ACCIDENT ANALYSIS ON TWO-LANE ROADS

A DISSERTATION

Submitted in partial fulfilment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

CIVIL ENGINEERING

(With Specialization in Transportation Engineering)

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled "**Accident Analysis on Two-Lane Roads**", in partial fulfillment of the requirements for the award of the degree of **MASTER OF TECHNOLOGY in CIVIL ENGINEERING** with specialization in Transportation Engineering submitted in the Department of Civil Engineering, Indian Institute of Technology, Roorkee is an authentic record of my own work carried out a period of about eight months from July 2002 to February 2003, under the supervision of Dr. Satish Chandra, Associate Professor, Department of Civil Engineering, Indian Institute of Technology, Roorkee, India.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

Date: Feb 27, 2003

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CERTIFICATE

This is certifying that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

The effects on traffic safety, as measured by accident rates, of pavement width radius of curve, gradient, sight distance, traffic volume, and design speed on curved section of two-lane highways are discussed in this report. There is a distinct tendency for accidents to decrease with increasing pavement width up to about 7.5m, and there is a negative relationship between radius of curve and accident rate.

Gradients of up to about 6 percent have a relatively small effect on the accident rate, but a sharp increase in the accident rate is observed on grades of more than 6 percent. There exists a negative relationship between available sight distance and accident risk. An accident rate of 2.0 accidents per million vehicles - Km is proposed in literature as a breakpoint between levels of safety and unsafety.

Accident data for last 10 years were collected at various sections of two lane intercity roads, from police FIR in Roorkee, Mangalore and Meerut. Traffic count and road condition data were collected from concerned PWD offices at Roorkee, Hardwar and Meerut. These data were analyzed statistically to see the effect of influencing parameter on accident rate.

It was found that the monthly variation in accident rate in a year is very marginal. Among various types of vehicles, trucks/lorry are involved in maximum and bicycle in minimum number of accidents. Further, it was found that accident rate increases with increase in AADT, where as accidents per million vehicles Km-year (MVKY) decreases with increase in AADT. Accidents and injuries per MVKY decreased over the period 1992-2001 and no particular trend was found for fatality rate. 1.05 percent of total road accidents occur due to bad road condition only. Accident prediction models were developed for each road based on accidents per Km-year, AADT and road condition rating.

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INTRODUCTION

1.1 General

An unplanned and uncontrolled event which results into personal injuries or death, damages to the property is known as an "accident". World Health Organization (WHO) had assessed traffic accident as the world's ninth most important health problem in 1990's. It is believed that by the year 2020, road crashes will be the third leading cause of deaths and disability (Nagraj et al. 2002).

There are nearly 40 million vehicles in India and about 4 millions are added every year (Motor Transport Statistics of India, 1997-98), while the road length has not proportionally increased over the years. With ever increasing traffic congestion, the serious problem is that of road accidents. In India more than 72,000 persons die every year and nearly 4 lakhs get injuries in about 3 lakhs road accidents (Nadaf, 1999). Road accidents in India for years 1980-1998 are shown in Table 1.1.

In India, 1 percent of the world's vehicle population exists but 5 percent of world's road traffic accidents occur. Fatality rates are 20 to 30 times higher as compared to such rates in U.S.A. and Japan. Road accidents are rising continuously in India. Probability of deaths due to road accidents had increased to two and half times in 1991 as compared to the deaths in the year 1971 (Sarin, 1998).

Due to increase in traffic and or political considerations, some roads are upgraded to higher category. Ambitious National Highways Development Project Phase-I (Golden Quadrilateral), Phase- II (N-S, E-W corridor) and addition of 11,068 Kms of state roads to National Highways is a recent example. On such up gradation, roads are improved; even then a few spots remain with inadequate geometrics.

Table 1.1 Road accidents in India

Year	No. of Registered Motor Vehicles (In Thousands)	No. of Accidents (In Thousands)	No. of Accidents Per 1000 Vehicles	(IN THOUSANDS)		
				No. of Persons Killed	No. of Persons Injured	Total (5+6)
1980	4521	153.2	33.89	24.6	109.1	133.7
1981	5391	161.2	29.90	28.4	114.0	142.4
1982	6055	166.2	27.45	30.7	126.0	156.7
1983	6973	177.0	25.38	32.8	134.1	166.9
1984	7949	195.0	24.53	35.1	156.2	191.3
1985	9170	207.0	22.57	39.2	163.4	202.6
1986	10577	215.5	20.37	40.0	176.4	216.4
1987	12618	234.0	18.54	44.4	139.0	234.4
1988	14818	246.7	16.65	46.6	214.8	261.4
1989	16920	270.0	15.96	50.7	229.7	280.4
1990	19152	282.6	14.76	54.1	244.1	298.2
1991	21374	293.4	13.73	56.4	255.0	311.4
1992	23507	260.3	11.07	57.2	267.2	324.4
1993	25505	280.1	10.98	60.7	287.8	348.5
1994	27660	320.4	11.58	64.0	311.5	375.5
1995	30295	348.9	11.52	70.6	323.2	393.8
1996	33783	355.1	10.51	72.0	330.0	402.0
1997	37231	290.4	7.80	61.0	290.8	351.8
1998	40939	306.0	7.47	65.5	304.6	370.1

(Source: Statistics of Road Accidents in India 1991-1998)

Drivers get involved with accidents during inclement weather and at night. A few locations of highways are not adequately designed for night driving. Some of the accidents are caused due to engineering deficiencies in the roads and some are due to drivers' error and vehicular defects.(Sharma and Dua, 2000).

Factors affecting accident and their contributions towards it were presented by Nadaf (1999) as follows-

- Drivers fault – 74%
- Passengers/Pedestrians - 5%
- Bad Road – 3%
- Mechanical Fault – 3%
- Bad Weather – 1%
- Others – 14%

Two-lane highways are important because they compose the predominant length of most highways system in every country. Two-lane highways provide the efficient mobility and accessibility function. Two-lane roads have typical characteristics of traffic flow where one lane is marked for use of vehicles in each direction. Approximately 5.0 million-Km of two-lane rural highways in the United States represent 97 percent of rural mileage and 80 percent of all U.S. highways miles (Choueiri et al., 1994). It is estimated that more than two third length of National Highways (NH), which are the main artery of Indian economy and carry about 70 percent of the total traffic, are of two-lane types (Chandra and Sinha, 2001)

1.2 Need and Objectives of Study

Of all the accidental deaths in India, road traffic accidents constitute the highest percentage, around 22 percent. About 25% of accidents take place on National Highways alone, causing more than one third of the total deaths in road accidents. The total economic loss to the society on account of road accidents is estimated to be in the range of Rs.3000 crores annually. Very little work has been done in India to analyze accidents on two-lane roads. The present work was undertaken to identify influencing factors for accidents on two-lane roads under mixed traffic condition. The major objectives of the present work are listed below.

(i) To study the monthly and annual variation in accident rate on selected stretches of two-lane roads

(ii) To study the effect of traffic volume on accident rate on two-lane roads

(iii) To study the effect of maintenance of road surface and shoulder on rate of accident.

(iv) To develop an accident prediction model based on AADT and road condition.

1.3 Outline of the Report

The work has been documented in the following manner. The first chapter gives overall understanding about the present accident scenario at national and international levels. It also includes the importance of the two-lane roads, factors affecting accident and their contributions, and defines objectives of the study. Chapter two is comprised of review of literature. Site selection for data collection, methodology adopted for data collection and extraction are discussed in third chapter. Analysis of data and related discussion are given in chapter four. Significant conclusions drawn from the study and recommendations for further work are given in chapter five.

REVIEW OF LITERATURE

Many factors may exhibit a measurable influence on driving behavior and traffic safety on two-lane highways. These include, but are not limited to,

(i) Human factors, such as improper judgment of the road ahead and traffic, speeding, driving under the influence of alcohol or drugs, driving inexperience, young people, handicaps (especially for the older segment of the driving population)and sex.

(ii) Physical features of the site, such as horizontal and vertical alignments and cross section combined with the degree for road-side development and access control.

(iii) Traffic factors like volume, traffic mix, and seasonal and daily variations.

(iv) Legal issues, such as mandatory state laws, type of traffic control devices at the sites, and degree of enforcement.

(v) Environmental factors, such as weather and pavement conditions.

(vi) Vehicle deficiencies, such as tyres, brakes and vehicle age.

All of the above factors constitute a complex mix of various causes of traffic accidents, of which the road itself represents only one factor, but a very important one. To show to what extent the road influences safety in traffic, the first step would be to select those elements that may well characterize the latter. These include, most important, the design parameters, the cross section, and traffic volume, since they can easily be evaluated in terms of size and number. However, these parameters affect the accident situation collectively rather than independently. Investigations into the relationship between one or a combination of design and traffic volume parameters and accident situation may give valuable results, as long as it is understood that these parameters are among a variety of influencing factors that are related.

This chapter covers effect on traffic safety, as measured by accident rates, of pavement width, radius of curve, gradient, sight distance, traffic volume and design speed on two-lane rural highways along with driver and vehicle characteristics. These geometric design parameters were chosen for analysis because it was anticipated that they would exhibit a measurable influence, and accident research studies have found statistically measurable impacts of these parameters on traffic safety.

2.1. Influence of Design Parameter

2.1.1. Pavement width

Fig 2.1 depicts the relationship between accident rate and pavement width as derived from the results of research done by Baldwin (1946). It indicates that adequate pavement widths are necessary for safe driving operation. The necessary widths are generally the result of the dimension of design vehicles and lateral clearance for transportation and safety maneuvers. If these widths are not sufficiently designed, impairment of traffic safety can originate. Therefore, it can be expected that there exists a certain correlation between pavement width and traffic safety. He indicated that the accident rate decreases as pavement width increases. It was found that pavement widths of less than 5.5m create unfavorable conditions for traffic safety and the gain in safety is relatively small for pavement widths greater than 7m.

Pignataro (1973) found that the total accident rate of million - vehicle mile decreased from 5.5 to 2.4 as the pavement width increased from 5m to 7.5m. Another study, covering about 385 km of highways that had been widened from 5.5m to 6.7m, Indicated that accident rate reduction ranged from 21.5 percent for low-volume roads to 46.6 percent for high volume rods.

Accident and traffic-volume statistics for lane width of 2.1-4.0 m are given in Table 2.1. The most common accidents, considering all lane widths, were run off road, opposite-direction, and rear-end. The only accidents that would be expected to decrease with lane widening were run-off-road and opposite-direction accidents (Zeeger et al. 1981).

Table 2.1 Lane width and accidents

Lane Width (m)	Sample Size (Km)	Number Of Accidents	Accidents Per Kilometer	Average AADT	Accidents Per Million Vehicle-Km
2.1	637	123	0.19	205	2.58
2.4	4518	1143	0.25	304	2.28
2.7	13273	6652	0.50	729	1.88
3.0	4082	4947	1.21	1862	1.78
3.4	1268	2017	1.59	3410	1.28
3.7	981	1743	1.78	3970	1.23
4.0	61	135	2.21	4483	1.35
Total	24820	16760	6.68	14963	1.68

Statistical analyses of accident by Zegeer et al. (1988b) on two-lane rural highways in Washington indicated a 40 percent accident rate reduction for 1.2 m of lane widening. The above result is shown in Table 2.2, which also reveals that as the amount of lane widening increases, the percent reduction in related accidents also increases.

Table 2.2 Percent reduction in related accident types for lane widening

Amount of Lane Widening (ft)	Percent Reduction in Related Accident Types
1	12
2	23
3	32
4	40

The research reported above has generally shown that accident rates decrease with an increase in pavement width of upto about 7.5m (25 ft) on two-lane rural roads. This increase in traffic safety was evident for all classes of radii of curves, gradients, and traffic volume.

2.1.2 Radius and degree of curve

Fig 2.2 shows the relationship between accident rate and the radius of the curve as derived from the results of research done by Baldwin (1946).

The safe and efficient movement of traffic is greatly influenced by geometric features of the highway. A review of accident spot map normally shows that accidents tend to cluster on curves, particularly on very sharp curves. The general opinion today is that the accident risk decreases as the radius of the curve increases. However, different opinions exist regarding the extent of this influence on the accident situation.

In a study of accidents in Great Britain, Flaherty (1974) found that the accident rate decreases as the radius of the curve increases. Baldwin (1946) also reported similar results.

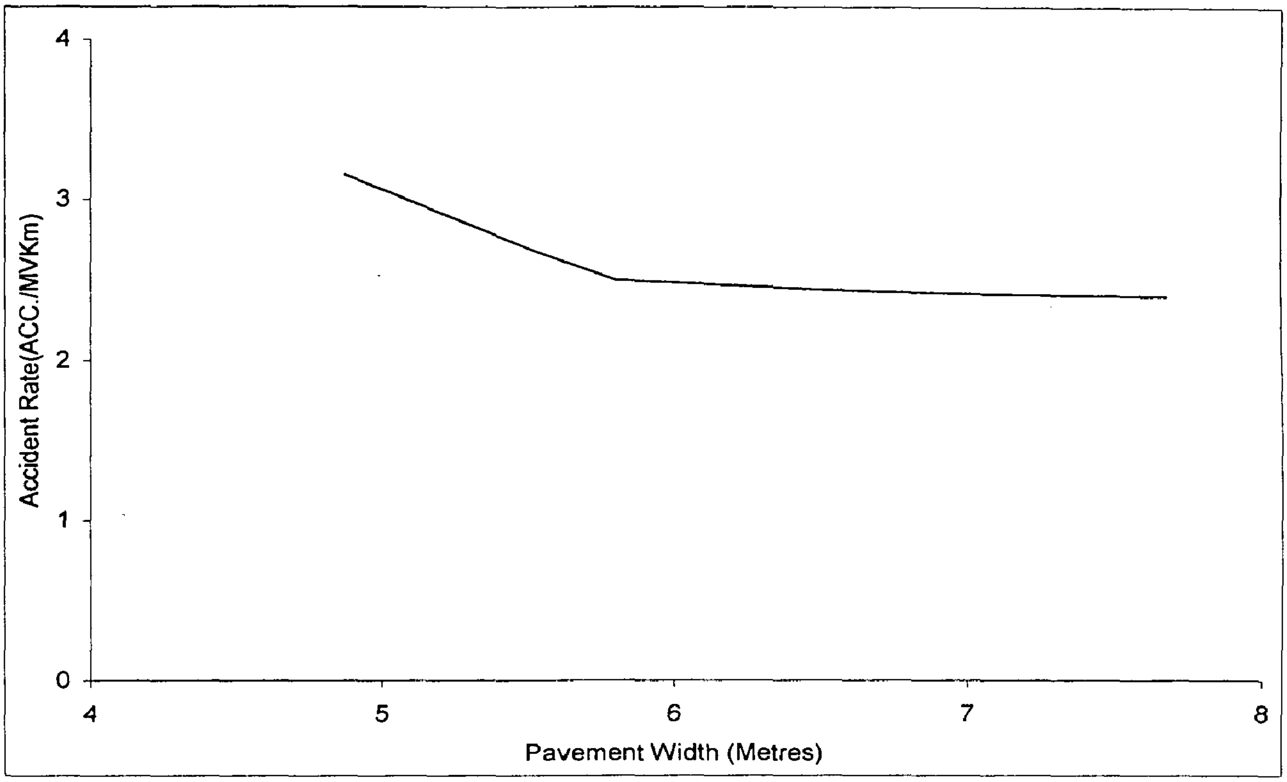


Fig 2.1 Accident rate as related to Pavement width.

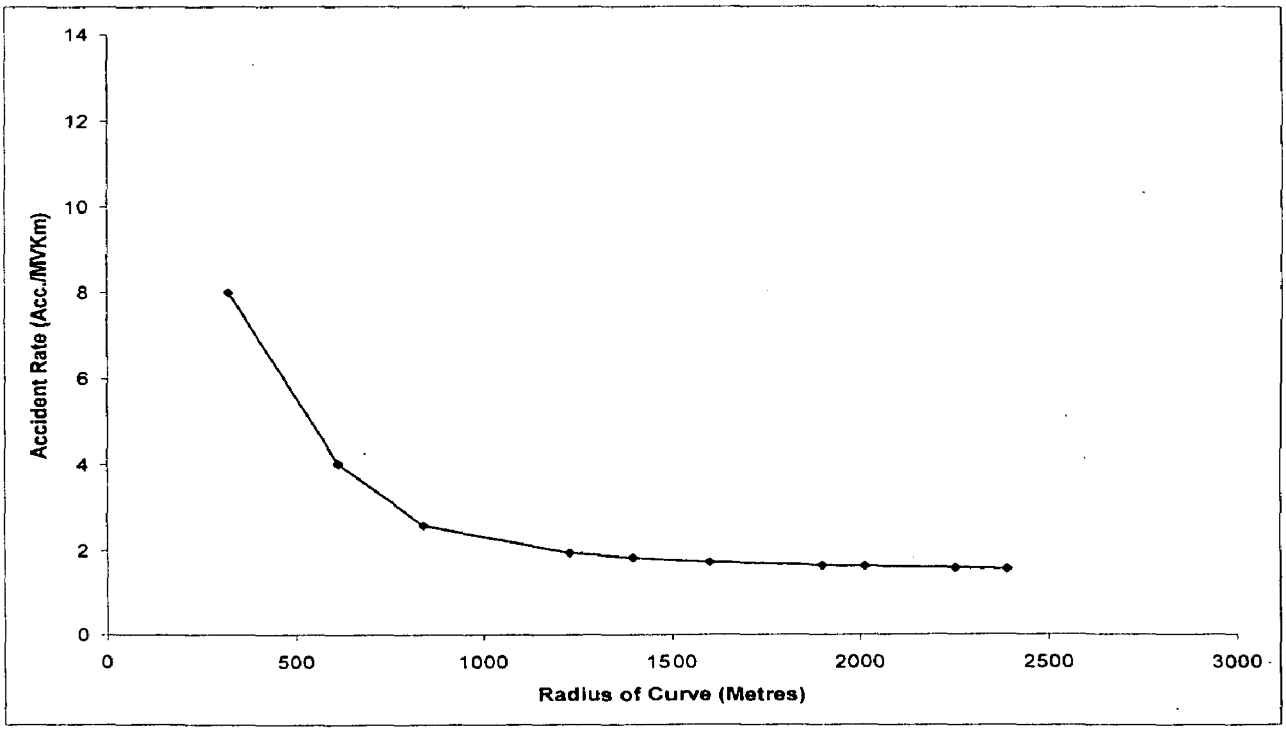


Fig 2.2 Accident rate as related to radius of curve.

2.1.3 Shoulder type and width

A study of the effect of shoulders on the accident rates of rural roads that was conducted in Texas found that two-lane highways without paved shoulders had the highest accident rates while two-lane highway with paved shoulder had the lowest rates for traffic volumes of less than 7,500 veh/day (Polus et al., 1999).

Accident rates summarized by Zegeer et al. (1981) for various shoulder widths, is shown in Table 2.3. As width lane width, the run-off-road and opposite-direction accident rates decreases as shoulder width increased to 2.7 m. There was a slight increase in rate for shoulders 3.0-3.7 m wide.

Table 2.3 Shoulder width and accidents

Shoulder Width (m)	Sample Size (Km)	Number of Accidents	Accidents Per Kilometer	AADT	Accidents per Million Vehicle Kilometers
None	17887	8790	0.49	751	1.79
0.3-0.9	6661	6610	0.99	1578	1.72
1.2-1.8	163	370	2.27	3566	1.74
2.1-2.7	138	188	1.36	3693	1.01
3.0-3.7	553	984	1.74	4088	1.17
Total	25402	16922	0.67	1074	1.70

Accident reduction factor for shoulder widening are shown in Table 2.4 (Zegeer et al., 1988 b). This table reveals that wider shoulders are associated with a reduction in related accidents.

Table 2.4 Percent reduction in related accident types for shoulder widening

Amount of Shoulder Widening (ft.) per side	Percent Reduction in Related Accident Types	
	Paved	Unpaved
2	16	13
4	29	25
6	40	35
8	49	43

Another study of relationship between shoulder design and accident rates on rural highway in Australia showed the safety benefits of paved shoulders on straight, curved and sloped roads. According to the analysis, the accident rate of two-lane roads with unpaved shoulders was approximately three to four times that for roads with paved shoulders. Non-stabilized shoulders, including loose gravel, crushed stone, raw earth, and turf, exhibit greater accident rates than stabilized (such as tar with gravel) or paved (such as bituminous or concrete) shoulders (Zegeer et al., 1988a)

2.1.4 Gradient

The operating speed of a vehicle is influenced by the characteristics of the vertical alignment. With increasing longitudinal grades, an increase in the non-homogeneity of traffic flow could increase the risk of an accident. Studies cited by Pignataro (1973) show that steeper grades increase the accident rates and skidding accidents on two-lane rural curved sections.

In a study that evaluated databases from Germany, Great Britain, and former USSR, Silyanov (1973) indicated that the accident rate increased as the gradient increased. Fig 2.3 illustrates the relationship between the accident rate and accident cost rate and the gradient for new designs and redesigns made in Germany.

It indicates that the longitudinal grade of between zero and +2 percent have the most favorable result. With increasing up grades, the accident rate gradually increases, where as with increasing down grades, the risk of being involved in an accident increases exponentially. Between up grade of +7 percent and down grades of –7 percent, the accident cost rate gradually increases. This is understandable since operating speeds are highest on steep down grades.

2.1.5 Sight distance

Sight distance, which is dependent on both horizontal and vertical alignments, is of great importance to traffic safety. A study of accidents on two-lane rural roads in Germany determined the following:

(a) As sight distance increase, the accident risk decreases.

(b) High accident rates were associated with sight distance of less than 100 m.

(c) With sight distances of between 100m and 200m, accident rates were about 25 percent lower than those associated with sight distance of less than 100m.

(d) For sight distance of more than 200m, no major improvements in accident rates were noted.

Another study of accidents on two-lane rural roads in Texas by Urbanik et al.(1989) indicated that limited sight distances, especially on crest vertical curves, could cause a marked increase in accident rates. An example would be a sharp horizontal curve hidden by a crest vertical curve.

2.1.6 Traffic volume

The rate of traffic accident in terms of number of accident per million vehicle miles (MVM) of travel increases with increasing traffic volume. However, the data supporting this relationship are highly scattered and are sensitive to the design and operational feature of the highway.

Veh (1937) examined the accident rates on section of two-lane in New Jersey and related these rates to the average daily traffic (ADT). This relationship is shown in Fig. 2.4. The data dispersion in Figure 2.4 is a reasonable representation of the amount of scatter reported subsequently by other researchers.

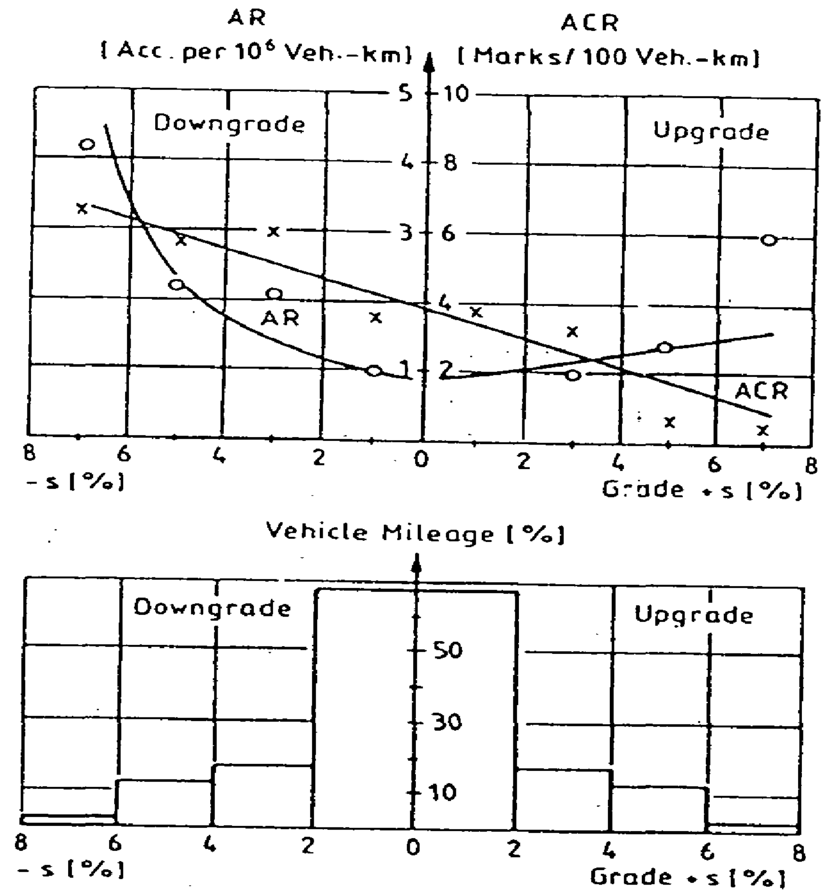


Fig. 2.3 Accident rate and accident cost rate versus grade

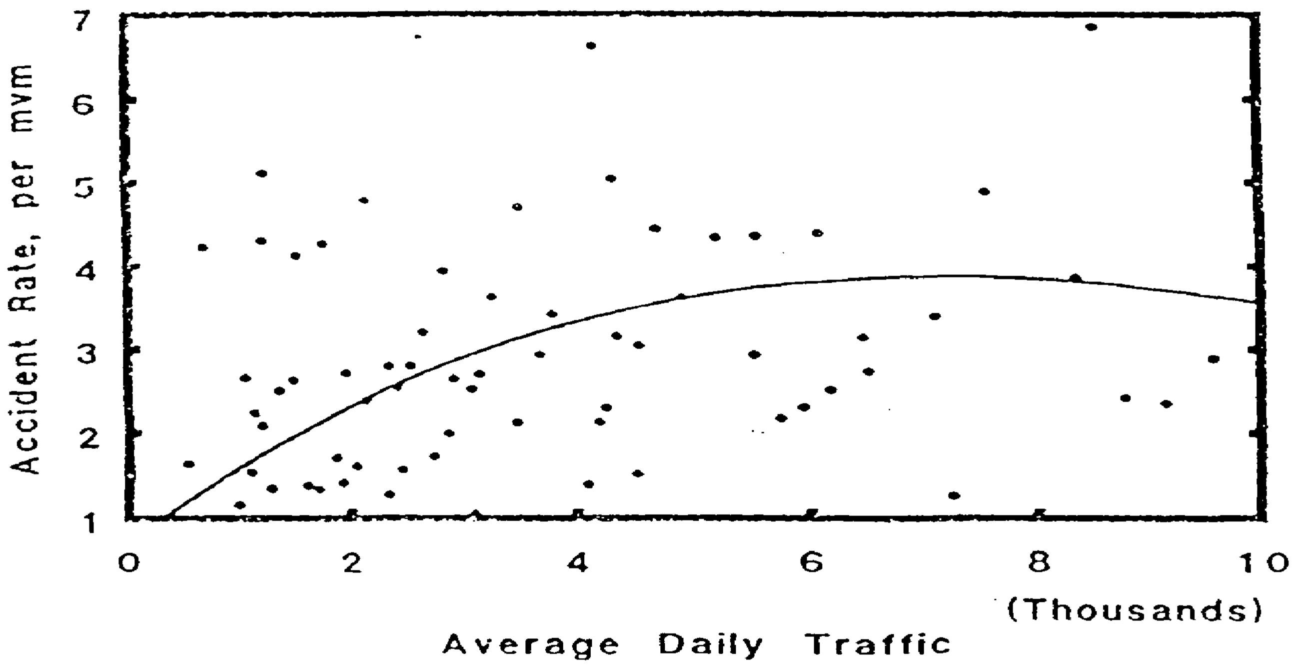


Fig 2.4 Relationship between accident rates and ADT

Another study conducted by Kilberg and Tharp (1968) found that the single vehicle accident rate decreased with increasing ADT, where as the multiple-vehicle accident rate increased with increasing ADT. However, the study was unable to define a relationship between total accident rate and ADT because in some instances the rate increased with increasing ADT and in other instances it decreased with increasing ADT. Similar results are reported by Roosmark and Fraeki (1970).

An investigation of accidents on two-lane rural roads in Austria established a U-shaped distribution between accident rate and traffic volume. Accident rate was at minimum for traffic volumes of between 6,000 to 6,500 vehicles per day. For traffic volumes of less than 6,000 to 6,500 vehicles per day, single-vehicle accidents dominated, and for traffic volume of more than 6,000 to 6,500 vehicles per day, multiple-vehicle accidents prevailed.

2.1.7 Speed

A study conducted by Lassarre (1998) indicated that changes in averages speeds have only a small influence on safety while greater homogeneity of speeds increase the safety level. The research has shown that a U-shaped relationship exists exists between the probability of a vehicle being involved in a crash and the deviation of the vehicle's speed from the mean speed of the traffic. This relationship indicates that the greater a vehicle speed deviates from the mean speed, the greater would be the probability of that vehicle being involved in a crash. This implies that driving both slower and faster than the mean speed increase the likelihood of being in a crash. Garber and Gadiraju (1998) have found that crash rates increases with increasing speed variance for all road types, but the crash rate does not necessarily increase with an increase in average speed.

2.1.8 Superposition of design parameters

Lamm (1980) studied the joint impacts of several design parameters, including radius of curve, lane width, gradient, sight distance, and traffic volume on accident rate. Sight distance was later removed from the analyses because it correlated highly with radius of the curve. Traffic volume was also excluded because it did not affect the accident rate significantly. The results shown in Fig 2.5 indicate an accident rate of 3.2 accident for 10^6 Veh-mile for certain assumed values of design parameters. These parameters are taken as the break point in road safety.

At 2.0 accidents per million vehicle km, Lamm (1980) found a level of safety of 0.9999 or 99.99 percent chances that a accident will not occur. From figure 2.6 and 2.7 an accident rate of 2.0 accidents per million vehicle km corresponds to:

- Radius of curve of about 350 m
- Lane width of about 3.3m
- Grade of about 6.5 percent, and
- Sight distance of about 100 m

Falling short of or exceeding the above values could result in an accident rate of greater than 2.0 accidents per million vehicle km.

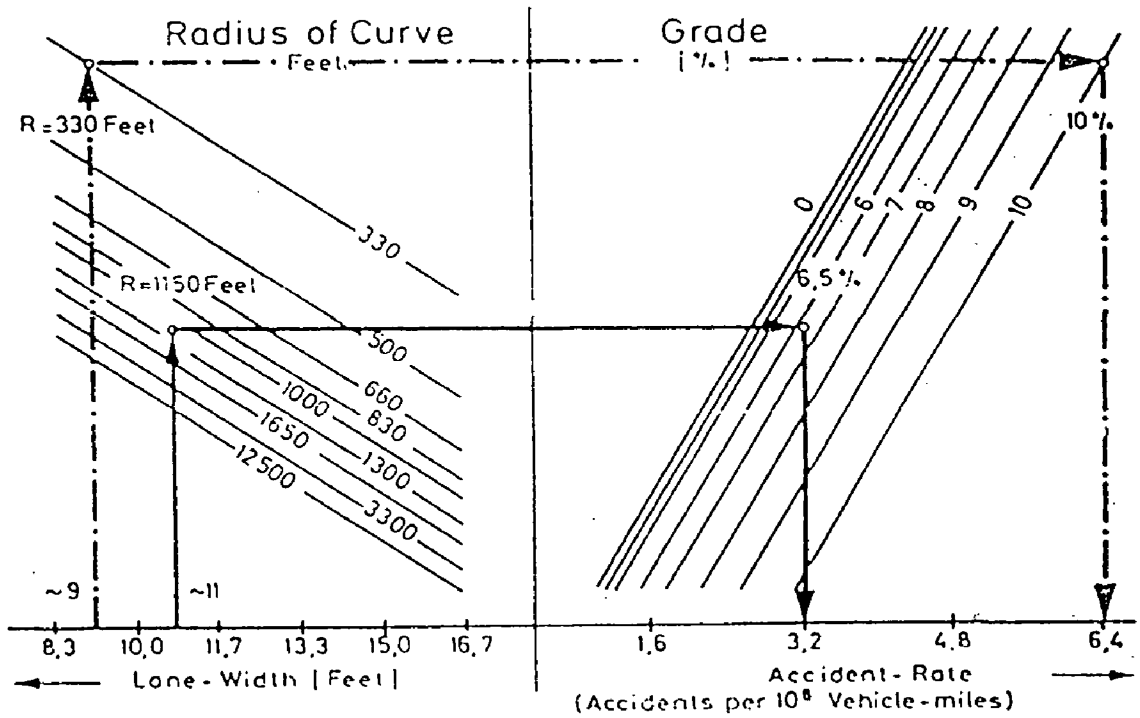


Fig 2.5 Nomogram for determining accident rate as a function of lane width, radius of curve and grade on two lane roads.

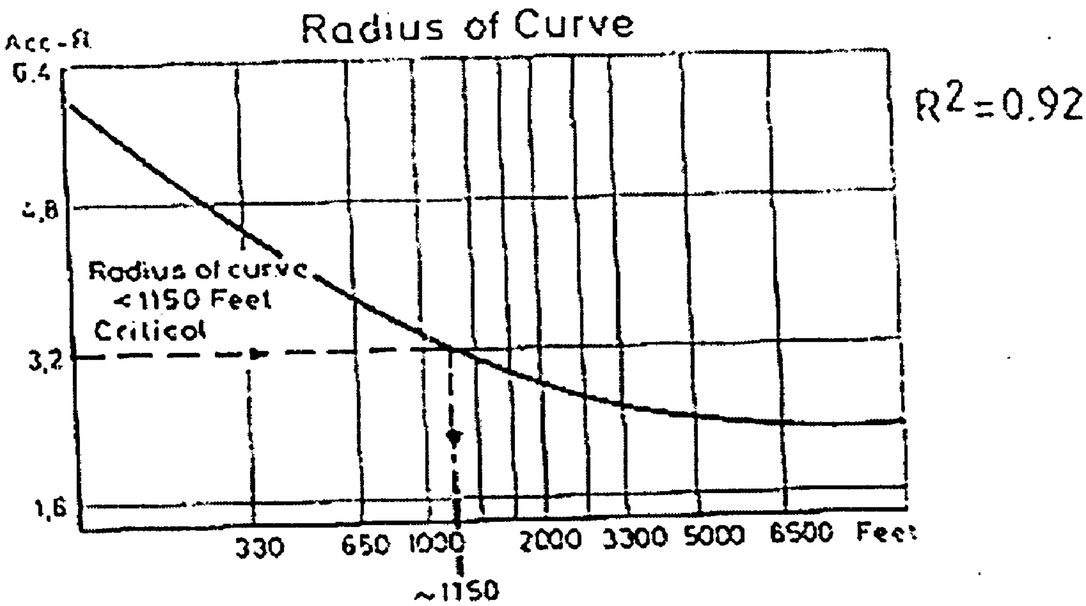


Fig 2.6 Accident rate as a function of radius of curve

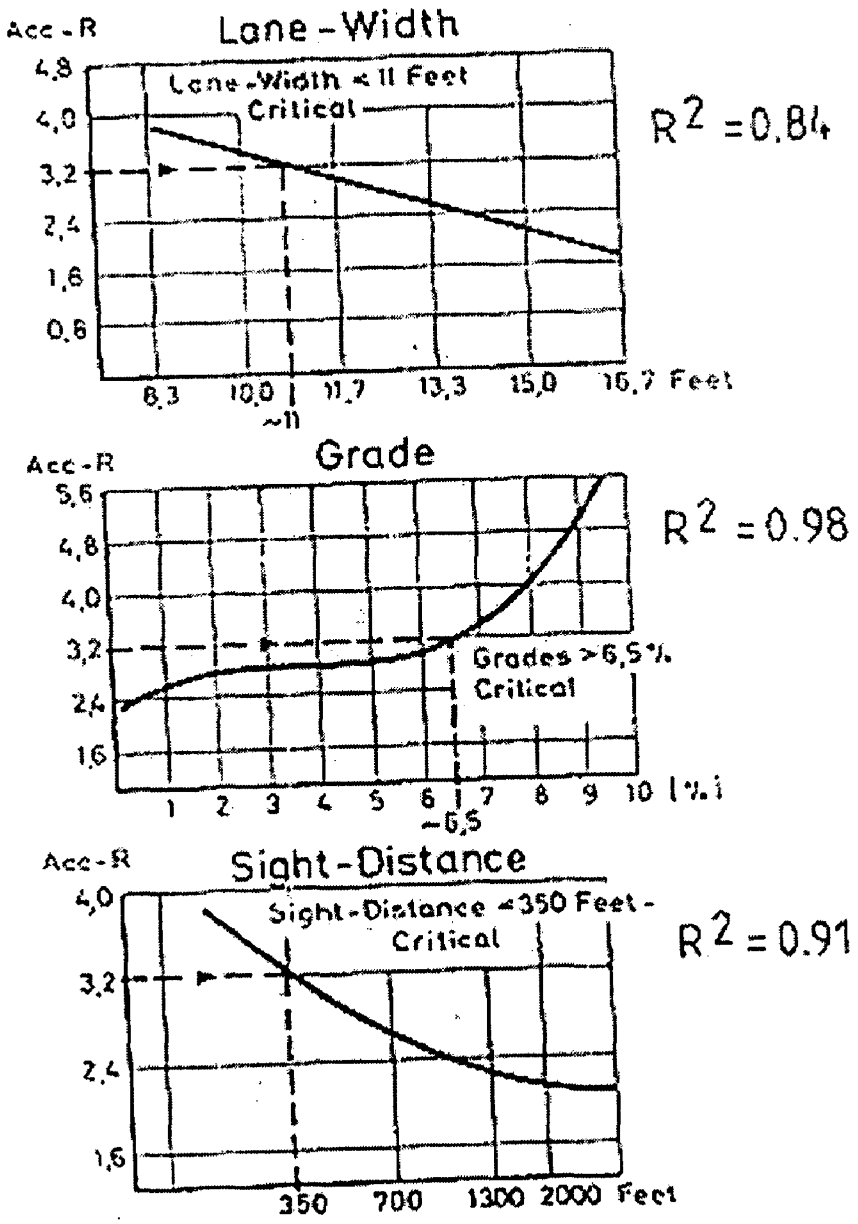


Fig 2.7 Accident rate as a function of lane width, grade, and sight distance on two-lane roads.

2.2 Influence of Other Parameters

2.2.1 Road side features

Analysis by Zeeger et al. (1988a) involved determining the types of roadside obstacles that are most commonly struck on roads with various traffic volume conditions. The frequency of six types of fixed-object accidents for different ADT categories is summarized in Table 2.5.

Table 2.5 Fixed-Object accidents by ADT group and type of obstacle struck on urban and rural highways.

ADT Group	Percent of Accidents by ADT class							
	Trees	Signs	Utility poles	Mail Boxes	Bridge Ends	Guard Rail	Other Obstacles	Total Fixed Objects Accs.
50-400	24.0	4.7	1.6	1.6	0.8	3.9	63.6	100.0
401-750	23.7	5.2	6.2	2.6	1.3	5.2	55.9	100.0
751-1000	22.4	1.9	5.4	1.3	0.4	6.9	61.7	100.0
1001-2000	15.8	5.4	6.7	2.6	1.9	10.9	56.7	100.0
2001-4000	15.8	6.8	10.8	4.9	1.0	10.8	49.9	100.0
4001-7500	13.8	6.7	17.5	5.7	0.9	9.3	46.1	100.0
>7500	10.9	7.9	22.1	5.8	1.2	9.5	42.6	100.0
Total	14.8	6.5	14.1	4.7	1.1	9.6	49.1	100.0

Zegeer and Parker (1983) found that utility pole accidents increased significantly with a decrease in pole offset or an increase in ADT or pole density. Mak and Mason (1980) also found that pole density and pole offset had an effect on the frequency of pole accidents. Hall et al. (1976) reported that most of the utility pole accidents involved poles that were either within 3.5 m of the roadway or on the outside of horizontal curves. Foody and Long (1974) reported that 37 percent of all single-vehicle fixed-object accidents involved objects 1.8 to 3.6 from the roadway. Also approximately 81 percent of the accidents involving roadside features occurred within 6.0 m of the roadway.

2.2.2 Degree of side slope

Relationship has been reported between the degree of side slope and roadside accident frequency. Graham and Harwood (1982) examined the effect of clear recovery zones and different side slopes and found that steeper side slopes caused an increase in single-vehicle, run-off road accidents for all ADT levels and roadway types.

Weaver and Marquis (1976) simulated various road side slope designs and discovered that vehicles leaving the roadway were less likely to roll if the slope was fairy flat. Based on model results for various side slopes, Table 2.6 was developed by Zeeger et al. (1988a) to show likely reductions in single vehicle accidents due to various side slope-flattening projects.

Table 2.6 Summary of expected percent reduction in single-vehicle accidents due to side slope flattening

Sides Slope Ratio in Before Condition	Sides slope Ratio in After Condition				
	3:1	4:1	5:1	6:1	7:1 or Flatter
2:1	2	10	15	21	27
3:1	0	8	14	19	26
4:1	-	0	6	12	19
5:1	-	-	0	6	14
6:1	-	-	-	0	8

2.2.3 Climatic conditions and operating environment

In summer, climate generally remains hot during the day. Trees near the carriageway are traffic hazard; even then plantation along roadside is required to give relief to driver from direct sunshine (Sharma and Dua, 2000). The dark hours between 8.00 pm to 12.00 midnight and early morning hours between 5.00 am to 8.00 am were more accident prone as compared to day hours in spite of low traffic volume in these hours. This may due to bad lighting conditions, over speeding, drinking and driving and low enforcement levels in these hours (Sarin,1998).

Accident also increases during foggy conditions (Sharma and Dua, 2000). A study by Chand (1998) shows that maximum number of accidents are registered in April where as the minimum number of accidents are registered in June. Though it is difficult to find out specific reasons for high and low frequency of accidents in a particular month, accidents are concentrated during early months of a year viz. from January to April. Further analysis of data indicated that, accident frequency seems to pickup during weekend (Sunday) and reach a substantially high level on Monday.

2.3 Accidents and Drivers

Studies have shown that 75% of road accidents in India are caused due to the drivers fault. The vehicle driver is therefore very important factor in road accidents. The driver's seat is no place for day-dreaming, Scenic–Viewing or distracting neither conversation, nor it is a place for persons who are ill, worried, and angry or in grief (Nadaf, 1999).

2.3.1 Driver welfare

Everyone in the society speaks of road accidents and 75% of the accidents are due to the faults of the drivers of heavy vehicles. It is agreed that the progress of a country depends in the transportation system, which is steered by the driver. But it is unfortunate that the welfare and facilities to the heavy vehicle drivers are ignored by the society. The heavy vehicle driver sector is deprived of the following facilities and provisions-

- It is an unorganized sector.
- Majority of them are illiterate, poor and generally come from rural family back ground.

- They are generally away from home for weeks together.
- They have no job security, no pay protection.
- No Medical facilities, no retirement benefits.
- They are not covered under any labour laws, motor vehicle Acts and Rule, Motor Transport Workers Act etc.

Considering the above facts how one can visualize, the minds of these drivers would be in place and happy. When their mind is full of worries there is every possibility of error of judgment, which may lead to accident (Nadaf, 1999).

2.3.2 Alcohol and driving

Alcohol causes serious driving errors such as :

- Driving too fast or too slow.
- Driving in the wrong lane.
- Running over the footpath.
- Changing lanes dangerously.
- Not signaling.
- Quick and jerky starts.
- Failure to use lights.
- Ignoring stop signs and red lights.

These errors increase the chances of accident. Driving after consuming alcohol is a serious offence (Nadaf, 1999).

2.3.3 Male and female drivers

One study was conducted in England by Stories (1985) found that, basically, little difference existed in the proportion of male and female drivers who were regarded as being at fault in accidents.

In another study, Foldvary (1979) hypothesized that because of differences between the sexes, female drivers on the average will be more cautious, more hesitant, and less affected by alcohol. He found that the overall involvement rate for women was 80 percent of that for men.

2.3.4 Older drivers

O.E.C.D, Paris (1985) compared the risks of being in an injury or fatal accident for the 25-64 age groups and the over -65 age group. The over-65 age group was found to be 2.5 to 5 times more likely to be involved in an injury accident.

Another study in U.S.A., has reported that older drivers tended to be responsible for accidents more often than younger drivers (McKnight and Simore, 1982).

2.4 Accidents and Vehicles

Of all the various types of motor vehicles, the motorcycle has by for the west accident risk. Motorcycle riders are at least twenty times more likely to be killed or injured per kilometer traveled than car drivers, although the youthfulness of many riders may well contribute to the high accident rates (Broughton, 1989).

Due to lack of public modes, people in metropolitan cities of India are compelled to use risky personalized modes like cycle and scooters creating many road safety and environmental problems. Especially two-wheelers form quite a substantial proportion of the total vehicle population in all these cities ranging between 40 to 90 percent. The data analyses of accidents in India show that motorized two-wheelers are at least five time more dangerous than four wheelers to road users as far as the chances of being killed in a road accident is concerned (Sarin, 1998).

Age of the vehicle is not the cause of the accident. Available statistics indicate that accidents are inversely proportional to the age of the vehicle and the severity of accident does not depend on the age of vehicle significantly (Gawhane, 1992).

The proportion of accidents in which a mechanical defect or failure of vehicles makes it a gross and obvious causative contribution is small. Accident study of 5 STUs in Tamil Nadu for the year 1987 revealed that only 1.3 percent of accidents are due to defective vehicles. Brakes, tyres, steering, transmission system, headlights, rear lights etc were the most persistent component to be attended. A defect, how so over minor it may be, could add to the driver's defect and cause an accident situation (Gawhane, 1992).

DATA COLLECTION

The only piece of information available for accident studies is the FIR (First Information Report) lodged in the police stations. It is difficult to have access to the accident particulars that are recorded in police diaries and files. The researchers are forced to tailor their model to suit this lack of information. Therefore, it is necessary to correlate influencing factors with accident rates and build mathematical models for predicting accidents using those information that are available in the FIR and PWD (Public Works Department) records. In addition to these records, the following documents were also reviewed.

(i) Statistics of Road Accidents in India (1991-1998), GOI, Ministry of Surface Transport (Now MORTH).

(ii) Motor Transport Statistics of India (1997-98), GOI, Ministry of Surface Transport (Now MORTH).

(iii) Accidental Deaths and Suicides in India (1999), National Crime Records Bureau, Ministry of Home Affairs, Government of India, New Delhi.

3.1 Roads Selected for Study

Two-lane roads emanating from or passing through two cities viz. Meerut and Roorkee were chosen for this study.

The following sections were selected for data collection.

(i) Km 153.0 - Km 184.0 on NH-58, Muzaffarnagar - Hardwar road.

(ii) Km 0 - Km 8.0 on NH-73, Roorkee – Saharanpur road.

(iii) Km 56.0 - Km 70.0 SH-14, Meerut - Bagpat road (MBR)

(iv) Km 40.0 - Km 31.0 on SH-14, Meerut - Garh road (MGR)

(v) Km 0.4 – Km 10.0 on SH-47, Meerut - Mawana road.

Figure 3.1 shows the road sections selected for this study.

3.2 Data collected from police records

With the prior permission of the concerned S.S.P. and S.H.O, the accident data were collected on two-lane highways from the six police stations as shown in Table 3.1.

TABLE 3.1 Police stations and road sections covered

Police Station	Road section covered under the police station
Mangalore	Km 153.0- Km 168.0 on NH-58
Kotwali, Civil lines, Roorkee	Km 168.0- Km 184.0 on NH-58
Gang-Nahar, Roorkee	Km 0- Km 8.0 on NH-73
Jani, Meerut	Km 56.0 – Km 70.0 on SH-14
Medical, Meerut	Km 40.0 – Km 31.0 on SH-14
Lalkurti, Meerut	Km 0.4 – km 10.0 on SH-47

The police stations have their own FIR records of several years. The data from these records of last ten years were extracted from the FIRs filed under IPC No. 279/337/338/304 A/427. The available information was filled in the proforma designed for this purpose. A sample copy of the proforma is shown in the Table 3.2.

Accident details during 1992 to 2001 on these road sections are shown in table 3.3. Accident data were collected year wise from each police station records and then sorted out month wise. The percent share of each month in accidents during years 1992-2001 was calculated based upon the number of accidents that occurred in a month to a year. Average monthly variations of accidents during 1992-2001 are shown in Tables 3.4 to 3.8.

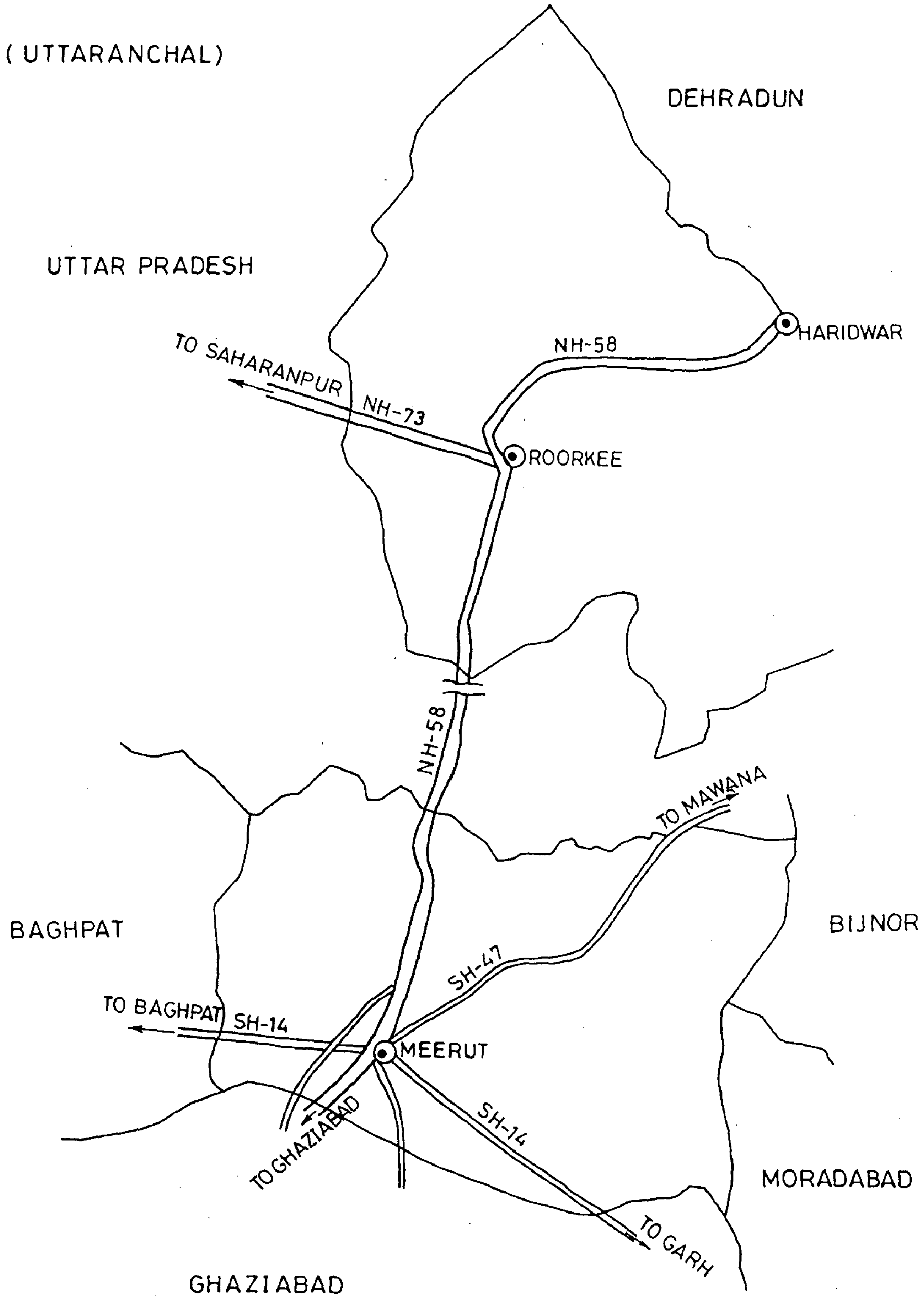


FIG.3.1 ROAD SECTIONS SELECTED FOR STUDY

Table 3.2 Proforma for accident data from FIR records

Date/Day/ Time	Location of Accident	Details of Accident	Vehicle(s) Involved	Possible Reasons	Any Other Information(s)

Page No ……

Table 3.3 Details of accidents

Year	NH-58			NH-73			SH-14 (MBR)			SH-14 (MGR)			SH-47		
	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T
2001	75	53	59	6	13	9	28	19	29	20	8	29	19	15	35
2000	76	29	57	6	4	9	45	14	27	20	7	28	29	22	30
1999	45	25	36	11	5	7	13	6	19	19	4	21	28	9	40
1998	50	27	50	4	5	5	8	9	14	13	4	29	16	10	20
1997	59	50	54	6	4	7	15	3	10	17	5	20	20	4	24
1996	37	37	59	4	2	5	26	8	21	13	3	14	6	6	10
1995	55	22	50	6	2	8	21	0	12	10	8	21	12	4	19
1994	37	31	43	6	1	5	13	6	12	20	13	34	9	3	13
1993	55	25	48	8	2	10	10	5	14	17	2	23	18	3	20
1992	39	29	49	7	2	7	9	10	13	24	5	30	21	10	26

I= Injury F= Fatality T= Total no. of accidents

Table 3.4 Average monthly variations in accidents during 1992-2001 on NH-58

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
2001	8	6	10	4	4	3	1	5	3	6	6	3
2000	2	4	2	7	4	7	3	3	7	6	7	5
1999	1	3	3	4	1	7	2	4	4	2	2	3
1998	3	5	7	3	5	3	4	8	1	5	5	1
1997	8	4	10	5	5	6	1	4	2	2	2	5
1996	10	8	3	3	4	5	5	6	1	3	4	7
1995	2	4	6	4	4	4	9	6	2	3	4	2
1994	1	3	0	4	6	3	7	1	5	2	6	5
1993	1	5	4	1	6	4	5	3	2	6	6	5
1992	6	4	4	3	6	6	3	2	5	3	4	3
Total	42	46	49	38	45	48	40	42	32	38	46	39
%	8.3	9.1	9.7	7.5	8.9	9.5	7.9	8.3	6.4	7.5	9.1	7.8

Table 3.5 Average monthly variations in accidents during 1992-2001 on NH-73

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
2001	0	0	0	0	1	0	2	3	1	1	1	0
2000	0	0	1	1	1	2	0	1	0	1	1	1
1999	2	1	0	0	2	1	0	0	0	0	1	0
1998	1	1	0	0	0	0	1	1	0	1	0	0
1997	2	2	1	1	0	0	1	0	0	0	0	0
1996	0	0	0	2	0	0	2	0	0	0	1	0
1995	1	1	2	0	0	0	0	0	0	2	0	0
1994	1	1	1	0	1	0	0	0	0	0	0	1
1993	0	1	1	3	2	2	0	0	0	0	0	1
1992	1	0	0	1	0	1	0	1	1	1	1	0
Total	8	7	6	8	7	8	6	6	2	6	5	3
%	11.1	9.7	8.3	11.1	9.7	11.1	8.3	8.3	2.8	8.3	7.1	4.2

Table 3.6 Average monthly variations in accidents during 1992-2001 on SH-14 (Meerut-Bagpat road)

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
2001	2	1	1	4	3	2	1	0	5	4	3	3
2000	0	1	2	2	8	2	5	0	1	1	2	3
1999	5	0	3	3	1	1	3	1	0	0	0	2
1998	1	0	0	3	0	2	2	1	1	0	1	3
1997	0	0	1	2	1	1	2	0	1	0	1	1
1996	3	0	0	1	3	5	4	1	2	1	1	0
1995	0	0	5	0	2	2	0	1	1	1	0	0
1994	1	2	1	1	2	1	0	0	2	1	0	1
1993	2	0	2	1	0	2	2	0	0	1	4	0
1992	0	2	2	3	2	1	1	1	1	0	0	0
Total	14	6	17	20	22	19	20	5	14	9	12	13
%	8.2	3.5	9.9	11.7	12.9	11.1	11.7	2.9	8.2	5.3	7.0	7.6

Table 3.7 Average monthly variations in accidents during 1992-2001 on SH-14 (Meerut - Garh road)

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
2001	2	2	2	1	4	4	2	0	1	3	3	5
2000	2	1	2	4	2	5	1	1	3	5	1	1
1999	2	4	1	1	4	1	2	1	0	1	1	3
1998	2	3	2	1	1	2	3	2	1	4	4	4
1997	3	3	3	2	1	1	2	2	0	1	0	2
1996	0	0	2	2	1	0	1	2	2	1	2	1
1995	5	3	3	0	1	2	3	0	0	1	2	1
1994	5	5	2	1	2	5	2	3	2	4	0	3
1993	2	1	3	2	2	2	1	0	2	1	2	5
1992	4	1	4	1	1	1	5	2	5	3	2	1
Total	27	23	24	15	19	23	22	13	16	24	17	26
%	10.8	9.2	9.6	6.0	7.7	9.3	8.9	5.2	6.4	9.6	6.8	10.5

Table 3.8 Average monthly variation in accidents during 1992-2001 on SH-47

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
2001	2	3	4	3	1	2	4	5	2	2	3	4
2000	2	3	2	1	0	2	3	3	3	5	4	2
1999	4	4	7	1	6	1	4	4	3	2	1	1
1998	3	2	2	0	3	3	2	1	0	2	1	1
1997	1	2	2	3	4	2	5	0	2	0	1	2
1996	1	2	0	0	1	2	2	1	1	0	0	0
1995	1	3	1	3	2	2	3	0	1	0	3	0
1994	1	2	0	2	3	0	0	2	0	1	1	1
1993	3	2	2	2	1	2	2	2	1	2	0	1
1992	2	2	7	3	0	2	1	1	2	2	2	2
Total	20	25	27	20	21	18	26	19	15	16	16	14
%	8.4	10.5	11.4	8.4	8.9	7.6	11.0	8.0	6.3	6.8	6.8	5.9

Vehicles those involved in accidents and reported in the F.I.R. records were extracted. The categories of vehicles include rickshaw, loader, animal drawn vehicles, matador, tempo van, and three-wheeler. Two wheelers include moped, motorcycle and scooter. Jeep, van, Toyota and car are grouped under Jeep/Car. Truck or lorry includes truck, lorry, tanker, tractor, minitruck, Tata-407. Numbers of vehicles of each category involved in accidents in last 10 years during 1992-2001 are shown in Tables 3.9 to 3.13.

Table-3.9 Vehicles involved in accidents during years 1992-2001 on NH-58

Year	Truck/ Lorry	Pedestrian	Bicycle	Bus	Car/Jeep	Two-Wheeler	Others	Total
2001	24	15	5	19	26	21	15	125
2000	30	20	7	11	19	10	12	109
1999	17	9	6	6	15	12	4	69
1998	21	16	6	13	18	15	8	97
1997	19	6	8	22	15	18	9	97
1996	28	22	7	12	19	12	15	115
1995	21	12	8	10	22	15	12	100
1994	26	10	9	10	12	8	8	83
1993	23	9	9	13	14	14	12	94
1992	21	12	8	15	18	15	9	98
Total	230	131	73	131	178	140	104	987
(%)	23.3	13.3	7.4	13.3	18.0	14.2	10..5	100

Table-3.10 Vehicles involved in accidents during years 1992-2001 on NH-73

Year	Truck/ Lorry	Pedestrian	Bicycle	Bus	Car/Jeep	Two-Wheeler	Others	Total
2001	5	2	0	0	1	5	5	18
2000	0	3	3	4	3	5	0	18
1999	2	0	1	4	2	4	1	14
1998	4	1	1	1	0	3	0	10
1997	5	2	1	2	1	2	1	14
1996	2	1	2	2	0	3	0	10
1995	5	2	2	2	3	1	1	16
1994	1	3	0	1	3	1	1	10
1993	3	3	2	1	8	0	3	20
1992	4	2	3	1	1	2	1	14
Total	31	19	15	18	22	26	13	144
(%)	21.6	13.2	10.4	12.5	15.3	18.0	9.0	100

Table 3.11 Vehicles involved in accidents during years 1992-2001 on SH-14 (MBR)

Year	Truck/ Lorry	Pedestrian	Bicycle	Bus	Car/Jeep	Two-Wheeler	Others	Total
2001	21	14	1	3	7	8	4	58
2000	12	8	1	5	9	9	7	51
1999	11	9	1	5	5	3	4	38
1998	9	6	1	4	2	2	2	26
1997	6	4	1	4	2	1	2	20
1996	13	8	2	9	2	4	2	40
1995	6	4	0	3	4	5	2	24
1994	7	4	2	1	5	3	1	23
1993	13	5	0	1	1	6	2	28
1992	10	3	0	3	0	7	3	26
Total	108	65	9	38	37	48	29	334
(%)	32.3	19.5	2.7	11.4	11.1	14.4	8.7	100

Table 3.12 Vehicles involved in accidents during years 1992-2001 on SH-14 (MGR)

Year	Truck/ Lorry	Pedestrian	Bicycle	Bus	Car/Jeep	Two-Wheeler	Others	Total
2001	8	6	3	3	8	20	3	51
2000	8	13	2	6	10	12	1	52
1999	7	6	3	1	10	12	2	41
1998	7	8	7	6	12	16	0	56
1997	6	8	3	10	4	7	4	42
1996	5	1	2	6	4	8	1	27
1995	6	5	5	0	7	8	4	35
1994	15	10	6	6	7	10	13	67
1993	9	11	3	2	10	7	2	44
1992	8	7	12	7	10	12	2	58
Total	79	75	46	47	82	112	32	473
(%)	16.7	15.9	9.7	9.9	17.3	23.7	6.8	100

Table 3.13 Vehicles involved in accidents during years 1992-2001 on SH-47

Year	Truck/ Lorry	Pedestrian	Bicycle	Bus	Car/Jeep	Two-Wheeler	Others	Total
2001	3	10	2	6	9	9	8	47
2000	4	9	3	4	7	8	7	42
1999	10	11	3	9	14	20	7	74
1998	5	7	1	4	9	7	6	39
1997	4	10	5	6	8	7	8	48
1996	1	5	0	4	5	3	4	22
1995	3	7	0	6	7	8	7	38
1994	0	8	1	0	5	3	9	26
1993	6	9	3	2	8	8	6	42
1992	3	11	2	5	13	8	7	49
Total	39	87	20	46	85	81	69	427
(%)	9.1	20.4	4.7	10.8	19.8	19.0	16.2	100

3.3 Data collected from P.W.D. Records

P.W.D. (Public Works Department) records are the main source of information for details of road conditions and maintenance work. The proforma used to record these details is shown in Table 3.14.

Table 3.14 Proforma for details of road section

Name of the Road .... **Category (..........)**

Km No.	Width of painted surface (m)	Type of surface	Year of renewal	Condition of surface	Name of village	Remark
1	7.00	SDBC	9/2001	A	Bhurahedi	---
2	7.00	SDBC	11/2000	B	Narson	---
---	---	---	---	---	---	---
---	---	---	---	---	---	Roorkee
---	---	---	---	---	---	---
---	---	---	---	---	---	---

Road conditions data were collected for all road sections included in the study, from NH Division of PWD Roorkee and Provincial Division of PWD, Meerut. In addition to the above, traffic volume data were also obtained from PWD records. These are shown in Table 3.15.

Table 3.15 Traffic volume data

Name/Number of the road	Year of count	Traffic Volume	
		CVPD	PCU/day
SH-14 (MBR)	2001	10695	51821
SH-14 (MBR)	2000	9781	48410
SH-14 (MGR)	2002	6023	25908
SH-47	2002	4816	31384
SH-47	2000	3942	24742
NH-58	1998	5113	20100
NH-73	1999	4563	17685

These data were used to predict traffic volume on a road in each year for the period 1992-2001. A growth rate of 7.5 % per year was assumed for this purpose. The calculated traffic volumes are shown in Table 3.16.

Table 3.16 Traffic volume data in PCU/day

Year	NH-58	NH-73	SH-14 (MBR)	SH-14 (MGR)	SH-47
2001	24970	20200	51821	23965	29030
2000	23228	18685	47935	21167	28853
1999	21608	17685	44339	20505	24839
1998	20100	16389	41014	18967	22976
1997	18592	15160	37938	17544	21253
1996	17197	14023	35093	16229	19659
1995	15907	12971	32461	15011	18184
1994	14714	11998	30026	13886	16821
1993	13610	11098	27774	12844	15559
1992	12590	10265	25691	11881	14392

ANALYSIS OF DATA AND DISCUSSION OF RESULTS

The data collected in the present study are analyzed and results obtained are discussed in this chapter.

4.1 Monthly Variation of Accidents

Average monthly variation in accidents during 1992-2001 on each road section is shown in bar charts 4.1 to 4.5. These results indicate that there is not definite trend for monthly variation in accidents. Accidents in the month of June-July are generally are quite high. It may be due to start of the rainy season in June-July in Northern part of the country. The earthen shoulder gets deteriorated in rains and pavement surface becomes slippery. Further, it is observed that accident rate is comparatively higher in early months of the year. No definite reason can be attributed to this trend, but it might be due to for or low visibility in winter seasons.

4.2 Vehicles Involved in Accidents

Figures 4.6-4.11 show the percent accidents involving a particular type of vehicle. It is observed that Trucks/lorry are involved in maximum number of accidents. A heavy vehicles is involved in almost 20.6 % (average) accidents. It is followed by two-wheeler (17.8%), jeep/car (16.4%), pedestrian (16.4%), others (10.2%) and bicycles (7.0%)

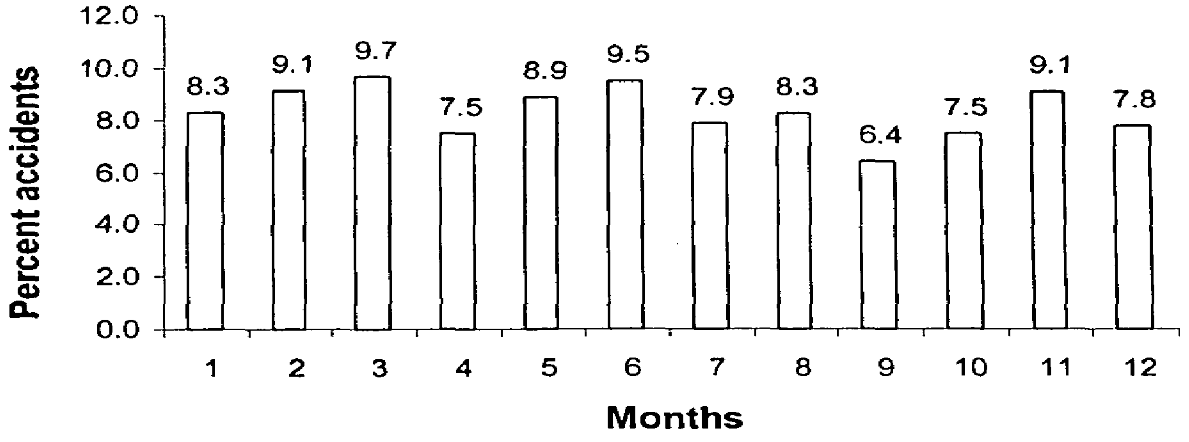


Fig. 4.1 Average monthly variation in accidents during 1992-2001 on NH-58

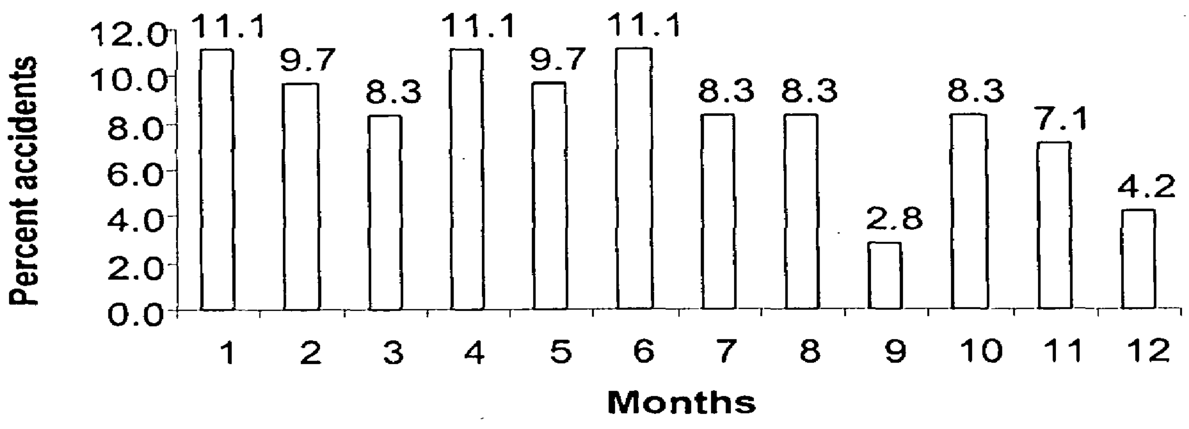


Fig. 4.2 Average monthly variation in accidents during 1992-2001 on NH-73

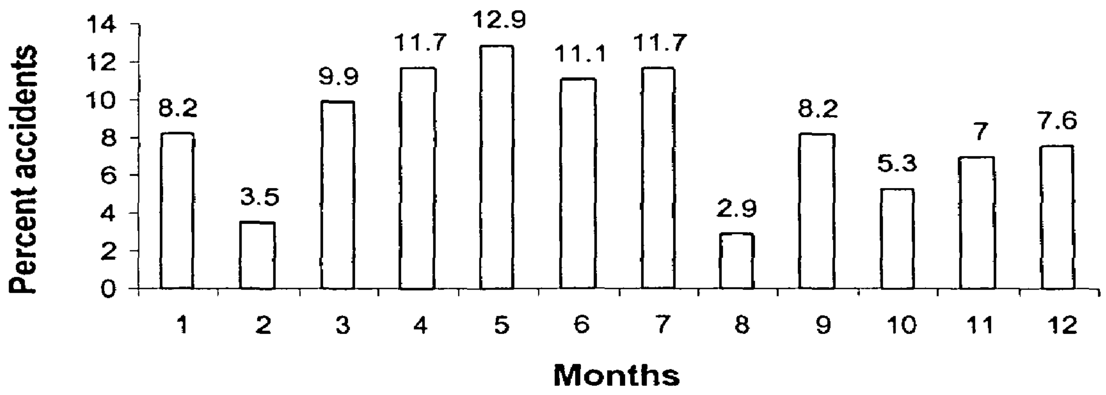


Fig. 4.3 Average monthly variation in accidents during 1992-2001 on SH-14 (MBR)

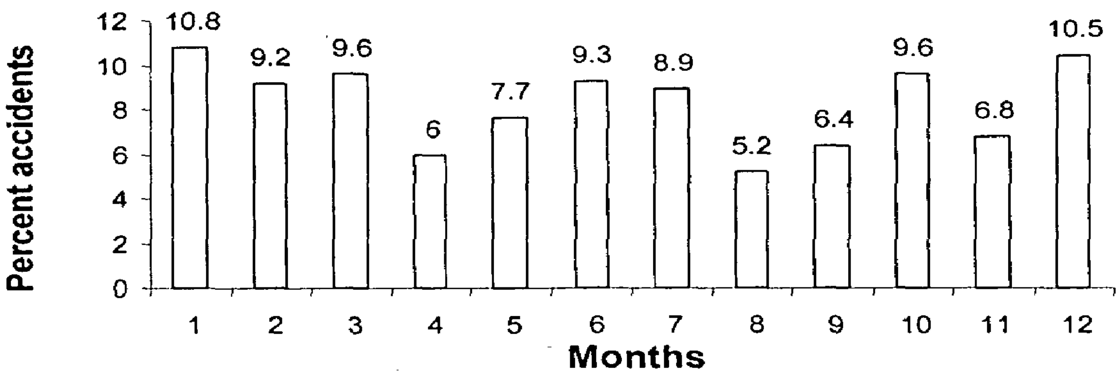


Fig. 4.4 Average monthly variation in accidents during 1992-2001 on SH-14 (MGR)

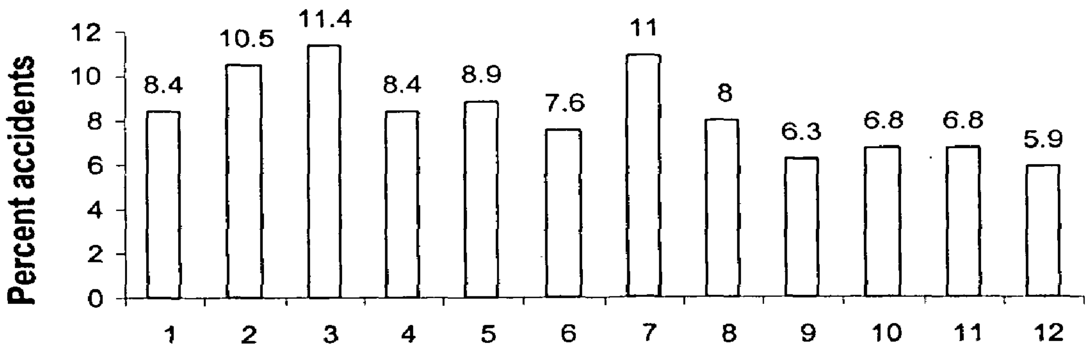


Fig. 4.5 Average monthly variation in accidents during 1992-2001 on SH-47

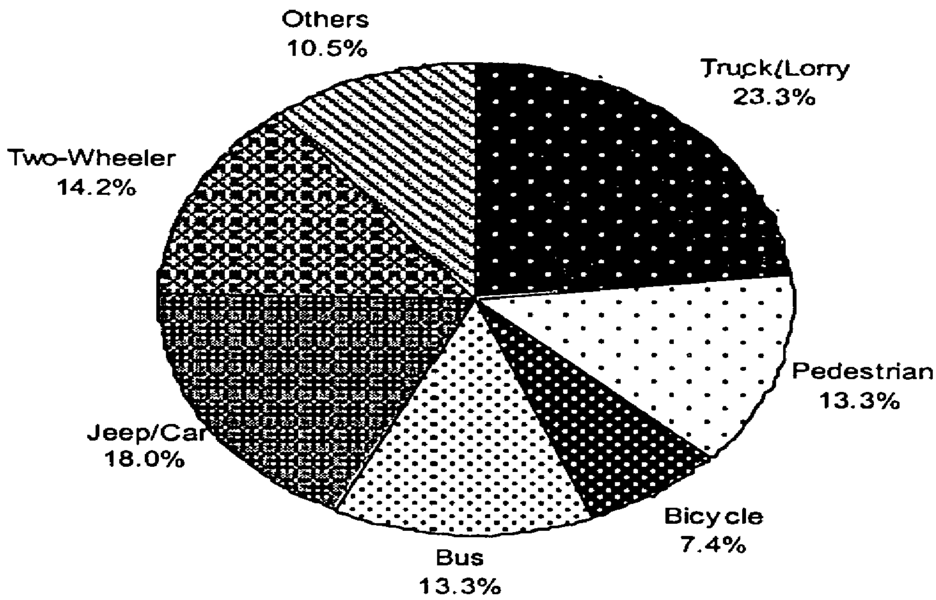


Fig.4.6 Vehicles involved in accidents during 1992 - 2001 on NH-58

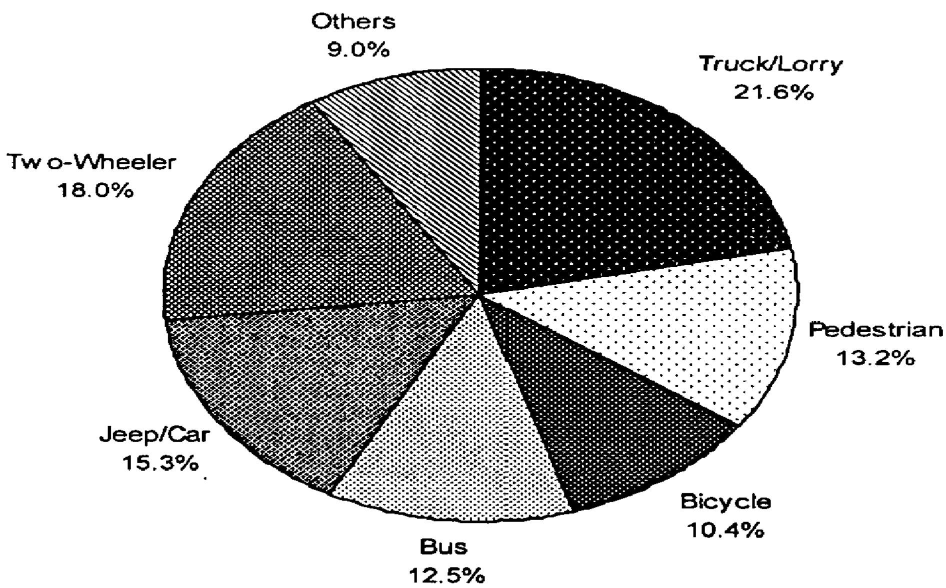


Fig. 4.7 Vehicles involved in accidents during 1992 - 2001 on NH-73

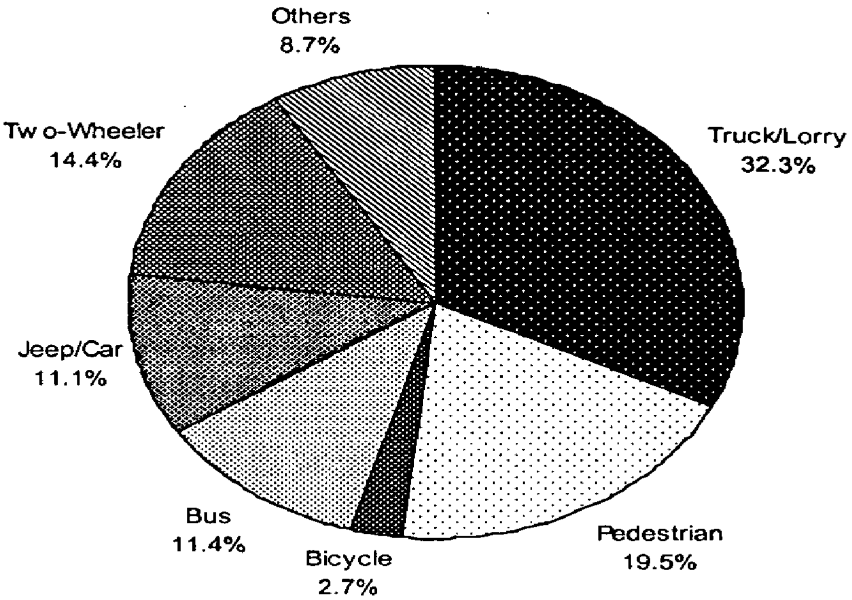


Fig. 4.8 Vehicles involved in accidents during 1992 - 2001 on SH-14(MBR)

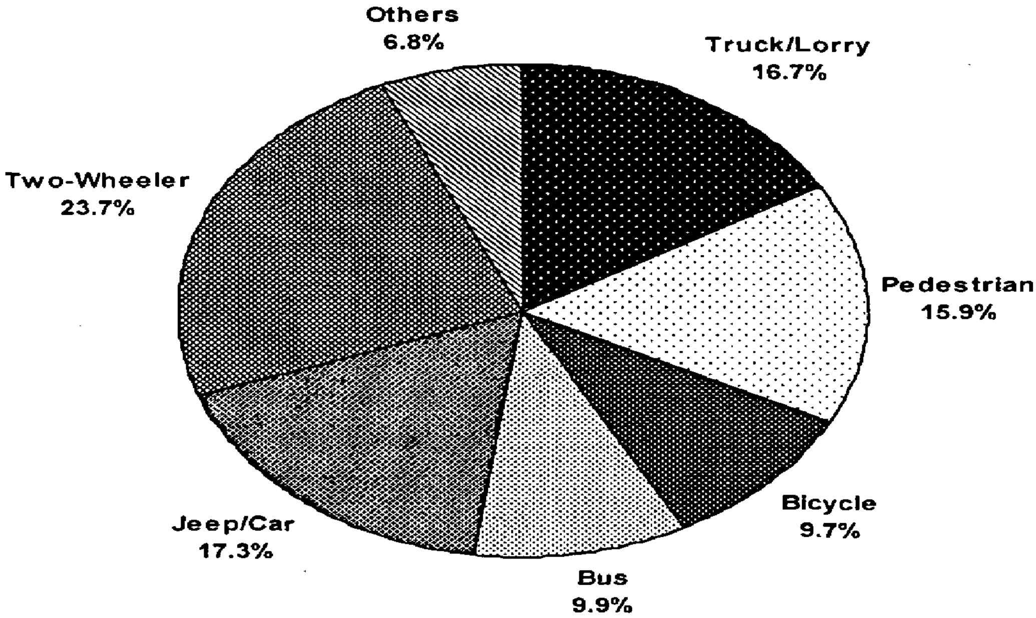


Fig. 4.9 Vehicles involved in accidents during 1992 - 2001on SH-14 (MGR)

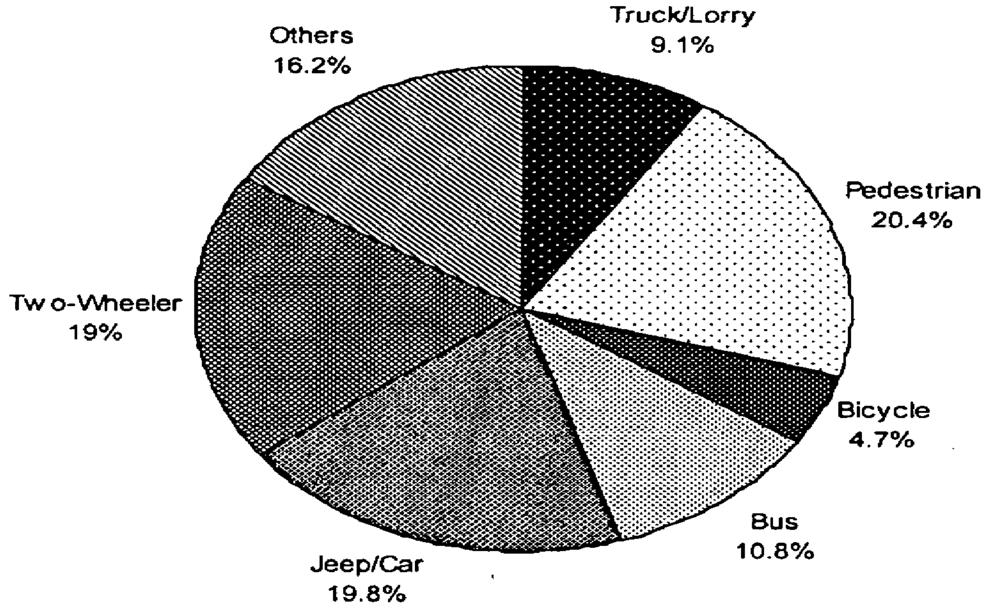


Fig. 4.10 Vehicles involved in accidents during 1992 - 2001 on SH-47

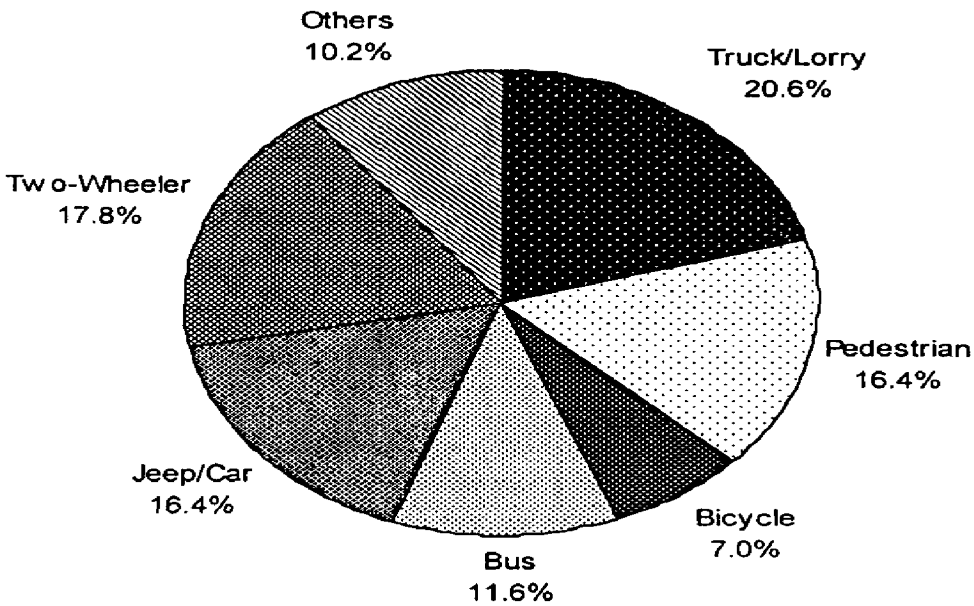


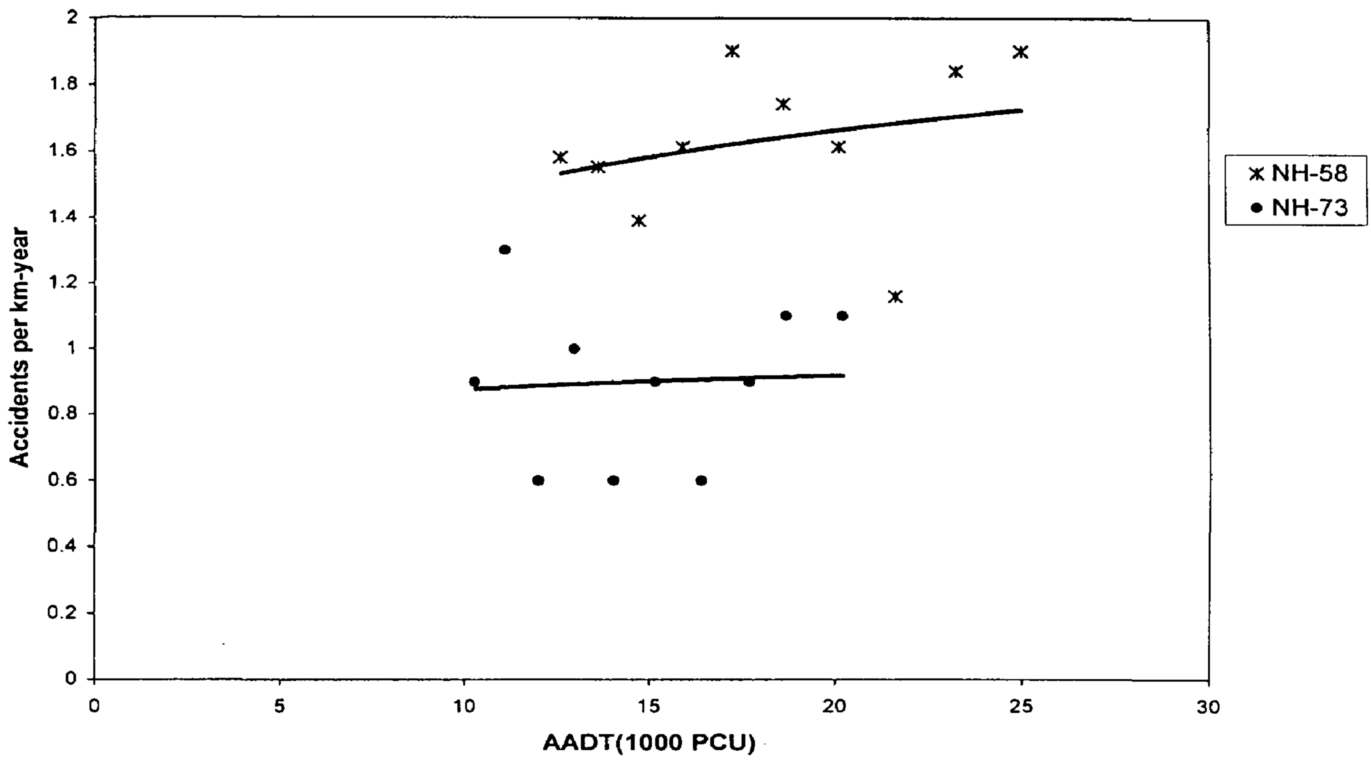
Fig. 4.11 Vehicles involved in accidents during 1992 - 2001 for all road secitions

4.3 Accidents as Related to Traffic Volume

In order to find the relationship between accident rate and traffic volume, accident rate was presented in two forms. In one case it was number of accident that occurred in a road section per kilometer per year and presented as accident per km-year. And in other case, it was the number of accidents that occur in a road section per million vehicles (MV) taken in terms of passenger car unit (PCU) per Kilometer (K) per Year (Y), represented as Accident per MVKY.

The rate of accidents in terms of accidents per Km-year as shown in Fig. 4.12 with increasing traffic volume. The curves indicate that accident rate per Km-year increases with AADT, but the rate of increase is different for different roads. It is very steep on SH-47 and very mild on SH-14 (MBR) and NH-73. The data supporting these relationships are a bit scattered and may be sensitive to the design and operational feature of the highway also.

Fig. 4.13 shows the plot between accidents per MVKY and AADT on the road. It was found that accidents per MVKY decreases with increase in AADT. However the rate at which this occurs differs from one road section to another. It may due to design and operational features of the highway and influence of other parameters like roadside features, degree of side slope, climate condition and operational environment.



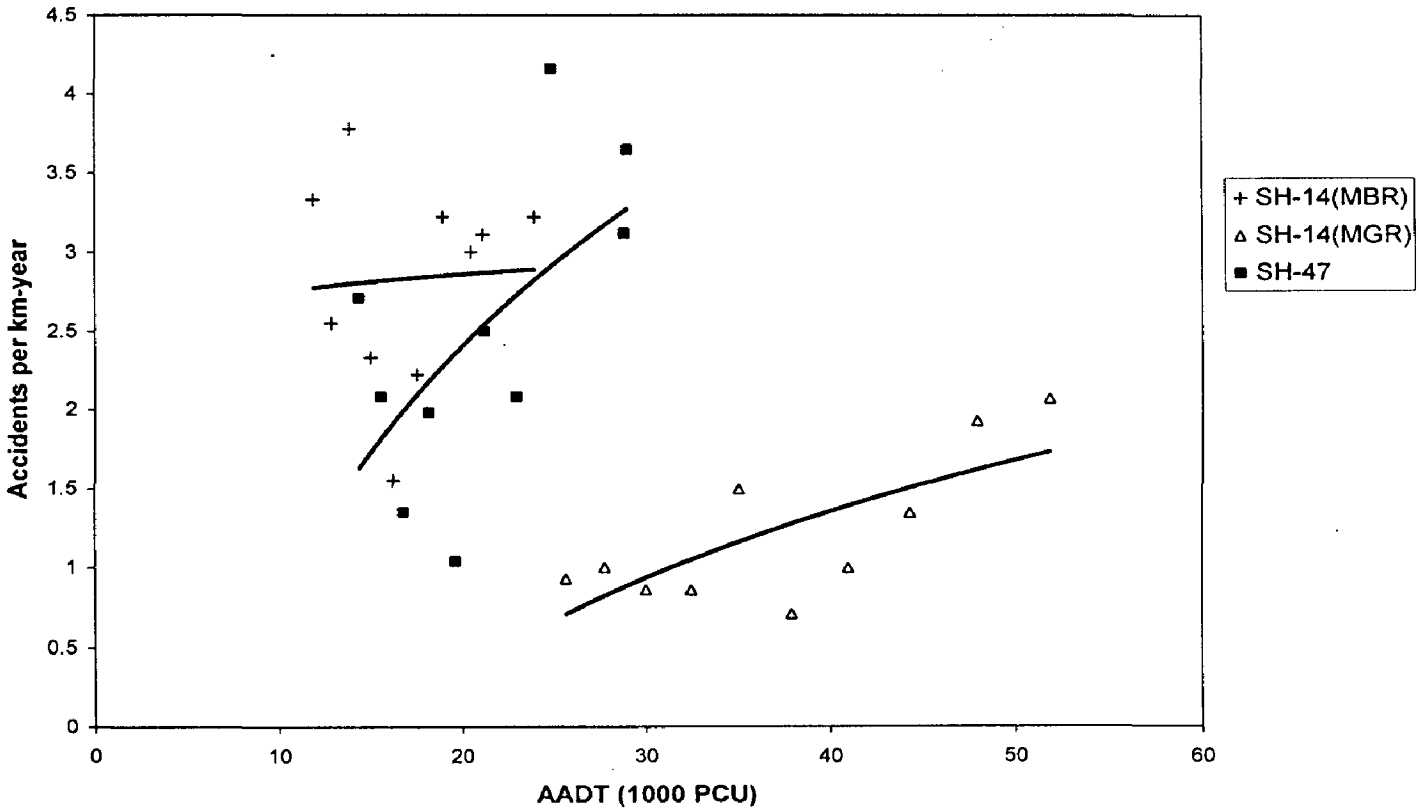


Fig. 4.12 Accidents per km-year as related to traffic volume

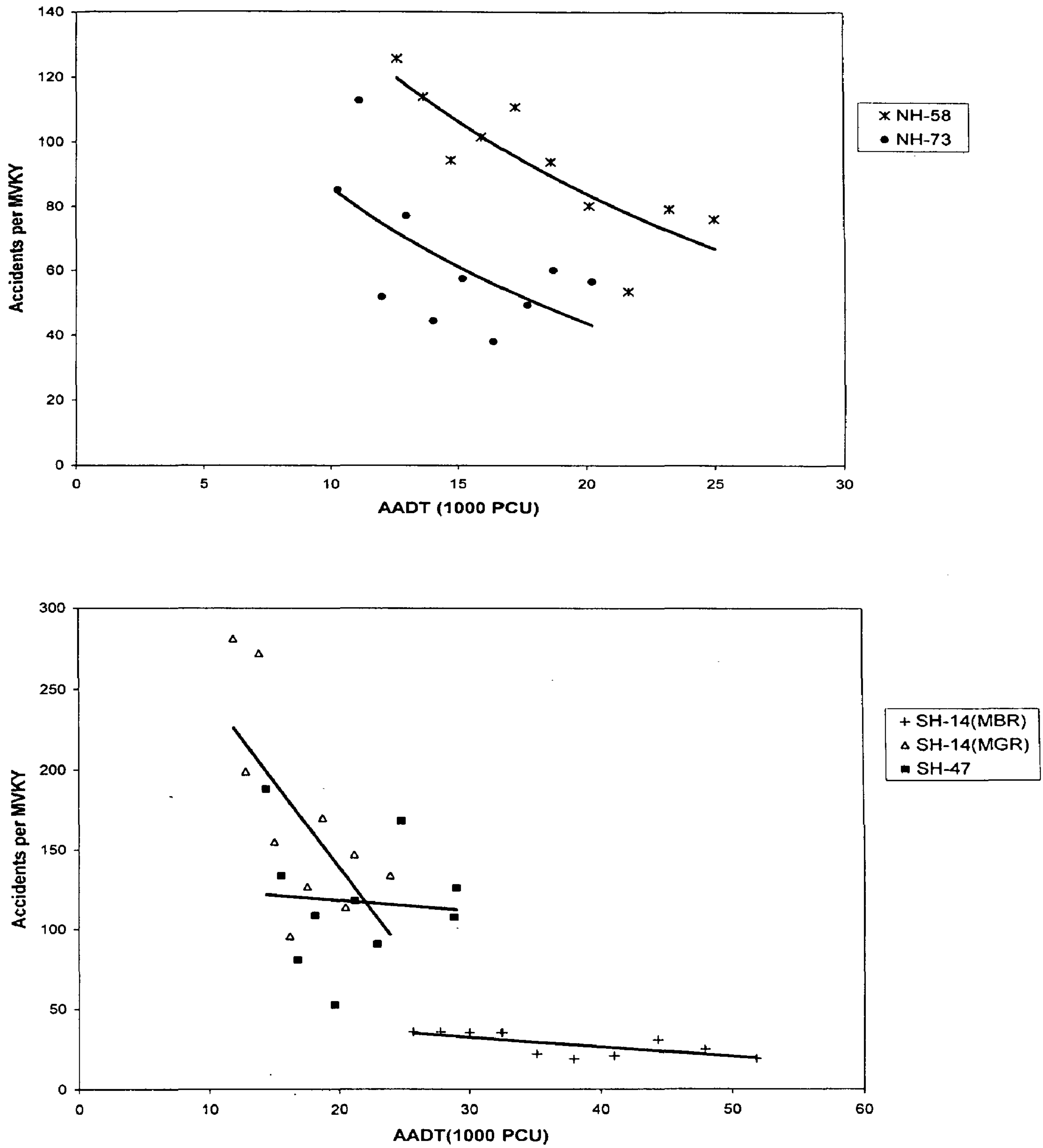


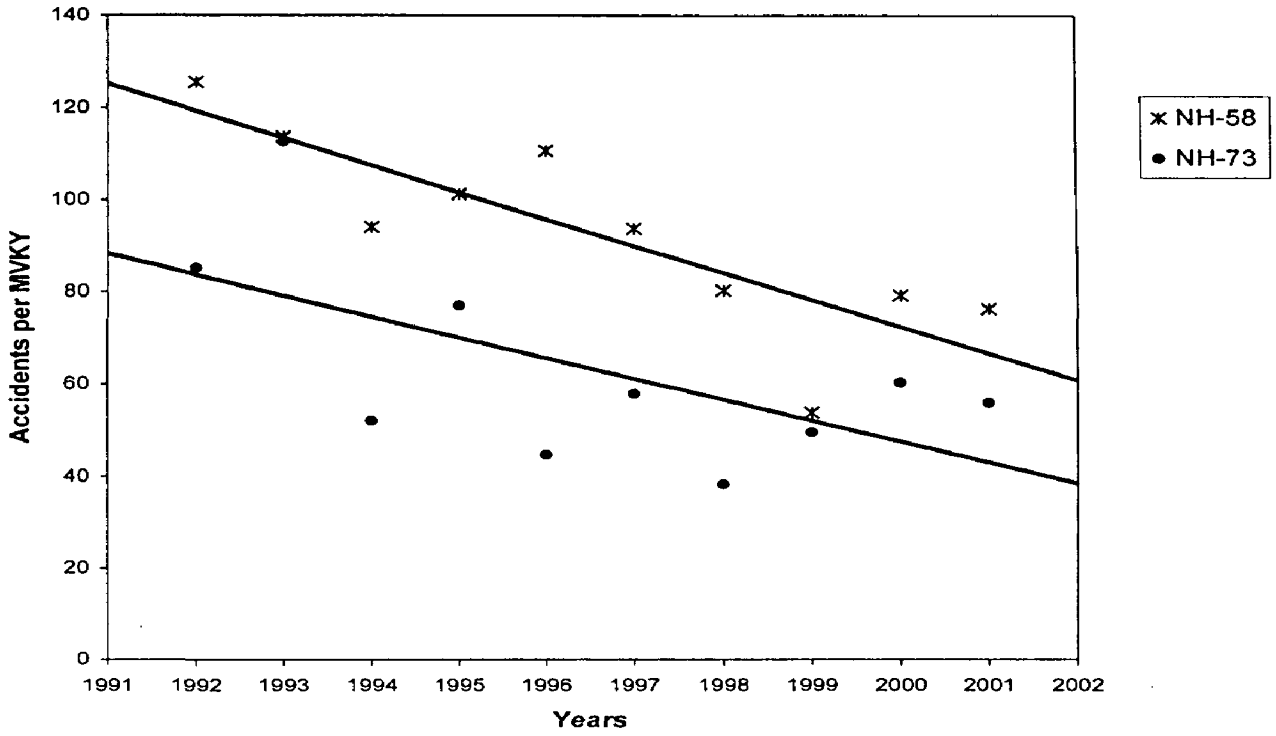
Fig. 4.13 Accidents per MVKY as related to traffic volume

4.4. Trend of Accidents, Injuries and Fatalities During 1992-2001

The yearly trend of accident per million vehicles -kilometer-year (MVKY) on different roads is shown in Fig 4.14. From the figures it is found that in all road sections accident rate per MVKY decreases in each subsequent year. This is an interesting fact to note that while the total numbers of accidents are increasing in each year, the accident rate per million vehicles -kilometer has increased over the years. This decreasing trend in accident rate may due to improvement in road and shoulder conditions and general awareness of road safety among road users. Though vehicles' and drivers' role in accidents cannot be ignored, liberal economic policy and 'education for all' programme of Government of India might have also reduce the accident rate on Indian roads.

The yearly trend of injuries is shown in Fig 4.15. In almost all road sections except in Meerut-Bagpat road (SH-14) injuries per MVKY has decreased in last 10 years. This trend may also be attributed to the cautious driving by small sized vehicles.

The yearly trend of fatalities shown in Fig 4.16. However it does not indicate any definite trend. The fatality rate per MVKY has increased. Substantially over the years on NH-73 and SH-47 while it has decreased on NH-58 and SH-14 (MGR). These contradictory natures of curves may be due to involvement of large size vehicles in accidents in some cases and not in other cases during the observation period.



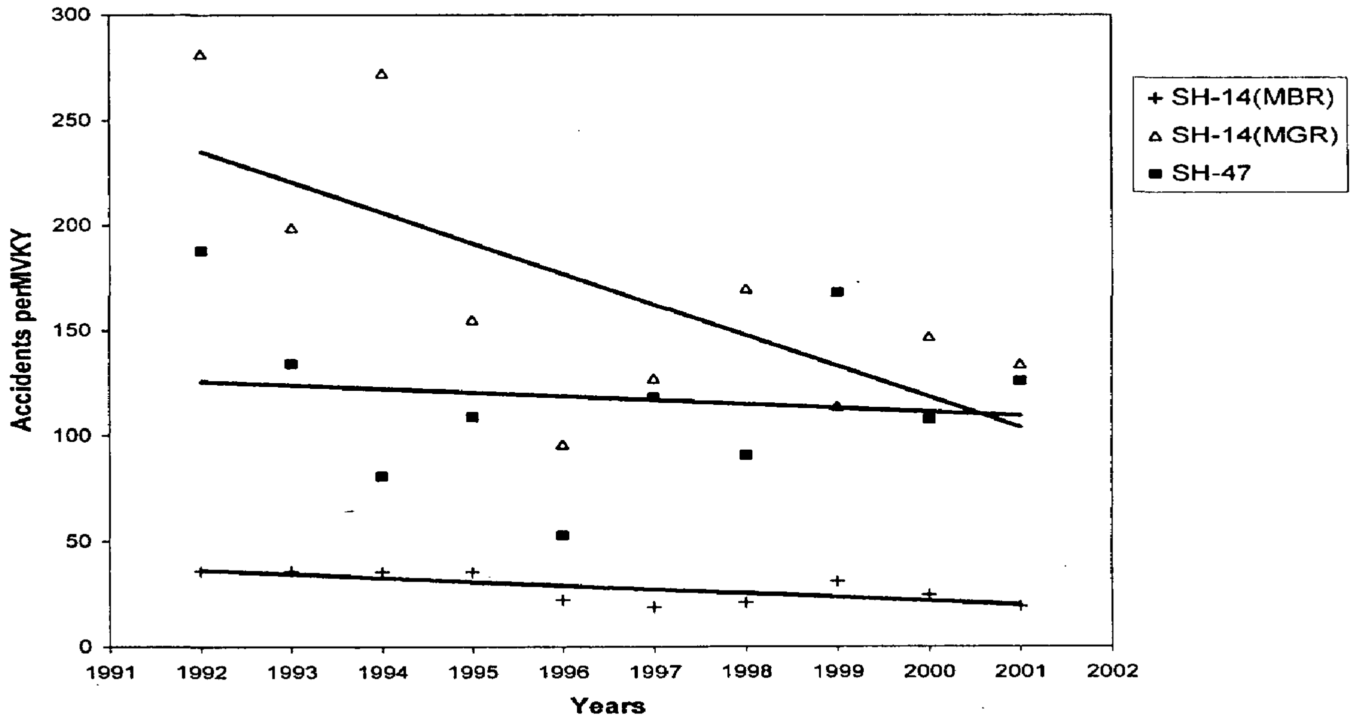


Fig. 4.14 Trend of accidents (1992-2001)

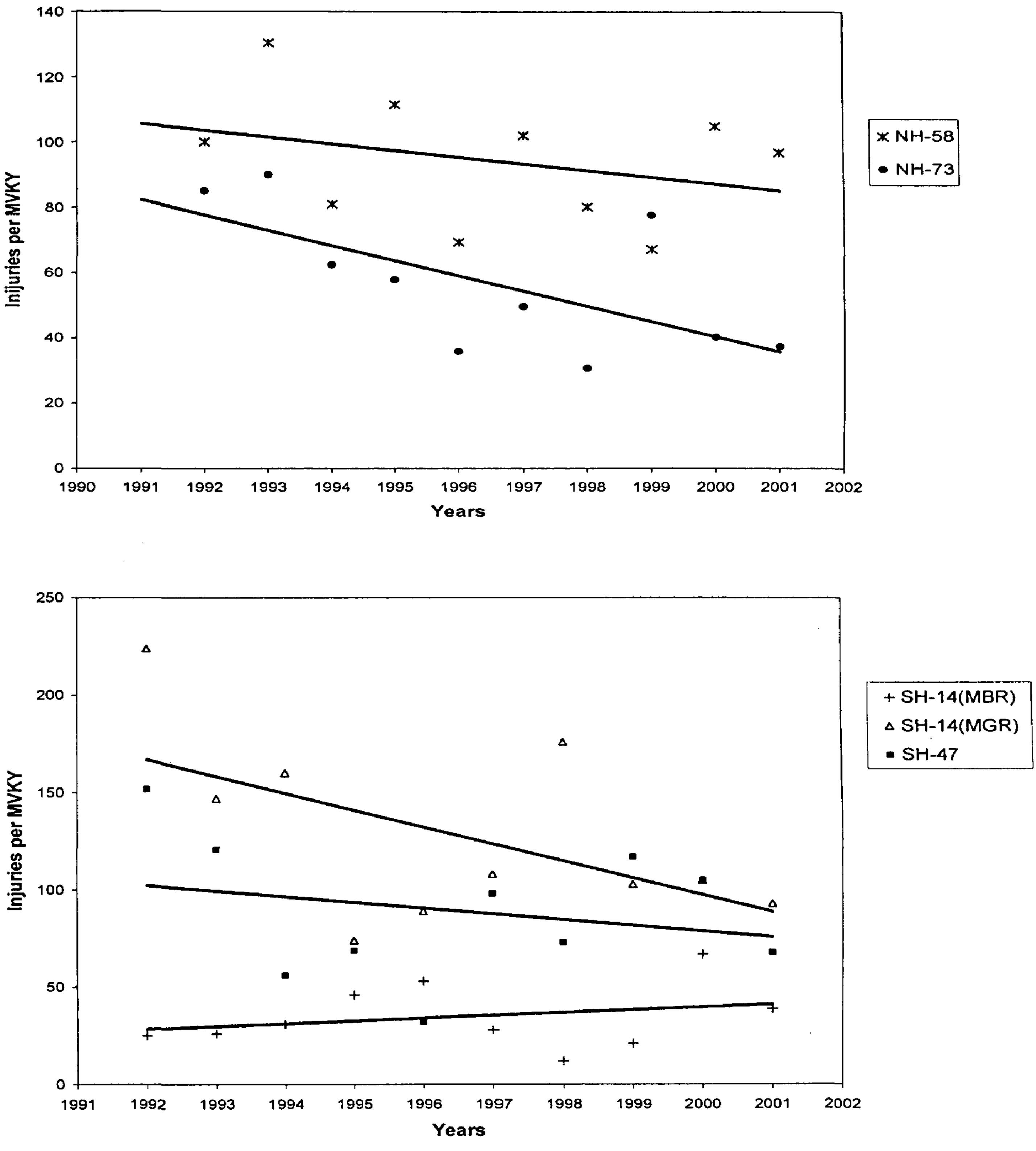
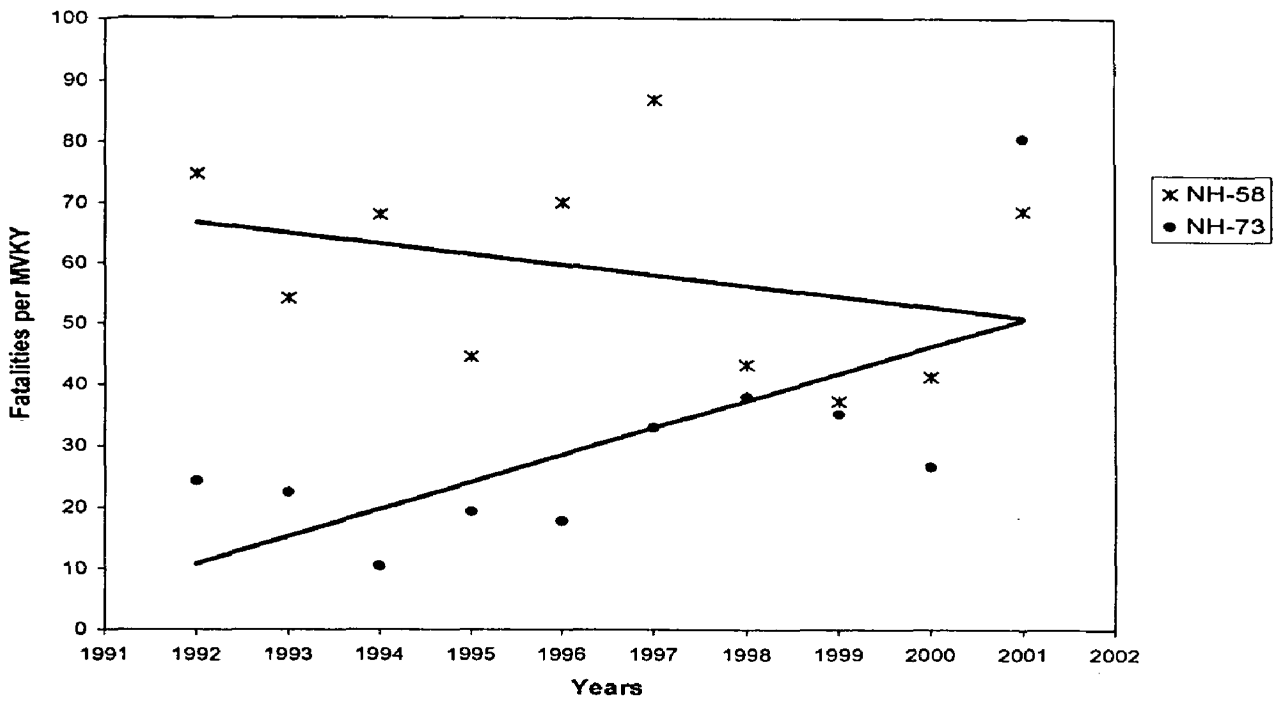


Fig.4.15. Trend of injuries (1992-2001)



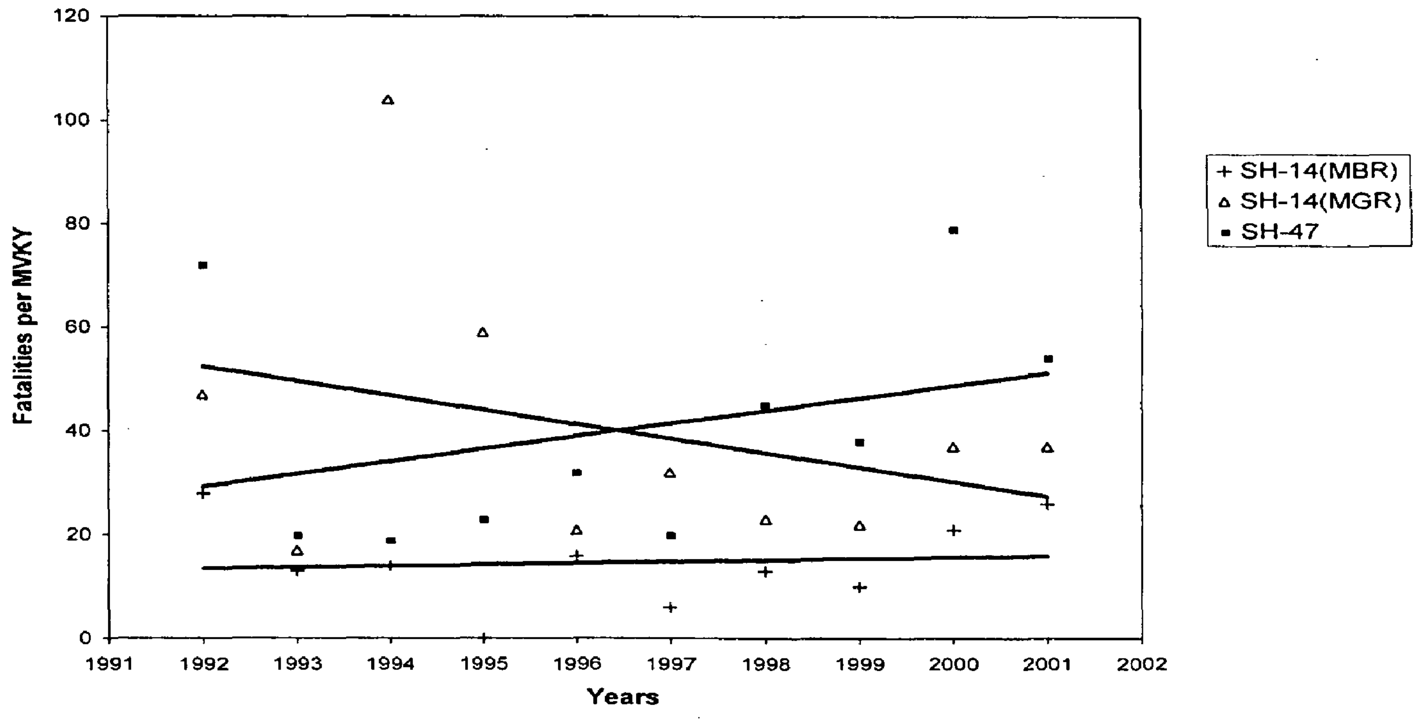


Fig. 4.16 Trend of fatalities (1992-2001)

4.5 Bad Roads and Accidents

Accident data available from statistics of road accidents in India 1991-1998 were also analyzed. Considering bad road as one of the causes of the road accidents, data of five states viz. Uttar Pradesh, Andhra Pradesh, Gujarat, Orissa and Tamil Nadu were used. Average percent accidents during 1991-1998 due to bad road are shown in Table 4.1.

Table 4.1 Average percent of accidents due to bad road

Year	State				
	Uttar Pradesh	Andhra Pradesh	Gujarat	Orissa	Tamil Nadu
1991	1.82	0.72	0.55	1.18	0.56
1992	1.05	0.14	0.48	2.29	0.95
1993	0.90	0.14	0.44	2.43	1.60
1994	0.52	0.04	0.25	1.65	1.14
1995	-	0.70	0.51	1.75	0.14
1996	1.84	1.08	1.55	1.23	0.33
1997	1.89	0.72	1.81	0.81	1.23
1998	1.94	1.00	2.05	1.64	1.19
Average	1.27	0.55	0.95	1.62	0.89

It was found that on an average 1.05 percent of total road accidents occur due to bad condition of the road only in these five states. If the same average is taken for the nation, then it can be inferred that at least 800 lives can be saved per year by maintaining the roads in better conditions.

4.6 Accidents Prediction Model

The portion of the road and shoulder where maintenance work was carried out in a particular year were noted from PWD records. Making a judicious judgment in consultation with PWD officials at Roorkee, Hardwar and Meerut, the section of a road and its shoulder were ranked on a 5-point scale as shown below.

Excellent 5

Good 4

Average 3

Poor 2

Bad 1

Excellent means road and shoulders were maintained very recently and bad means road and shoulder were not maintained within last four years. This decimal way of ranking is primarily due to the maintenances works not being carried out in a single year for the whole stretch of a road.

The accidents per Km-year were regressed with AADT and road and shoulder conditions rank

Table 4.2 Results of regression analysis

Road	C_0	C_1	C_2	R^2
NH-58	2.10	1.1×10^{-6}	-0.17	0.79
NH-73	2.37	3.9×10^{-6}	-0.42	0.93
SH-14(MBR)	1.38	2.0×10^{-5}	-030	0.88
SH-14 (MGR)	4.12	3.4×10^{-5}	-0.60	0.92
SH-47	5.40	5.4×10^{-6}	-0.98	0.92

The general form of equation is represented as

Accidents/Km-year = $C_0 + C_1$ (AADT) + C_2 (Road and Shoulder Condition Rank [CR])

The results of regression analysis on 5 roads are given in Table 4.2. All coefficients were found statistically significant at 95% level of confidence.

The prediction model for NH-58 can be represented as

Accidents/Km-year = $2.1 + 1.1 \times 10^{-6}$ (AADT) – 0.17 (CR)

Like wise for other road section models are as follows

NH-73, Accidents/Km-year = $2.37 + 3.9 \times 10^{-6}$ (AADT) – 0.42 (CR)

SH-14, Accidents/Km-year = $1.38 + 2.0 \times 10^{-5}$ (AADT) – 0.88 (CR)
(MBR)

$$\text{SH-14, Accidents/Km-year} = 4.12 + 3.4 \times 10^{-5} (\text{AADT}) - 0.60 (\text{CR}) (\text{MGR})$$

$$\text{SH-47, Accidents/Km-year} = 5.4 + 5.4 \times 10^{-6} (\text{AADT}) - 0.98 (\text{CR})$$

The above equations indicate that the accident/Km-year increases with AADT, but decreases with improvement in condition of the road or shoulders or both.

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

(1) The available literatures on accident analysis indicate that 75 percent of road accidents in India are caused due to drivers' error. Motorised two-wheelers are at least five times more dangerous than four-wheeler to road users as far as the chances of being killed in a road accident is concerned.

(2) There is no definite trend for monthly variation in accident on a section of highway. But the accidents in the months of June-July are generally higher. It may be due to fast deterioration of earthen shoulder by rain in these months.

(3) Heavy vehicles like truck/bus are involved in maximum number of accidents on two –lane roads. It is estimated that a heavy vehicles is involved in almost 21% accidents followed by two-wheelers (17.8%), car and pedestrians (16.4% each), and bicycles (7.0%).

(4) Accident rate in terms of number of accidents per Km-year increases with traffic volume. But the accident rate in terms of number of accident per million-vehicle kilometer-year (MVKY) decreases with increase in traffic volume.

(5) Both accident and injury rate per MVKY show a declining in trend over time whereas fatality rate does not follow a definite trend.

(6) The data analyzed for 5 states indicated that 1.05 percent of road accidents occur due to bad condition of the road. It means around 800 lives can be saved per year by proper maintenance of road and side shoulders.

(7) Accident prediction model developed on five roads in the present study show that number of accidents per kilometer- year increases with AADT and decreases

with improvement in road/shoulder condition. It is estimated that number of accidents per Km-year may reduce by 9-27 % when road /shoulder condition is improved.

(8) Road sections and corresponding accident models are as follows-

I. NH-58, Accidents/Km-year = $2.1 + 1.1 \times 10^{-6}$ (AADT) – 0.17 (CR)

II. NH-73, Accidents/Km-year = $2.37 + 3.9 \times 10^{-6}$ (AADT) – 0.42 (CR)

III. SH-14, Accidents/Km-year = $1.38 + 2.0 \times 10^{-5}$ (AADT) – 0.88 (CR) (MBR)

IV. SH-14, Accidents/Km-year = $4.12 + 3.4 \times 10^{-5}$ (AADT) – 0.60 (CR) (MGR)

V. SH-47, Accidents/Km-year = $5.4 + 5.4 \times 10^{-6}$ (AADT) – 0.98 (CR)

5.2 Recommendations

The present study is based on observations taken at five sections of two-lane road of Northern India. Collecting more data at various sections spread all over the country may further extend this study.

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