DEVELOPMENT OF ACCIDENT MANAGEMENT SYSTEM FOR NATIONAL HIGHWAYS

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 with Diversification to Traffic Engineering)

By

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CANDIDATE'S DECLARATION

I hereby declare that the work presented in this dissertation entitled **"DEVELOPMENT OF ACCIDENT MANAGEMENT SYSTEM FOR NATIONAL HIGHWAYS"** in partial fulfillment of the requirements for the award of the degree in **Master of Technology in Civil Engineering** with specialization in ***Transportation Engineering*** *and diversification in Traffic Engineering*, submitted at the Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee, is an authentic record of my own work carried out during the period from September, 2002 to February, 2003 under the supervision of **Dr. S. S. Jain**, Professor & Coordinator, Centre of Transportation Engineering (COTE), Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee, **Dr. M. Parida**, Assistant Professor, Transportation Engineering Section, Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee and **Shri A. P. Bahadur**, Chief Engineer (PIC), Ministry of Road Transport and Highways (MORTH), Government of India, New Delhi.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

Place: **Roorkee**

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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ABSTRACT

Every year nearly 85,000 persons are reportedly killed and more than 3,00,000 are injured on Indian roads. An accident takes place every 1.5 minutes and in every 6.2 minutes a person dies in road accidents. The National Highways though constitute only 2% of the total road network but carry 40% of the traffic and accounts for 25% of road accidents, out of which 34% lead to fatalities and 28% to injuries.

Accident Management System (AMS) is defined as a process of developing an accident database, identifying accident prone locations and evolving corrective measures.

Study has been carried out on sections of National Highways No. 58, 73 and 72A. Accident data for the selected highway sections have been collected from police stations for the last 10 years (1992-2001).

Accident Black Spot is a location, whether link or node, on a highway where accidents repeatedly occur or a large number of accidents occur over a period of time. In this dissertation, Accident Black Spots have been identified considering Accident Rate (AR), Accident Fatality Rate (AFR), Accident Severity Index (ASI) and No. of Accidents per 1,00,000 veh.km of travel as parameters for analysis. Threshold values of these four parameters have been calculated at 95% confidence level. Based on these threshold values, Accident Black Spots have been identified.

Subsequently, generalized remedial measures have been evolved based through on site observation.

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INTRODUCTION

1.1 General

Most of the developing countries in the world are increasingly confronted with rapid growth of population coupled with numerous economic activities. This has resulted in significant increase in motor vehicle population, which is one of the primary factors causing road accidents. Magnitude of road accidents in India has gone up to an alarming proportion. This is attributable to the rapid growth of motor vehicles and the inadequacy of the road system.

Various studies on road accidents indicate that most of the accidents occur over a certain stretch of the road. The locations where a minimum of 4 accidents occur in one year in an area of 0.1 km^2 on highway are called accident black spots [11].

There are several causative factors for the road accidents, which include vehicular characteristics, human factors and road characteristics. The wide range of vehicle types has different dimensional and operating characteristics. They are forced to share the same roadway, forming a very complex mix of traffic flow. Wide disparity in running speed, speed change and other vehicular characteristics of different classes of vehicles, different driving experiences, various level of service under a set of prevailing traffic and roadway conditions in mixed traffic flow have led to ever increasing problems of accidents

1.2 Global Scenario of Accidents

Around 5,00,000 persons are killed on the roads annually throughout the world and those injured are many fold [24]. Developing countries are having huge fatality rate (number of persons killed per accident) in comparison to the developed countries.

Many countries are experiencing an annual vehicle growth rate of around 17% [21]. Examples are India (17%), China (18%), Vietnam (18%) and Malaysia (15%). The number of deaths and injuries has been reducing steadily in the developed countries whereas the number of deaths in Asian countries is rising at alarming rates. During 1981-1993, the number of road accident deaths has increased in Asia Pacific Region by 95% whereas total population has increased only by 24% [23].

1.3 Accident Scenario in India

Every year nearly 85,000 persons are reportedly killed and more than 3 lakh are injured on Indian roads [23]. An accident takes place every 3 minutes and a person killed every 10 minutes. The figure keeps on increasing. More than ten million road accidents have taken place on Indian roads after motor vehicles came to India and almost 1.5 million people have lost their lives and many more have suffered injuries. Table – 1.1 shows the road accidents, persons killed and persons injured in India

TABLE – 1.1 Road Accidents in India

Year	Road Accidents (in thousands)	Person Killed (in thousands)	Person Injured (in thousands)
1970	114.10	14.50	70.10
1971	120.20	15.00	70.70
1972	122.30	16.10	76.40
1973	121.60	17.60	79.30
1974	114.30	17.30	76.70

1975	116.80	16.90	77.00
1976	124.70	17.80	82.50
1977	135.40	20.10	95.60
1978	146.30	21.80	99.50
1979	144.40	22.60	102.90
1980	153.20	24.60	109.10
1981	161.20	28.40	114.00
1982	166.20	30.70	126.00
1983	177.00	32.80	134.10
1984	195.00	35.10	156.20
1985	207.00	39.20	163.40
1986	215.50	40.00	176.40
1987	234.00	44.40	189.00
1988	246.70	46.60	214.80
1989	270.00	50.70	229.70
1990	282.60	54.10	244.10
1991	294.00	56.60	257.20
1992	259.30	57.20	270.00
1993	279.30	60.60	289.70
1994	315.70	64.00	312.10
1995	349.00	71.10	323.20
1996	368.15	74.56	340.92
1997	365.23	74.48	345.29
1998	380.85	78.99	359.13

Source: [23]

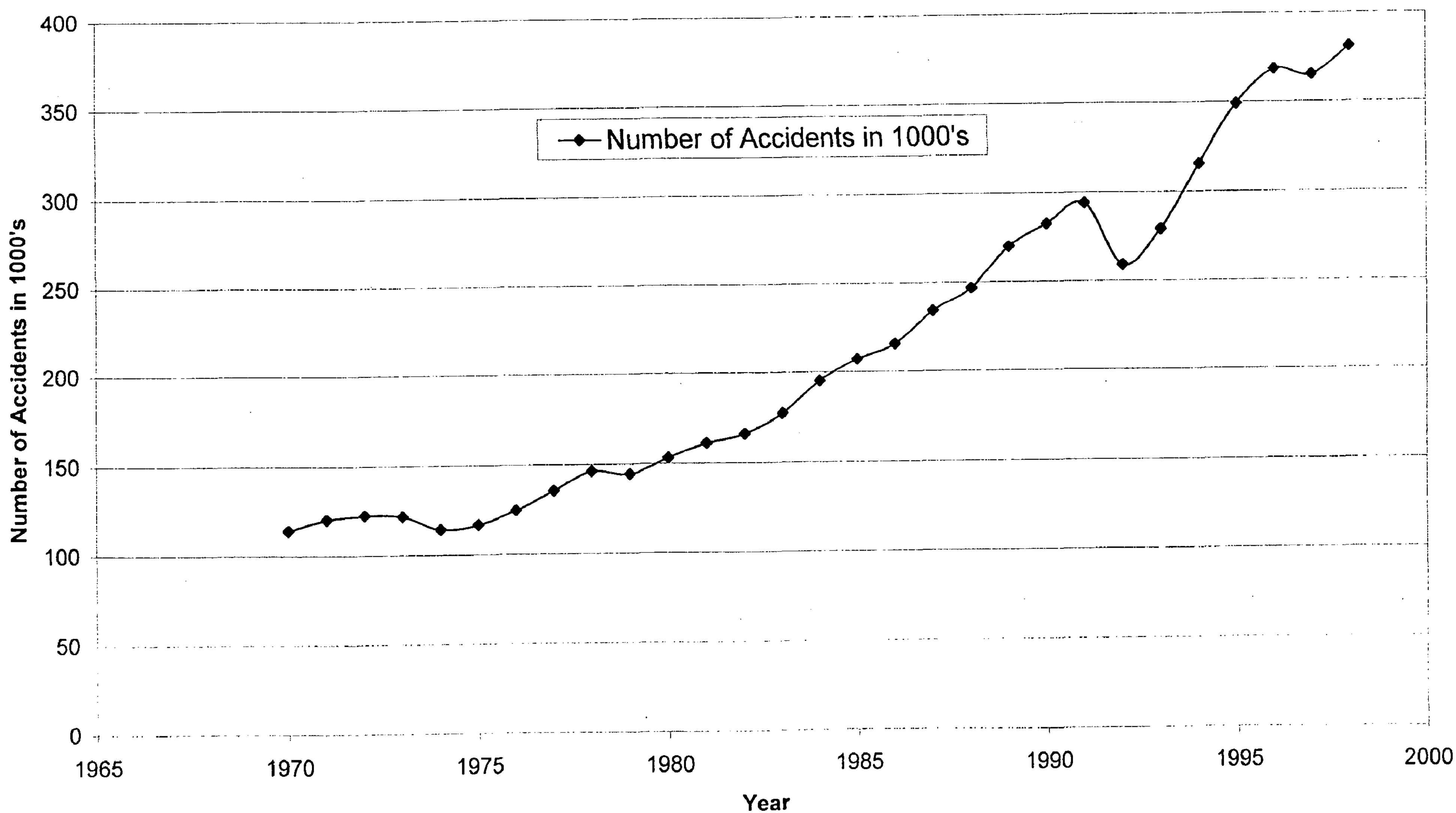


Fig. 1.1: Growth of Accidents in India

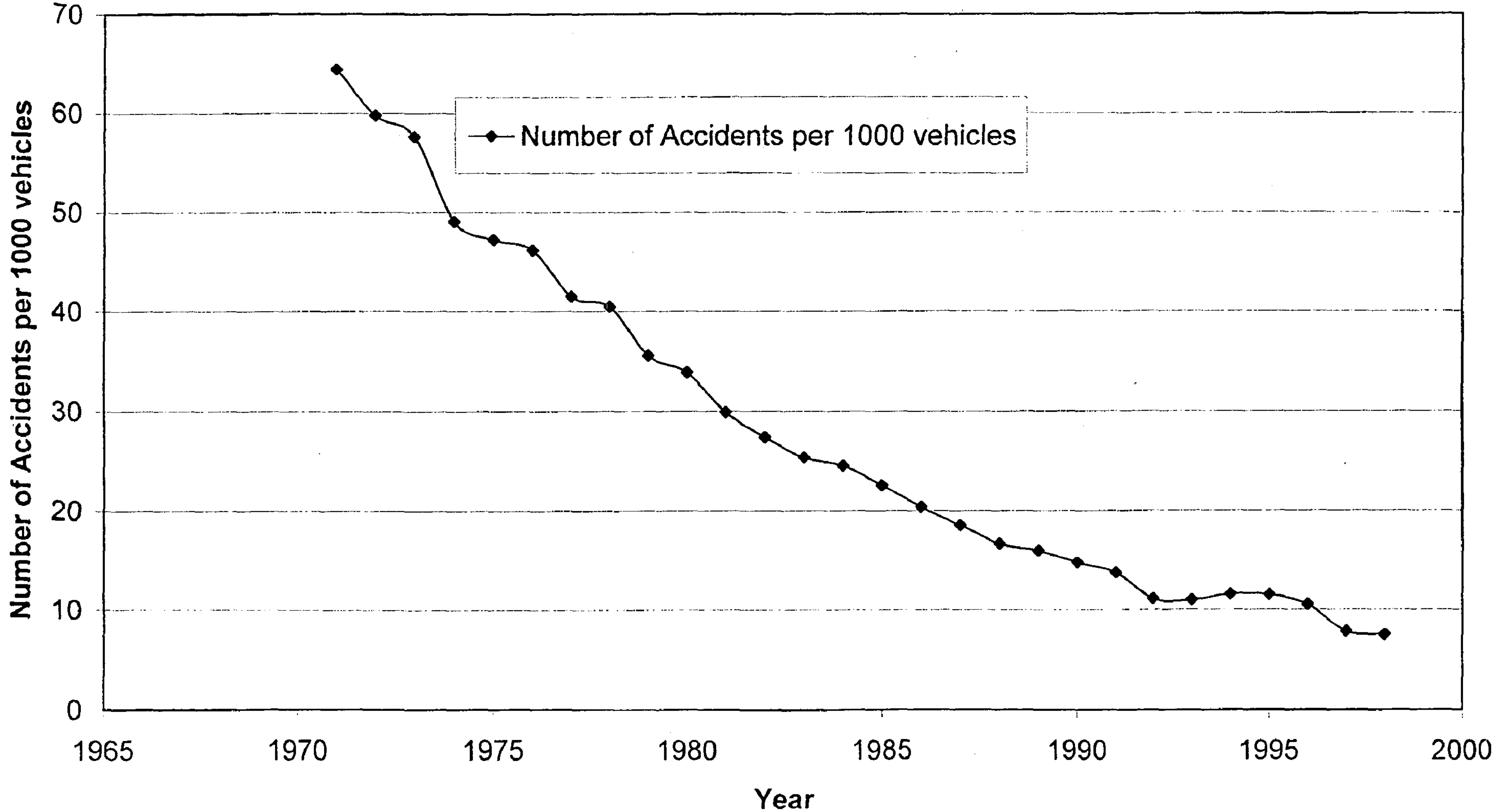


Fig. 1.2: Number of Accidents per 1000 vehicles

The vehicle population is going up and the accident number is going up but one silver-lining is that accident rate per 1000 vehicles is coming down tremendously i.e., from 64.75 (1971) to 7.47 (1998). This indicates that there is a general improvement in vehicles or drivers are more alert or road conditions are better. But this figure is still on higher side if compared to other developed countries. Our accidents are going up from 120.2 thousand (1971) to 306.0 thousand (1998).

The Indian share in world vehicle population is not even 1% but in case of road accidents, it has 6% share while the motorization level is second lowest in the world. This tells how rich we are in accidents.

The economic loss due to road accidents is estimated to be about Rs.6000 crore every year. This loss has been made only on accidents on roads but it does not include losses due to pollution by vehicles which are going up day by day. Technically, deaths due to pollution by vehicles or life long invalidity – asthma-bronchitis and so on, which are not counted on road losses, in fact should be part of it by the ministry report on accidents.

1.4 Comparison of Road Accidents

As the number of road accidents recorded in other countries in the world is very significant, it would be noteworthy to indicate the recent statistics on road accidents of sixteen countries which can be compared with India.

TABLE – 1.2 Table Showing Comparison with Other Countries w.r.t. Number of Accidents, Persons Killed and Persons Injured

Countries	Number of Accidents			Persons Killed			Persons Injured		
	1995	1996	1997	1995	1996	1997	1995	1996	1997
Austria	38959	38253	39695	1216	1027	1105	51974	56700	52696
Belgium	50744	48749	49007	1449	1356	1364	70305	68259	69493
Canada	166950	158973	NA	3347	3082	NA	241800	230885	NA
Chekoslovia	28764	29340	28376	1384	1388	1597	37164	37917	36008
France	132949	125406	125200	8412	8080	7989	181403	170117	168600
Germany	388003	373082	380835	9454	8758	8549	512141	493158	501094
Hongkong	14812	14397	14776	260	263	241	19613	18879	19552
Italy	182761	183415	NA	6512	6198	NA	259571	264213	NA
Japan	761789	771084	780399	10679	9942	9640	922677	942203	958975
Netherland	14473	11561	11238	1227	1099	1076	10210	10462	16162
Spain	83586	85588	86607	5751	5483	5604	121432	124157	130851
Sweden	15626	15321	15752	572	537	541	21173	20810	21279
Switzerland	23030	21578	22076	692	616	587	28759	26539	27286
USA	2254241	2292351	2222280	41817	42065	41967	3485000	3511000	3399000
UK	230376	235939	240046	3621	3598	3599	30855	316704	323845
India	349043	355100	290855	71140	698000	74204	323162	282162	309464

Source: [23]

The above figures show that India is fourth in the world in accidents after U.S.A., Japan and Germany but in case of fatalities we are number one. In case of injuries again we are ranked at number 5 after U.S.A., Japan, Germany and Malaysia. Being number one in case of fatalities despite at number fourth in the case of accidents; it speaks of poor medical assistance to victims on Indian roads. This clearly exhibits the result of the safety measures initiated in the western countries to minimize the road accidents.

1.5 Accident Scenario on National Highways

The road accidents are increasing rapidly on National Highways. The fatalities of road accidents has increased from 64,000 in year 1994 to 85,000 in year 2001. The 2% length of National Highways carries 40% of goods traffic, while 7% of State Highways carry 30% of goods traffic.

The National Highways though constitute only 2% of the total road network, 25% of road accidents occur on them, out of which 34% lead to fatalities and 28% to injuries.

1.6 Need of the Study

It is not possible to eliminate the accidents altogether on the roads, but they can be minimized. Accidents may be minimized by improving the geometric parameters of the roads i.e. acute geometrical features such as sharp horizontal curves, steep gradients or combination of them. To assess the situation to know the causes of accidents, one has to conduct a comprehensive study on accidents and come out with identification of causes and improvement measures that can be implemented to reduce the accidents.

1.7 Objective of the Study

The objectives of this study are as follows:

- To work out a management system for accidents occurring on National Highways in a step by step manner.
- To plot km-wise fatal and non-fatal accidents.
- To find out most dangerous and most vulnerable road users on National Highways.
- To identify accident prone locations on National Highways.
- To evolve remedial measures for the identified accident prone locations.

1.8 Scope of the Study

Accident Management System (AMS) is defined as a process of developing an accident database, identifying accident prone locations and evolving corrective measures. The scope of a realistic AMS may be quite large. In this dissertation, the scope of work is to present the accident scenario on National Highways around Roorkee. Study has been carried out on sections of National Highways No. 58, 73 and 72A. Kilometer wise analysis of accidents has been carried out and accident prone locations have been identified on the basis of Accident Rate (AR), Accident Fatality Rate (AFR), Accident Severity Index (ASI) and no. of accidents per 1,00,000 veh.km. For some of the accident black spots, generalized remedial measures have been suggested.

1.9 Composition of the Thesis

The present report has been divided into six Chapters. The First Chapter introduces the problem and brings out the Global and Indian Scenario of accidents. Scope and Objective of the Study have also been discussed. Second Chapter contains Literature Review in which techniques adopted for accident black spots identification are discussed. Third Chapter deals with the methodologies adopted. Fourth Chapter illustrates data collection. Fifth Chapter contains data analysis and discussion of results and finally Sixth Chapter presents the conclusions drawn from the present study and recommendations for the future work.

LITERATURE REVIEW

2.1 Accident Black Spots Identification

2.1.1 General

Black spots (BS) or Accident Prone Locations (APL) are highway locations where the potential for accidents is unacceptably high when compared to the established risk tolerance criteria [9]. In order to effectively utilize available funds for safety improvements, one must first designate high priority BS locations. In traditional BS programs aimed at improving highway safety, locations are identified as accident prone based on the total number of accidents. This criteria provides no consideration whether the accident were caused or could be corrected by road improvements. The traditional method results in the identification of locations that are not truly hazardous from a road safety authority perspective and consequently may lead to a misapplication of safety improvement funding. Therefore, accidents should be categorized into one or a combination of the three highway system components: the driver, the vehicle and the road.

2.1.2 Poisson regression model

In the Poisson Regression Model [9], the reported number of accidents on a section is expressed as a function of different highway geometric features. Baker and Nedler (1987) provided some details as to the nature of Poisson Regression Model, which is of the form

$$P(X_i) = \frac{(\mu_j \times Exp_i)^{x_i}}{X_i} \times e^{\mu_j Exp_i} \quad \text{.......} (2.1)$$

where μ_j = Accident rate for route section group j expressed as linear function of different features

X_i = No. of accidents on section 'i'

and Exp_i = Exposure for section 'i' (veh/km)

2.1.3 Modified empirical baye's technique [25]

In traditional BS programs, locations are identified as accident prone if they exhibit significant number of accidents above an established norm. In the modified BS program, locations must exhibit significant (i.e. road-related) accidents to be identified as accident prone. In this method, the number of accidents at any location is considered as a random variable. Location 'i' will be identified as accident prone if there is a significant probability that the location's accident rate, λ_i, exceeds the observed regional accident rate, X_R. Thus, location 'i' is identified as accident prone if –

$$P(\lambda_i > X_R / N_i, V_i) > \delta$$

or, equivalently if

$$\left[1 - \int_0^{X_R} \frac{\beta_i^{\alpha_i}}{\alpha_i!} \lambda^{\alpha_i - 1} e^{-\beta_i \lambda} d\lambda \right] > \delta \quad \text{.................................... (2.2)}$$

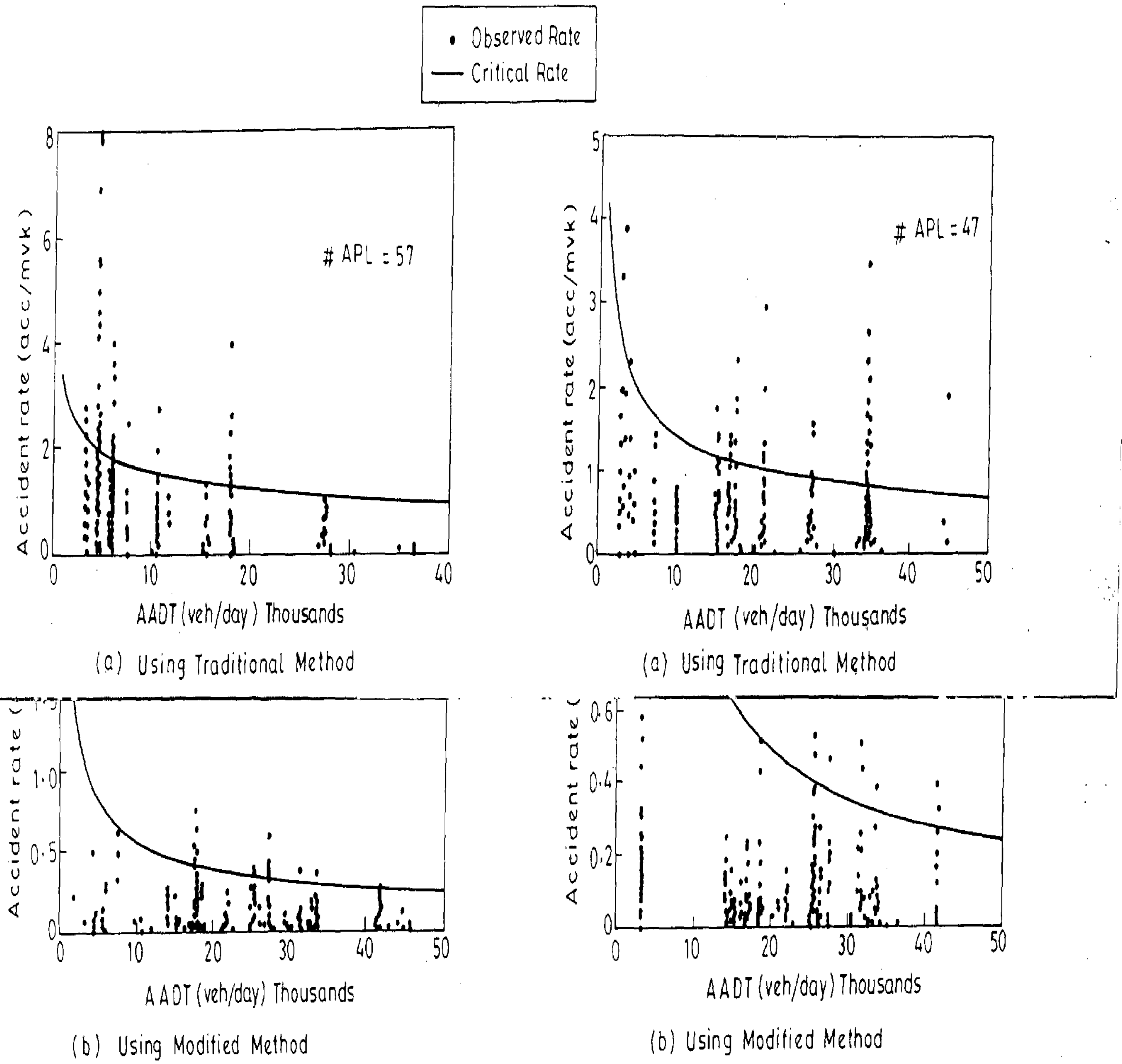
where, δ represents the confidence level desired, such as 0.95 or 0.99 and $X_R = \frac{\sum_{i=1}^{m} N_i}{\sum_{i=1}^{m} V_i}$. α and β are chosen so that the mean and variance associated with the gamma distribution are equal to the mean $(\bar{x})$ and variance (s^2) of the sample. α and β are taken as

$$\beta = \frac{\bar{x}}{s^2} \; ; \; \alpha = \beta \bar{x}$$

2.1.4 Case study

To illustrate the application of the modified black-spot program, the method was applied to the South Coast Region of the Province of British Columbia, Canada. Using police-reported accident data from 1989 through 1991 accident-prone locations were identified by both the traditional black-spot method and the modified method. Results from the two methods were compared and are presented in Fig. 2.1. This reduction in accident rate in the modified method is a direct result of replacing each accident with a weight between zero and one proportional to its road correctability.

The results indicate that the modified method identified a fewer number of accident-prone locations due to the accident correctability criteria. This will increase the potential effectiveness of safety-improvement projects by limiting the list of accident-prone locations. This is very important in situations when the road authority has resources to address only a limited number of black spots; it is important to focus on those with the highest potential of accident reduction.



Accident-Prone Locations for Signalized Intersections Using Traditional and Modified Methods

Accident-Prone Locations for Multilane Sections Using Traditional and Modified Methods

Fig. 2.1 Comparison of Poisson Regression Model and EB Model

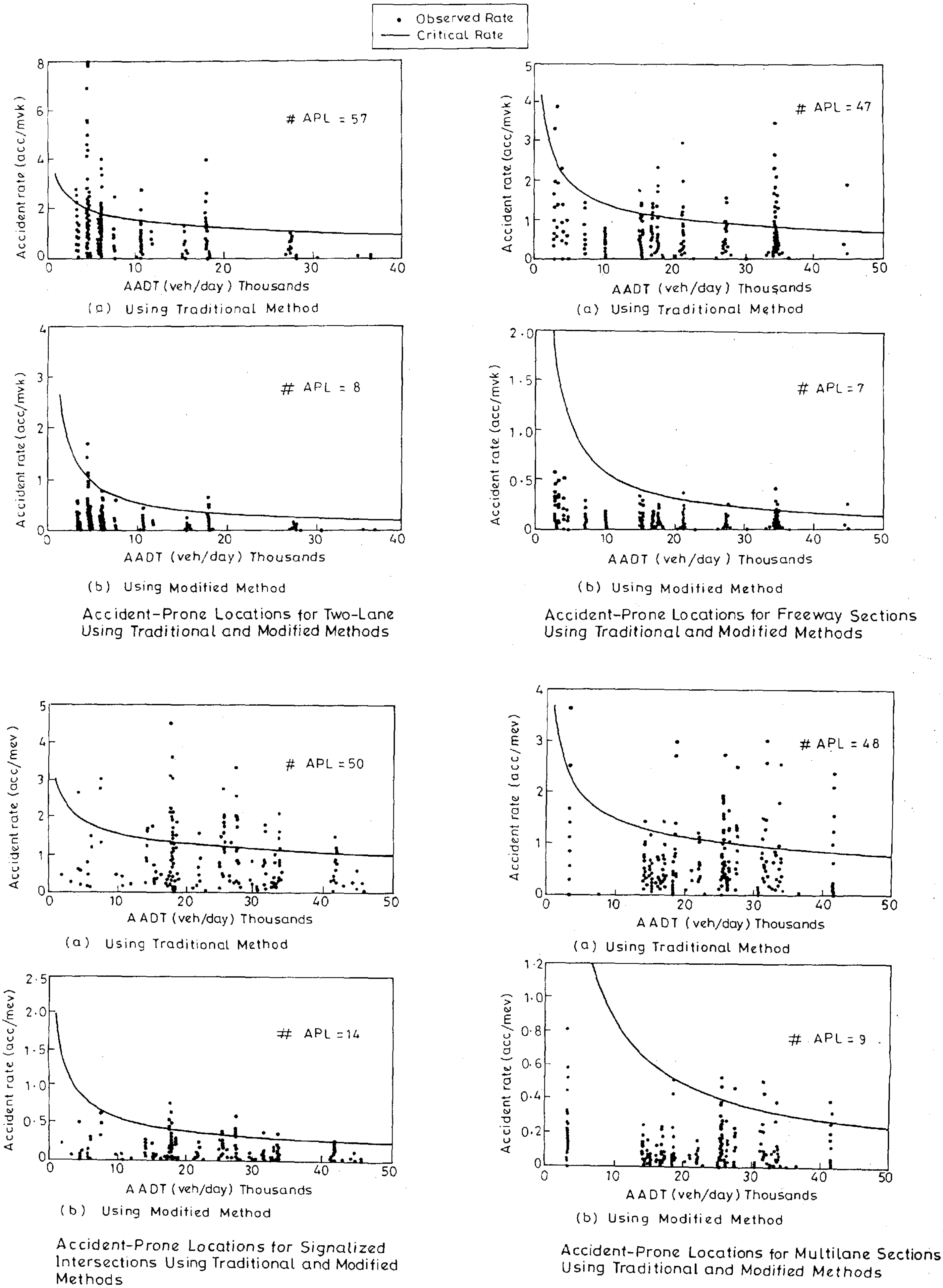


Fig. 2.1 Comparison of Poisson Regression Model and EB Model

2.2 Methodology Adopted Abroad

Methodologies adopted in countries such as Federal Republic of Germany, Ireland, Denmark, France, Great Britain, U.S.S.R. and Italy has been discussed below [10]:

2.2.1 Federal Republic of Germany and Ireland

Instead of using the simplest method of black spot detection i.e., the pin-up maps, Federal Republic of Germany finds it better to mark the accidents by the "cause of accidents" or by the "type of accidents" (i.e., driving accidents, accidents as a result of collision, single vehicle accidents and many sub-classes of these, etc.). This not only helps in detecting the "black spot" but also the causes and types of accidents which finally helps in improvement measures.

In Ireland, the past accident data was related to the average annual daily traffic (AADT) of the form

Accident Density (accident per unit length of road) = a(AADT)b

where, a, b, are parameters calibrated at an aggregated homogeneous level.

This formula is then used to estimate the expected number of accidents for a given stretch.

2.2.2 Denmark and France

In Denmark, the following statistical detection method is applied.

$$E(U_i) = a.N_j^p.L_j \quad \text{.. (2.3)}$$

where, 'a' and 'p' are calibrated parameters for that category of roads and are calibrated through regression methods. N_j is traffic flow and L_j is the length of section j.

The probability that 'u' accidents will occur fro a given $E(U_j)$ is

$$P_r(U_j = u) = \frac{(a.N_j^p.L_j)^u}{u} * e^{-(a.N_j^p.L_j)} \quad \text{.........................(2.4)}$$

The black spot idea is now associated with the differences between observed values of U_j and the expected values $E(U_j)$.

2.2.3 Great Britain

In Great Britain, definitions of accident prone sites with accident rate criteria have three main components (a) number and type of accidents, (b) time period and (c) length of road or size of area.

2.2.4 U.S.S.R.

In U.S.S.R., the "Safety coefficient" and "Accident coefficient" methods are used for detecting black spots.

The "Safety coefficient" method is established on the precondition that the motorist's nervo-physical tension at the beginning of a dangerous road section grows with an increase in the ratio between the speed on a subsequent road section (V) and the speed that can be attained at a preceding one (V_{en}).

Safety coefficient: $K_s = V/V_{en}$

On the basis of traffic accident data for many roads and traffic speed change data, limit figures of safety coefficients were established (i.e. $K_s > 0.8$ safe, $K_s < 0.4$ very dangerous, etc.)

The "Accident coefficient" method is established on the basis of traffic accident statistics. The degree of danger is estimated by using "total" accident coefficient (K_{acc}), which is the product of partial accident coefficients (K_1 K_2.................... K_{14}) taking into account the influence of separate horizontal and vertical elements. The partial coefficients are the ratio of the number of accidents for a given horizontal or vertical element and that for a standard straight road stretch.

A road section is considered dangerous if the total accident coefficient exceeds 25-40 or 15-20 (in road construction or new road projects respectively).

2.2.5 Italy

Accidents depend upon road section and volume of traffic using it. Following formula to calculate relative dangerousness rate has been advocated:

$$P_{RC} = \frac{(a.i + b.f + c.m) \times 10^3}{L \times 365 \times AADT} \quad \text{..............................} \quad (2.5)$$

where, i, f, m are accidents, injuries and fatalities rate per year on section of length L. And a, b, c are relative weights which are assumed to transform one accident, one injury and one fatality respectively into conventional units of economic burden.

By analyzing such set of indices, one can identify black spots in order to facilitate decision making about successive steps of black spot detection and elimination.

2.3 Accident Remedial Measures

Accident savings can often be obtained as a valuable and intentional by-product of a traffic management scheme and some schemes are implemented purely, or largely, for safety reasons. However, a systematic approach to the problem of accident reduction has been shown to lead to greater benefits in relation to costs than by pursuing one-off schemes.

A systematic appraisal of all the sites of particular types which could be treated in a local authority's area, together with the different forms of treatment which could be applied, will have to achieve good use of resources devoted to such schemes.

2.3.1 Remedial Approaches

Programs for remedial treatment may be of several different kinds, for example:

Black Spot Programs are the most generally used type of program. Treatment is individually tailored to suit those sites which are likely to yield the highest economic rate of return from accident reduction.

Mass Action Program, in which a particular type of remedy is selected (for example, anti-skid surfacing) and a systematic search is made for sites which are likely to benefit from that form of treatment, resulting in economies of scale in the use of such treatments.

Route Program, in which the principal accident sites along a continuous stretch of major road, are treated together. Measures considered might include improved street lighting, improved road markings, parking controls, the redeployment of turning movements between junctions and alteration of speed limits.

Area Programs, in which treatment is applied systematically within an area (usually a residential area). Measures might include access controls to reduce through traffic, use of road humps and diagonal barriers at cross-roads to reduce speed; and selected road closures.

During the early stages of remedial work within an urban area, a black spot program is likely to give the most cost-effective results. But later, when the majority of high yield sites have been dealt with, a more widespread approach using a route program or an area program may be more beneficial. However, new black spots can develop over time and a continuous program of monitoring and review is needed, including sites which have already been treated.

These types of approaches are particularly suited to suburban areas where large numbers of distributed accidents happen, but where dense clusters of accidents occur, black spot treatments will remain most effective.

2.3.2 Selection of sites for treatment

Sites should be selected for treatment on the basis of a screening process carried out against selected criteria. It is common practice to use the total number of accidents which have occurred at the site within last three years (a period long enough to give an indication of the average annual frequency with reasonable confidence) as an initial test.

What is regarded as a black spot may vary considerably from one part of the country to another. In a dense metropolitan area a site may be recognized as a black spot if it has, for example, twelve accidents in three years. In a less urbanized area, a site with four accidents in three years might be regarded as exceptional.

Sites with very high accident frequencies are not necessarily good candidates for simple remedial measures as they may have more deep-seated problems which might require more drastic solutions.

It will, therefore, be clear that great care is required in selecting sites for treatment since the likelihood of a particular site benefiting from remedial work is more important that a high accident rate alone, even though the latter give rise to public pressure for a quick solution.

2.3.3 Selection of priority sites

In principle, the sites with the highest rates of return should be treated first because this criteria leads to the maximum savings in accidents for every rupee invested. However, in practice only single sites and routes can be accessed strictly according to this criterion and even with these, there is no guarantee that some of the more worthwhile sites will not be eliminated during the initial screening where the criterion for selection including the identification of sites with above average occurrence of particular categories of accident. Computer based analysis techniques can now make this a feasible proposition because of their rapid data handling capabilities.

2.3.4 Hazard based remedies

A summary of the road characteristics that can affect road safety along with the remedial measures which could be considered is provided in Table 2.1. Besides these, various traffic engineering measures might also help to alleviate these problems.

Table 2.1: Remedial Measures

Characteristics which affect road safety	Remedial Measures
Road Layout	
Horizontal alignment: substandard provision associated with accidents involving loss of control and overtaking. Overdesign associated with excessive speed. Horizontal curves can reduce visibility.	Appropriate geometric standards, layout and surface materials can help reduce speed and skidding. Speed control devices. Superelevation can reduce likelihood of loss of control, improves drainage and grip in wet weather. Signs and markings can give advance warning of hazards. Anti-skid surfacing.
Vertical Alignment: poor visibility at crests associated with overtaking accidents on two-way roads. Down grades can increase stopping distance.	Appropriate geometric standards as above. Crests and sags should not contain sources of unexpected conflict such as turning or parked vehicles or pedestrian crossing. If this is unavoidable then displaced centre lines at crests and mini roundabouts at sags can help.
Carriageway width: roads associated with greater risks for pedestrians crossing. Excessive speeds relating to the character of the road rather than to that of the road environment.	Refuges and pedestrian crossings. Footbridges and subways. Speed control devices and road narrowing. Sheltered parking with footway extensions where pedestrians waiting to cross are visible to drivers.
Junctions: accidents associated with conflicting movements.	Reduce and simplify conflicts by closures, banned movements, one-way street, improved junction control and reducing the number of junctions. Clearer provision for pedestrians at junctions or at convenient points nearby.
Road Surface	
Surface texture: accidents due to skidding and badly maintained surfaces	Rough or permeable textures give better skid resistance and additional tyre noise may have safety advantages for pedestrians and others. Special anti-skid treatment at critical braking points such as approaches to pedestrian crossings and signals. Proper maintenance program and

	reinstatements.
Markings: Smooth markings can lead to skidding. Poor visibility and lack of markings can lead to confusion.	Use marking material which is visible at night and effective in the wet. Markings should promote discipline and alert drivers to hazards.
Road Margins	
Kerb:	Vertical kerbs give protection to pedestrians and positive drainage yet cause problems to those with a mobility handicap. Provide lowered kerbs at specific points.
Hard shoulder and central reserve.	Valuable safety margin for out-of control vehicles – the wider the margin the lower the probability of severe impact. Use crash barriers where space is at a premium.
Lighting: A poor standard or design can cause reflection off wet roads. Bad spacing can create unnecessary shadows.	Correct spacing and height for lighting columns. Special illumination of pedestrian crossings.
Vehicle Access To And From The Carriageway	
Frontage development: conflicting access movements to and from frontage development associated with accidents on major arterials.	Reduce conflicts by providing access elsewhere – access road, rear access.
Parked and loading vehicles: reduce visibility for pedestrians and constrict carriageway. Deflect cyclists. Contribute to accidents at junctions.	Waiting and loading restrictions. Provision for on and off-street parking. Provision for delivery.

2.3.5 Monitoring the effects of remedial measures

When monitoring the effectiveness of remedial treatment at a site, accident data before treatment and data for at least three years afterwards should be compared. Although in practice shorter time periods often have to be used, they will be statistically less soundly based.

2.3.6 Case study

For ensuring better roads safety in India, Chakraborty et. al. [5] had undertaken this study with prime objective of establishing a scientific system for identifying accident black spots and formulation of safety improvement schemes for National Highways and their prioritization. This prototype study had been planned to be carried out under four-stages:

Stage 1: Identification of Representative Sections

Under this, 18-representative sections of around 100 km each were identified based on terrain, number of lanes and traffic commensurating to National Highways spectrum as well as accident data.

Stage 2: Evolution of System

Under this, a computer based system for identification and rectification of accident black spots was evolved on scientific basis considering various parameters affecting road safety. With this approach in view, a system was developed as Micro-Computer Road Safety Management Package (RSMP), comprising following modules:

- DBM (Data Base Management)
- AIM (Accident Identification Module)
- ARM (Accident Remedial Module)

'DBM' contains all data files on vehicle, road, traffic, climate and accident characteristics and general information on road network.

'AIM' was developed based on relationships established through statistical analysis of accident data vis-à-vis major contributing factors, separately for nodes and links for identification of accident black spots.

'ARM' was developed based on relationship of accident casual factors and possible engineering remedies under given road environment and traffic conditions.

Stage 3: Safety Audit

Under this, a Safety Audit of accident black spots for six-critical sections has been carried out based on economic losses and improvement costs for various alternative improvement strategies.

Stage 4: Implementation of Remedial Measures

Under this, the remedial measures that are found cost-effective as a result of Safety Audit were implemented for two-most critical sections and monitored on continual basis.

Finally, as a result of this prototype study and similarity in road and traffic environment, the recommendations were made for extension of this work to other Highways in the country.

METHODOLOGY ADOPTED

3.1 General

In this dissertation, methodology has been developed for the black-spot identification for National Highways taking into consideration the road accidents for the last ten years (1992 to 2001) and traffic volume. Eventhough causes of accidents can be many traffic engineering parameters are of specific relevance to a professional approach by a transportation engineer to study highway accidents.

A Methodology Flow-chart for this study is shown in Fig. 3.1.

3.2 Geometric Parameters of Road

The roadway width, shoulder width, grade, width of bridge, sight distance, number of lanes, radius of horizontal curve and coefficient of friction have been taken as geometric parameters of the road.

3.2.1 Cross Section Elements

Under cross section elements, the considerations for the width of pavement, formation and land, the surface characteristics and the cross slope of the pavement are included. Cross section details are shown in Fig. 3.2(a).

(I) Road Width or Formation

Width of formation or roadway is the sum of width of pavement or carriageway including separators (if any) and the shoulders. Formation or road way width is the

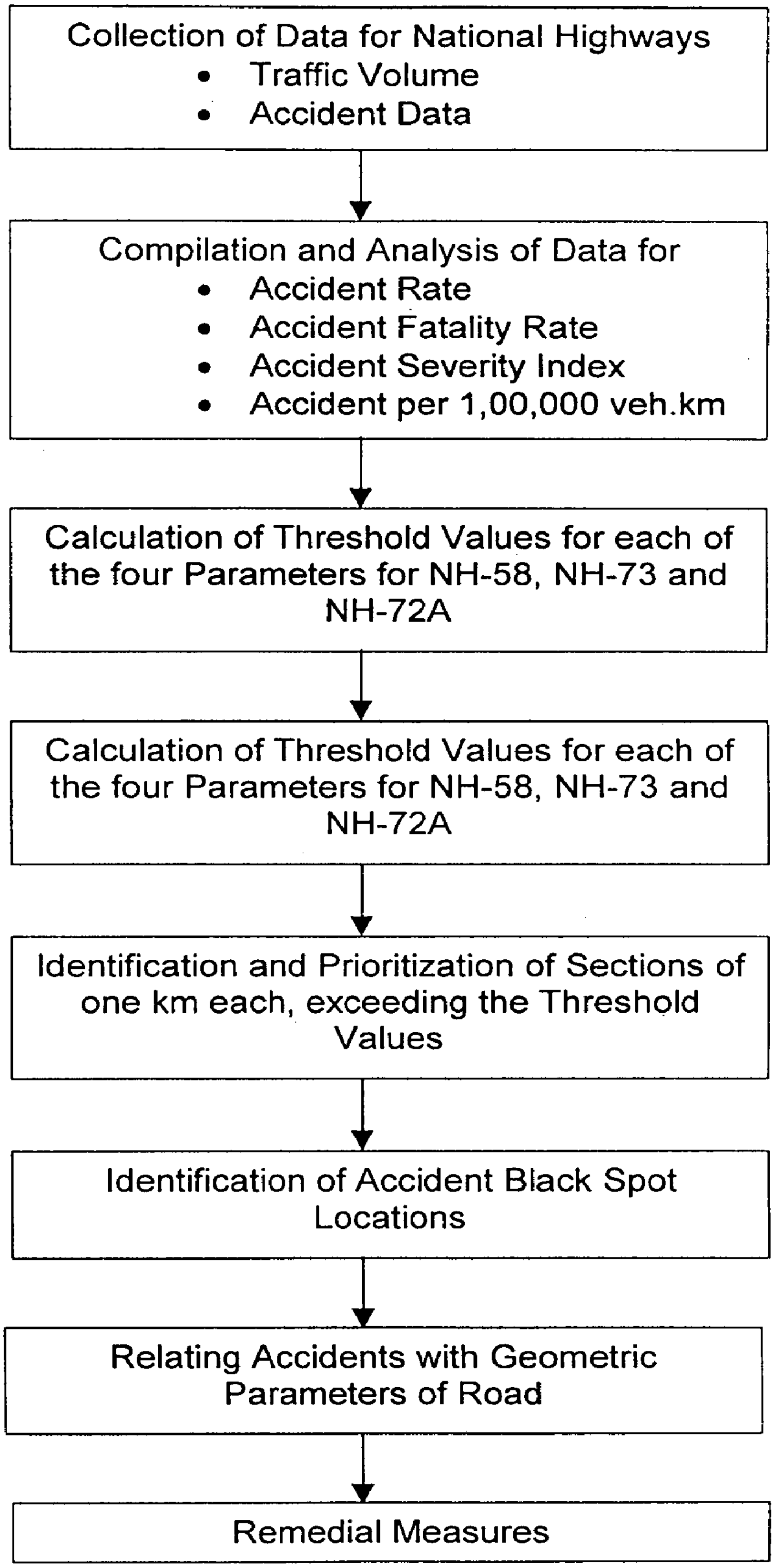


Fig: 3.1 Methodology Flow-chart

top width of the highway embankment or the bottom width of highway cutting excluding width of side drains as shown in Fig. 3.2 (a).

(II) Width of Pavement or Carriageway

The pavement or carriageway width depends on the width of traffic lane and number of lanes. The carriage way width intended for one line of traffic movement may be called a traffic lane. The lane width is determined on the basis of the width of vehicle and the minimum side clearance which may be provided for safety. Double lane width is shown in Fig. 3.2 (b).

The width of road way standardized by IRC are given in Table 3.1

Table 3.1 Width of Roadway of Various Classes of Roads

S. No.	Road Classification	Roadway width (m) at	
		Plain & Rolling Terrain	Mountainous and Steep Terrain
1.	National & State Highways (a) Single lane (b) Two lanes	 12.0 12.0	 6.25 8.80
2.	Major District roads (a) Single Lane (b) Two lanes	 9.0 9.0	 4.75 -
3.	ODR (a) Single Lane (b) Double Lane	 7.5 9.0	 4.75 -

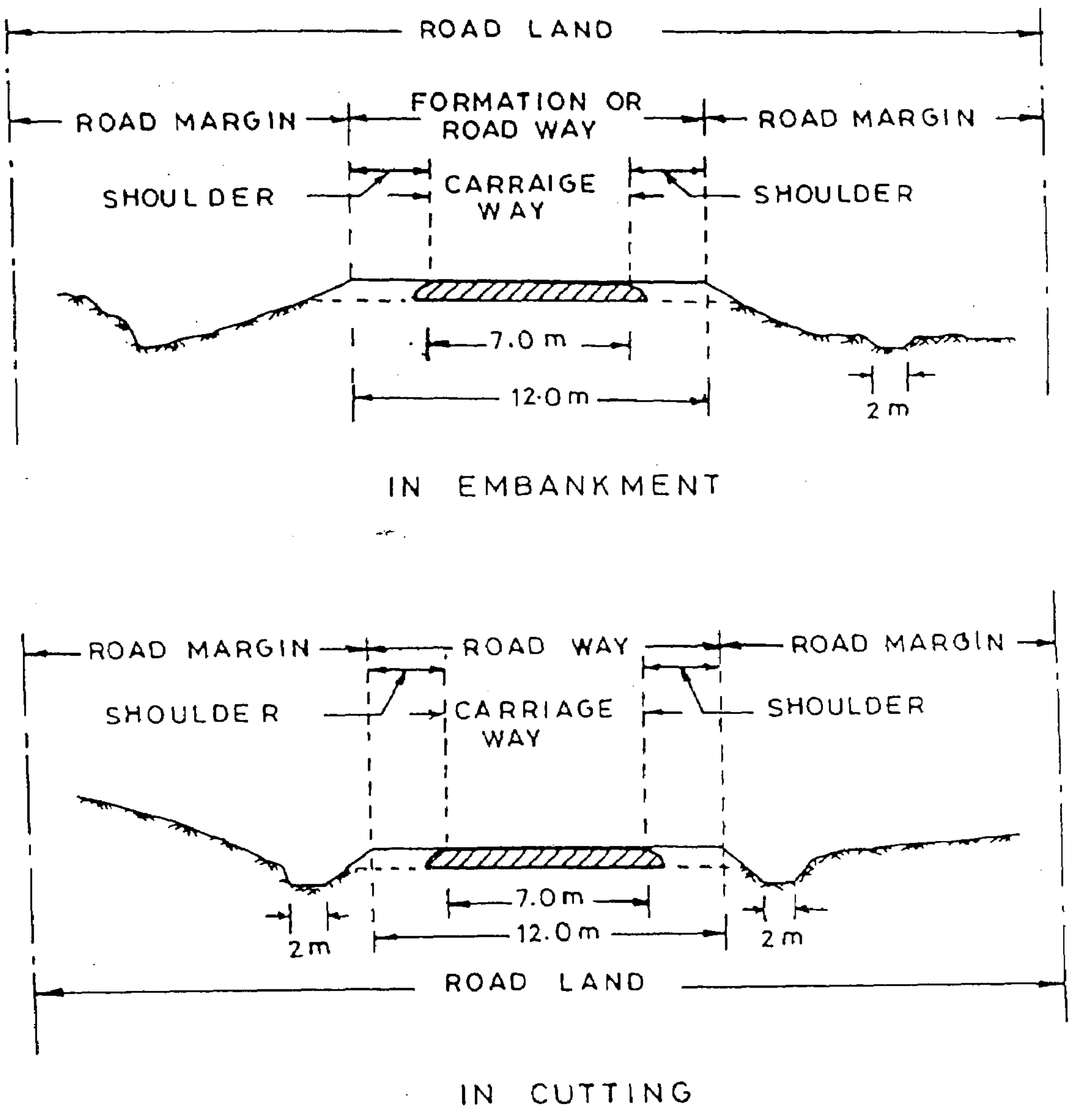
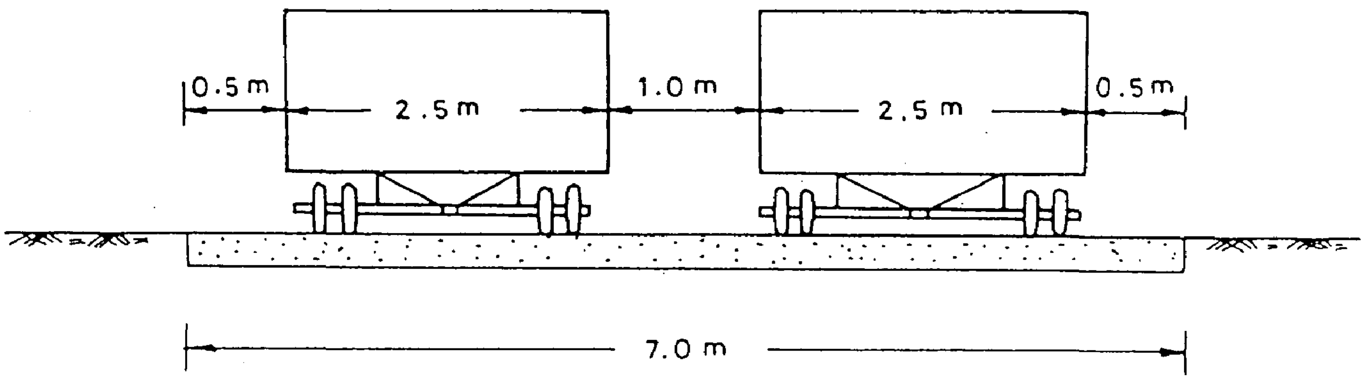


Fig. 3.2 (a) Cross-section Details of National Highways



3.2 (b) Width of Carriageway for Two Lane Pavement

(III) Right of Way

Right of way is the area of land acquired for the road, along its alignment. The width of this acquired land is known as land width and it depends on the importance of the road and future development.

(IV) Shoulder

Shoulders are provided along the road edge to serve as an emergency lane for vehicle compelled to be taken out of the pavement or the roadway.

3.2.2 Sight Distance Consideration

The minimum sight distance available on a highway at any spot should be sufficiently long to stop a vehicle traveling at design speed, safely without collision with any other obstruction. Sight distance is a minimum distance measured along the road surface at which an object of height 0.15 m can be seen by a driver whose eye is at a height of 1.2 m above the road surface.

3.2.3 Pavement Surface Characteristics

The pavement surface depends on the pavement type which is decided on the availability of materials, volume and composition of traffic, subgrade and climatic considerations. The pavement of highway is flexible with bituminous surface. The important surface characteristics of the pavement are the friction, unevenness, light reflecting characteristics and drainage of surface water.

3.2.4 Grade Measurement

Highway alignment has different grades at different locations. The grade of the highway at different sections is measured with the help of Clinometer.

3.2.5 Measurement of Horizontal Curve Radii

The radius of horizontal curve is measured by taking any two points on the curve. The distance between the points is measured with the help of measuring tape straightly. The radius of horizontal curve (R) is measured from the following formula:

$$R = \frac{x^2 + y^2}{2y}$$

where, x = centre of the straight length of curve from centre of the road

y = vertical intercept from the centre of the road

3.3 Traffic Volume Count

One of the fundamental measures of traffic on a road system is the volume of traffic using the road in a given interval of time. It is also termed as flow and it is expressed in vehicles per hour or vehicles per day.

Traffic volume has been counted to obtain information about the number and movement of vehicles within or through an area or at selected points within an area. The traffic volume was counted by manual counts. This kind of count uses field observers to obtain traffic volume data. Traffic volume was taken for a period of 24 hours at different locations on the selected highways.

By calculating average annual flow and the length of the highway, average annual veh.km. of travel has been calculated. This has been used in calculating average accidents per 1,00,000 veh.km. of travel.

3.4 Criteria for Accident Black Spot Identification

An accident usually occurs from a complex interaction of vehicle, road, road user and/or environment factors and hence considered a multi- factor event whereas Accident Black Spot is a location whether link or node, where accidents repeatedly occur or a large number of accidents occur during a period of time.

The following four criteria have been adopted for ranking based on accident data:

(i) Accident Rate (AR)

(ii) Accident Fatality Rate (AFR)

(iii) Accident Severity Index (ASI)

(iv) Accidents per 1,00,000 veh. km.

Here "Accident Rate" and "Accident Fatality Rate" have usual meaning and denote the average accident number and fatalities respectively per km per year.

"Accident Severity Index" denotes average accident weightage points per km per year, based on following weightage points assigned to the severity of each accident (as recommended by TRRL, UK in Interim Guide on "Identifying, Prioritizing and Treating Hazardous Locations on Roads in Malaysia", 1995).

Fatality = 6

Serious Injury = 3

Minor Injury = 0.8

Non-injury = 0.2

In police records, only fatal and serious injury accidents are reported whereas minor injury and non-injury accidents are hardly reported. So, due to non-availability of reliable data on minor injury and non-injury accidents, their weightage has been taken as 1.0.

The criticality of each section for various configurations was determined based on threshold values for AR, AFR, ASI and No. of accidents per 1,00,000 veh.km. These threshold values represent critical accident rate at 95% confidence level and have been taken as average accident rate (based on last 10 years accident data) plus 1.5 times of standard deviation (i.e. $\overline{X} + 1.5\sigma$).

The accident locations where any one or more than one of the four selected parameters (AR, AFR, ASI and No. of accidents per 1,00,000 veh.km) exceed their threshold values have been considered as Accident Black Spots.

DATA COLLECTION

4.1 General

For the identification of accident black spots, data has been collected from primary and secondary sources. Data which are gathered on the basis of field study are primary data and the data which are collected from secondary sources like police stations, insurance agencies and hospitals are secondary data. The details of data collected in connection with this thesis along with reasons for selection of the chosen National Highways are given below.

4.2 Selection of National Highways

The development of Hardwar-Rishikesh, Dehradoon and Mussoorie as important tourist destinations in the International tourist map, expansion of new educational institutions at Roorkee and other industrial developments have resulted in increased traffic demand on the National Highway corridor around Roorkee.

The Maha Kumbh and Ardh Kumbh at Hardwar and other festivals attract unmanageable number of pilgrims and during these events there is traffic chaos. During the rainy season, devotees of Lord Shiva (Kawaria) collect water from Hardwar and walk down to Pura Mahadeo near Meerut and almost for a period of one month the highway is hardly available for traffic.

Besides its religious and economic importance, it provides access to China border and it is a road of strategic importance. Therefore, NH-58 has been selected for the identification of black spots.

In order to have different set of road and traffic conditions, different National Highways have been considered. So, besides NH-58, NH-73 and NH-72A have also been included in this study. The study area is shown on Fig. 4.1.

4.3 Collection of Accident Data

The source of accident data are police records, insurance agencies, hospitals etc. For this particular study, the data of road accidents has been extracted from the police records with the prior permission of the concerned S.H.O's. The police stations have their own FIR records for so many years. The FIR's related to road accidents are recorded under IPC No. 279/337/338/304A/427.

Though a lot of details are required for every accident, the details available in the FIR reports are very limited. For example, the reason for accident in every case has been given as fast and careless driving. Depending upon the details available in the FIR reports, a Performa was prepared to record the accident data. A sample copy of the Performa is given in Fig.4.2.

Accident data for the last ten years (1992 to 2001) has been collected from the following police stations:

- Kotwali, Roorkee
- Manglore Police Station, Mangalore
- Jwalapur Police Station, Hardwar
- Gangnahar Police Station, Roorkee
- Bhagwanpur Police Station, Bhagwanpur
- Fatehpur Police Station, Chhutmalpur

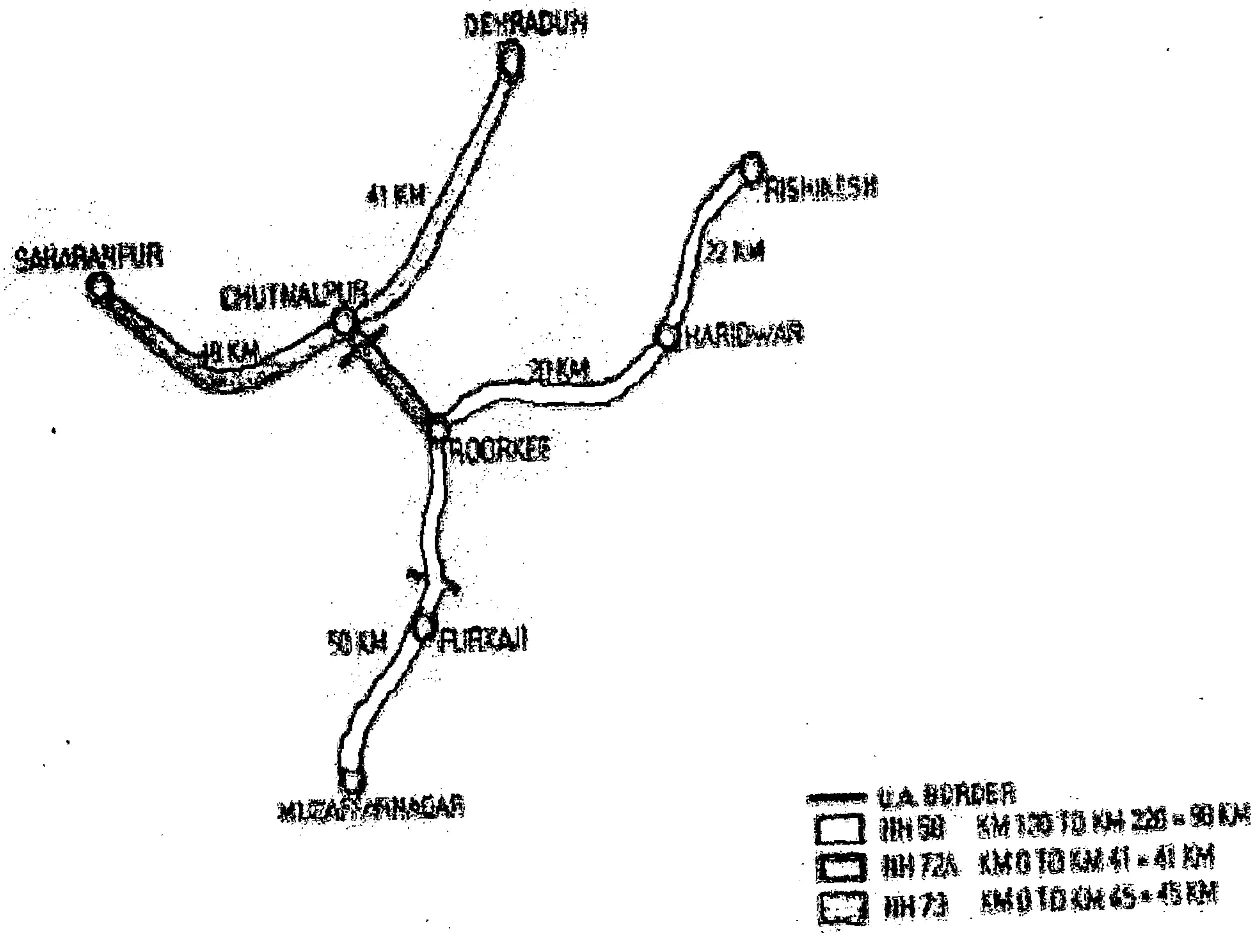


Figure 4.1: Study Area

CENTRE OF TRANSPORTATION ENGINEERING (COTE)
CIVIL ENGINEERING DEPARTMENT
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE, ROORKEE

FIR No.	Date/Day/Time	Location of Accident	Details of Accident	Vehicle(s) Involved	Possible Reasons	Any Other Information(s)

Fig. 4.2 Performa for Accident Data

4.4 Primary Data Collection

Primary data were collected on the basis of field study. From the studies traffic volume data has been taken for the following locations:

(i) Roorkee to Manglore

(ii) Roorkee to Hardwar

(iii) Roorkee to Chhutmalpur

DATA ANALYSIS AND DISCUSSION OF RESULTS

5.1 General

Analysis of the accident data on the three National Highways selected i.e., NH-58, NH-73 and NH-72A has been carried out in sections of one kilometer each. Accident Rate, Accident Fatality Rate, Accident Severity Index and Accidents per 1,00,000veh.km has been calculated and the sections exceeding the threshold values has been identified as accident prone sections. Finally, Accident Black Spots have been identified.

5.2 Kilometer wise Analysis of Accidents

Histograms of fatal accidents, serious injury accidents and total accidents have been presented in Fig. 5.1.

5.3 Time and Month-wise Analysis of Accidents

Time-wise analysis of accidents has been presented in Fig. 5.2. From this analysis, it is established that maximum number of accidents occur between 3pm to 5pm. Month-wise histogram of accidents is given in Fig. 5.3.

5.4 Victim of Accidents and Vehicles at Fault

A mode-wise analysis of victims of accidents and vehicles at fault is presented in Table 5.1. Percentage-wise histogram is plotted in Fig. 5.4.

For NH-58 as well as for NH-73 and NH-72A, the most vulnerable road users are pedestrians which come out as 24.3% for NH-58 and 22.22% for NH-73 and

NH-72A. Similarly, mode-wise analysis of vehicles at fault is presented in Table 5.1 and percentage-wise histogram is given in Fig. 5.5. It shows that the most dangerous mode for other road users on NH-58 is truck (37.15%) whereas on NH-73 and NH-72A, it is bus (29.33%) followed by truck (28.44%).

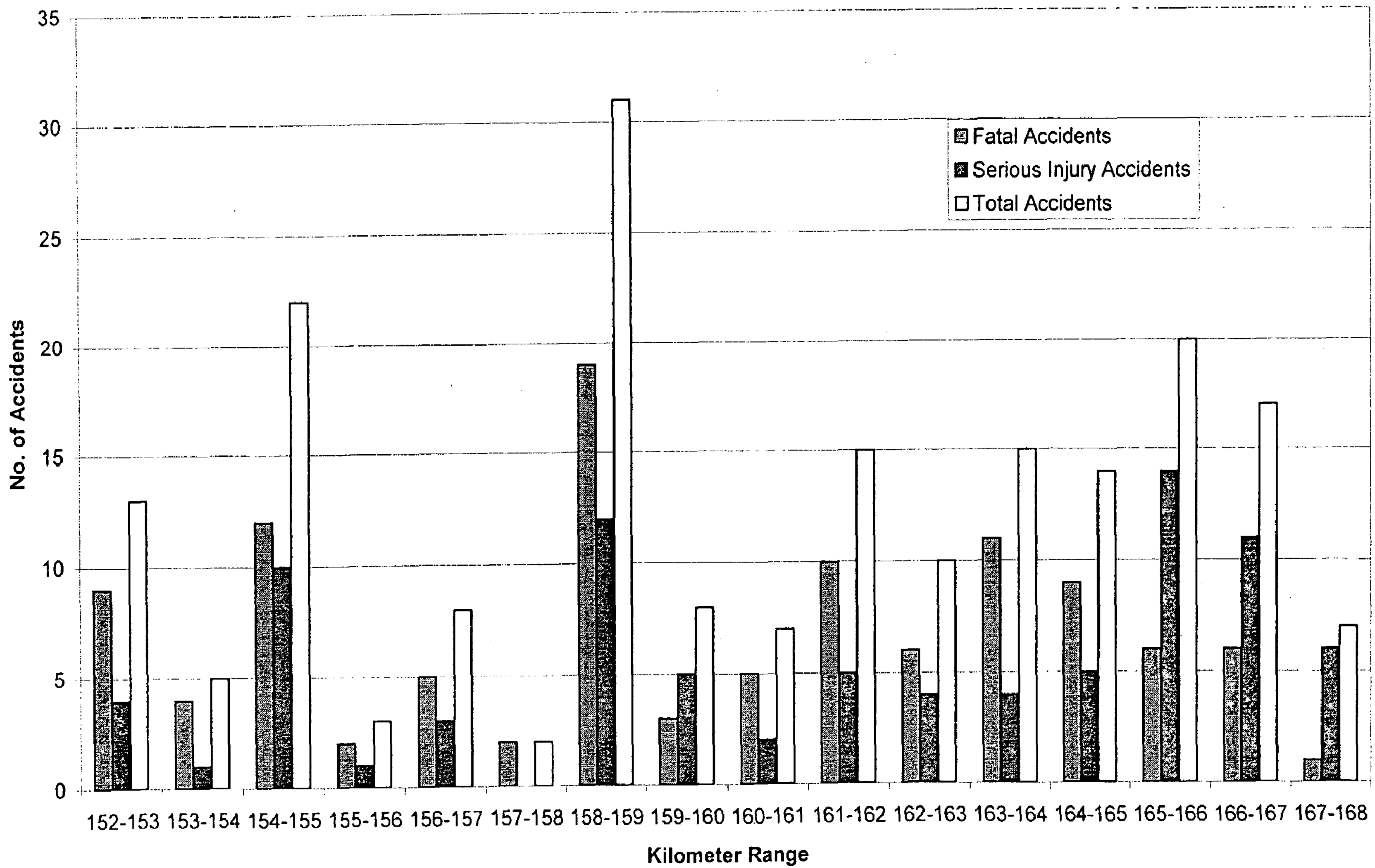


Fig: 5.1 (a) Km-wise Accidents on NH-58 (152-168)

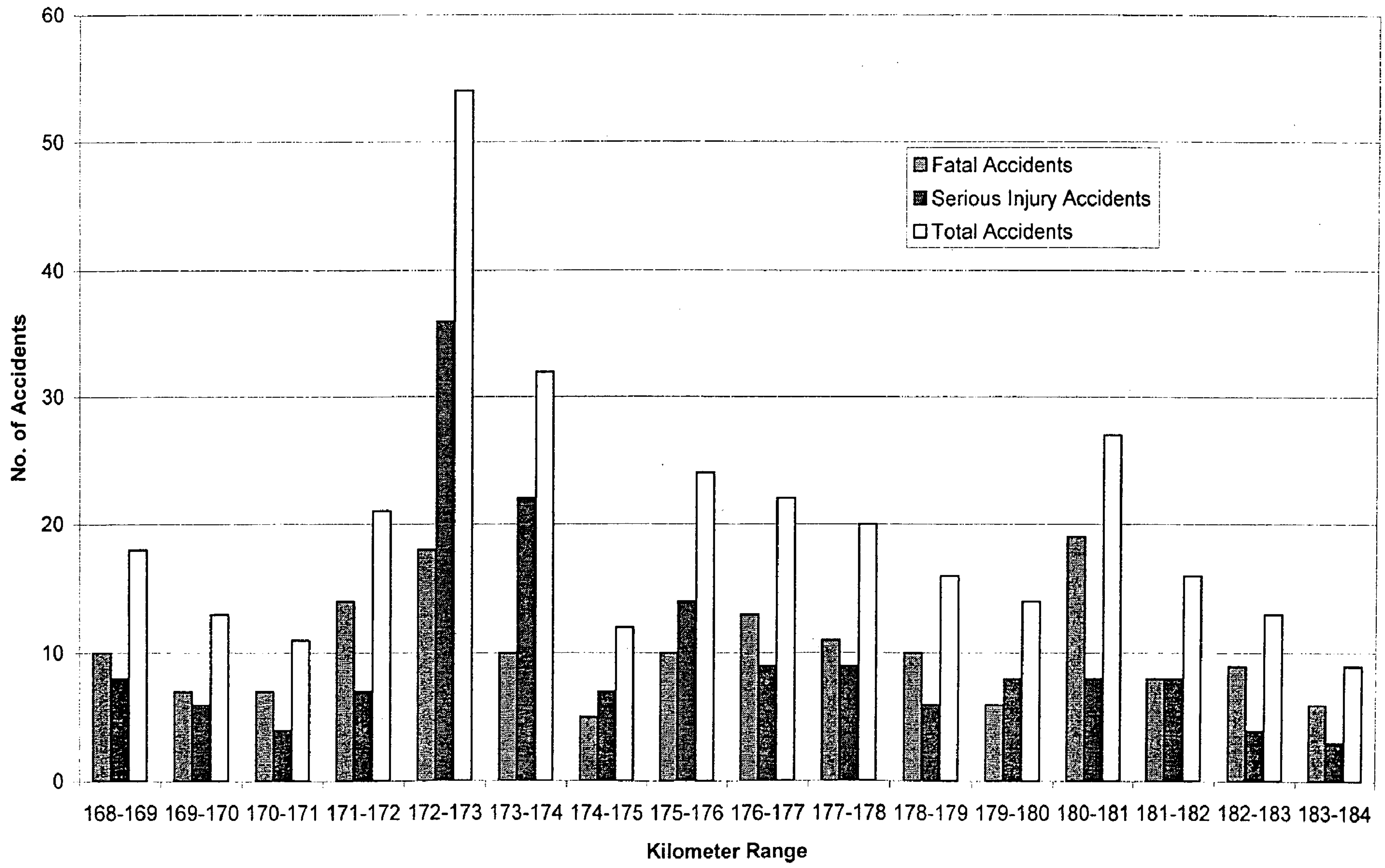


Fig: 5.1 (b) Km-wise Accidents on NH-58 (168-184)

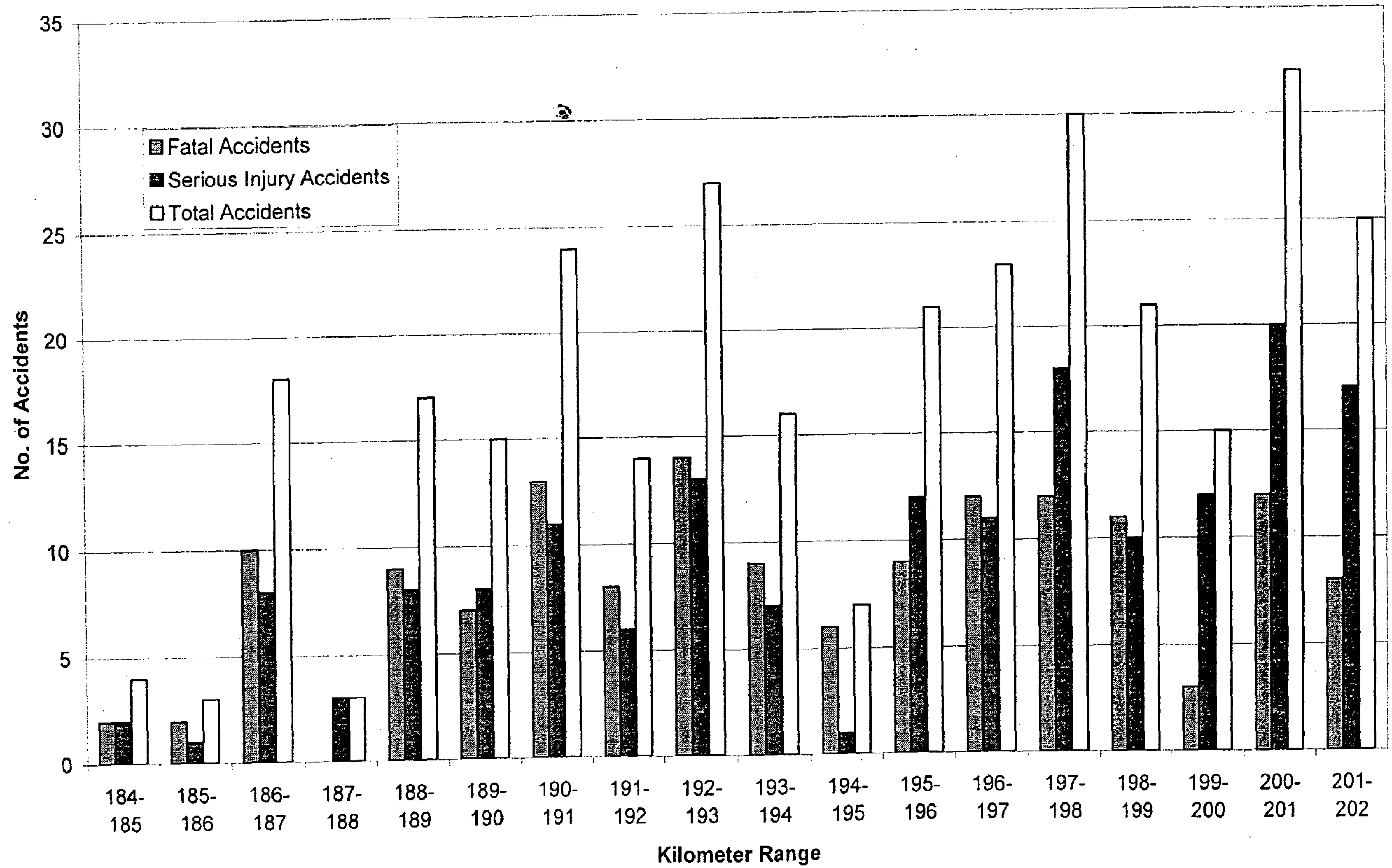


Fig: 5.1 (c) Km-wise Accidents on NH-58 (184-202)

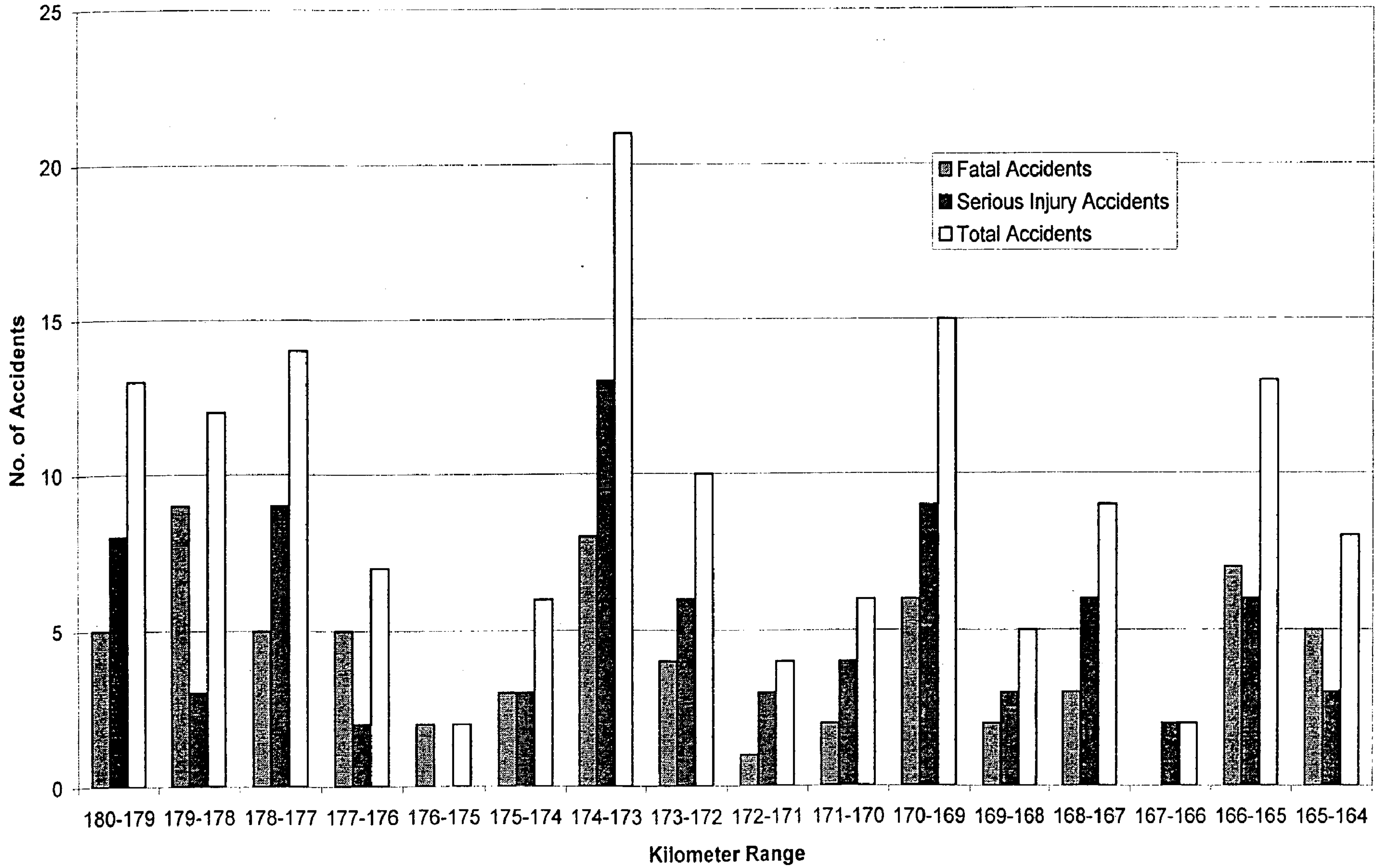


Fig: 5.1 (d) Km-wise Accidents on NH-73 (180-164)

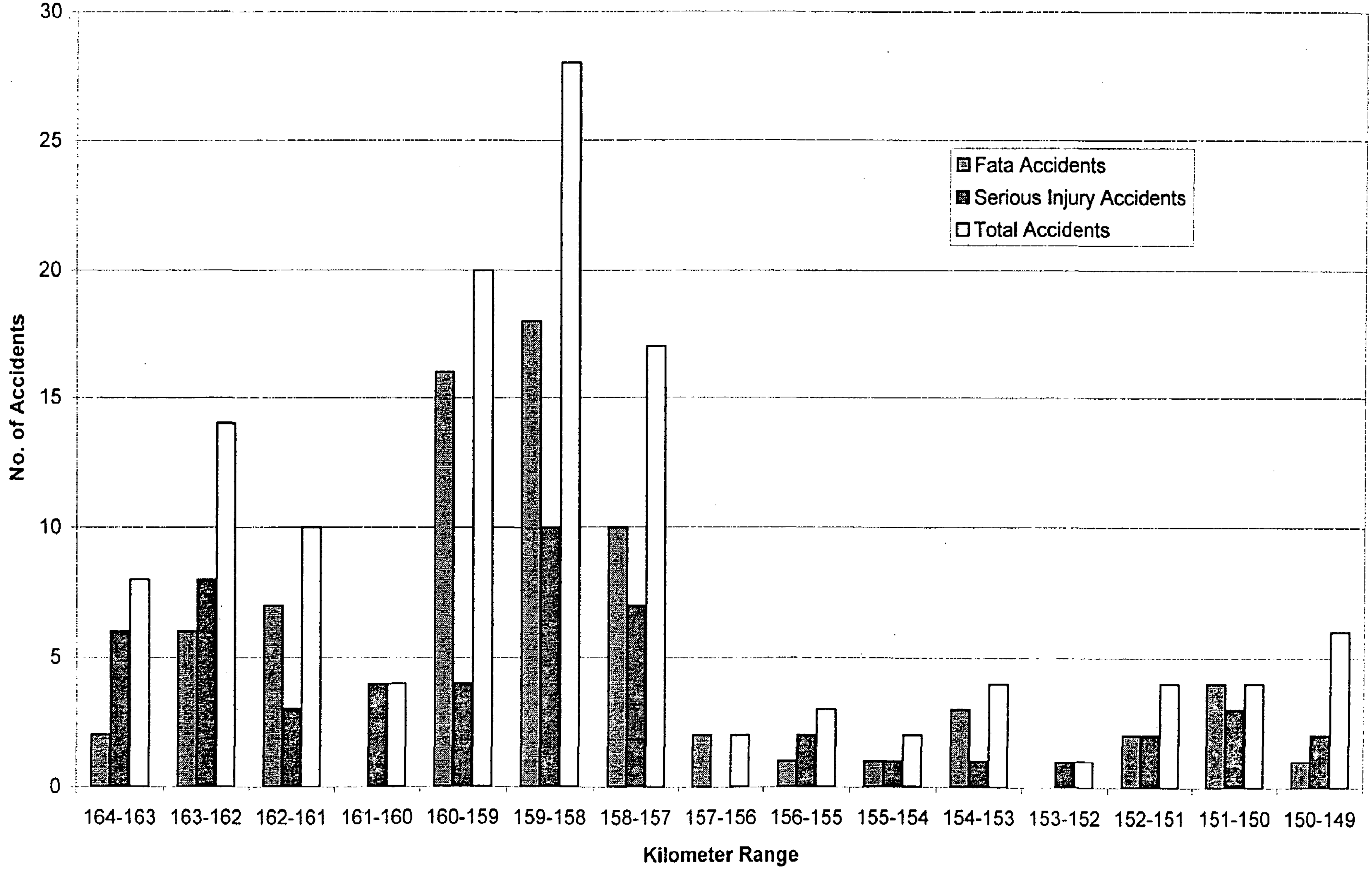


Fig: 5.1 (e) Km-wise Accidents on NH-73 (164-149)

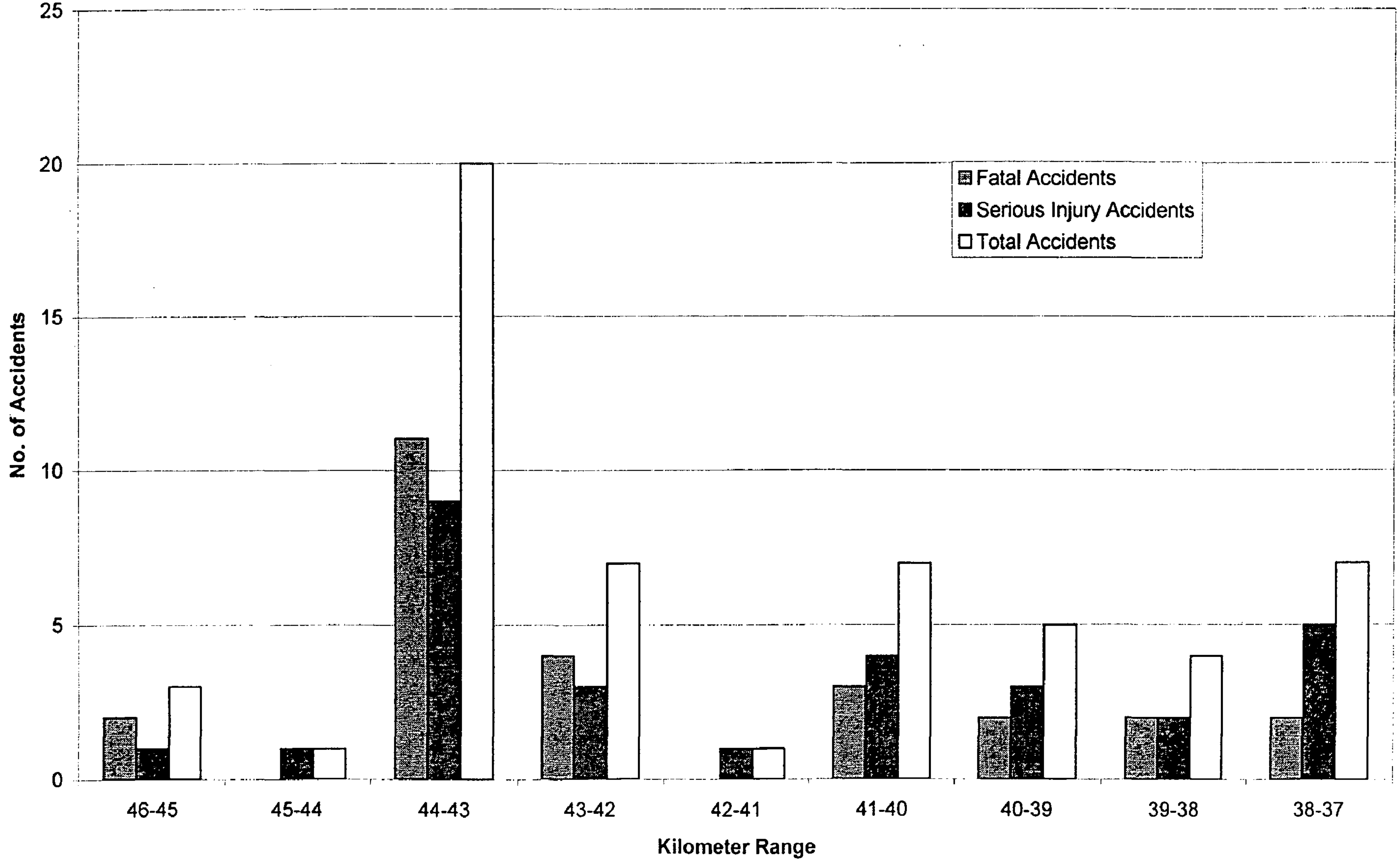


Fig: 5.1 (f) Km-wise Accidents on NH-72A (46-37)

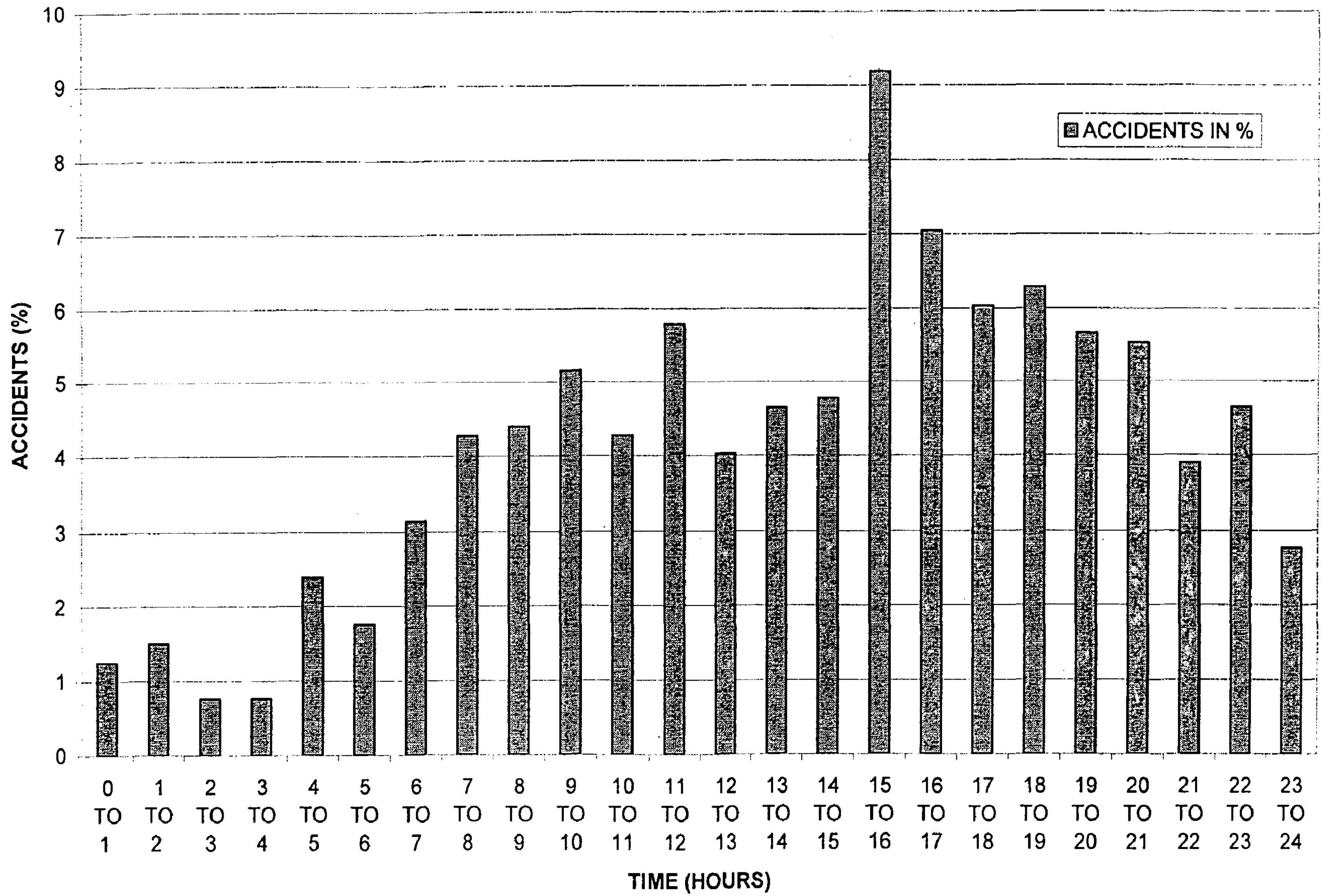


Fig: 5.2 TIME - WISE ACCIDENTS

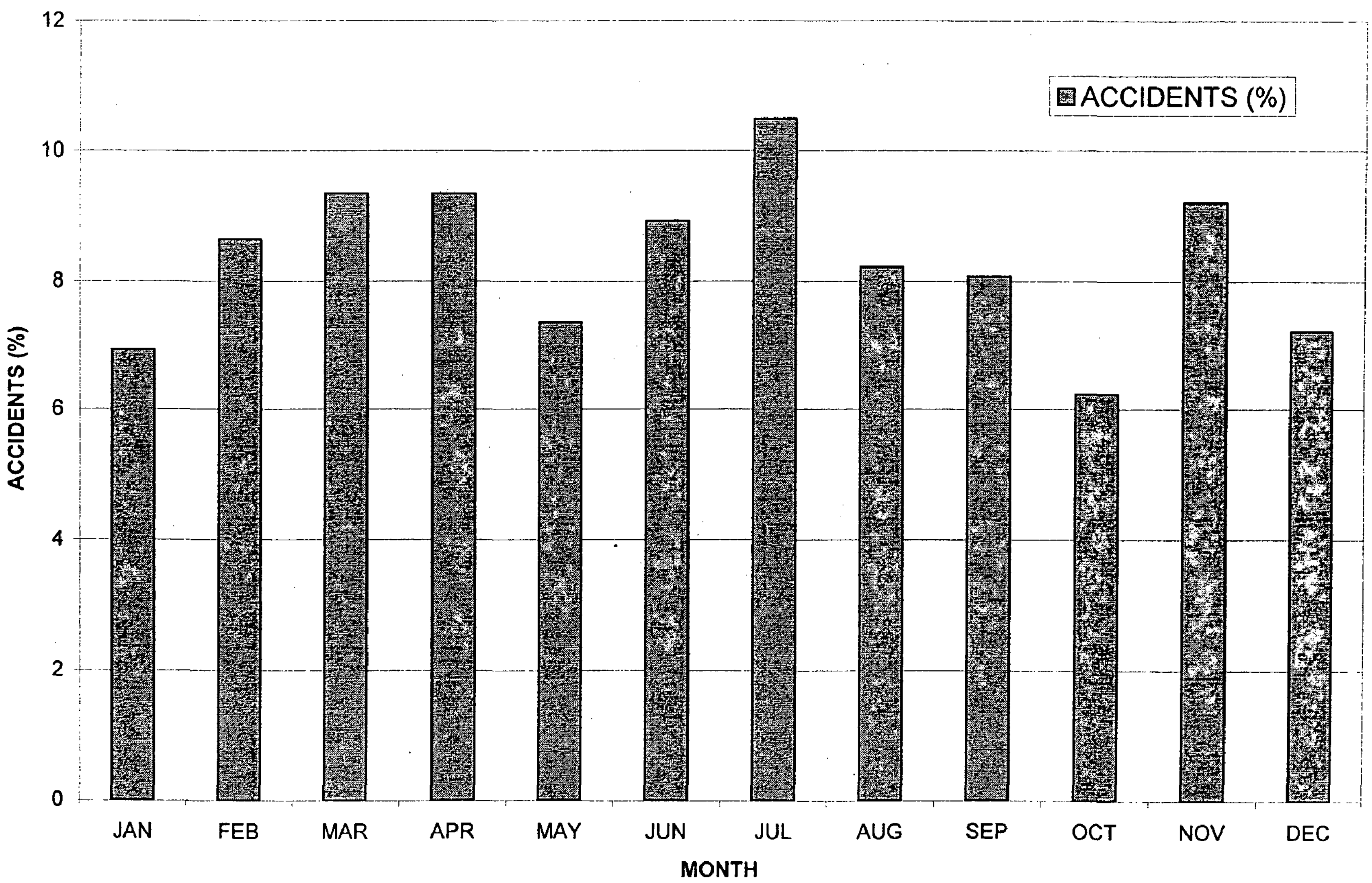


Fig: 5.3 MONTH WISE ACCIDENTS

TABLE: 5.1 (a) VICTIM V/S VEHICLE AT FAULT FOR NH-58

Victim	Vehicle at Fault							
	Bus	Truck	Jeep/ Car	Scooter/ M. Cycle	Unknown	Others	Total	%
Bus	7	21	4	1	1	3	37	4.32
Truck	10	16	5	2	0	1	34	3.97
Jeep/Car	44	79	13	2	2	18	158	18.46
Scooter/ M.Cycle	30	65	46	6	14	20	181	21.14
Cycle	20	46	29	8	8	15	126	14.72
Cycle Rickshaw	3	6	2	2	1	0	15	1.75
Pedestrian	26	56	35	25	44	22	208	24.30
Unknown	4	10	3	1	3	4	25	2.92
Others	34	19	8	1	2	9	73	8.53
Total	178	318	145	48	75	92	856	-
%	20.79	37.15	16.94	5.61	8.76	10.75	-	100

TABLE: 5.1 (b) VICTIM V/S VEHICLE AT FAULT FOR NH-73 AND 72A

Victim	Vehicle at Fault							
	Bus	Truck	Jeep/ Car	Scooter/ M. Cycle	Unknown	Others	Total	%
Bus	0	8	0	0	0	0	8	3.56
Truck	5	1	0	0	0	0	6	2.67
Jeep/Car	11	12	2	2	1	11	39	17.33
Scooter/ M.Cycle	7	15	3	2	2	7	36	16
Cycle	23	6	4	4	2	2	41	18.22
Cycle Rickshaw	0	1	1	0	0	1	3	1.33
Pedestrian	9	8	6	7	16	4	50	22.22
Unknown	2	0	1	0	1	0	4	1.78
Others	9	13	2	0	0	14	38	16.89
Total	66	64	19	15	22	39	225	-
%	29.33	28.44	8.44	6.67	9.78	17.33	-	100

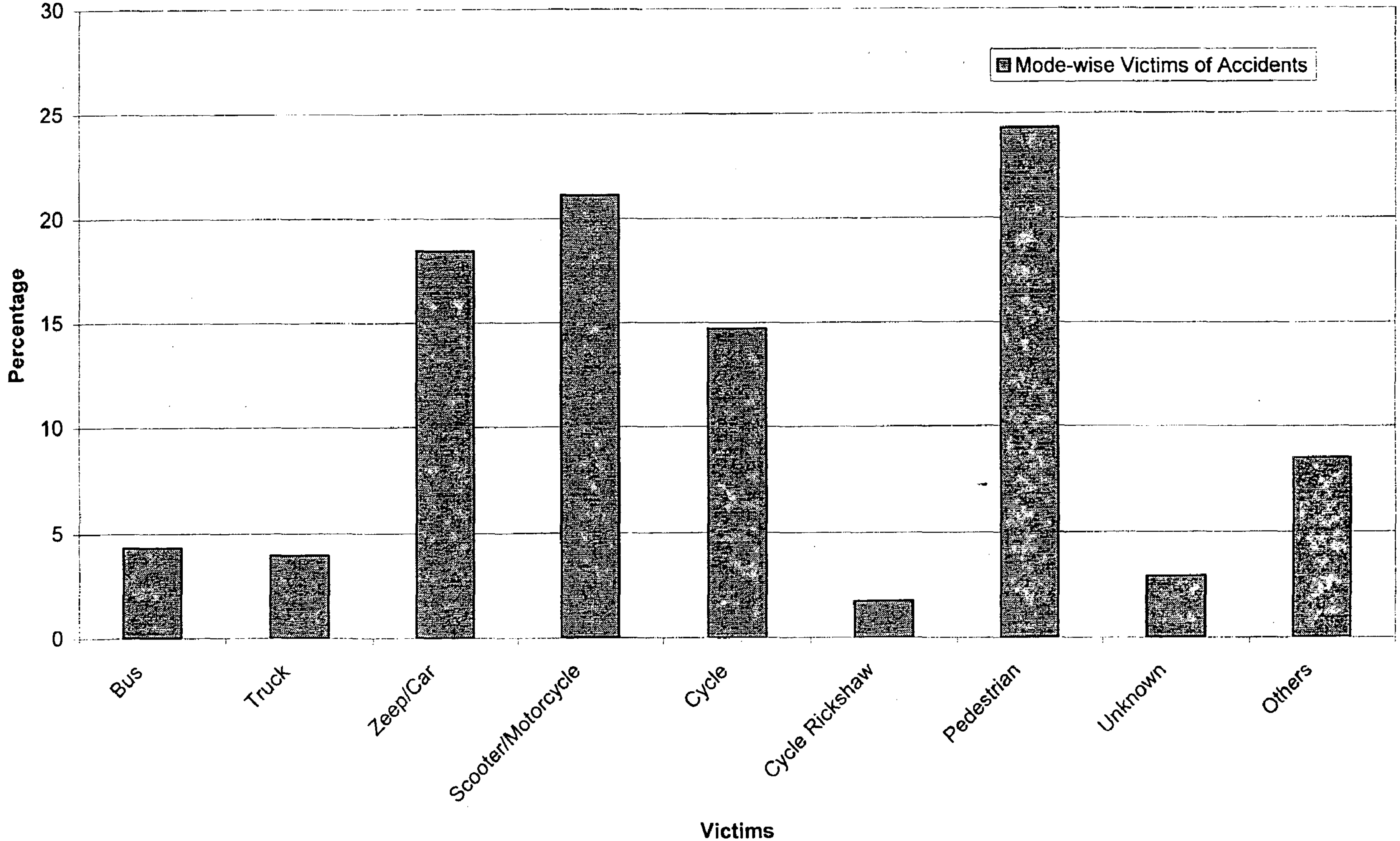


Fig: 5.4 (a) Mode-wise Victims of Accident on NH-58 (in %)

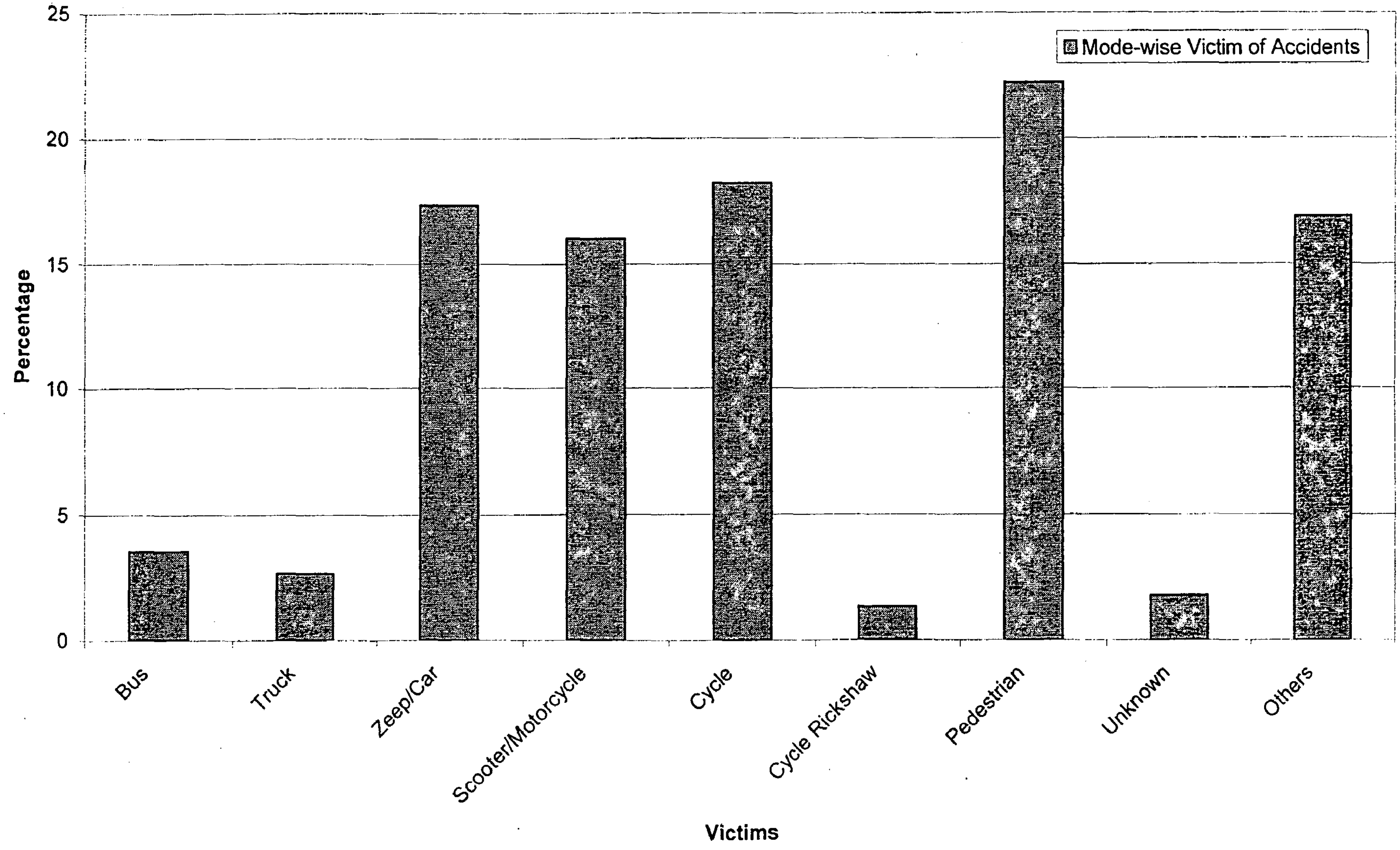


Fig: 5.4 (b) Mode-wise Victim of Accidents on NH-73 & 72A (in %)

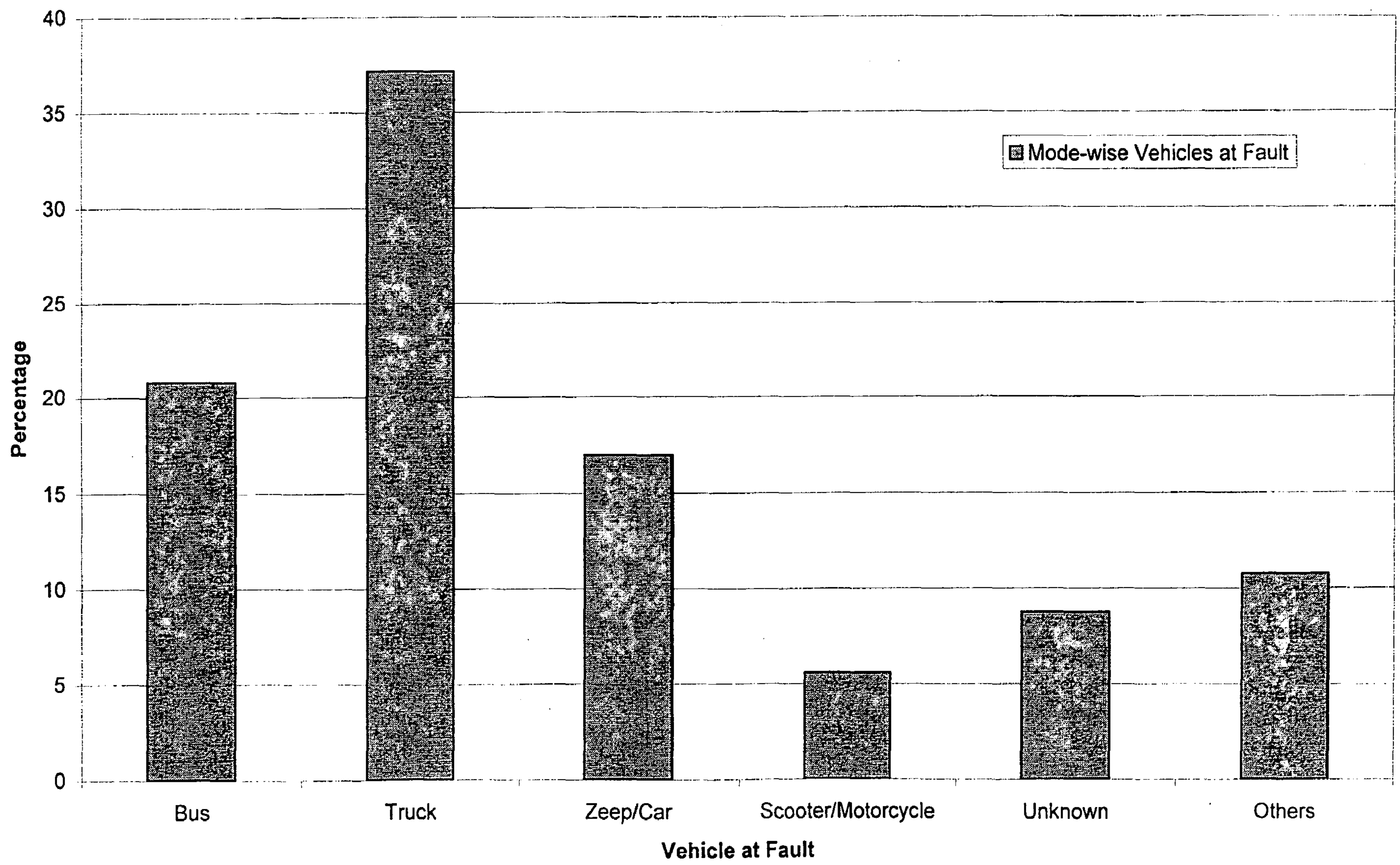


Fig: 5.5 (a) Mode-wise Vehicles at Fault at NH-58 (in %)

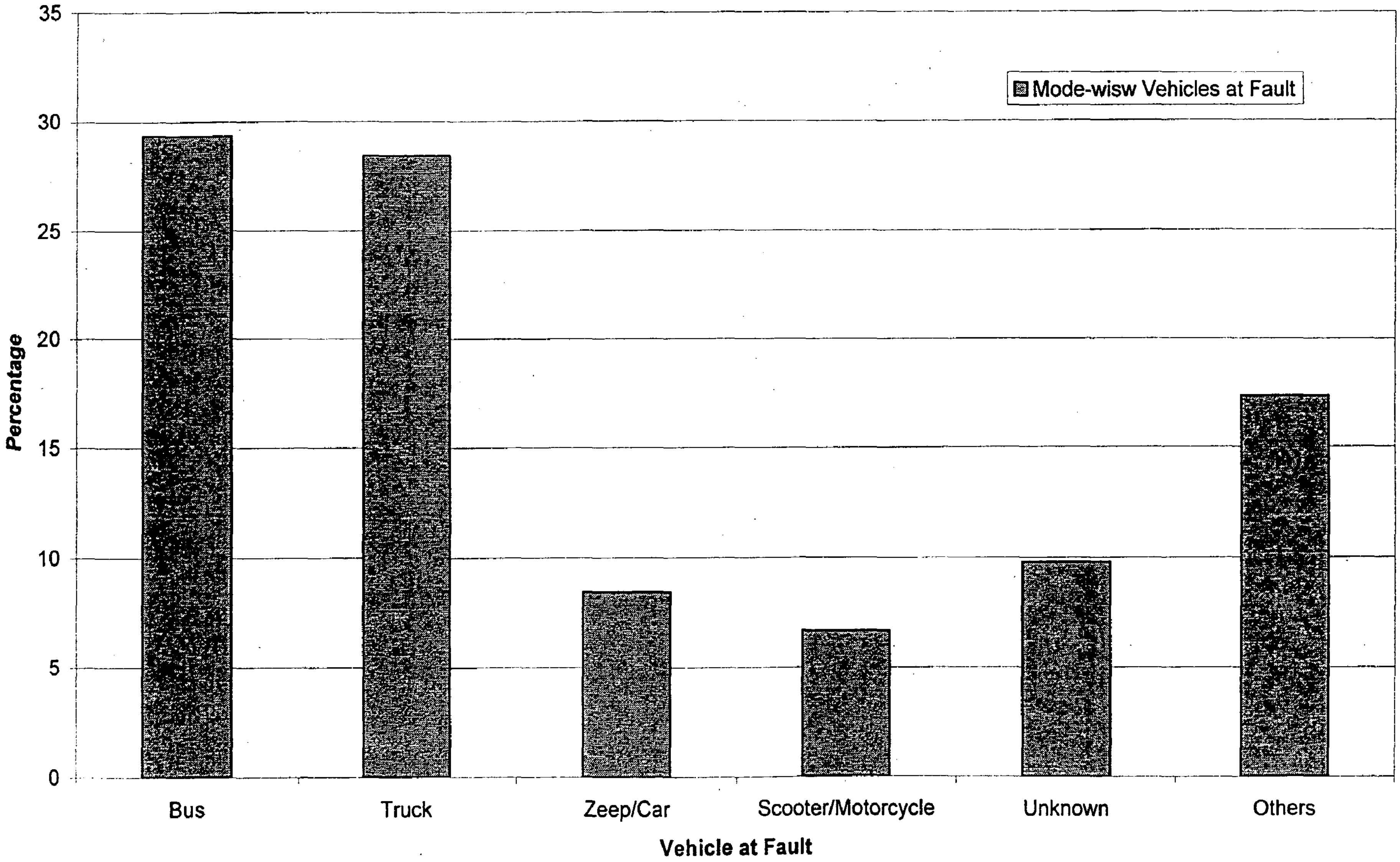


Fig: 5.5 (b) Mode-wise Vehicles at Fault at NH-73 & 72A (in %)

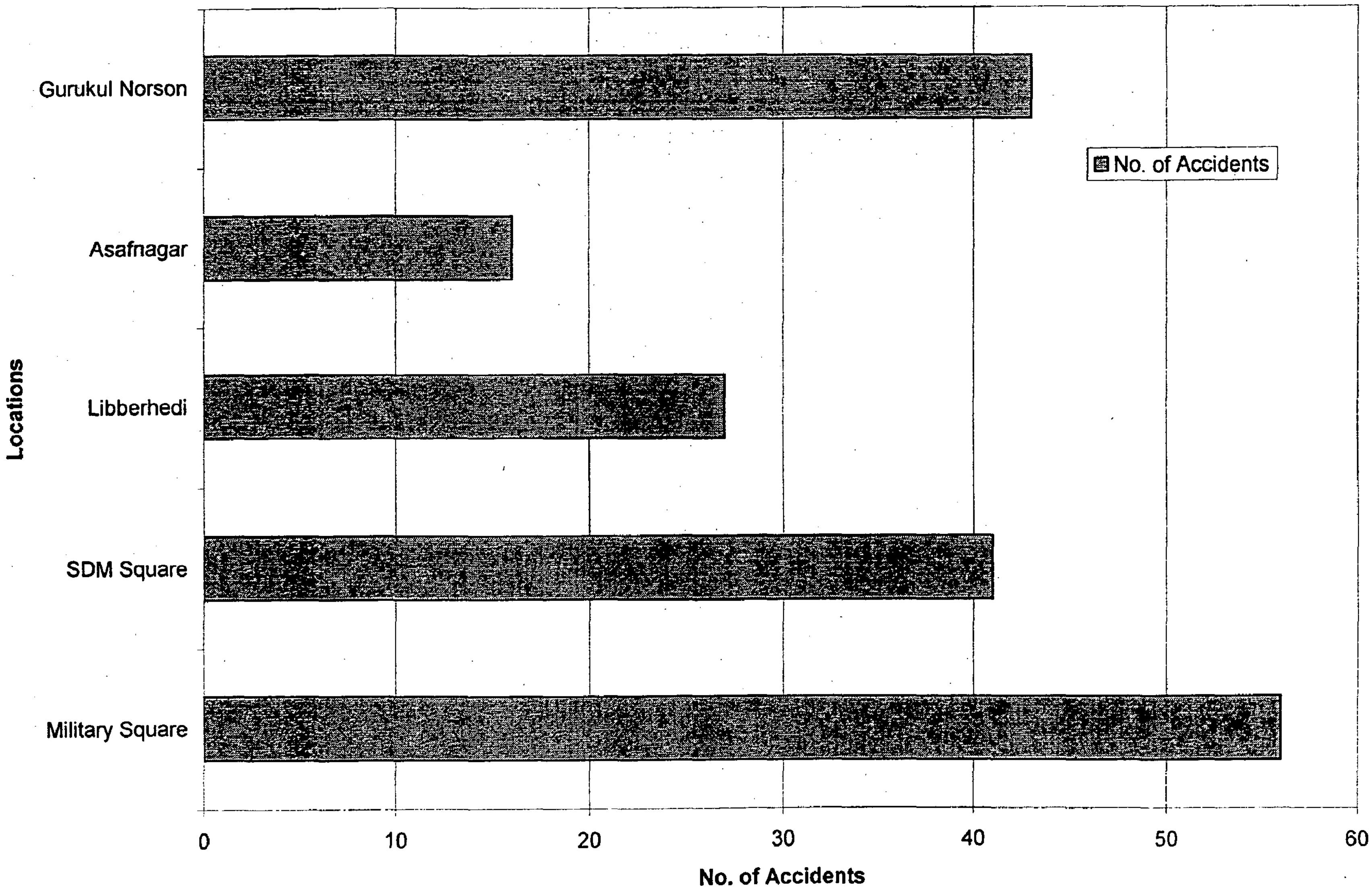


Fig: 5.6 (a) Accident Locations-Roorkee to Mangalore

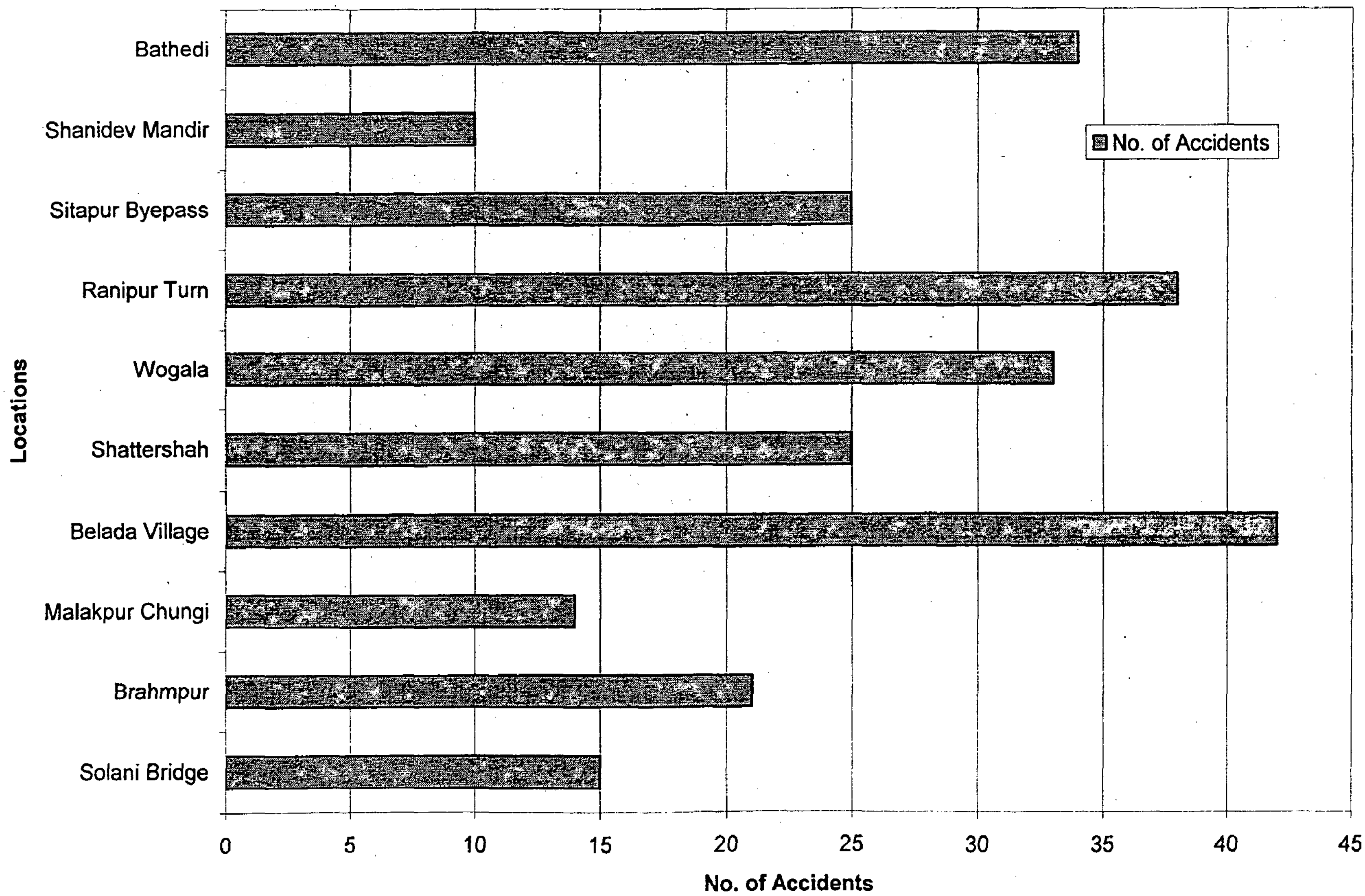


Fig: 5.6 (b) Accident Locations-Roorkee to Hardwar

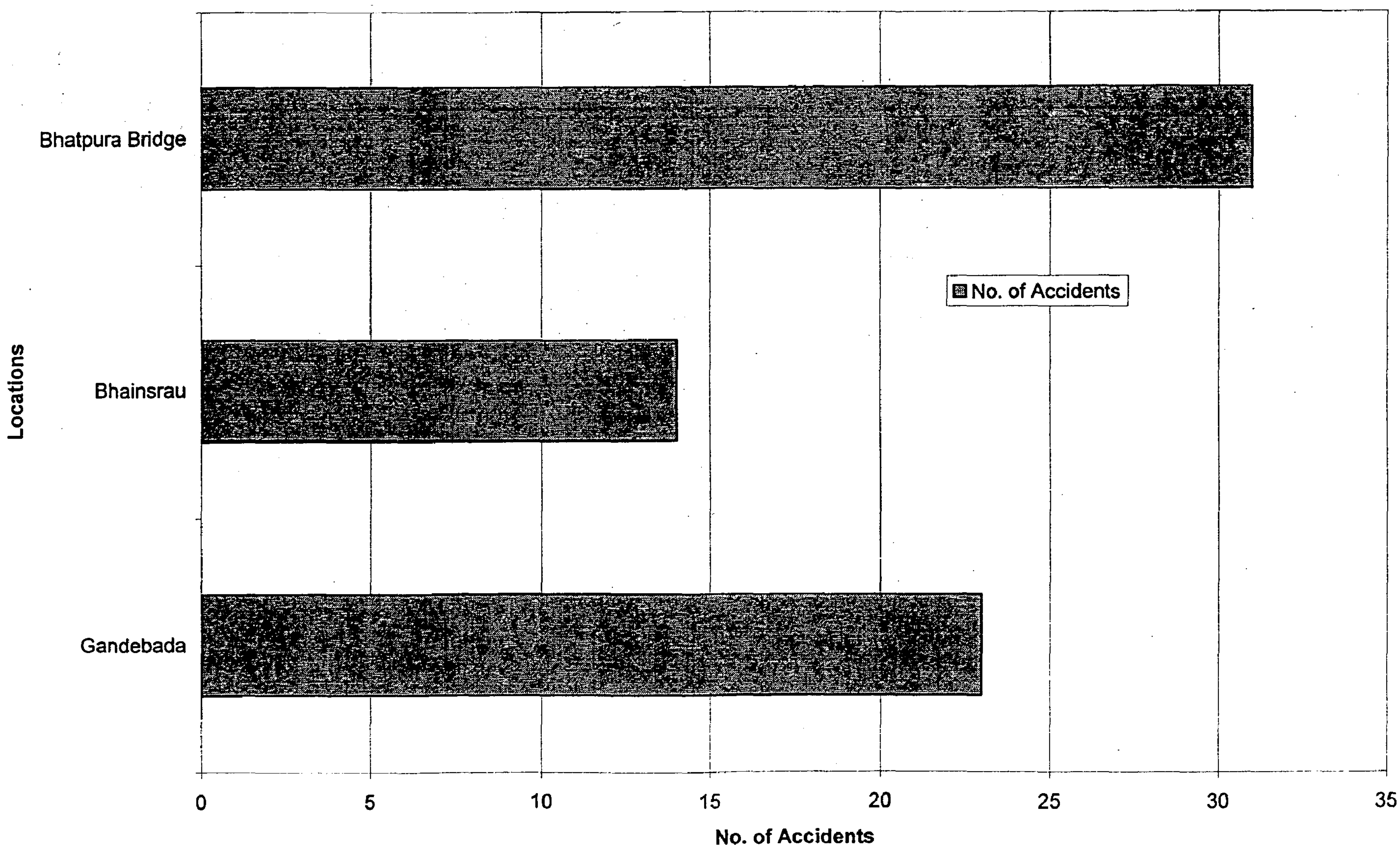


Fig: 5.6 (c) Accident Locations-Roorkee to Chhutmalpur

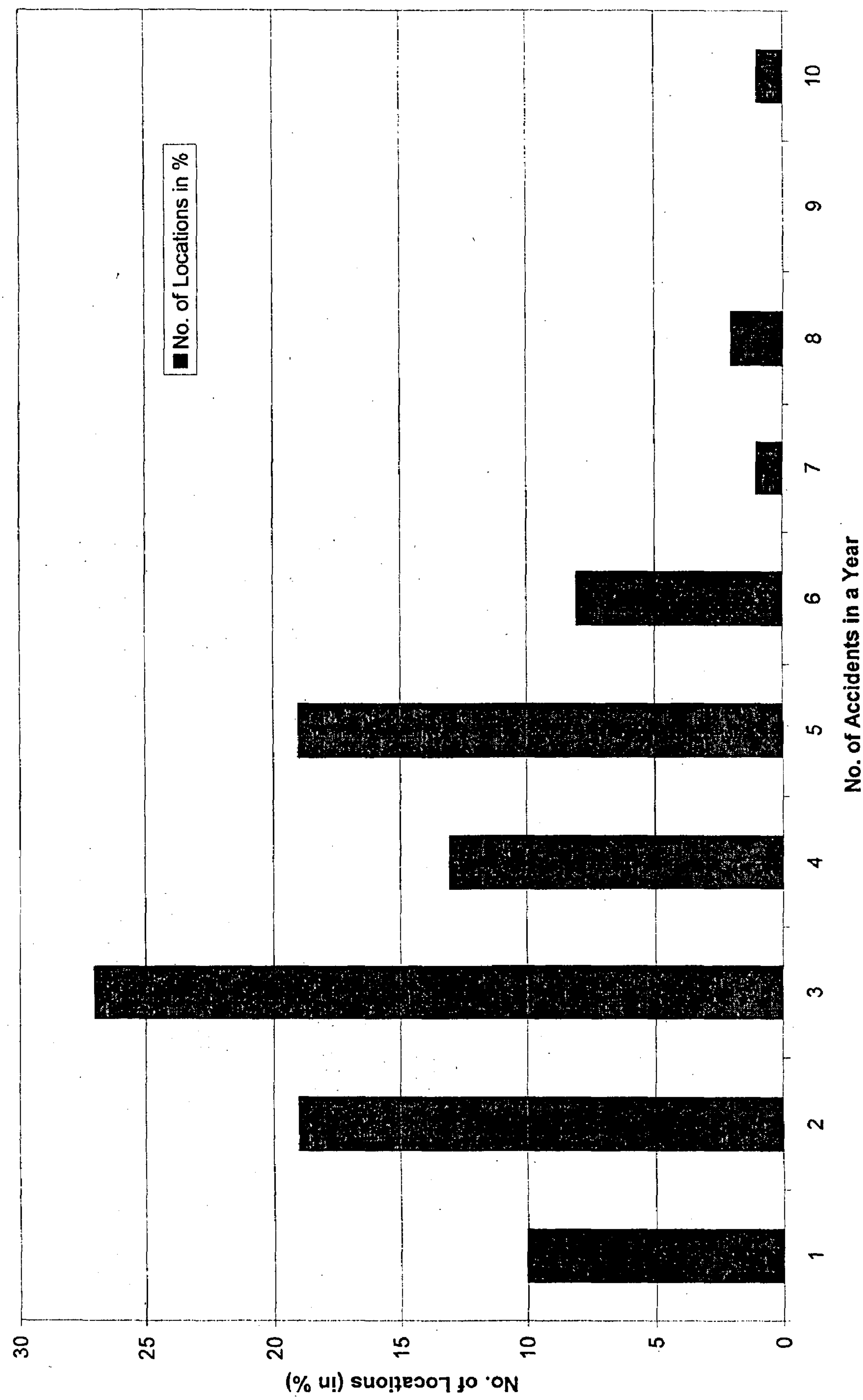


Fig: 5.7 Accident Frequency Distribution (in %)

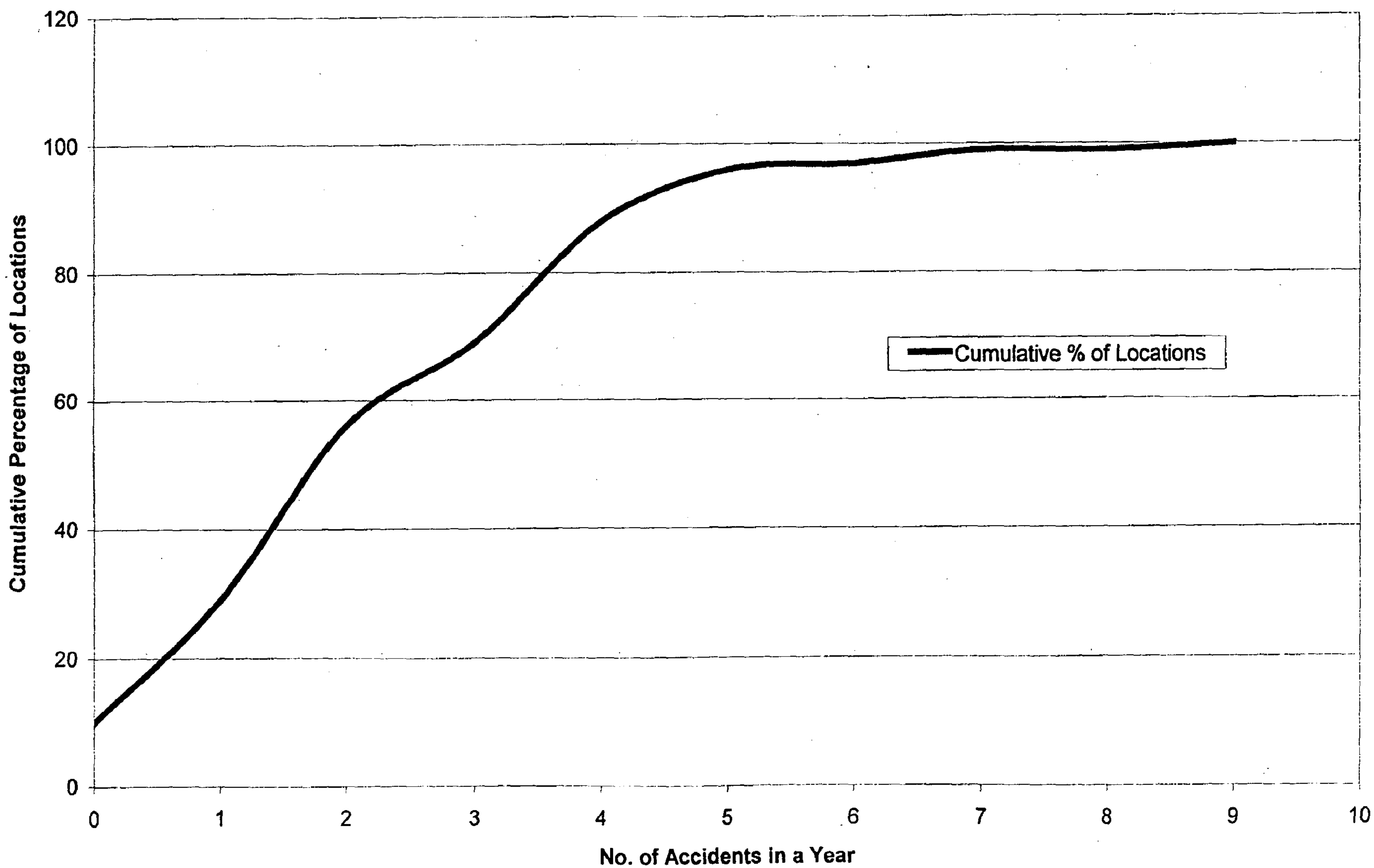


Fig: 5.8 Cumulative Distribution of Accidents

5.5 Identification of Accident Black Spots

All the stretches of the three selected National Highways has been divided into sections of one kilometers and following four parameters have been calculated for each section:

(a)Accident rate (AR)

(b)Accident fatality rate (AFR)

(c) Accident severity index (ASI)

(d) Accidents per 1, 00,000 veh.km

For all the four parameters, threshold values have been calculated and the sections which exceed the threshold value for any of the above parameters have been identified as accident prone. Detailed calculations are shown in Table 5.2 and the threshold values have been presented in Table 5.3. On the basis of this analysis, 13 sections of one km each have been identified as Accident Prone Stretches and are given in Table 6.1.

Any location, whether link or node, is declared as an Accident Black Spot if four or more accidents occur in one year in an area of 0.1 km^2 on the highway.

In this analysis, Accident Rate, Accident Fatality Rate and Accident Severity Index have been considered to identify Accident Black Spots. A location has been declared as an Accident Black Spot if any one or more than one of the selected parameters exceed their respective threshold values. Detailed calculations are shown in Table 5.5 and the threshold values are given in Table 5.6. As a result of this analysis, seven Accident Black Spots have been identified and are given in Table 6.2.

Table 5.2 Km-wise Analysis of Accidents

Serial No.	National Highway No.	Section Length	Km Range	ASI	Average Value		Accident Rate	Fatality Rate	Traffic Volume (2002)	No. of Accidents/ 1,00,000 veh.km
					Total Accidents	Fatalities				
1	58	1 km	152-153	6.6	13	10	1.3	1.0	12990	10.01
2	58	1 km	153-154	2.7	5	4	0.5	0.4	12990	3.85
3	58	1 km	154-155	10.2	22	19	2.2	1.9	12990	16.94
4	58	1 km	155-156	1.5	3	2	0.3	0.2	12990	2.31
5	58	1 km	156-157	3.9	8	6	0.8	0.6	12990	6.16
6	58	1 km	157-158	1.2	2	3	0.2	0.3	12990	1.54
~~**7**~~	~~58~~	~~1 km~~	~~158-159~~	~~**15**~~	~~31~~	~~37~~	~~**3.1**~~	~~**3.7**~~	~~12990~~	~~**23.87**~~
8	58	1 km	159-160	3.3	8	4	0.8	0.4	12990	6.16
9	58	1 km	160-161	3.6	7	5	0.7	0.5	12990	5.39
10	58	1 km	161-162	9	15	12	1.5	1.2	12990	11.55
11	58	1 km	162-163	4.8	10	6	1.0	0.6	12990	7.7
12	58	1 km	163-164	7.8	15	16	1.5	1.6	12990	11.55
13	58	1 km	164-165	6.9	14	10	1.4	1.0	12990	10.78
14	58	1 km	165-166	7.8	20	10	2.0	1.0	12990	15.4
15	58	1 km	166-167	6.9	17	7	1.7	0.7	12990	13.09
16	58	1 km	167-168	2.4	7	1	0.7	0.1	12990	5.39
17	58	1 km	168-169	8.4	8	14	1.8	1.4	12990	13.86
18	58	1 km	169-170	6	13	9	1.3	0.9	12990	10.01
19	58	1 km	170-171	5.4	11	9	1.1	0.9	12990	8.47
20	58	1 km	171-172	10.5	21	18	2.1	1.8	12990	16.17
21	58	1 km	172-173	**21.6**	54	20	**5.4**	2.0	12990	**41.57**
22	58	1 km	173-174	12.6	32	10	**3.2**	1.0	12990	**24.63**
23	58	1 km	174-175	5.1	12	6	1.2	0.6	12990	9.24
24	58	1 km	175-176	10.2	24	9	**2.4**	0.9	12990	18.48
25	58	1 km	176-177	10.5	22	15	2.2	1.5	12990	16.94
26	58	1 km	177-178	12	20	19	2.0	1.9	12990	15.40
27	58	1 km	178-179	7.8	16	13	1.6	1.3	12990	12.32
28	58	1 km	179-180	6	14	7	1.4	0.7	12990	10.78
29	58	1 km	180-181	**13.8**	24	23	**2.4**	**2.3**	12990	18.48
30	58	1 km	181-182	7.2	16	9	1.6	0.9	12990	12.32
31	58	1 km	182-183	6.6	14	8	1.4	0.8	12990	10.78
32	58	1 km	183-184	4.5	9	8	0.9	0.8	12990	6.93
33	58	1 km	184-185	1.8	4	2	0.4	0.2	12990	3.08
34	58	1 km	185-186	1.5	3	3	0.3	0.3	12990	2.31
35	58	1 km	186-187	8.4	18	12	1.8	1.2	12990	13.86
36	58	1 km	187-188	0.9	3	0	0.3	0	12990	2.31
37	58	1 km	188-189	7.8	17	12	1.7	1.2	12990	13.09

38	58	1 km	189-190	6.6	15	11	1.5	1.1	12990	11.55
39	58	1 km	190-191	11.1	24	26	**2.4**	2.6	12990	13.48
40	58	1 km	191-192	6.6	14	7	1.4	0.7	12990	10.78
41	58	1 km	192-193	12.3	27	18	**2.7**	1.8	12990	20.79
42	58	1 km	193-194	7.5	16	9	1.6	0.9	12990	12.32
43	58	1 km	194-195	3.9	7	9	0.7	0.9	12990	5.39
44	58	1 km	195-196	9	21	12	2.1	1.2	12990	16.17
45	58	1 km	196-197	10.5	23	18	2.3	1.8	12990	17.71
46	58	1 km	197-198	12.6	30	13	3.0	1.3	12990	23.09
47	58	1 km	198-199	9.6	21	13	2.1	1.3	12990	16.17
48	58	1 km	199-200	5.4	15	5	1.5	0.5	12990	11.55
49	58	1 km	200-201	13.2	32	12	**3.2**	1.2	12990	**24.63**
50	58	1 km	201-201	9.9	25	9	**2.5**	0.9	12990	19.24
51	73	1 km	180-179	5.4	13	7	1.3	0.7	7840	16.58
52	73	1 km	179-178	6.3	12	10	1.2	1.0	7840	15.03
53	73	1 km	178-177	5.7	14	6	1.4	0.6	7840	17.86
54	73	1 km	177-176	3.6	7	6	0.7	0.6	7840	8.93
55	73	1 km	176-175	1.2	2	3	0.2	0.3	7840	2.55
56	73	1 km	175-174	2.7	6	4	0.6	0.4	7840	7.65
57	73	1 km	174-173	**8.7**	21	16	**2.1**	1.6	7840	**26.79**
58	73	1 km	173-172	4.2	10	6	1.0	0.6	7840	12.76
59	73	1 km	172-171	1.5	4	2	0.4	0.2	7840	5.1
60	73	1 km	171-170	2.4	6	2	0.6	0.2	7840	7.65
61	73	1 km	170-169	6.3	15	8	1.5	0.8	7840	19.13
62	73	1 km	169-168	2.1	5	3	0.5	0.3	7840	6.38
63	73	1 km	168-167	3.6	9	3	0.9	0.3	7840	11.48
64	73	1 km	167-166	0.6	2	0	0.2	0	7840	2.55
65	73	1 km	166-165	6	13	10	1.3	1.0	7840	16.58
66	73	1 km	165-164	3.9	8	9	0.8	0.9	7840	10.04
67	73	1 km	164-163	3	8	2	0.8	0.2	7840	10.04
68	73	1 km	163-162	6	14	7	1.4	0.7	7840	17.86
69	73	1 km	162-161	5.1	10	9	1.0	0.9	7840	12.76
70	73	1 km	161-160	1.2	4	0	0.4	0	7840	5.1
71	73	1 km	160-159	**10.8**	20	42	**2.0**	**4.2**	7840	**25.51**
72	73	1 km	159-158	**13.8**	28	26	**2.8**	**2.6**	7840	**35.71**
73	73	1 km	158-157	8.1	17	12	1.7	1.2	7840	21.68
74	73	1 km	157-156	1.2	2	5	0.2	0.5	7840	2.55
75	73	1 km	156-155	1.2	3	1	0.3	0.1	7840	3.82
76	73	1 km	155-154	0.9	2	1	0.2	0.1	7840	2.55
77	73	1 km	154-153	2.1	4	4	0.4	0.4	7840	5.1
78	73	1 km	153-152	0.3	1	0	0.1	0	7840	1.26
79	73	1 km	152-151	1.8	4	3	0.4	0.3	7840	5.1
80	73	1 km	151-150	1.5	4	4	0.4	0.4	7840	5.1
81	73	1 km	150-149	3	6	7	0.6	0.7	7840	7.65
82	72A	1 km	46-45	1.5	3	3	0.3	0.3	6550	4.58
83	72A	1 km	45-44	0.3	1	0	0.1	0	6550	1.53
84	72A	1 km	44-43	**9.3**	20	15	**2.0**	**1.5**	6550	**30.54**
85	72A	1 km	43-42	3.3	7	7	0.7	0.7	6550	10.69

86	72A	1 km	42-41	0.3	1	0	0.1	0	6550	1.53
87	72A	1 km	41-40	3	7	4	0.7	0.4	6550	10.69
88	72A	1 km	40-39	2.1	5	2	0.5	0.2	6550	7.63
89	72A	1 km	39-38	1.8	4	5	0.4	0.5	6550	6.11
90	72A	1 km	38-37	2.7	7	3	0.7	0.3	6550	10.69

TABLE 5.3: Mean, Standard Deviation and Threshold Values of Selected Parameters

Parameter	Mean			Standard Deviation			Threshold Value		
	NH 58	NH 73	NH 72A	NH 58	NH 73	NH 72A	NH 58	NH 73	NH 72A
Accident Rate	1.66	0.88	0.61	0.95	0.65	0.57	2.37	1.85	1.47
Fatality Rate	1.08	0.70	0.43	0.68	0.83	0.46	2.10	1.94	1.12
Accident Severity Index	7.61	4.01	2.7	4.07	3.13	2.69	13.71	8.70	6.74
Accidents/ 1,00,000veh.km	12.81	11.25	9.33	7.30	8.22	8.75	23.76	23.58	22.46

Table 5.4 Location-wise Analysis of Accidents

S. No.	Location	Km	NH No.	Accidents		AR	Fatality	AFR	ASI
				Fatal	Severe Injury				
1	Gurukul Norson	152.2-152.6	58	26	18	**4.4**	31	**3.1**	**21.0**
2	Mandawali	158.6-158.9	58	5	9	1.4	6	0.6	5.7
3	Tashipur	160.3-160.5	58	7	8	1.5	9	0.9	6.6
4	Libberhedi	161.3-161.5	58	10	18	2.8	12	1.2	11.4
5	Bijhauli	162.3-162.5	58	7	6	1.3	7	0.7	6.0
6	Manglore Town	165.1-165.4	58	6	8	1.4	8	0.8	6.0
7	Peerpura	167.8-168.2	58	4	6	1.0	5	0.5	4.2
8	Asafnagar	169.3-169.5	58	11	6	1.7	13	1.3	8.4
9	Military Square	173.2	58	31	25	**5.6**	42	**4.2**	**26.1**
10	SDM Square	173.6	58	15	26	**4.1**	17	1.7	16.8
11	Malakpur Chungi	175.1	58	6	8	1.4	7	0.7	6.0
12	Solani Bridge	176.1	58	11	4	1.5	20	2.0	7.8
13	Shanidev Mandir	177.6	58	4	6	1.0	6	0.6	4.2

14	Brahmpur	178.1	58	13	8	2.1	16	1.6	10.2
15	Belada	180.2-180.6	58	17	25	**4.2**	20	2.0	17.7
16	Bathedi	184.1-184.6	58	23	11	3.4	34	**3.4**	17.1
17	Shattarshah	186.1-186.4	58	14	11	2.5	19	1.9	11.7
18	Wogala	191.3-191.8	58	24	9	3.3	33	**3.3**	17.1
19	Ranipur Turn	192.4	58	21	17	3.8	32	**3.2**	17.7
20	Shamshan Ghat	194.5	58	4	9	1.3	7	0.7	5.1
21	Railway Fatak, Sitapur	197.5	58	3	7	1.0	4	0.4	3.9
22	Sitapur Bypass	198.3	58	30	12	2.5	16	1.6	11.4
23	Mangal Singh Chowk	200.4	58	4	7	1.1	4	0.4	4.5
24	Shanker Ashram	200.9	58	9	4	1.3	13	1.3	6.6
25	Ram Nagar Square	179.3	73	4	8	1.2	5	0.5	4.8
26	Idgah Square	176.2	73	5	6	1.1	7	0.7	4.8
27	Saliar	173.4-173.6	73	11	7	1.8	16	1.6	8.7
28	Puhana	171.6-171.9	73	8	4	1.2	9	0.9	6.0
29	Bhainsrau	159.5-159.7	73	7	7	1.4	8	0.8	6.3

30	Gandewada	158.4-158.6	73	9	14	2.3	11	1.1	9.6
31	Bhatpura Bridge	43.2	72A	19	12	3.1	28	2.8	15.0

Table 5.5 Mean, Standard Deviation and Threshold Values

Parameter	Mean	Standard Deviation	Threshold Value
Accident Rate	2.18	1.21	4.0
Fatality Rate	1.5	1.03	3.03
Accident Severity Index	9.95	5.73	18.55

5.6 Remedial Measures

Remedial measures need to be undertaken for all the accident prone stretches and locations. Through onsite investigation causes of recurring accidents have been identified and accordingly remedial measures have been suggested. Remedial measures for three sample accident prone locations are presented in Table 5.6. However, it is recommended that detailed engineering investigations need to be undertaken for these sites before working out these remedial measures.

Table 5.6 Remedial Measures Evolved

S. No.	Location	Km (NH 58)	No. of Accidents		Causes of Accident	Remedial Measures
			Fatal	Serious Injury		
1.	Military Square	173.2	31	25	**(a)** Sight distance for the traffic on minor road is inadequate. **(b)** Pedestrian volume is quite high.	**(a)** Improvement of alignment on minor road is required. **(b)** A rotary with median, channelisers is required.
2.	SDM Square	173.6	15	26	**(a)** Lot of movement of buses and trucks. **(b)** On street parking. **(c)** Presence of rickshaws etc.	**(a)** Bypass is required to reduce traffic in Roorkee urban area. **(b)** On street parking should not be allowed near intersections and bus-stand.

3.	Ranipur Turn	192.4	21	17	**(a)** Bad visibility in night. **(b)** Turning traffic is high.	**(a)** Proper illumination is required. **(b)** Modification of edge marking is required to warn road users.

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

From the present study, following conclusions have been drawn:

(1) On the basis of Accident Rate, Accident Fatality Rate, Accident Severity Index and Accident rate per 1,00,000 veh.km, following sections of 1 km each have been identified as accident prone and are given in Table 6.1

Table 6.1 Kilometer Sections Exceeding the Threshold Values

Serial No.	NH Number	Km Range
1	58	158-159
2	58	172-173
3	58	173-174
4	58	175-176
5	58	180-181
6	58	190-191
7	58	192-193
8	58	200-201
9	58	201-202
10	73	174-173
11	73	160-159
12	73	159-158
13	72A	44-43

The above sections have been identified at 95% confidence level and are based on last 10-years accident data.

(2) Following Accident Black Spots have been identified on NH-58, NH-73 and NH-72A on the basis of accident analysis and are given in Table 6.2

Table 6.2 Accident Prone Locations

S. No.	Location	Km	NH Number
1	Gurukul Norson	152.2-152.6	58
2	Military Square	173.2	58
3	SDM Square	173.6	58
4	Belada Village	180.2-180.6	58
5	Bathedi Village	184.1-184.6	58
6	Wogala Village	191.3-191.8	58
7	Ranipur Turn	195.1	58

(3) Victims of accidents on NH-58 are pedestrians (24.30%), scooterists/motorcyclists (21.14%) and passengers of jeep/car (18.46%) whereas on NH-73 and NH-72A victims are pedestrians (22.22%), cyclists (18.22%) and passengers of jeep/car (17.33%).

(4) Mode-wise analysis of vehicles at fault on NH-58 are truck (37.15%), bus (20.79%) and jeep/car (16.94%) whereas on NH-73 and NH-72A mode-wise vehicles at fault are bus (29.33%), truck (28.44%) and others (17.33%).

On NH-73 and NH-72A, others are quite significant as there are large number of animal drawn vehicles (ADV) and tractor trailers which have been considered into others.

(5) The peak period for accidents comes out as 3pm-5pm.

6.2 RECOMMENDATION

In police records, important informations like collision diagram and exact location of accident are not recorded. This information is vital in working out engineering improvement measures at accident prone locations. Effort be made to record each accident and design a data base with simplified data input performa. This will be useful to analyze the accidents in a rational manner to increase safety on roads.

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