452	1570	10/ 5/89	1200	0	4	2	Suzuki	Bus	-	0	head on collision	1570
Police Station Wah.												
453	1572	1/13/88	1500	1	0	0	Bus	-	-	1	bus hit the pedestrian	1572
454	1572	10/ 5/89	1130	1	0	0	Bus	-	-	1	bus hit the pedestrian	1572
455	1572	2/14/88	1800	1	1	0	Bus	-	-	2	bus hit the pedestrians	1572

(continued)

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles Involved --->			Peds.	Remarks	Km.
456	1572	2/13/89	1600	1	0	0	Car	-	-	1	car hit the pedestrian	1572
457	1572	7/19/89	1100	0	1	0	Car	-	-	1	car hit the pedestrian	1572
458	1572	8/19/89	1700	0	1	0	Car	-	-	1	car hit the pedestrian	1572
459	1572	8/26/90	1930	0	1	0	Car	-	-	1	car hit the pedestrian	1572
460	1572	3/17/89	1940	1	0	0	Jeep	-	-	1	jeep hit the pedestrian	1572
461	1572	12/18/89	320	1	0	0	Truck	-	-	1	truck hit the pedestrian	1572
462	1572	2/11/89	2015	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1572
463	1572	1/ 8/90	1745	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1572
464	1572	6/ 3/88	2145	0	1	1	Car	BC	-	0	car hit the BC	1572
465	1572	8/16/90	1530	1	0	1	Jeep	MC	-	0	jeep hit the MC	1572
466	1572	6/23/88	645	1	0	1	Truck	BC	-	0	truck hit the BC	1572
467	1572	7/20/88	1800	0	1	1	Wagon	BC	-	0	wagon hit the BC	1572
468	1572	2/ 9/89	1300	0	1	1	Wagon	BC	-	0	wagon hit the BC	1572
469	1572	12/14/89	1700	1	0	1	Wagon	Tree	-	0	wagon hit the tree	1572
470	1572	4/ 4/88	1900	0	4	2	Car	Suzuki	-	0	car hit the standing suzuki	1572
471	1572	2/27/89	1600	0	1	2	Bus	Jeep	-	0	jeep damaged	1572
472	1572	3/21/88	2100	1	1	2	Suzuki	Tonga	-	0	suzuki hit the tonga and Horse dead	1572
473	1572	9/25/90	1900	0	4	2	Wagon	Suzuki	-	0	wrong crossing	1572
474	1573	3/ 6/89	715	1	0	0	Bus	-	-	1	bus hit the pedestrian	1573
475	1573	12/23/89	1030	1	0	0	Truck	-	-	1	truck hit the pedestrian	1573
476	1573	8/26/90	1230	1	0	0	Truck	-	-	1	truck hit the pedestrian	1573
477	1573	8/ 6/88	1030	1	1	1	Bus	MC	-	0	bus hit the MC	1573
478	1573	2/ 6/89	1300	0	1	1	Tractor	MC	-	0	MC hit the tractor	1573
479	1574	2/20/89	1000	0	1	0	Car	-	-	1	car hit the pedestrian	1574
480	1574	2/ 2/88	1315	1	0	0	Jeep	-	-	1	jeep hit the pedestrian	1574
481	1574	4/22/89	1300	0	1	0	Suzuki	BC	-	0	suzuki hit the BC	1574
482	1574	5/10/88	1130	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1574
483	1574	11/29/90	1330	0	2	1	Truck	Car	-	0	car hit the truck	1574
484	1574	8/ 9/88	0	0	0	1	Jeep	Truck	-	0	jeep damaged	1574
485	1574	11/ 6/89	815	0	4	1	Bus	Wagon	-	0	wagon hit bus from back	1574
486	1574	11/24/90	1330	0	0	1	Wagon	Bull Cart	-	0	wagon hit the Bull Cart	1574
487	1574	7/ 1/89	1630	0	2	2	Car	Car	-	0	car hit the second car	1574
488	1574	3/30/89	1330	0	8	2	Wagon	Bus	-	0	wagon hit the bus from back	1574
489	1574	3/ 3/88	1030	0	3	2	Car	Wagon	-	0	wrong crossing	1574
490	1575	6/ 3/88	430	0	6	0	Bus	-	-	0	bus turned down	1575
491	1575	3/31/90	930	0	1	0	Tractor	-	-	1	tractor hit the pedestrian	1575
492	1576	7/19/88	1100	0	1	0	Bus	-	-	1	bus hit the pedestrian	1576
493	1576	5/23/89	840	1	0	0	Car	-	-	1	car hit the pedestrian	1576
494	1576	12/16/89	2030	0	1	1	Wagon	BC	-	0	wagon hit the pedestrian	1576
495	1579	7/15/89	1730	1	0	0	Car	-	-	1	car hit the pedestrian	1579
496	1579	11/26/88	630	1	0	0	Truck	-	-	1	truck hit the pedestrian	1579
497	1579	4/14/88	1930	1	0	0	Wagon	-	-	1	wagon hit the pedestrian	1579
498	1580	4/ 8/88	1815	0	1	0	Bus	-	-	1	bus hit the pedestrian	1580
499	1580	5/20/89	930	0	1	0	Car	-	-	1	car hit the pedestrian	1580

Rec#.	Km.	Date	Time	FTL	INJ	PDO	<--- No. of Vehicles	Involved	--->	Peds.	Remarks	Km.
500	1580	5/10/90	1100	1	0	0	Car	-	-	1	car hit the pedestrian	1580
501	1580	1/ 4/90	1715	1	0	0	Truck	-	-	1	truck hit the pedestrian	1580
502	1580	12/24/89	1840	1	1	1	Bus	BC	-	0	bus hit the BC	1580
503	1580	10/ 7/88	1900	0	5	1	Car	Bus	-	0	car damaged	1580
504	1580	1/ 8/88	500	1	0	1	Truck	Car	-	0	truck hit the standing car	1580
505	1580	7/ 5/88	1945	1	0	2	Wagon	Car	-	0	head on collision	1580
506	1580	7/18/88	1830	1	5	3	MC Wagon	Suzuki	-	0	wagon hit MC & Suzuki	1580
507	1581	8/12/88	730	1	0	0	Truck	-	-	1	truck hit the pedestrian	1581
508	1581	10/23/88	930	0	1	1	Pickup	MC	-	0	pickup hit the MC	1581
509	1581	11/12/89	1030	1	0	2	Bus	Wagon	-	0	head on collision	1581
510	1581	5/11/88	345	1	0	2	Truck	Tractor	-	0	truck hit the tractor	1581
511	1582	3/17/89	1930	0	1	1	Car	Tonga	-	0	tonga damaged	1582
512	1583	5/ 1/88	1200	0	1	0	Bus	-	-	1	bus hit the pedestrian	1583

Appendix E

The SPSS Program for Data Analyses

SPSS COMMAND AND PROGRAM FILES FOR DATA ANALYSIS

```
SET MORE = OFF.

************************************************************
* 2-LANE ANALYSIS.
************************************************************


TITLE '2-LANE ANALYSIS'.

DATA LIST FREE FILE = '2L2W.DAT'/ KM (A) RIBBON SPATHS
GDRAIL PWIDTH SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB
HZINDX ACCFRQ ACCRAT.

VARIABLE LABELS KM 'KILOMETER No.'
  RIBBON 'RIBBON DEVELOPMENT' /
  SPATHS 'SPECIFIC LATERAL PATHS'/
  GDRAIL 'DEFICIENT GUARDRAIL' /
  PWIDTH 'DEF. PAVEMENT WIDTH' /
  SWIDTH 'DEF. SHOULDER WIDTH' /
  PMARKS 'DEF. PVT. MARKINGS'  /
  INTSEC 'INTERSECTION DEFCY.' /
  ISLAND 'ISOLATED LANE DEFICIENCIES' /
  PVCOND 'PVT. CONDITION RATG.'/
  SIDEOB 'ROADSIDE OBSTRUCTION' /
  HZINDX 'HAZARD INDEX'/
  ACCFRQ 'ACCIDENT FREQUENCY'/
  ACCRAT 'ACCIDENT RATE'.
SAVE OUTFILE = '2L2W.SYS'.


GET / FILE '2L2W.SYS'.

COMPUTE ANACFQ=(ACCFRQ/3.0).
COMPUTE ANACRT=(ACCRAT/3.0).
VARIABLE LABELS ANACFQ 'ANNUAL ACCIDENT FREQUENCY'
                ANACRT 'ANNUAL ACCIDENT RATE'.

DESCRIPTIVES / VARIABLES ALL.


* CORRELATIONS.

CORRELATIONS / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ WITH RIBBON SPATHS
GDRAIL PWIDTH SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB
ANACFQ.


* FREQUENCY DISTRIBUTIONS.

FREQUENCY / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ HZINDX / FORMAT
NOTABLE / HISTOGRAM NORMAL / PERCENTILE 15 85 / STATISTICS
DEFAULT.
```

```
* TEST FOR MULTICOLLINEARITY.

REGRESSION / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ / STATISTICS
COLLIN / DEPENDENT ANACFQ / METHOD ENTER.

REGRESSION / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ / STATISTICS TOL
/ DEPENDENT ANACFQ / METHOD ENTER.


* REGRESSION ANALYSIS.

* BACKWARD ELIMINATION METHOD.

REGRESSION / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ / DESCRIPTIVES /
DEPENDENT ANACFQ / METHOD BACKWARD.

* FORWARD SELECTION.

REGRESSION / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ / DESCRIPTIVES /
DEPENDENT ANACFQ / METHOD FORWARD.

* STEPWISE SELECTION.

REGRESSION / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ / DESCRIPTIVES /
DEPENDENT ANACFQ / METHOD STEPWISE.


* EXAMINE TRAFFIC VARIABILITY EFFECT.

CORRELATIONS / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS INTSEC ISLAND PVCOND SIDEOB WITH ANACFQ ANACRT.

REGRESSION / VARIABLES RIBBON GDRAIL ANACRT / DEPENDENT
ANACRT / METHOD BACKWARD.


* EXAMINE RESIDUALS.

REGRESSION / VARIABLES RIBBON GDRAIL ANACFQ / DEPENDENT
ANACFQ / METHOD BACKWARD / RESIDUALS DEFAULT HISTOGRAM
(RESID PRED) OUTLIERS NORMPROB (RESID PRED).


* REGRESSION ANALYSIS WITH ONE DATA SET.

* GEOMETRIC DATA ONLY.

* BACKWARD ELIMINATION METHOD.
REGRESSION / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS ANACFQ / DEPENDENT ANACFQ / METHOD BACKWARD.
```

```
* FORWARD SELECTION.
REGRESSION / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS ANACFQ / DEPENDENT ANACFQ / METHOD FORWARD.

* STEPWISE SELECTION.
REGRESSION / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS ANACFQ / DEPENDENT ANACFQ / METHOD STEPWISE.


* CONFLICT DATA ONLY.

* BACKWARD ELIMINATION METHOD.
REGRESSION / VARIABLES INTSEC ISLAND ANACFQ / DEPENDENT
ANACFQ / METHOD BACKWARD.

* FORWARD SELECTION.
REGRESSION / VARIABLES INTSEC ISLAND ANACFQ / DEPENDENT
ANACFQ / METHOD FORWARD.

* STEPWISE SELECTION.
REGRESSION / VARIABLES INTSEC ISLAND ANACFQ / DEPENDENT
ANACFQ / METHOD STEPWISE.


* SUBJECTIVE RATING DATA ONLY.

* BACKWARD ELIMINATION METHOD.
REGRESSION / VARIABLES PVCOND SIDEOB ANACFQ / DEPENDENT
ANACFQ / METHOD BACKWARD.

* FORWARD SELECTION.
REGRESSION / VARIABLES PVCOND SIDEOB ANACFQ / DEPENDENT
ANACFQ / METHOD FORWARD.

* STEPWISE SELECTION.
REGRESSION / VARIABLES PVCOND SIDEOB ANACFQ / DEPENDENT
ANACFQ / METHOD STEPWISE.


* HAZARD INDEX DEVELOPMENT.

COMPUTE HI = (RIBBON + SPATHS + GDRAIL + PWIDTH + SWIDTH +
PMARKS + INTSEC + ISLAND + PVCOND + SIDEOB).

DESCRIPTIVES / VARIABLES ALL.

CORRELATIONS / VARIABLES RIBBON SPATHS GDRAIL PWIDTH SWIDTH
PMARKS INTSEC ISLAND PVCOND SIDEOB HZINDX HI WITH ANACFQ.


* GRAPH BETWEEN HZINDX AND ANACFQ.

PLOT / FORMAT REGRESSION / TITLE 'HAZARD INDEX 2-LANE'/
VERTICAL 'Annual Acc. Freq'/ HORIZONTAL 'Hazard Index' /PLOT
ANACFQ WITH HZINDX.
```

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***************************************************************
* 4-LANE ANALYSIS.
***************************************************************

TITLE '4-LANE ANALYSIS'.

DATA LIST FREE FILE = '4LDH.DAT'/ KM (A) RIBBON SPATHS
MEDOPN GDRAIL PWIDTH SWIDTH PMARKS INTSEC ISLAND PVCOND
SIDEOB HZINDX ACCFRQ ACCRAT.

VARIABLE LABELS KM 'KILOMETER No.'
  RIBBON 'RIBBON DEVELOPMENT' /
  SPATHS 'SPECIFIC LATERAL PATHS'/
  MEDOPN 'MEDIAN OPENINGS'/
  GDRAIL 'DEFICIENT GUARDRAIL' /
  PWIDTH 'DEF. PAVEMENT WIDTH' /
  SWIDTH 'DEF. SHOULDER WIDTH' /
  PMARKS 'DEF. PVT. MARKINGS'  /
  INTSEC 'INTERSECTION DEFCY.' /
  ISLAND 'ISOLATED LANE DEFICIENCIES' /
  PVCOND 'PVT. CONDITION RATG.'/
  SIDEOB 'ROADSIDE OBSTRUCTION' /
  HZINDX 'HAZARD INDEX'/
  ACCFRQ 'ACCIDENT FREQUENCY'/
  ACCRAT 'ACCIDENT RATE'.
SAVE OUTFILE = '4LDH.SYS'.


GET / FILE '4LDH.SYS'.

COMPUTE ANACFQ=(ACCFRQ/3.0).
COMPUTE ANACRT=(ACCRAT/3.0).
VARIABLE LABELS ANACFQ 'ANNUAL ACCIDENT FREQUENCY'
                ANACRT 'ANNUAL ACCIDENT RATE'.
DESCRIPTIVES / VARIABLES ALL.


* CORRELATIONS.

CORRELATIONS / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ WITH RIBBON
SPATHS MEDOPN GDRAIL PWIDTH SWIDTH PMARKS INTSEC ISLAND
PVCOND SIDEOB ANACFQ.


* FREQUENCY DISTRIBUTIONS.

FREQUENCY / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ HZINDX /
FORMAT NOTABLE / HISTOGRAM NORMAL / PERCENTILE 15 85 /
STATISTICS DEFAULT.

* TEST FOR MULTICOLLINEARITY.

REGRESSION / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ /
STATISTICS COLLIN / DEPENDENT ANACFQ / METHOD ENTER.
```

```
REGRESSION / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ /
STATISTICS TOL / DEPENDENT ANACFQ / METHOD ENTER.


* REGRESSION ANALYSIS.

* BACKWARD ELIMINATION METHOD.

REGRESSION / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ /
DESCRIPTIVES / DEPENDENT ANACFQ / METHOD BACKWARD.

* FORWARD SELECTION.

REGRESSION / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ /
DESCRIPTIVES / DEPENDENT ANACFQ / METHOD FORWARD.

* STEPWISE SELECTION.

REGRESSION / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB ANACFQ /
DESCRIPTIVES / DEPENDENT ANACFQ / METHOD STEPWISE.


* EXAMINE TRAFFIC VARIABILITY EFFECT.

CORRELATIONS / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB WITH ANACFQ
ANACRT.

REGRESSION / VARIABLES RIBBON GDRAIL INTSEC ANACRT /
DEPENDENT ANACRT / METHOD BACKWARD.


* EXAMINE RESIDUALS.

REGRESSION / VARIABLES RIBBON GDRAIL INTSEC ANACFQ /
DEPENDENT ANACFQ / METHOD BACKWARD / RESIDUALS DEFAULT
HISTOGRAM (RESID PRED) OUTLIERS NORMPROB (RESID PRED).

* REGRESSION ANALYSIS WITH ONE DATA SET.

* GEOMETRIC DATA ONLY.

* BACKWARD ELIMINATION METHOD.
REGRESSION / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS ANACFQ / DEPENDENT ANACFQ / METHOD BACKWARD.

* FORWARD SELECTION.
REGRESSION / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS ANACFQ / DEPENDENT ANACFQ / METHOD FORWARD.

* STEPWISE SELECTION.
REGRESSION / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS ANACFQ / DEPENDENT ANACFQ / METHOD STEPWISE.
```

```
* CONFLICT DATA ONLY.

* BACKWARD ELIMINATION METHOD.
REGRESSION / VARIABLES INTSEC ISLAND ANACFQ / DEPENDENT
ANACFQ / METHOD BACKWARD.

* FORWARD SELECTION.
REGRESSION / VARIABLES INTSEC ISLAND ANACFQ / DEPENDENT
ANACFQ / METHOD FORWARD.

* STEPWISE SELECTION.
REGRESSION / VARIABLES INTSEC ISLAND ANACFQ / DEPENDENT
ANACFQ / METHOD STEPWISE.


* SUBJECTIVE RATING DATA ONLY.

* BACKWARD ELIMINATION METHOD.
REGRESSION / VARIABLES PVCOND SIDEOB ANACFQ / DEPENDENT
ANACFQ / METHOD BACKWARD.

* FORWARD SELECTION.
REGRESSION / VARIABLES PVCOND SIDEOB ANACFQ / DEPENDENT
ANACFQ / METHOD FORWARD.

* STEPWISE SELECTION.
REGRESSION / VARIABLES PVCOND SIDEOB ANACFQ / DEPENDENT
ANACFQ / METHOD STEPWISE.


* HAZARD INDEX DEVELOPMENT.

COMPUTE HI = (RIBBON + SPATHS + MEDOPN + GDRAIL + PWIDTH +
SWIDTH + PMARKS + INTSEC + ISLAND + PVCOND + SIDEOB).

DESCRIPTIVES / VARIABLES ALL.

CORRELATIONS / VARIABLES RIBBON SPATHS MEDOPN GDRAIL PWIDTH
SWIDTH PMARKS INTSEC ISLAND PVCOND SIDEOB HZINDX HI WITH
ANACFQ.


* GRAPH BETWEEN HZINDX AND ANACFQ.

PLOT / FORMAT REGRESSION / TITLE 'HAZARD INDEX 4-LANE'
/VERTICAL 'Annual Acc. Freq'/HORIZONTAL 'Hazard Index' /PLOT
ANACFQ WITH HZINDX.


FINISH.
```