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CAUSES OF ROAD TRAFFIC ACCIDENTS AND POSSIBLE COUNTER MEASURES ON ADDIS ABABA-SHASHEMENE ROADS

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ABSTRACT

Road traffic accidents occur as a result of several factors associated with the traffic system, namely: road users, road environment and vehicles. In year 2004/5, 93% of all accidents involved human factors, 5% accounted for vehicle factors, and 2% were associated with road environments according to the Federal police report. Despite having low road network density and vehicle ownership, Ethiopia has a relatively high accident records. In this regards, the traffic accident death rate per ten thousand motor vehicles in 2001/02-2004/5 was in the range of 129 and 145. Road accidents are concentrated in few of the regions in the country. The capital city of Addis Ababa and Oromia region account for 58 per cent of all fatal accidents and two thirds of all injuries.

This study is carried out to identify black spots and possible causes of road traffic accidents and to identify low cost engineering countermeasures. The research is done by reviewing road traffic growth, the existing legislative framework of road transport, and road traffic accidents for the last four years in the country. Previous studies were also reviewed having access to the information in other countries in order to understand the existing knowledge and experiences.

Road and traffic data were collected from fieldwork and accident data were gathered from pertinent police stations. Each accident spots was measured with reference to kilo meter post that is available in the Addis Ababa-Shashemene road. A total of 1108 reported accidents were collected out of which 309 were fatal accidents, 206 were serious injuries, and 86 were slight injuries and 507 were property damages.

Statistical analysis was made on the collected accident data. The characteristics of accident in built-up (towns) and non built up (rural) areas were tabulated and analyzed separately. Forty-six per cent of the accidents occurred in built-up areas, which covered only 17.7 percent of the study road length. Pedestrian accidents and multiple-vehicle accidents were dominated in urban areas. Single vehicle non-pedestrian and rollover accidents were higher in non-built-up areas. Fifty-two percent of the accidents occurred at tangent and level section of the roads. This is associated with speed limit violation. The results of the study indicated that increases in accident rates were highly associated with gradient and sharp curves. ADT, numbers of

lanes and grade have positive relationships with accident rates i.e. the section with less traffic, lanes and grades resulted in less accident rates whenever these variables increased.

Similarly, accidents were plotted using GIS software and nine accident black spots were identified. Out of these, six were on scheme roads and three were at intersections. Greater or equal to ninety percentile of accident rate for schemes and junctions were applied in order to select these dangerous sections. At ninety percentile, rate of accident was 3.459 Mvkm for scheme. Six road sections were found above either of the two accident rates. In case of junctions, ninety percentile was 0.728626 Mv junctions. Three spots had above the ninth percentile value and considered for in-depth study.

The main causes of accidents at black spots were identified to be unavailability of proper pedestrian facilities, high volume of pedestrian traffic, drivers' fatigue, lack of awareness of traffic rules and regulations, and violation of speed limit. In addition, densities of accidents per kilometer were verified as a function of access points in towns. Narrow bridges, inadequate sight distances at curves, road curvature, no proper traffic signs, and faded road markings are usually causes of accidents.

Finally, low cost engineering measures are recommended to reduce the number of road accidents at identified black spots and other sections. However, the effect should be evaluated after some period.

1. INTRODUCTION

Road traffic accidents occur as a result of several factors associated with the traffic system, namely: road users, road environment, and vehicles. In Ethiopia, in 2004/5, 93% of all accidents involved human factors, 5% accounted for vehicle factors, and 2% were associated with road environments according to the Federal police report.

1.1. Definition of the Problem

Road accident in Ethiopia is one of the worst accident records in the world, as expressed per 10, 000 vehicles. Moreover, road accidents are concentrated in Addis Ababa which is the capital city of Ethiopia and Oromia region accounting for 58 per cent of all fatalities and two-third of all injuries. TRL and Ross Silcock [2] reported that while Addis Ababa has the largest number of road accidents, Oromia has the largest number of fatalities. Oromia has two-third more fatal accidents than Addis Ababa. Not only the traffic accidents are concentrated in Addis Ababa city and Oromia region but also the volume of motorized traffic are very high as compared to the other parts of the country.

The Addis Ababa – Shashemene road is found in Oromia region. In 2004, it had an AADT of 9765 at Debre Ziet, 6257 at Modjo, 2694 at Ziway, and 1757 at Bulbula-Kuyera road sections in 2004. These AADTs are high when compared to other trunk roads in the country.

The Interim National Road Safety Coordination Office has made a study of identifying black spots along the road. However; as observed, the method they used in the study was not appropriate since black spot criteria were not developed and ranking of sites was not applied properly. In addition, the analysis of accidents on individual site was not conducted to identify the causes of road traffic accidents. Furthermore, the condition of existing road environment and traffic factors were not properly investigated and analyzed. As a result, the road segment is re-considered for an in-depth investigation due to highest fatality record accidents. Besides, as the Interim National Road Safety Coordination Office Report [1] indicated that the number of fatalities on the road was total of 505, injury accidents was 538 and property damages was 606 during 1993 -1995 (E.C) periods from Dukem to Tikur Wiha (Shashemene).

Compared to other road networks in the country, the geometry, the road condition, the topography and the like seem good. It was constructed recently with the funds donated by the European Union. However, the situation with regard to the accident the on the road is worst as compared to others in the country. Therefore, due attention should be given to the problem to be addressed.

1.2. Objectives of the Research

The research has the following three objectives:

(i) To identify locations with abnormally high number of road traffic accidents, that is probably at specific sites (section of roads) or spots;

(ii) To investigate possible causes of road accidents on black spots section; and

(iii) To propose low cost engineering counter measures.

1.3. Scope of the Research

The scope of the study was limited to Addis Ababa-Shashemene road, which is from Addis Ababa, 24+700 kilometers near to Akaki Customs checking point up to Melka Oda near to Shahemene city, 243+500 kilometers with a total length of 218.8 kilometers. Besides, the study focuses on its direction in identifying black spot and/or sections along the route. Countermeasures were proposed for most dangerous sections/spots only.

1.4. Organization of the Research

The report is organized in to six chapters. Chapter one is an introduction to the paper and contains statement of the problem, objectives, scope, organization of the report and limitation of the research. Chapter two presents an overview of the road transport network, road transport traffic growth and legislative framework of road transport in short. The current situation of the road safety in the country, the present accident situations and reasons for high number of road traffic accidents are reviewed and discussed in this chapter. In chapter three, more detailed literature review has been done. In Chapter four, the method used to conduct of the research is described and details of the method of the research work have been stipulated. In chapter five, characterizations of accidents were discussed and identification of black spot was done. In addition, analyses of black spots were undertaken in order to identify causes of accidents. Furthermore, the chapter incorporated identification of causes of accidents that is supported by site visit, in-depth investigation and engineering measures for black spots have been proposed for implementation. Finally, based on the analyses, and discussion, the research comes up with a general conclusion which is in chapter six.

1.5 Limitation of the Research

During the preparation of this document, the writer faced many problems such as finance to undertake the whole tasks as the university allotted very small money which was not sufficient. Regarding time constraint, interview was made with few drivers along the route.

Besides, since Traffic Police Officers were engaged in many tasks and were usually out of their offices, it was difficult to get them.

2. ROAD NETWORK AND TRAFFIC ACCIDENTS IN ETHIOPIA

2.1. Country Description

Ethiopia is located in the horn of Africa. The land area is 1.1 million square kilo meter and the 2005 population was about 75 million making population density about 70 persons per square kilo meter. Ethiopia became a land locked country after the independence of Eritrea in 1993.

The country is making a progress in economy. In 2005/06, real GDP growth reached 7.9 percent from a yearly average of 4.8 per cent since 1994/95. In year 2005, the country growth rate was 11.6 according to Economic Commission for Africa.

2.2. Road Network

There has been a lot of progress in road construction in recent years in the country, which improved land transport considerably. Table 2.1 shows progress in road network and road density between 1997 and 2005.

Table 2.1: Change in Road Network and Road Density (1997 – 2005)

Year	Population × 1000	Road Network (km)				Growth Rate (%)	Road Density	
		Asphalt	Gravel	/1000 popn.Rural	/1000sq. km Total		/1000 popn.	/ 1000 sq. km
1997	57717.4	3708	12162	10680	26550		0.46	24.14
1998	592110	3760	12240	11737	27237	4.5	0.46	25.22
1999	60983	3812	12250	12600	28662	3.3	0.47	26.06
2000	63108	3824	12250	15480	31554	10.1	0.50	28.69
2001	65742	3924	12467	16480	32871	4.2	0.50	29.88
2002	67953.1	4053	12564	16680	33297	1.3	0.49	30.27
2003	69093.9	4362	12340	17154	33856	1.7	0.49	30.78
2004	71560.8	4635	13905	17956	36496	7.8	0.51	33.18
2005	72584.3	4972	13640	18406	37018	1.4	0.51	33.60

Source: Ethiopian Roads Authority, Eight years assessment of RSDP, January 2006

The total road network of the country at the beginning of Road Sector Development Program (RSDP) in 1997 was about 26,550 km with a road density of 0.46 and 24.14 per 1000 people and square km of area respectively. Due to the construction of new gravel and regional roads during 9 years of RSDP, the total road network has increased to 37,018 km in 2005 with an average annual growth rate of 4.2% percent. With a total land area of 1.1 million sq. km, the 2005 population of 75,067,000 and a road network of 37,018 km, the current road density becomes 33.6km per 1000 sq. km and 0.49 km per 1000 people, indicating an increment of about 9.5 km and 0.03km from 1997 with respect to area and population respectively [28].

2.3. Road Traffic Growth

Increasing economic prosperity, with annual GDP growth of about 7% on average was achieved for the last 10 years. This, in turn, led to a rapid increase in the traffic volume over the past 4 years, as shown in Table 2.2.

Table: 2.2 Inspected and Registered Vehicles by Type and Size

Type of Vehicle	2001/02	2002/03	2003/04	2004/05	Average Annual Growth Rate
Private Cars	47562	51493	59812	59785	7.9
Station Wagon	6406	6936	8472	11887	22.9
Taxi Less Than 5 Seats	5077	5732	6714	6508	8.6
Taxi 5-12 Seat	6477	6757	5540	7996	7.3
Bus Less Than 30 Seats	8955	8844	8186	10539	5.6
Bus Above 30 Seats	2805	2729	2599	3613	8.8
Truck (Up To 70 QUNTL)	25578	25393	32517	34014	10
Truck (71-180 QUNTL)	12840	13824	10724	16430	8.8
Trailer	3605	3972	4530	6334	20.7
Truck Tractor	1378	1153	904	1736	8.0
Semi- Trailer	65	239	86	53	-6.6
Tanker	1421	1527	1052	1936	10.9
Trailer	693	741	450	1202	20.1
Semi-trailer	32	20	236	5	-46.1
Others	3005	3578	3985	4271	12.4
TOTAL	**125899**	**132938**	**145807**	**166309**	**9.7**
Growth rate per annum		**5.5**	**9.7**	**14.06**	

Source: Ethiopian Transport Authority, Annual report for Year 20004/05

The total number of vehicles experienced a steep rise, and in particular, station wagons and trailers contributed to a considerable vehicle population. The number of private cars increased annually at about 8% between 2001/2 and 2004/5. The number of station wagons jumped dramatically from 6406 in year 2001/2 to 11887 in year 2004/5 at the rate of about 23% per year. In 2001/2, private cars comprised about 38% of all inspected and registered vehicles and in 2004/05 it comprised about 36 % with the rest comprising 62% and 64% respectively.

2. 4. Legislative Framework of Road Transport in Ethiopia

The road traffic law of Ethiopia is too old and can't be applied to the current situation. From this perspective, the Roads Transport Authority has been reorganized as the Ethiopian Transport

Authority and it has now started revising the road transport regulations. In this regard, the Authority had hired a consultant to identify the short falls of the existing legislations and regulations which were introduced in different years. The consultant finalized and submitted the report to the Authority four year ago. The report has identified three problems in the Ethiopian Roads Transport Legislation [4]. Accordingly, the Road Transport Regulation Proclamation no. 14/1992, Definitions of Powers and Duties of the Central and Regional Executive Organs of the Transitional Government of Ethiopia Proclamation No. 41/1993, and Definition of Powers and Duties of the Executive Organs of Ethiopia Proclamation No. 4/1995 became susceptible to different interpretations and their practical implementation. This caused misunderstandings and controversies between the respective offices of the federal government and the regional states regarding the demarcation of the powers and duties between the Federal Road Transport Authority and Regional Road Transport Bureaus.

The second problem was the absence of activities to regularly update and consolidate the several road transport legislations that were issued from time to time since 1943. Several amendments, deletions and replacements were made but no systematic compilations of these legislations were made so far. This made it difficult for users to find and trace relevant legislations and to identify and determine which law or provision is still valid, amended, repealed or replaced. This statement is true regarding the following four groups of legislations in road transport activities in Ethiopia:

i) Laws on Identification, Registration and Inspection of Vehicles
   a) Declaration of Motor Vehicles Proclamation No. 11/1942;
   b) Motor Vehicle and Trailer (identification, registration and inspection) Regulation No.360/1969;
   c) Motor Vehicles and Trailer (identification, inspection and regulation) Regulations Amendment No.77/1983; and
   d) Special Commercial Vehicle Registration and Operator's License Regulations No. 50/1976.

ii) Legislations on Motor Vehicle Operator's (driving) License
   a) Motor Vehicle Operator's (License) Regulations No.362/1969;
   b) Motor Vehicle Operator's License (amendment) Regulations No.41/1976; and

c) Special Mobile Equipment Identification and Operator's License Regulations No. 50/1976.

iii) <u>Legislations on Traffic Control</u>

a) Transport Regulations Legal Notice No.16/1943;

b) Transport (amendment) Regulations no.37/1943

c) Transport (amendment) Regulations no.279/1963;

d) Transport (carriage) Regulations no.28/1943; and

e) The Road Traffic (Speed Limit) Regulation No. 361/1969

iv) <u>Legislations on Vehicle Size and Weight</u>

a) Vehicle Size and Weight Regulations No 261/1962; and

b) Vehicle Size and Weight (Amendment) Council of Ministers Regulations No. 11/1990

The third problem was related to the role of the Ministry of Trade and industry in registering and giving business licenses to persons and enterprises engaged in road transport activities pursuant to the Commercial Registration and Business Licensing Proclamation No. 67/1997. However, till now, the proposed regulations have not been implemented and the problems are still prevalent.

2.5. Current Situation of Road Safety

A recent study [24] has shown that the country's traffic accidents and fatalities have increased in the last three yeas. The total traffic accidents increased by 17 per cent and fatalities increased by 10 per cent. The situation is likely to be even more severe than shown in the statistics due to the possible significant under-reporting. The traffic accident death rate per ten thousand motor vehicles in 2001/-2004/5 is in the range of 129 and 145 [24].

2.5.1. Road Accident Recording Systems in Ethiopia

Regional departments of the Traffic Police are responsible for the recording of all traffic accidents under their jurisdictions. The Federal Police Commission is responsible for national accident data compilation and processing. In each Region's Woreda Police Station, accident data are reported manually. The traffic police accident data form contains accident classification, date, time, day of the week, year, age of the driver, sex, education of the driver, ownership of the vehicle, service year of the vehicle, defects of the vehicle, location of accident, road traffic condition, road surface condition, road junction type, weather and illumination condition, collision type, and property damage and parties injured (age, sex, physical fitness and the like).

Monthly reports are submitted to pertinent the Region Police Commissions. A yearly report from the Region Police Commission will then be submitted to the Federal Police Commission to generate national accident statistics. In Ethiopia, much of the information is needed for the traffic police's own activity, primarily, to enforce the law and carry out prosecutions. Some of the accident data are of no direct interest or use to the police, but are vital to the work of other organizations.

2.5.2. Present Accident Situation

i) Motor vehicle involvement

Vehicles which were responsible for road accidents have been collected. Table 2.3 shows that fatal accidents are concentrated on trucks with capacity of 11-40 quintals, and on trucks capacity of 41-100 quintals. Similarly, Station wagons and taxi had major shares in traffic accidents during those years.

Table 2.3:- Motor Vehicle Involvement in Road Traffic Accidents between 2001/02-2004/05

Description	Automobile	Station wagon	Pick up	Truck 11-40qt	Truck 41-100 qt	Truck with trailer	Taxi	bus	others
Fatal	288	430	703	1199	1278	362	737	703	628
Serious injury	700	690	1091	1267	993	282	1451	880	588
Slight Injury	185	1022	1148	1099	883	160	2163	805	649
Property damage	7662	14596	3764	4258	3385	1495	7148	3028	982
Total	**8835**	**16738**	**6706**	**7823**	**6539**	**2299**	**11499**	**5416**	**2847**

Source: -Federal Police Commission, Road Traffic Accident Statistics Office, 2005

ii) Collision Variation by time of a day

Road traffic accidents are concentrated between 8:00 in the morning to 18:00 hours in the evening as shown in Figure 2.1.

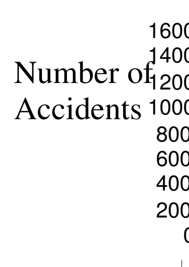


Figure 2.1 Hourly Variations of Accidents for Year 2004/05

iii) Age of Drivers and Road Accident Severity

Table 2.4 shows accident severity involvement by age of drivers in the country. For example, over forty-three per cent of the drivers involved in collisions were between 18 and 30 which is the highest number of accidents exhibited in this age group. The age group 31-50 had a share of around thirty-six per cent. The National Roads Safety Coordinating Office and other stakeholders should work with these two age groups in order to investigate and identify the problems and recommend possible solutions.

Table 2.4:- Drivers' age and severity of accidents for year 2004/5

Age of Drivers	Fatal	Serious Injury	Slight Injury	Property Damage	Total	Percent
Below 18	48	49	56	84	237	1.4
18-30	933	1180	1192	4428	7733	43.6
31-50	627	809	857	4076	6369	35.9
Above 51	109	115	168	1002	1394	7.9
Unknown	84	215	458	1232	1989	11.2
Total	**1801**	**2368**	**2731**	**10822**	**17722**	**100.0**

Drivers age 51 and over were involved in 7.9% of the collisions. Older drivers were involved in fewer collisions, but they tend to drive less frequently and for shorter distances. Figure 2.2 shows age of drivers and severity of accidents.

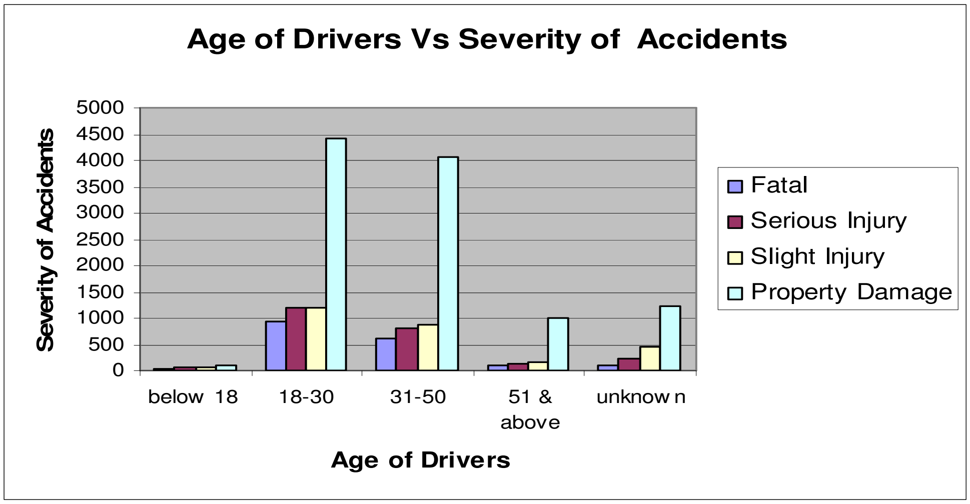


Figure 2.2 Drives' age and severity of accident

iv) Effect of age on fatality risk

Further, statistical analysis was done on severity of accidents in relation to drivers education, sex, age, service years of vehicles, drivers relationship with vehicles, and accident place Appendix I shows details.

2.5.3. Possible Reasons for High Number of Road Traffic Accidents

According to the report provided by the Interim National Road Safety Coordination Office [1], the reasons for the relatively high number of road traffic accident include

(i) Lack of driving skills;
(ii) Poor knowledge of traffic rules and regulations;
(iii) Violation of speed Limit;
(iv) Insufficient enforcement;
(v) Lack of vehicle maintenance;
(vi) Animal drawn carts and animals frequently using in main highways;
(vii) Lack of safety conscious design and planning of road network;
(viii) Disrespect of traffic rules and regulations;
(ix) Lack of general safety awareness by pedestrians; and
(x) Lack of medical facility in general, which increase the severity of accidents.

The apparent causes of accidents were identified by Traffic Police Officers. These causes were not accurate as identified on- the-spot of accident investigations. Usually, the report by the traffic police indicates a single cause of each accident but not multiple causes of the accident. However, the causes of road accidents are normally multi-factors always preceded by a situation in which one or more of road users have failed to cope with the road environment. As a result of lack of appropriate training of the Traffic Police Officers, it is difficult to know the real causes of road traffic accidents in the country. As shown in Table 2.5, the major causes of accidents are: failure to give-way for vehicles and pedestrians, overtaking in winding horizontal curves, following too close, improper turning and speeding. These seven causes contributed to 73 per cent of the total accidents in year 2004/05. The rest of the possible reasons accounted for less than 27 per cent.

Table 2.5 Possible reasons for high number of road traffic accident

No.	Description	Degree of Severity				Total	Percentage
		Fatal	Serious Injury	Slight Injury	Property Damage		
1	Drunk Driving	5	1	2	13	21	**0.12**
2	Drug Driving	7	10	8	10	35	**0.2**
3	Driving Without respecting Right hand Rule	89	119	124	693	1025	**5.78**
4	Failure to give-way for vehicle	37	111	120	1231	1499	**8.46**
5	Failure to give-way for Pedestrian	313	952	1382	68	2715	**15.3**
6	Following to close	42	47	81	2435	2605	**14.7**
7	Overtaking on crust vertical curve	8	4	6	18	36	**0.2**
8	Overtaking on winding horizontal curve	5	10	6	1219	1240	**7**
9	Improper turning	35	75	64	1706	1880	**10.6**
10	Speeding	413	223	342	983	1961	**11.1**
11	Improper Overtaking	34	55	64	43	196	**1.11**
13	Not respecting Traffic Rules	81	34	116	661	892	**5.03**
19	Driving with Fatigue	12	6	2	30	50	**0.28**
20	Driving Without Attention	25	62	29	489	605	**3.41**
21	Driving above Speed Limit	5	3	1	7	16	**0.09**
22	Failure in vehicle	152	103	94	472	821	**4.63**
27	Due to road Environment	105	103	82	61	351	**1.98**
28	Pedestrian failure to respects traffic rule	63	90	59	157	369	**2.08**
29	Others	243	304	74	444	1065	**6.01**
30	Unknown	127	56	75	82	340	**1.92**
	Total	**1801**	**2368**	**2731**	**10822**	**17722**	**100**

Source: -Federal Police Commission, Road Traffic Accident Statistics Office, 2005

3. REVIEW OF STUDIES ON CAUSES OF ROAD TRAFFIC ACCIDENTS AND POSSIBLE COUNTER MEASUERS

3.1. Introduction

This part contains the review of previous studies on causes of road traffic accidents and possible counter measures which were contributed by different researchers. The occurrences of traffic accidents are rare and random in space and time. However, road safety and road incident reduction are related to many other fields of activity such as education, driver training, publicity campaigns, police enforcement, road traffic policing, the court system, the National Health Service and Vehicle engineering [3].

3.2. Road Environment

Road environments have impacts on occurrences of road traffic accidents. In developed countries, there are continuous efforts to meet the safety standards of roads through safety audit during the planning, designing, and operation stage. Terje's [13] indicates that, in Africa road network is expanding fast, maintenance standards have started improving lately, and there is potential for improving the safety standards of the roads. However, Berhanu [3] reports that, in Ethiopia, the police have limited road and traffic engineering skill in general and thus they underestimate the contribution of roads and environments to traffic accidents and specially they lack trainings on subject area.

3.2.1. Road Alignment

An important factor, which affects the occurrence of road traffic accidents in terms of frequency and severity, is road alignment. Inconsistent horizontal alignments of roads, sharp curves and grades are known for their substantial and adverse safety impacts [3].

i) Horizontal Alignments

A recent study [14] shows that accidents on horizontal curves are causes for concern in all countries. A study in Denmark has found that about 20 per cent of all personal injury accidents and 13 per cent of all fatal accidents occur on curves in rural areas; and in France, over 20 per cent of fatal accidents occur on dangerous curves in rural areas. Accidents on bends are major problems in many developing countries, although the proportion of such accidents is dependent on both topography and demography of each country.

Table 3.1 Casualties at Bends in Developing Countries

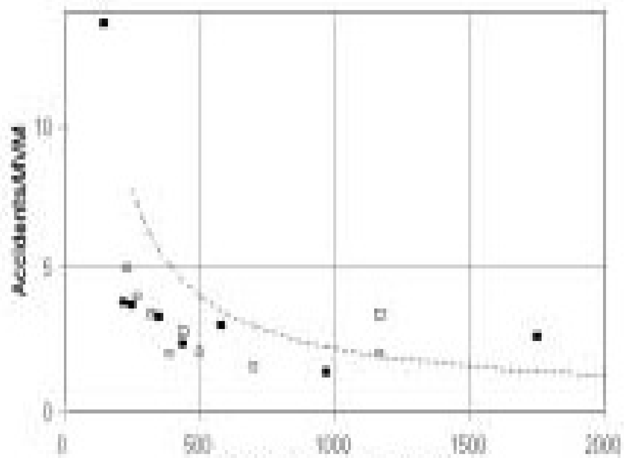
Country	Proportion of Casualties in Rural Areas	Casualties at Bends	
		Rural	Urban
Botswana	71.1%	19.6%	8.6%
Zimbabwe	47.3%	25.0%	5.0%
Papua New Guinea	71.5%	46.9%	16.1%

Source: Highway design note 2/01, TRL, Old Wokingham Road, Berkshire, UK RG45 6AU.

Choueiri [15] reviews a number of studies, which generally has shown that sharp curves result in much higher crash rates than more gentle curves; sections with curvature of between 5 and 10 degrees have at least twice the crash rate of sections with curvature of 1 and 5 degrees, and sections with curvature of between 10 and 15 degrees have crash rates four times as great. In terms of curve radius, 200 m seems to be the point below which crash rate greatly increases. The evidence suggests that curve flattening is highly effective in reducing crashes.

Numerous studies have been reviewed by Leisch & Associate [16] confirming that there are several elements of horizontal alignment which are associated with horizontal curve safety. The safety of a horizontal curve- its accident frequency and severity- is partly determined by features internal to it (radius or degree of curve, super elevation, etc.) and partly by features external to it (density of curves upstream, length of the connecting tangent sections, sight distance, etc.) that influence driver expectation and curve approach speed.

When the accident rate is plotted against the radius it appears as if increasing the radius from 200 m to 300 m has a much larger beneficial effect on the accident rate than an increase from 900 m to 1000 m as shown in Figure 3.1. This has been at times misinterpreted to mean that in the relationship there is some natural bend or ‘knee’ around R=500 m and therefore increasing the radius beyond, say, 500 m is unimportant [16].



Radius of curve in meter

Figure 3.1 Five Early Studies Radius of Curvature

Lamm observed that curvatures greater than 350 degrees/mile (approximately 220 degrees per kilometer) produced relatively high crash rates and were used in very few cases in modern German design practice. The crash rate which corresponds to this degree of curvature is 2.0 per million vehicle kilo meters, and Lamm suggests that this represents an acceptable level of safety [15].

ii) Vertical Curve

There are three main effects of vertical road alignments, which are closely associated with the occurrences of traffic accidents. These are excessive speeds and out-of-control vehicles on down grades, differential speed between vehicles created on both down and up grades, and low range of visibility that often occurs in the immediate vicinity of steep grades at the crest of vertical curves. Ross Silcock Partnership [17] indicates that it may be difficult for driver to appreciate the sight distance available on crust curve and he may overtake when it is insufficient for him to do so safely. This can be extremely expensive to provide safe overtaking sight distances on crust curves. However, a complete ban on overtaking would be difficult to enforce because of the presence of very slow moving vehicles, the lack of driver discipline in selecting places, poor maintenance of road marking and signs. Successive short vertical curves on straight section of road may produce misleading forward visibility.

Berehanu [3] summarizes the effects of vertical curve in such a way that steep grades have higher accident rates than mild ones. He extends that grades of less than 6 per cent have little effect, but grades steeper than this are associated with higher accident rates. Down grades are greater problems, particularly for truck safety than upgrades. A combination of horizontal curves under 450m and grades over 4 per cent are not recommended. Poor condition of the horizontal and vertical alignments of a road can result in visual effects, which contribute to accidents and are detrimental to the appearance of the road [17].

3.3.2. Sight Distance

This is the ability to see ahead in order to stop safely or overtake vehicle or view approach intersection. Sight obstructions on the road, generally occur due to the presence of deep cuts, embankments, vegetation, walls and the like on the inside of the horizontal curves and intersection quadrants, and sharp crest vertical curves themselves. Types of sight distances are: stopping sight distance, passing sight distance, intersection sight distance, and decision sight distance. Berehanu [3] reviews various studies that value and consider uses of the above sight distances. However, there are variations among different design standards. These sight distances vary with design or operational speeds of road section, perception/reaction time, eye, height, object height and pavement friction.

Choueiri [15] reviews studies which suggest that inadequate sight distance may be a factor in 20 to 25 per cent of rural accidents resulting from overtaking manoeuvres. The actual percentage of crashes in which sight distance has a role would clearly be related to the extent of overtaking manoeuvres, which in turn is related to traffic flow. Most studies appear to indicate that crash rates are higher with low sight distances, but they change little when the sight distance is 150-200 m or greater.

Berehanu (3) reviews studies in Sweden that a decrease of accident rates with increasing sight distance was observed, especially single-vehicle accidents at night. In British study, it was reported that on rural roads sight distances shorter that 200m were relatively more likely to be found at accidents sites through their association with horizontal curves.

The TRB Study [18] in the USA for which accident data were collected for carefully matched sites with and without sight-distance restrictions due to vertical curvature, found accident frequencies to be 52 per cent greater than overall at sites with sight restrictions than at control sites.

3.2.3. Road Cross-Sectional Elements

Various studies revealed that road cross sectional elements are the most important road related features which affect road safety. Road cross-sectional elements comprise lanes, shoulder, side slope, back slope, and clear zone.

i) Lane and shoulder width

According to Roadrigues [19], lane widths of 3.4-3.7 meters have been shown to have the lowest accident rate on rural roads. Lane widths of less than 3m have been shown to contribute to multi-vehicle accidents. Berhanu [3] reviews numerous studies that lane and shoulder width affects run off the road and opposite direction accidents. The rates of these accidents decrease with both increasing lane and shoulder width, but the marginal effect of increasing width on accident rates decrease as either the base lane width or the base shoulder width increases. Lane width of 3.4 to 3.7 meters has the lowest accident rate and represents the balance between safety and traffic flow [3]. For 3.0 meters lane a shoulder of 1.5 meters or greater, and for 3.3 to 3.6 meters lanes shoulders of 0.9 or greater reduces the accident rate significantly [3]. Choueiri et al review that widening narrow lanes bring safety benefits up to a width of 3.7 meters, with little benefit beyond that unless the road carries large volumes of trucks [15]. Other studies carried out in the USA shows that there were safety benefits in sealing shoulders and suggested 1.5m as the optimum width for sealed shoulders. This finding was broadly confirmed by Swedish study which found that accidents decrease with shoulders up to 2 meters wide, but there is little additional benefit obtained with shoulders greater than 2.5 meters [15]. Generally, lane width has greater effect on accident rates than shoulder width.

ii) Road side features and side slopes

Roadside encroachments begin when the vehicle inadvertently leaves the travel lanes, veering toward the roadside. Most encroachments are quite harmless: the driver is able to regain control of the vehicle on the shoulder and safely return to the travel lanes. When coupled with nearby roadside hazards, however, encroachments can result in roadside accidents [18]. Such accidents comprise a significant number of the accidents that occur: on two-lane rural roads, more than 30 percent of all accidents involve single vehicles running off the road [18].

The Transport Research Board Report [18] reviews that past research on the safety of the roadside environment has produced important improvements to roadside hardware; including, for example, the development of barriers that better contain and more safety redirect errant vehicles, sign and luminaries supports that break away on impact, causing little damage to the striking vehicle and its occupants. In addition, design standards occasionally provide for clear recovery areas- boarders beginning at the edge of the travel lanes with travel lanes, traversable slopes and free of hazardous obstacles. Improved designs for drainage structures such as culvert headwalls reduce hazards posed by unforgiving obstacles.

Entry of an errant vehicle on to the roadside border does not in itself mean that an accident is inevitable. Although some dangers always exist, the chances of recovery are excellent if the border is reasonably smooth, flat, and clear of fixed objects and other non traversable hazards. The chances of successful recovery diminish as the ground slope within the border. Safety researchers generally agree that at speeds of approximately 55mph, safe clear zones should have side slopes no steeper than about 6:1 and should extend outward at least 30ft from the edge of the travel lanes. When the border is flat, unintended encroachments on tangent alignments seldom extend beyond the 30-ft range [18].

3.3. Access Management

Access management is a new response to the problems of congestion, capacity loss, and accidents along roadways. Koepke and Lavinson [20] call for significant improvements in access control, spacing, and design to preserve the functional integrity and operational viability of the road system.

Constantly growing traffic congestion, concerns over traffic safety, and the ever increasing costs of upgrading roads have generated a new interest in managing access to the highway systems. Access management is the process that provides access to land development while simultaneously preserving the flow of traffic on surrounding roadways. Three issues kept in the forefront of access management are: safety, capacity, and speed. Fewer direct accesses, greater separation of driveways, better driveway design and location are the basic elements of access management.

Many studies over the past 40 years have shown that accident rates rise with greater frequency of driveways and intersections. Each additional driveway increases accident potential. Roughly 240 roadway segments in the USA, involving more than 37,500 accidents, were analyzed in detail [21]. According to this study, For example, a segment with 60 access points per mile would be expected to have an accident rate 3 times higher than a segment with 10 access points per mile. In general, each additional access point per mile increases the accident rate by about 4 percent.

In urban areas, undivided highways had 9.0 accidents per million vehicle miles as compared with 6.9 for two-way left-turn lanes (TWLTLs) and 5.6 for non traversable medians [21]. In rural areas, undivided highways had 3 accidents per million vehicle miles as compared with 1.4 for TWLTLs and 1.2 for non traversable medians [21].

In urban and suburban areas, each access point (or driveway) added would increase the annual accident rate by 0.11 to 0.18 per million vehicle miles on undivided highways and by 0.09 to 0.13 per million vehicle miles on highways with TWLTLs or non traversable medians [21]. In rural areas, each point (or driveway) added would increase the annual accident rate by 0.07 per million vehicle miles on undivided highways and 0.02 per million vehicle miles on highways with TWLTLs or non traversable medians [21].

3.4. Intersections

On two-lane rural highways, intersections are ranked together with horizontal curves and bridges as the most likely locations for accident concentration. According to the National Safety Council estimates in USA, 56 per cent of all urban accidents and 32 per cent of all rural accidents occur at intersection [18]. Although the average accident occurring at intersection is not as severe as the one occurring on the open road, there is nonetheless, a concentration of severe accidents at intersection. Of all the fatal accidents in the United State, 29 per cent of those that occur on urban highways and 16 per cent of those that occur on rural highways are intersection related. It is logical to concentrate on such types of high accident record areas. For safety and traffic management reasons, selection of intersection design depends on the AADT of the major and minor road. Roundabouts have the least accident rates as observed in developed countries and best countermeasures from safety of intersection point of view [12].

3.5. Narrow bridges

Bridges are often located on sag vertical curves where approach traffic is on down grades and a factor responsible for increasing speed which contributes to the losing control of vehicles. Bridges are also more dangerous when located on bend road sections. Berehanu [3] notes that bridges are over represented in accidents relative to the total length of the road system. Traffic accidents are also severe at bridges. An extensive review of literature on the safety effects of bridges by Mak in Berehanu points out features including bridge width, curved bridge, approach roadway alignment and adverse surface condition as the most prevalent factors of bridge accidents. Based on the findings of the cited studies, Mak in Berehanu suggests that at least the bridge shoulder should be 1.8 m wider than the approach traveled way width on rural two-lane highways (i.e. 0.9m shoulder width on each side should be carried across the bridge) [3]. Besides, frequency and severity of traffic accident at bridges can be reduced through the provision of adequate visual information to enable the driver control and navigate safely on bridges.

Run-off-the-road crashes and head-on collisions are frequently associated with narrow bridges. Such crashes are related to lack of maneuvering room because of narrow lanes, shoulders and roadside hazards or curbing. Combining these factors with excessive speed might end in deadly results. Crashes involving narrow bridges are often fatal. The crash rates may be lowered by increasing lane and shoulder width or completely replacing bridges [22].

Other study made by the Transport Research Board indicates that hazards associated with bridges can be significant [18]. Roadway constriction at narrow bridges reduces the opportunity for safe recovery by out-of –control vehicles and can result in end –of –bridge collisions. Furthermore, bridge approaches are often on a downward grade, a factor responsible for increases in speed, and, particularly in the case of older spans, are often sharp-curved.

3.6. Road User Information and Campaign

Elvik [8] points out that road users ought to acquire the knowledge needed to travel safely by means of formal training and their own experiences. Nonetheless, insufficient knowledge of traffic regulations, traffic signs, vehicles and other elements may be some of the factors contributing to unsafe behavior and road accidents. Road user information and campaigns are intended to reduce accidents by promoting safer behavior in traffic, by giving road users improved knowledge and more favorable attitudes towards such behavior [8] . Another objective is increased understanding of restrictive measures which are introduced to increase safety, such as speed limits.

Elvik evaluated a number of studies on the effects of information campaigns on the number of accidents [8]. He reviews that most campaigns targeted at road accidents in general have not led to statistically significant changes in the number of accidents. However, campaigns made to specific target group such as use of seat belt, drink-driving campaign and the like have led to a decrease in number of accidents in particular types during the campaign periods.

Effects of information campaigns on behavior were analyzed (Elliott 1993) that results show a change in road user behavior by means of information and campaigns [8]. Elliott (1993) concludes the following regarding the conditions for succeeding in an information campaign for safer behavior in traffic [8]:

i) Greater changes in behavior are achieved when the initial proportion of road users exhibiting the desired behavior was lower than when a high proportion of road users had the desired behavior at the start.

ii) Greater changes in behavior are achieved when information campaign are combined with increased police enforcement than when they are not.

iii) Campaigns clearly stating which type of behavioral change is desired, and why it is important to change behavior, lead to greater behavioral changes than campaigns that simply encourage people to be careful in general terms.

iv) The use of television as a medium in the campaign appears to lead to greater changes in behavior than other media. This may possibly be due to the fact that television is a medium which reaches a wider public than other media.

3.7. Black Spot Definition, Criteria and Treatment

3.7.1. Black Spot Definition

Rokytová [7] defines black spot as locations that are generally classified after an assessment of the level of risk and the likelihood of a crash occurring at a location. Black spot safety work can be described as the task of improving road safety through alterations of the geometrical and environmental characteristics of the problematic sites in the existing road network. In towns and cities, there is a tendency for traffic accidents to cluster at specific places, often at intersections. A concentration of accidents at a specific spot may partly be due to inappropriate road design or inappropriate traffic control at that place. In such cases, the clustering of accidents can be avoided or reduced by improving road design or traffic control.

3.7.2. Black Spot Criteria and Analyses

An accident black spot on a National Highway in Norway is defined as any place with a maximum length of 100 meters, where at least four injury accidents have been reported to the police during a four year period [8]. Thus, a black spot in the UK may well have only five injury accidents in three years, while a city in Bangladesh may have black spot defined as having more than 10 injury accidents in a year [9].In most developed countries, black spots are defined as the locations where there are 12 accidents in 3 years per 0.3 kilometers [10]. In Czech Republic, the black spot criterion is that junctions or 250 m-long road sections that are considered as black spots on condition that at least 3 road accidents with injuries occurred within 1 year or at least 3 road accidents with injuries of the same type occurred within 3 years or at least 5 road accidents of the same type occurred within 1 year [7]. Study on single carriage way trunk road [26] revealed that the criterion used to delineate road sections for accident analysis are age of opening, carriageway width, kerbs, hard strips, and speed of the road section.

Elvik [8] points out black spots on national highways in Norway have heavy traffic but do not have particularly high accident rates when compared with places which are not

Table 3.2 Distribution of accident black spot on national highways in Norway

Annual Average daily traffic	All national highways	Black Spots
Up to 1,499	71%	2%
1,500-3,999	19%	8%

4,000-7,999	6%	20%
8,000-11,999	2%	21%
12,000-19,999	1%	26%
20,000 and more	1%	23%

classified as accident black spots. In the period 1984-87, accident black spots were distributed according to traffic volume and accident rate as shown in Table 3.2. Ranking of black-spots were done with various alternatives Johannessen and Kristian [12] show three alternative methods of ranking black spots. These are number of accident with personal injury or serious personal injury, accident rates (accident per million vehicle kilo meter) and potential for accident reduction. In Belgium, potential accident reduction ranking method is employed taking into account the weight of each severity at each site where in three years three or more accidents have occurred. Then, a site is considered to be dangerous when its priority value (P), calculated using the following formula, equals 15 or more [9]:

$$P = X + 3*Y + 5*Z,$$

Where

P = priority value

X = total number of light injuries

Y = total number of serious injuries

Z = total number of deadly injuries

Researchers have proposed several alternative methods for targeting and ranking black spots. However, there is no such thing as the correct ranking.

Analysis of accident at individual sites:-Once the accident sites prioritized for investigation have been determined, there are usually three steps of accidents analysis, as follows [23]:

i) A preliminary analysis is carried out on the accident data to understand the accident types and conditions. Collision diagrams and accident factor grids (or stick diagrams) are useful tools at this stage.

ii) A site investigation is carried out by specialist accident investigators to determine the exact conditions at the location. The investigation will observe traffic flows and road user behavior at the times of accidents most frequently occur, determine what other information may be required (such as speed measurements and skid resistance), and start to define the problems associated with the location. Where data are limited, observation of conflicts (either simply by watching traffic informally to see typical maneuvers and conflicts or via formal conflict studies) can provide insights into the problems to be addressed; and

iii) A detailed analysis of the accidents occurring at that location is then carried out. This should include simple statistical tests to determine whether the accidents have resulted from a real increase in risk or are a result of random fluctuation. The information should be presented in a report, which will typically include a collision diagram and an accident factor grid, the accidents having been classified into types and the dominant causal factors determined. Perhaps the most important part is to recommend remedial measures for the location and justify them on a cost benefit basis. This is done by estimating the cost of the improvements and predicting the accidents that will be prevented to ensure value for money. Once all black spot sites have been investigated, a prioritized list for action over the road network can be established and the implementation process set in motion.

3.7.3. Black Spot Treatment

Treatment of black spots using low cost engineering measures is one of mechanism measures that help to reduce accidents at dangerous spots. The most popular low cost engineering measures incorporates: rumble strip, traffic signs and road markings, road light and roundabouts.

i) Rumble Strip

It is a safety device that alerts and let the drivers to make a change on the driving operation. It consists of some repeated pattern on pavement surface, that creates vibration on vehicles when tires role over on it. Rumble strip is used to tip or alert drivers in changing geometric of the road or driver approaches to any unusual dangerous road sections or spots. The application of rumble strips on rural areas has been associated with 20 to 60 per cent of accident reductions [27].

ii) Traffic Signs and Road Marking

The main functions of traffic signs and road markings are to provide warnings, regulations, and guidance information for road users. The report on traffic signs and road markings revealed that road signs and markings are important to regulate the use of a road, warn of dangerous situations and guide road users to their destinies in a uniform and safe way.

Traffic signs provide a safe environment to road users by guiding drivers to directions for route finding; controlling the use of road with mandatory signs; warning drivers of any substandard or unusual features with warning signs, aiding road users to identify the situation ahead and anticipate hazards; providing consistency within the road signing system, with similar situations receiving the same treatment; providing night-time and day-time visibility; informing services rendered to users and emergencies.

Regarding to road markings, there are delineation systems installed on road pavements for:

- Vehicle position and movement control through visual information that identifies the legal and safety limits of roadway;
- Driving direction regulation, changing lane and overtaking;
- Zone or lane identification, where maneuvers are allowed, forbidden or mandatory;
- Lane discipline increment, particularly during night periods and adverse weather conditions; and
- Dangerous zones identification aid, like obstacles or pedestrian crossings.

By use of reflective stud on pavement road marking, average accident reductions of 10 to 40 per cent may be achieved [27]. This measure is particularly effective in roads without any marked limits, and is able to improve from 30 to 40 per cent in accident reductions.

iii) Traffic channelization

Traffic channelization is reducing conflicts between vehicles to vehicles and pedestrians. It facilitates correct trajectory selection; capacity increase and traffic control and maximizes driver/road communication. It also facilitates the easiness of driving processes by reducing the number of decisions that a driver must deal with at a certain place, giving him time to think of the next decision. In a single carriageway two-way-two-lane roads, there are two traffic channelization solutions: the first is to introduce turning lanes (left or right) which are secure places for vehicles that are going to turn, thus reducing risks of accidents and encouraging drivers to wait for the right time to turn; and the second solution is to use shoulders as an additional lane for overtaking vehicles that are waiting to turn left [27]. This solution is not very expensive, since, shoulders are already paved, it's only necessary to paint the corresponding markings. Traffic channelization measures may contribute to reductions (15% to 57 %) in the number of personal injury accidents [27].

iv) Road Lights

Road lights are intended to provide enough lighting for drivers to travel with comfort and safety during night periods or under low visibility conditions. This solution is commonly applied where there is the possibility of conflicts between vehicles and pedestrians or cyclists. In rural roads, the implementation of lighting on unlit roads may lead to a 64 per cent reduction in fatal accidents and 20 to 50 per cent of total accident reduction [27].

v) Round About

In Norway, roundabouts have the lowest accident rate per million vehicles as compare with all types of control [12]. A normal crossroad has 32 possible conflict points where traffic streams merge, cross or diverge. By introducing a roundabout, the conflict points reduce to eight. As accident countermeasures, roundabouts may be appropriate where the following contributory factors appear consistently in accident records: -a high proportion of turning maneuvers; and excessive speed through the intersection. It reduces the number of injury accident by 10 to 40 per cent depending on the number of legs and the provision of traffic control devices [8].

4. RESEARCH METHOD

To attain the objectives stated in chapter one, the method applied to data collection, analysis, generation and interpretation of results; and finally with conclusions and recommendations.

4.1. The Study Site

The study site is a road from Addis Ababa, kilometer 24+700 near to Blue Nile crasher site up to Melka Oda near to Shahemene city, kilometer 243+500 with a total length of 218.8 kilometer. The road is a two-lane two-way highway with high standard in the country. The section between Addis Ababa Modjo is the main route of the country's import and export corridor from the port Djibouti. The road is also part of the Trans East African Highway that is envisaged from Cairo in Egypt to Hebron in Botswana. Furthermore, more fertile land which is suitable for agriculture is located along the route especially large scale farmers of flowers and other plants, and also coffee growing peasants are inhabited at the sides of the road. In general, the road connects the capital city of the country to sea ports of neighboring countries as well as recreation centers, and to the main agricultural potential area. The road traverses through ten towns.

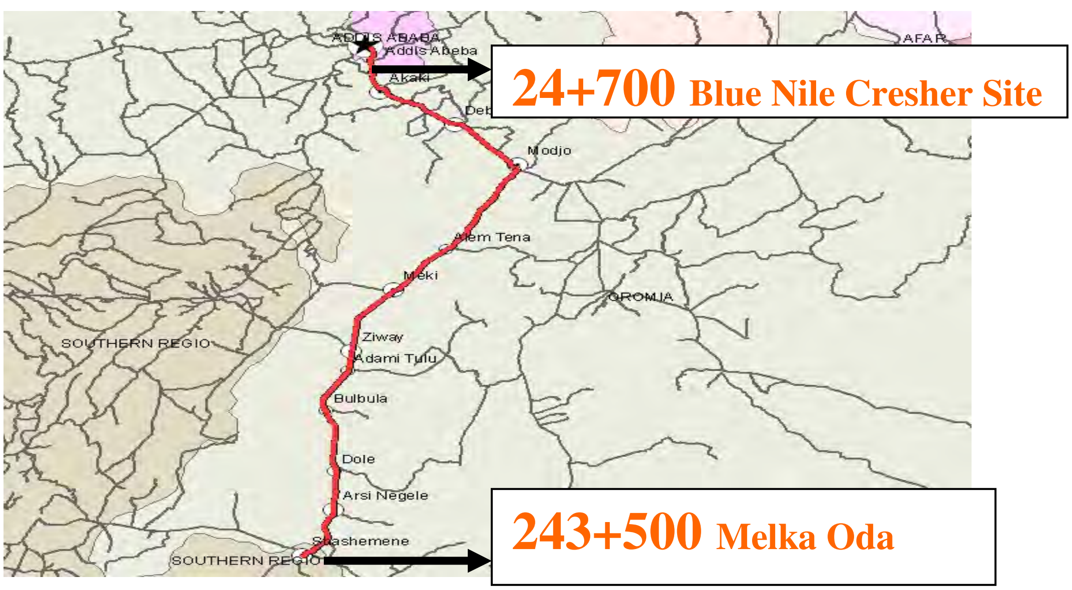


Figure 4.1 Map of the study road: Addis Ababa-Shashemene Road

In the suburbs of these towns, many cash crop growing farmers are living and as a result these towns are relatively good in their economic status and have strong link with the capital city. Due to these facts, the road is considered as the most vital route in terms of economic and traffic volume. It is also the only means of land transport to connect eastern and southern parts of the country. In 2006, traffic count indicated that ADT was 10,027 from Akaki to Debre Zeit, 6901 from Debre Zeit to Modjo, 2683 from Modjo to Ziway, 1812 from Ziway to Bulbula, and 1875 from Bulbula to Shashemene. Although it is an important route, the accident rate is very high due to many reasons. Therefore, this report focuses on the identification of dangerous spots, diagnosis of possible causes and proposition of low cost engineering measures, in order to reduce road accidents along the study road. It is expected that the out put of this research will be replicated on other national roads.

Figure4.2 Typical section showing the traffic mix on Addis Ababa-Shashemene road

Locations of accidents were reported most importantly based on permanent structure and also by taking a reference to kilometer posts. Approximate locations of accidents were taken using police records on spots. Accidents on the study area are recorded and documented in each police station and summaries are dispatched to the Federal Police Commission. Even though, the report available at the Federal Police Commission does not give detailed information. For example; accident locations are not included in the report sent to the Federal Police Commission.

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4.2. Definitions of Terminologies

Different authors suggest different definition for road traffic accidents. In general, definition of road traffic accident considered here is:

> "An accident is a rare, random, multi-factor event always preceded by a
> situation in which one or more road users have failed to cope with
> the road environment." [5]

In Ethiopia, road accidents are classified into three severity categories: fatal, injury and property damage. Injured casualties are divided into two subcategories: slight injury and serious injury. Slight injury refers to persons with minor fractures, scratches etc. not requiring hospitalization whereas serious injury denotes persons with major but not life-threatening injuries as in-patients in hospital. All reported accidents not involving injuries or deaths are classified as property damages. However, the common understanding is that, road traffic accident is one that results in property damage and/or injury of road users and involves at least one motorized vehicle.

The following terminologies are used in the study.

Schemes: Road section delineated using the criteria that is carriageway width, presence of shoulder, traffic volume and speed limits for identification of black spots and analysis.

Link: Road between junctions which may contain one or more access points and also may contain one or more minor junctions or accesses including one or more minor links;

Junction: Where traffic on the road has to give way or stop, where the road joins another road at a priority junction;

Junction length: Junctions were considered as having zero length.

Link length: Length of a minor link, or the total length of the major links scheme.

Scheme length: Total length of schemes which is equal to the sum of the link lengths.

Link accidents: Accidents which occur on the road but not within 30 meters of a junction.

Junction accidents: Accidents which occur on the road at or within 30 meters of junction.

In order to identify dangerous spots, criteria were taken into account in delineating schemes of one road section from another. These criteria include: -uniformity of carriageway width, kerbs, presence of shoulders, traffic volume (ADT) and speed limits.

4.3. Data Collection

To attain the stated objectives, previous research studies were reviewed that were found to be relevant to the objectives of this research. The literature review provided a broad background of the existing knowledge of road safety and insight into the problems encountered by the researchers at different stage of their works. The knowledge and experience gained during this period helped the writer of this paper in developing reliable, efficient and effective study approach to focus on stated goals.

Before data collection was carried out; training was provided to three enumerators to arm them with knowledge on how to gather reliable data. During the fieldwork, three types of data were gathered. These were: accident data, road data, and traffic data.

4.3.1. Traffic Accident Data

Road traffic accident data were collected from sixteen traffic police stations for the study period of June 2003 to May 2006. Eight of them were found in built–up areas (towns) along the road and the rests were in rural areas.

The source of road accident data were accident booklets compiled by Traffic Police Officers. To acquire reliable data, a road traffic accident form was designed. The form included:-

- Date, day and time of accident,
- Vehicle type and ownership,
- Driver sex, age and education,
- Weather, road, and illumination condition,
- Accident type,
- Degree of severity, and
- Number of victims (driver, passenger, and pedestrian), sex, age, severity; and

●Location of accident,

To back up various analyses and investigations, a road traffic accident data base were established. The data base consists of three-year accidents which were collected from the police stations. During this period, around 1,151 road accidents were gathered. In this regard, 1,108 accident locations were identified but 43 locations were difficult to identify. Furthermore, to determine the location of accident spot, each accident location was measured up to the accidents spot from a kilometer post that is available along the road side.

4.3.2. Traffic Data

Traffic data were required to undertake the analysis of road safety problems for the road under consideration. These data were helpful in determining the type of measures that were applicable at the site. Besides, the result of traffic counts and compositions were used as one of the inputs or yardsticks to develop criteria in delineating the study road. In this

case, traffic flow was important and thus was gathered during the field work. Traffic counts were conducted on three locations along the road. The first location was taken at 42 kilometers from Addis Ababa near to the entrance of Debre-Zeit town. The second was conducted at kilometer 70+ 980 in front of the Modjo Customs checking points. The other one was carried out at 183+000 kilometer from Addis Ababa Bulbula town near to children Amba Junction. These locations were selected based on the traffic sites of the Ethiopian Roads Authority. The traffic count period was for seven days from 6:00 to 18:00 hours local time that included a 24-hour count on one normal day and on one market day (Saturday). Counts were carried out on two directions at each location. According to the Ethiopian Roads Authority, vehicles are classified to eight groups. The ERA vehicle types composed: Car (automobile), station wagon, small bus, large bus, small truck, medium truck, heavy truck and articulated truck. The same classifications of vehicles were used in this research. Furthermore, additional ADT (Average Daily Traffic) was collected from Scott Wilson traffic count and from the Ethiopian Roads Authority.

Based on the traffic count, ADT was calculated for each road segments. The factor that was applied for conversion to ADT is given under.

Estimate on ADT can be done as follows:

ADT= Vi x f

Where, Vi = Average daily traffic of vehicle i of two directions of the week is divided by seven.

f = two days 24 hour traffic count data was summed up and divided by two to get average traffic for full day (24 hr). The average 24 hour traffic data will be divided by the sum of two day time (6 a.m. - 6 p.m.) traffic.

4.3.3. Road Data

The road factors being investigated in the geometric design includes horizontal curvature, road width, shoulder width, and grade of the road. Road data is available the Ethiopian Roads Authority as-built drawing of the road plan and profile. These were substantiated through actual measurements and visual inspection, which was made on the road site. The gathered road data consisted of:

- Carriage way width
- Shoulder width
- Curve length
- Radius of horizontal Curve
- Grade (Inclination of the road)
- Tangent

4.4. Methods of Analyses

In order to characterize the populations of accidents, statistical analysis was applied to determine the uniformity of the collected data. The arithmetic mean, standard deviation and coefficient of variation of the accident data were calculated for each scheme. The arithmetic mean and standard deviation were used to compare the total accidents on the route with the black spot sites. This helps to know which accidents are significantly higher compared to accidents of other locations (black spot sites).

Accident rates were also calculated for each scheme, link and junction with relation to some of the geometric design parameter and traffic factors. Accident rate is defined as follows (3).

$$A\ (\text{road section}) = \frac{A \times 10^{6}}{365 \times T \times AADT \times L}$$

$$A\ (\text{junction}) = \frac{A \times 10^{6}}{365 \times T \times AADT}$$

Where,

A (road section) = accident rates per million vehicle-kilometer on road sections,

A (junction) = accident rates per million vehicle entering a junction,

A = number of reported accidents,

T = time frame of the analysis, years

AADT = average annual daily traffic, and

L = length of the road section, in kilometer

The above formulae were also applied to determine the accident rates at the black spots. Moreover, cross tabulation of accidents were carried out to describe accidents with respect to built-up and non built-up area of the study road.

4.5. Sites and Black Spot Identification

Based on the three years accident data, accidents were plotted along the road to give a rough location of accidents. The standard markings were used to describe the main types and the seriousness of the accidents. The mapping process was made using GIS software. In order to plot accidents and identify the black spots, step-by-step procedures were used to obtain the desired results. The following procedures were employed:

- Locate the actual accident spots on the grounds in kilometer;
- Assign appropriate symbol shown in Table 4.1;
- Create a data base for accidents;
- Link the data to GIS; and

- Plot the accidents on the digitized road map.

Table 4.1 Symbols Used in Mapping Accident Distribution Along the Study Road.

Types/Severity	Fatal Accident	Injury Accident	Non-injury Accident
Vehicle to Vehicle	O	O	O
One Vehicle	□	□	□
Pedestrian Involved	∇	∇	∇

In addition, in calculating accident rate for each delineated section, minimum, lower quartile, median, upper quartile, 90 per cent and the maximum of accident rates were summarized to sort those places that have higher accidents. The other criterion that was employed in the selection of accident sites was that an accident rate greater than or equal to the 90th percentile for both road sections and junctions were considered as a black spot. The road safety engineering manual [5] recommended that greater than or equal to average plus one standard deviation (≈85 per cent] is considered to be a black spot for further detail studies. When the spread of accident rates among the schemes is large, the 90th percentile will be a better measurement [26]. Then, descriptive analyses of accidents were made on the segments in the study.

In-depth analysis of individual accident location: These parts are detailed analyses of accidents based on the available information. Three methods of ranking of accident prone sites were discussed in earlier chapters. Theses are: number of accident with personal injury or serious personal injury accident rate per million vehicle kilometer and potential accident reduction methods. By applying the criteria for delineation of road sections, prioritization of black spot /sections are made using potential accident reduction methods.

To prioritize those black spots, the ratios of accident costs by degree of severity were established by TRL [2]. The weight given for fatal accident is 5.0, for serious injury is 3.0, for slight injury and property damage are 2.0 and 1.0 respectively.

$$P = \frac{(1* W+2*X + 3*Y +5*Z),}{D} \qquad \text{where}$$

W= total number of property damage

X = total number of light injuries

Y = total number of serious injuries

Z = total number of deadly injuries

D= distance of the black spot section in kilo meters

After calculating P, the weighted value of severity was divided by the distance of black spot section to prioritize sections for treatment. A priority value of equals 20 or more is selected for immediate treatment.

According to ranking made of accident prone sites, stick diagram is prepared to investigate problems for some sites. The stick diagram consists of accident month, date, time, severity, illumination condition, weather, road surface, number of vehicles involved in accidents, types of vehicles, casualty number and collision type of the dangerous road section. In the case of junctions, the same was done to identify causes of accidents on dangerous road sections. Analysis of accidents and correlation were applied on specific site of dangerous location.

Furthermore, site visit has been carried out to support intermediate conclusion. The site visit was conducted to note road environment and traffic situation. In some circumstances, site measurements concerning visibility and the likes have been undertaken.

4.6. Counter measures Identification

Having identified the probable causes of the accident, possible countermeasures have been suggested to improve the road accident situation along the road. The counter measures usually used are low cost engineering measures which include traffic signs and road markings, chanalization, improvement lighting, and the like. Figure 4.3 shows the flows of work activity followed in the research work.

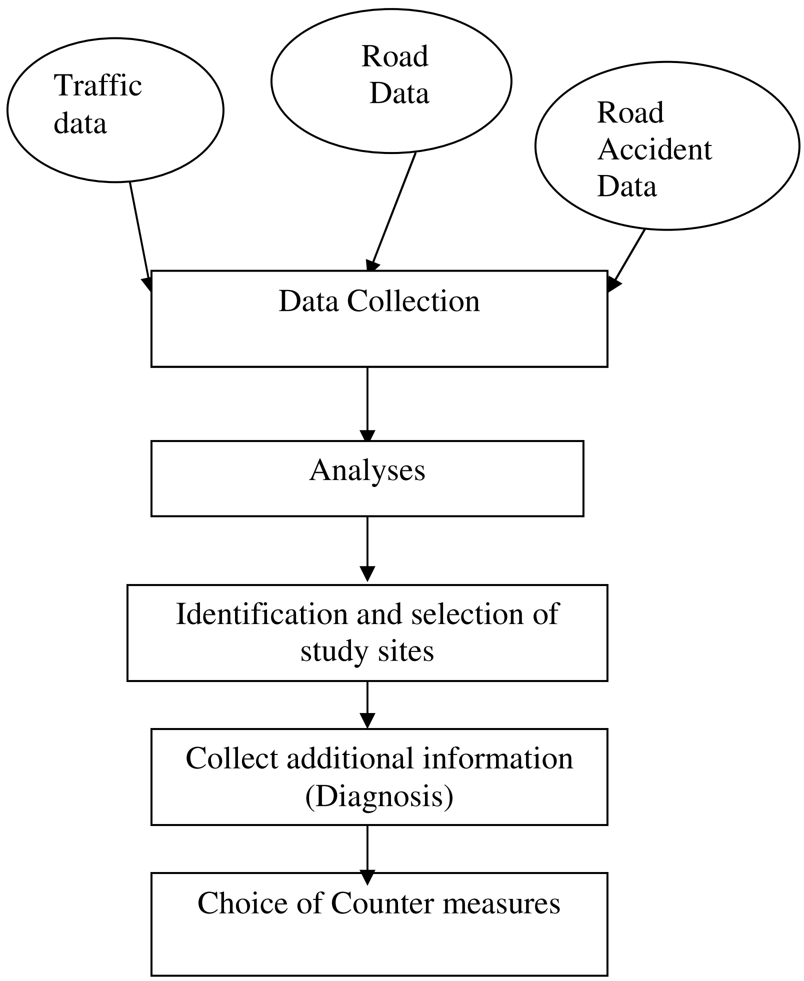


Figure 4.3 Flow chart showing the major activities carried out during the research work.

5. ANALYSIS AND DISCUSSION

5.1. Characteristics of accidents

Before starting identification of black spots, it is important to look the characteristics of total accidents database. The accidents database of the Addis Ababa-Shashemene Road that were established for this study contain all accidents reported by traffic police at the study sites along the 218.8 kilo meters during the study period of June 2003 to May 2006. A total of 1,151 accidents were reported out of which 601 were injuries and the rest were property damages. Of the injury accidents, 309 were fatal, 206 and 86 were serious and slight injuries respectively. However, 43 accidents were without defined locations. As a result, the total number of accidents became 1,108. Accordingly, the injury accidents reduced to 579 out of which 300 were fatal, 197 were serious injury, and 82 were slight injury.

The uniformity of the accident data were determined by verifying the consistency of the data i.e. by calculating arithmetic mean, standard deviation and coefficient of variation. The result was shown that the coefficient of variation is greater than 1.0 which is 1.67; and the standard deviation is very substantial. These values indicated that the degree of variation from one accident data to another was very high, even if the means were drastically different from each other. Because of this, it is better to see accident data by segregating into built-up and none built-up areas.

To have general outlook, it is better to see the accident distribution in relation to built-up and non built-up area using the following pie chart as shown in Figure 5.1. The built-up area covers 17.7 per cent of the study road section and 46 per cent of the total number of accidents. When we see this share of the road and percentage of accidents in built-up area, it requires further analysis on the built-up area with that of non built-up road section because, accidents are more clustered within the built up area.

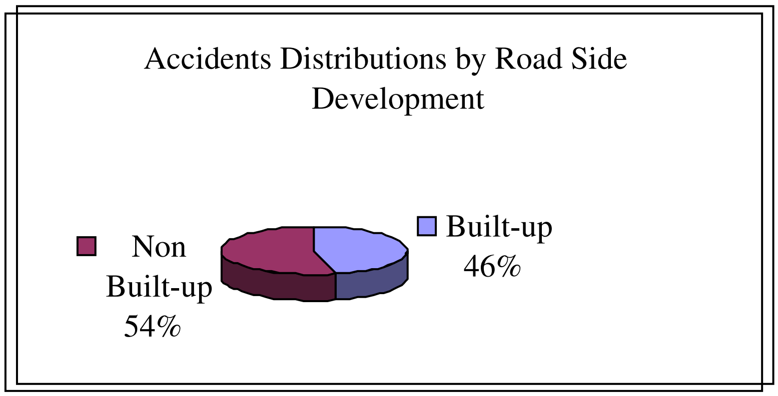


Figure 5.1 Accident Distributions by Road Side Development

Table 5.1 Characteristics of Accidents Distribution

Accident Type	Built-up Area	Non Built-up Area
Study Road Length	17.7%	82.3%
Pedestrian	53.7%	46.3%
Night time Collision	36.5%	63.5%
Single Vehicle (non pedestrian)	36.5%	63.5%
Two or More Vehicles Involved	48.7%	51.3%
Rollover	23.9%	76.1%
Number of Casualties	39.4%	60.6%
Car occupants accidents	27.8%	72.2%

As indicated in Table 5.1, pedestrian and multi- vehicles accident were dominant in urban areas in relation to the total study road section. On the contrary, non built-up area has a higher share single vehicle (non pedestrian) accident and night time collision. Car occupant accidents and number of casualties were dominated in rural area.

5.1.1. Accidents in the Built-up Area

(i) Variation Time of Accident

Time variation: Figure 5.2 shows the distribution of accidents in relation to months for built-up areas. The monthly distributions of accidents show more accidents in the wet season and less in dry season.

For instance, accidents were registered higher in the months of Sene (June), Hamle (July), Nehase (August), Meskerem (September), and as well as in Tikimt (October). On the other hand, Figure 5.3 presents accident variation by days of a week. This shows that there is no significant variation between them. However, a higher value is depicted on the graph during the week-end days i.e. Saturday and Sunday. This is due to the fact that many of the residence of Addis Ababa spent their week-ends in resort or recreational centers along this route. Figure 5.4 shows hourly variation of accidents and the peak frequency corresponds with morning and afternoon traffic volume peaks. However, more accidents occurred during 1500-1800 hours which is in the afternoon. Most probably, drivers are stressed and fatigued during these hours as a result of hot tropical weather condition.

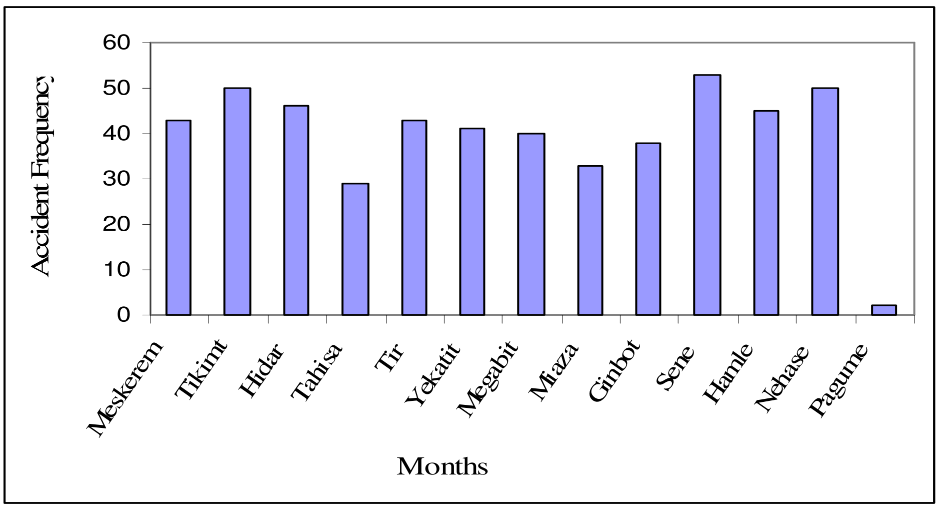


Figure 5.2 Accidents Distribution by month in built-up areas

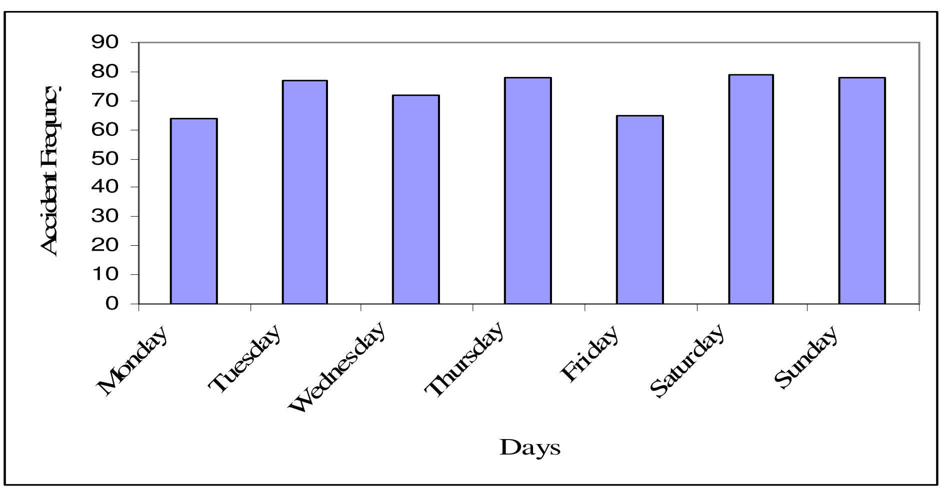


Figure 5.3 Accidents Distribution by days of a week in built-up areas

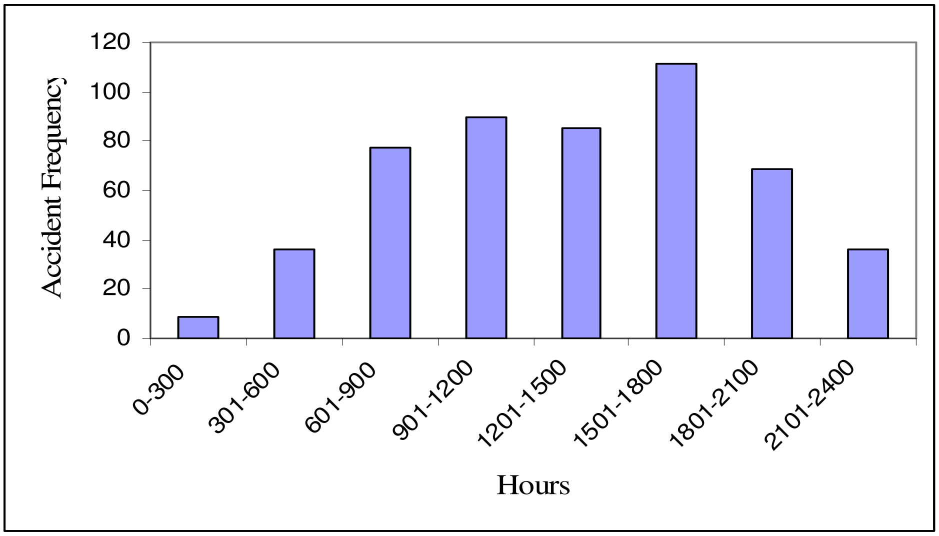


Figure 5.4 Accidents Distribution by hours a day in built-up areas

(ii) Demographical Analysis

A breakdown of collisions by drivers' age with accident severity is provided in Table 5.2. Over sixty two percent of the drivers involved in collisions were between the ages of 18 and 34. In this age group, about seventeen per cent were between 18 and 24 years old. Nationally, drivers of this age group are fewer in number but their contribution to accidents seem to be very high.

Table 5.2 Distribution of accidents by drivers' ages

Drivers' Age	**Fatal**	**Serious**	**Slight**	**Property**	**Total**	**%**
18-24	25	18	9	34	86	16.76
25-34	57	47	21	108	233	45.42
35-44	21	25	15	50	112	21.83
45-54	16	8	3	24	51	9.94
Above 55	4	7	1	8	20	3.90
Unknown	6	3	0	2	11	2.14
Total	**129**	**108**	**49**	**227**	**513**	**100**
%	**25.15**	**21.05**	**9.55**	**44.25**	**100**	

Education of younger drivers may be an appropriate area of focus. Drivers aged between 25 and 34 have a share of 45 per cent. This age group is most active in the economy and most of them are hired drivers. In this regard, about 86 per cent of the drivers are hired or employed as professional drivers.

(iii) Accidents by vehicle types

Accident data collected in built-up area indicated that vehicles most frequently involved in accidents were trucks 11-40 quintals (22%). Figure 5.5 shows the types of vehicles in built-up area.

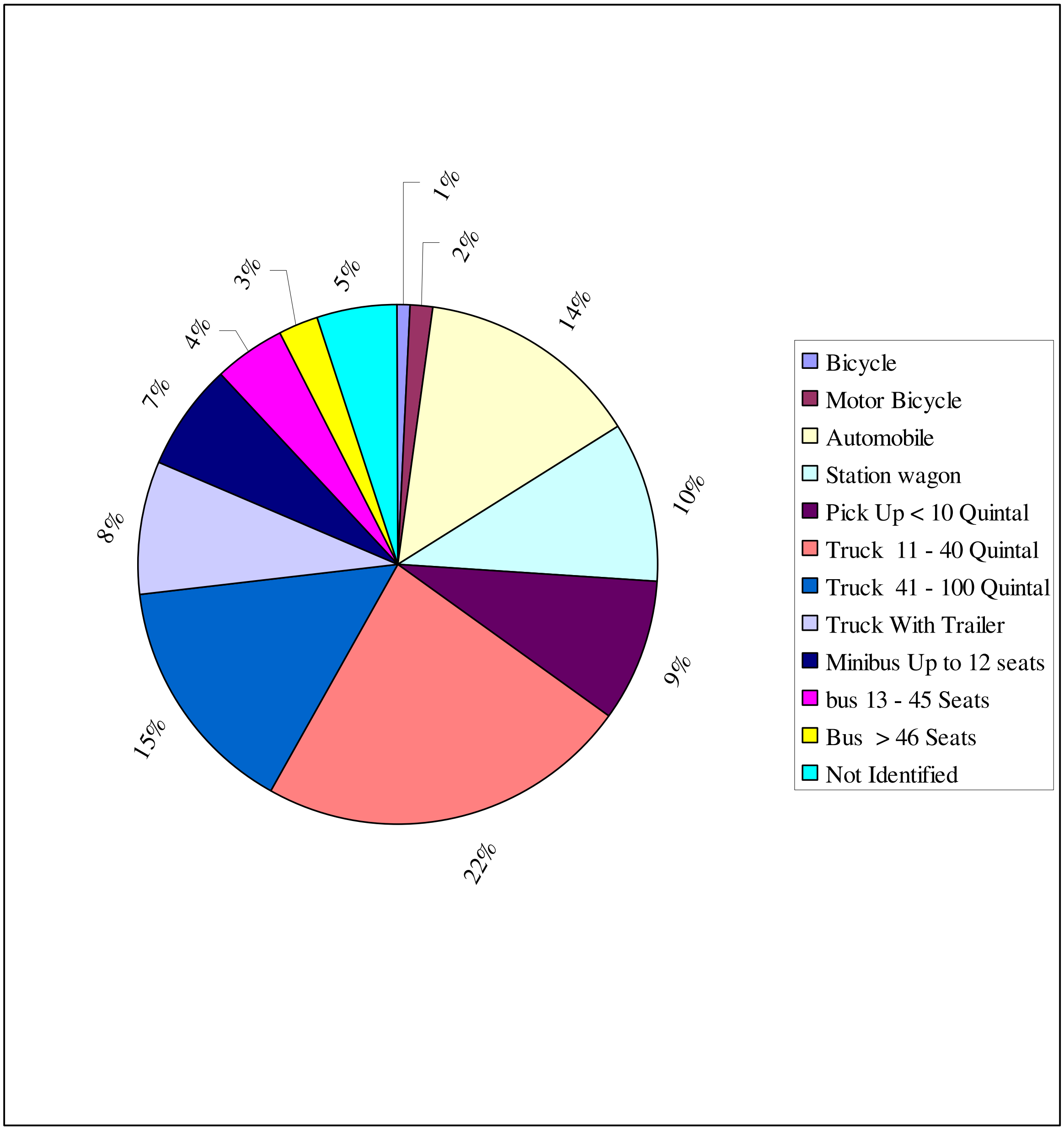


Figure 5.5 Type of vehicle involved in accident in built-up area

These are medium trucks with a capacity of 35 quintals, most commonly known by their trade marks ISUZU. The second most frequently involved in accidents were the trucks with 41- 100 quintals

(15%) as indicated in Figure 5.5. These vehicles are usually operated by professional drivers for extended hours by chewing chat (stimulant leaf). As a result, fatigues together with speed are the main causes for accidents in these types of vehicles.

According to Table B-1 in Appendix II, the involvement of vehicles in pedestrian collisions was significantly higher than other types. It had a share of 39.58 Per cent out of which about 24 percent of collisions were caused by truck 11-40 quintals. It is clear that Isuzu trucks whose carrying capacity of 35 quintals were the major contributors of this category. They caused the highest number of property damages and road user injuries. The above is substantiated by Table B-2 in Appendix II. Besides, heavy trucks without trailers (truck 41-100 quintals) were registered as the second hazardous vehicles in terms of causing fatalities, and injuring road users and property damage during the three year period. In general, this shows that there was a big problem regarding drivers' competency, pedestrians' behavior and poor pedestrian facilities in towns.

In terms of collision types, the majority of accident severity resulted in pedestrian accidents, other collision types like head on, nose-tail, side, side with angle collision, roll over, fall from vehicle, collision with animals, collision with static objects and collision with parked vehicles had minor contributions to accidents in built-up areas. As can be seen from Table B-3 in Appendix II, collisions with pedestrians accounted for about 39.4 per cent during three year period.

As shown in Table 5.3, the highest percentage of fatalities was with pedestrians that accounted for about 65.31 per cent followed by passengers with 25.85 per cent and then by drivers with 8.84 per cent. It is true that urban environment here in Ethiopia does not have proper pedestrian facilities. Furthermore, road users are not well aware of traffic rules and regulation in the country. In major area of the study road sections especially in built-up area, carriageways or the edge of carriageways are used as footways. It is common to observe pedestrian and vehicle conflicts.

Night time accident casualties accounted for 31 percent and the rest were occurred during day times. The distribution of accident casualty with night and day time is depicted in Table B-4 and B-5 in appendix II.

Table 5.3 Severity of Injuries Casualties by Road Users in Built-up Area

Accident Type	Drivers		Passengers		Pedestrians		Total	
	Number	%	Number	%	Number	%	Number	%
Fatal	13	8.84	38	25.85	96	65.31	147	100
Serious	18	12.25	43	29.25	86	58.5	147	100
Slight	6	8.82	25	36.75	37	54.41	68	100
Total	37	10.23	106	29.28	219	60.49	219	100

5.1.2. Accidents in Non Built-up Areas

(i) Variations Time of Accidents

Time variations of accidents in non-built-up areas are shown Figure 5.6. Monthly variations of accidents show peak values of accidents during the months of Hidar (November), Tir (January), Sene (June) and Nehase (August). These do not exhibit consistent variation of accidents during wet and dry seasons of the year.

Figure 5.7 show that weekly variations of accidents reach peaks on Friday and Saturday. The highest number of accidents on Friday and Saturday can be caused most probably because of related to high traffic volume especially when delivery trucks are transporting agricultural produces to market places in Addis Ababa. The lowest numbers of accidents were recorded on Sunday and Monday.

Figure 5.8 shows those hourly variations of accidents exhibits variation of accidents. The graph shows that the same variation of accidents with that of the built-up area. Peak accidents were recorded between 600 hours in the morning and 2100 hours in the evening. The variation of accidents with time follows the hourly variation traffic volume. As observed in the graph, the traffic volume reached peak value between 1500 hours and 2100 hours. Furthermore, there is a restriction or ban of heavy trucks to enter Addis Ababa during day time. But they are allowed to enter after 1900 hours in the evening. Therefore, they approach the capital city in the evening and traffic volume becomes higher during these hours. In general, there is a strong correlation between traffic volumes and collision frequency.

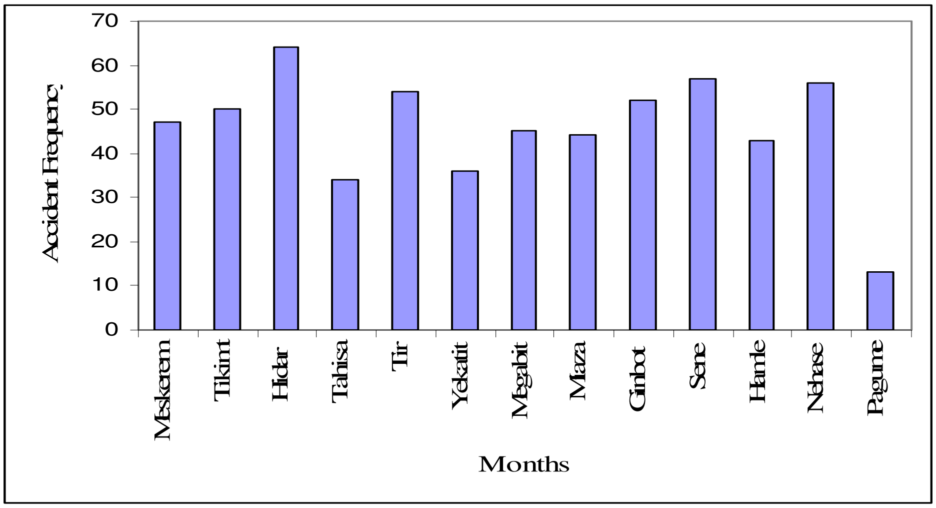


Figure 5.6 Accidents Distribution by month in non built up areas

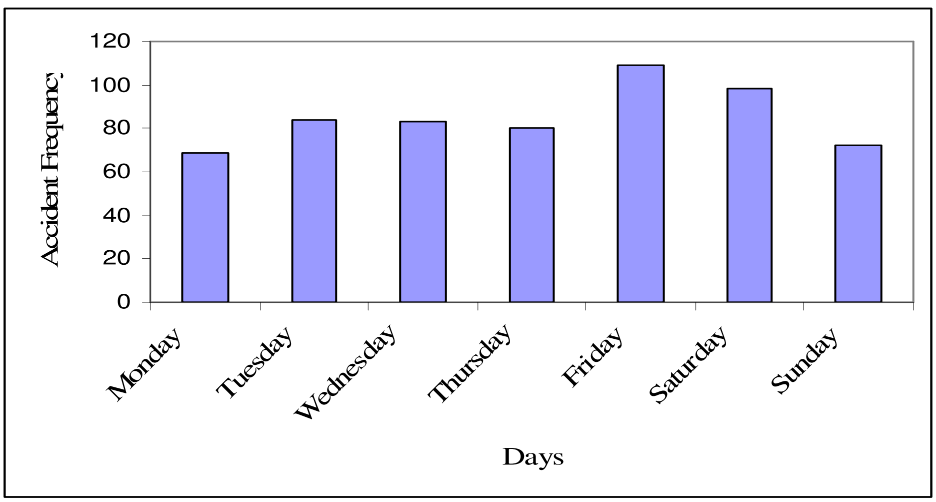


Figure 5.7 Accidents Distribution by days of a week in non built up areas

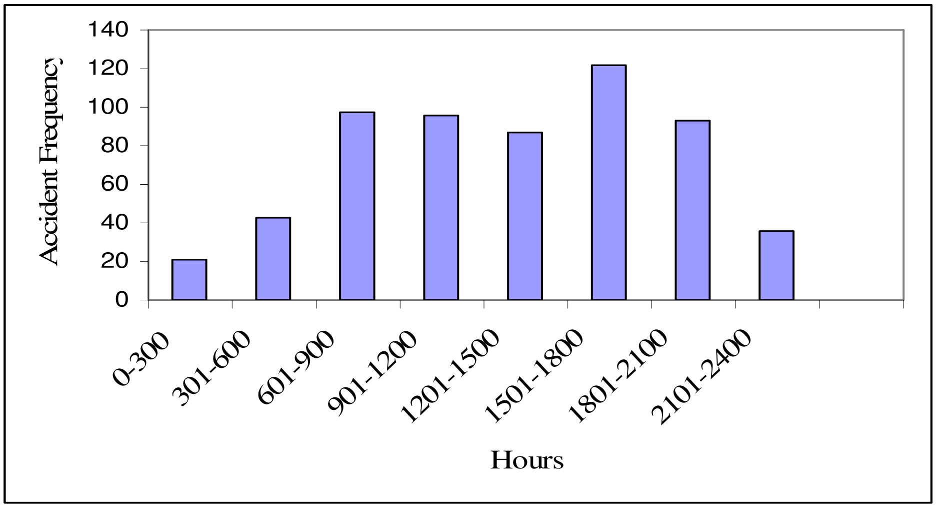


Figure 5.8 Accidents Distribution by hours of a day in non built up areas

(ii) Demographical Analysis

Table 5.4 shows accident distribution in respect of drivers' age in built up area. Over forty seven percent of the drivers involved in collisions were between 25 and 34 years of age. This group is highly engaed in economic activity. Based on the analyses, about 48 per cent of fatal accident occurred by this age group. Hence, this group should be the area of focus of policy makers.

About 13 per cent of collisions occurred by the age group between 18 and 24 years old. Although drivers of this age group are fewer in number in the country. Similarly, group especial attention of the policy makers should focus on this group.

Table 5.4 Drivers' Age with Accident Severity in Non Built-up Area

Driver Age	Fatal	Serious	Slight	Property	Total	%
18-24	19	13	2	44	78	13.11
25-34	78	39	10	156	283	47.56
35-44	45	16	11	64	136	22.86
45-54	19	18	8	29	74	12.44
Above 55	6	2	2	8	18	3.02
Unknown	4	1	0	1	6	1.01
Total	**171**	**89**	**33**	**302**	**595**	**100**
%	**28.74**	**14.96**	**5.55**	**50.75**	**100**	

(iii) Accidents by vehicle types

Figure 5.9 indicates that the most frequently involved vehicles in accidents were trucks with 11-40 quintals capacity (28%). The second most frequently involved vehicle were trucks with 41- 100 quintals capacity (15%). As compared to the built-up road sections, accidents were more clustered to trucks. The causes of crash of these types of vehicles in non-built-up area are the same as for built – up area.

As shown in Table B-6 in appendix II, the involvement of vehicles in pedestrian collisions and rollover accidents were significantly higher than other types with 29.41 and 23.53 per cents respectively. Similarly, 26.86 percent of pedestrian collision and 37.86 percent rollover accidents were caused by truck with 11-40 quintals capacity.

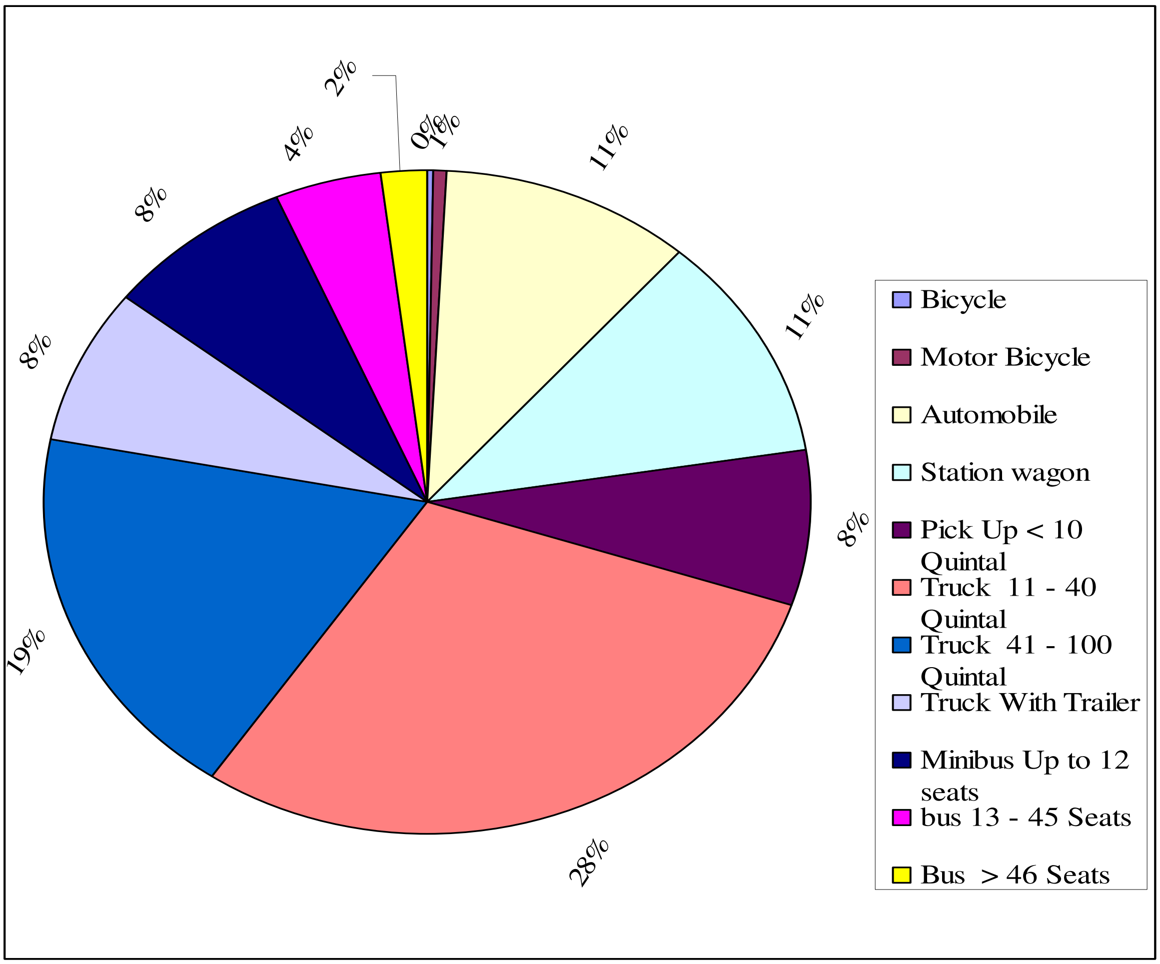


Figure 5.9 Type of Vehicle Involved in Accident in Non Built-Up Area

Like accidents in towns, Isuzu with carrying capacity of about 35 quintals were the major contributors for both collisions types. The shares of rollover accidents were significant in non built area due to the fact that drivers operate their vehicles at high speeds. This is corroborated in Table 5.1 which depicts that non-built-up area has the highest share of single vehicle non-pedestrian accidents.

In case of severity by vehicle type, trucks with carrying capacity of 11-40 quintals (ISUZU 3.5 Tons) caused the highest number of accidents as shown in Table B-7, appendix II. The next vehicle type that caused the highest number of accidents and injuries as well as property damages was heavy truck with capacity 41-100 quintals.

During the three years period, severity by collision types in non built-up area, the majority accident severity resulted from collision with pedestrian and rollover accidents. As depicted in Table B-8, Appendix II rollover accidents caused the major property damages. However, collision with pedestrians had the worst record in causing injuries.

As shown in Table 5.5, the major causalities occurred in vehicle occupants who accounted for about 66.67 per cent. While in case of urban environment, the majority of causalities were pedestrian which accounts about 60.49 per cent. Moreover, 36.7 per cent of fatal, 62.45 per cent of serious and 69.09 per cent of slight injury accidents were on passengers and 14.16 per cent of fatal, 16.59 per cent of serious and 3.6 per cent of slight injury accidents on drivers.

Table 5.5 Injury Severity of Casualties by Road Users in Non Built-Up Area

Accident Type	Drivers		Passengers		Pedestrians		Total	
	Number	%	Number	%	Number	%	Number	%
Fatal	32	14.61	79	36.7	108	49.3	219	100
Serious	38	16.59	143	62.45	48	20.96	229	100
Slight	4	3.6	76	69.09	30	27.27	110	100
Total	74	13.26	298	53.41	186	33.33	558	100

Night time accident casualties accounted for 23 percent and the rest were occurred during day time. As compared to urban area, the night time casualty is less. This is because night time driving is less customary practice in the country. The other reason is that due to security reasons, people do not plan trips to the country sides. The distribution of accidents of casualty with night and day time is depicted in Table B-9 and B-10 in appendix II.

5.2. Relationship among Road Traffic Accidents, Road Design Elements and Traffic Factors

It is possible to develop a relationship among road traffic accidents with that of traffic flows and geometric design variables. In this regard, simple categorical analysis was made based on accidents versus road alignments. Furthermore, correlations of accidents with different geometric design elements were also made.

5.2.1. Roadway Alignment

Horizontal curves, steep grades, and vertical curves bring additional challenges to drivers, resulting in increased risk of collisions. During the three years period, the number of accidents on horizontal curves was less than the tangent sections.

Figure 5.10 shows a breakdown of collisions according to roadway alignment. Accordingly, 52 per cent of the collisions occurred on level and tangent sections and similarly, 48 per cent occurred on horizontal curves or grades.

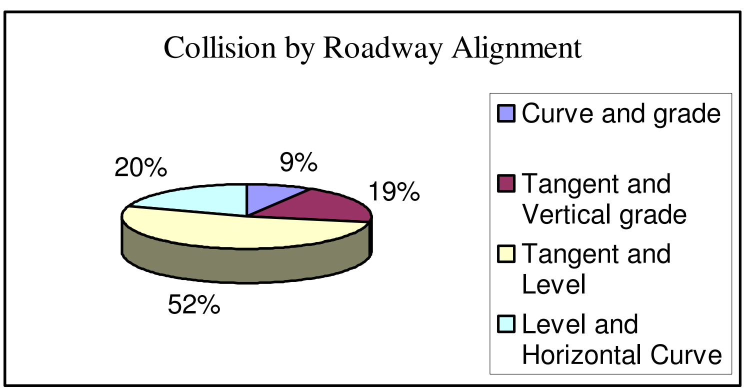


Figure 5.10 Collision by Roadway alignment.

These road alignments were cross tabulated with respect to the areas of development as shown in Table 5.6. The 46 per cent of the collisions occurred on the tangent and level section of the road in built-up area. Whereas, accidents on curve and grade, tangent and vertical grade, level and horizontal curve shared 54 percent of collisions in built-up area. However, non built-up road section accounted for 44 per cent of collision on horizontal curves and grade road section.

Table 5.6 Accidents distribution based on roadway alignment with area of development

Description	**Built-Up**		**Non Built-Up**		**Total**	
	no	%	no	%	no	%
Curve and grade	40	7.8	59	9.87	99	8.91
Tangent and Vertical grade	69	13.45	151	25.38	220	19.86
Tangent and Level	235	45.81	328	55.63	563	50.83
Level and Horizontal Curve	169	32.94	57	9.58	226	20.39
Total	**513**	**100**	**595**	**100**	**1108**	**100**

The remaining 56 per cent occurred on tangent and level road sections. In general, accidents on curves and grades are dominantly occurring in built-up (town) areas.

5. 2.2. Variation of Accident rates with Road and Traffic Factors

(i) Accident rate with AADT

The risk of road traffic accidents varies with respect to Average Daily Traffic on the road. As shown in Table 5.7, accidents rate is very high in lowest traffic volume. The same is true in the case of average rate of injury accidents per MVK. The lowest AADT road (Ziway- Bulbula) is riskier by 75.48 per cent than the highest AADT road section (A.A- Debrezeit) in average accident rates per Mvkm. The road between Modjo-Ziway-Bulbula-Shashemene operates at service level of A or B. The level of service gives more freedom to drivers to choose the operating speed. Hence, drivers operate their vehicle above the speed limit.

Table 5.7 Variation of Accident risk with the variation of Average Annual Daily Traffic

No. Road Segment	Total length (Km)	Average length (Km)	AADT	Average accident rates per MVK	Std deviation for Av. acc. rate	Av. Injury accident rates per MVK	Std deviation for Av. Injury acc. Rate

8	23.72	2.965	10027	0.8896	2.257	0.4833	1.059
2	22.58	11.29	6901	0.89083	2.87	0.38095	0.353
12	88.7	7.39	2683	0.9325	1.628	0.52573	1.002
3	22.96	11.48	1812	2.28291	1.276	1.25121	1.001
7	60.84	8.69	1875	1.5611	1.13	0.82458	1.001

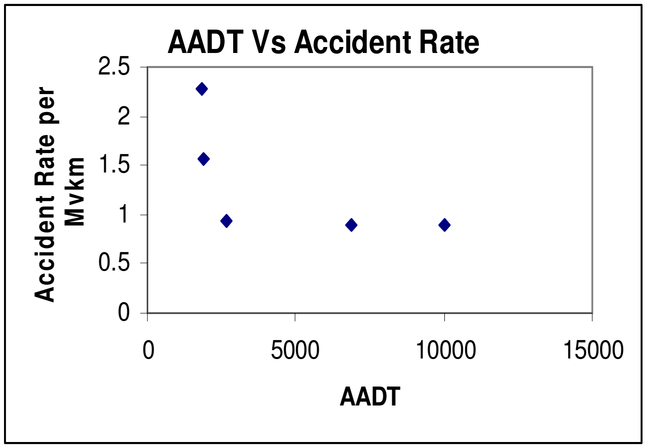


Figure 5.11 ADT with Accident Rate

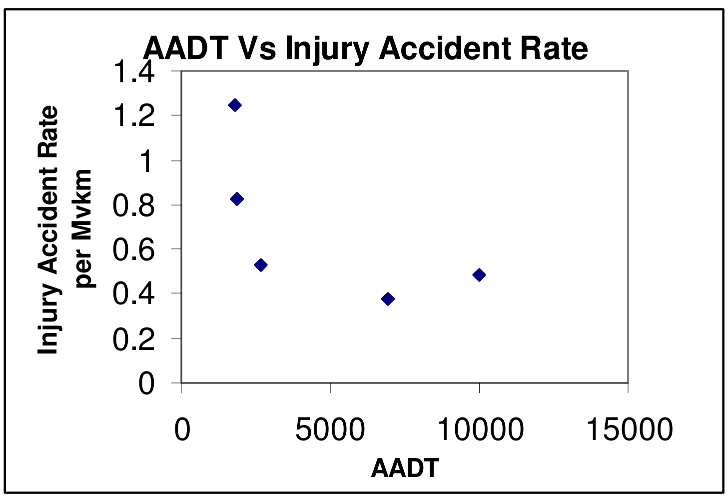


Figure 5.12 ADT with Injury Accident Rate

(ii) Accident rate with number of lanes

As shown in Table 5.8, the effects of the number of lanes are positively correlated with accident and injury risks. It is evident that accident rate is low on 2-lane undivided roads while high on four-lane undivided roads. The results are similar as examined the injury accidents rate. As discussed above, accidents are more concentrated in built-up area and four lanes are usually found in this section. Besides, pedestrians are not well aware of traffic regulation and thus carelessly cross this undivided road improperly. In addition, undivided roads have general disadvantages of safety effects during crossing. Especially on four lane road, pedestrians take longer time while crossing and thus they are easily exposed to traffic accidents.

Table 5.8 Variation of accident risk with the variation of Average number of lanes

Av. number of lanes	No. Road Segment	Total length (km)	Average accident rates per MVK	Std deviation for Av. acc. rate	Av. Injury accident rates per MVK	Std deviation for Av. Injury acc. Rate
2	16	184.26	0.98279	1.475	0.49744	0.788
3	3	7.34	1.34079	1.22	0.71144	0.581
4	13	27.2	2.81815	3.163	1.54998	1.675

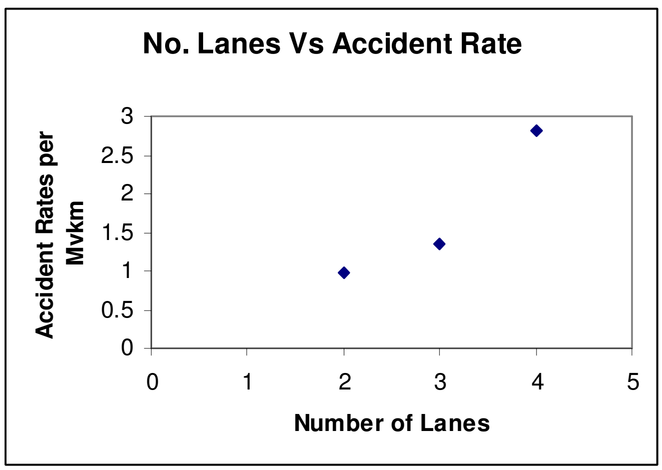


Figure 5.13 Number of lanes with accident rate

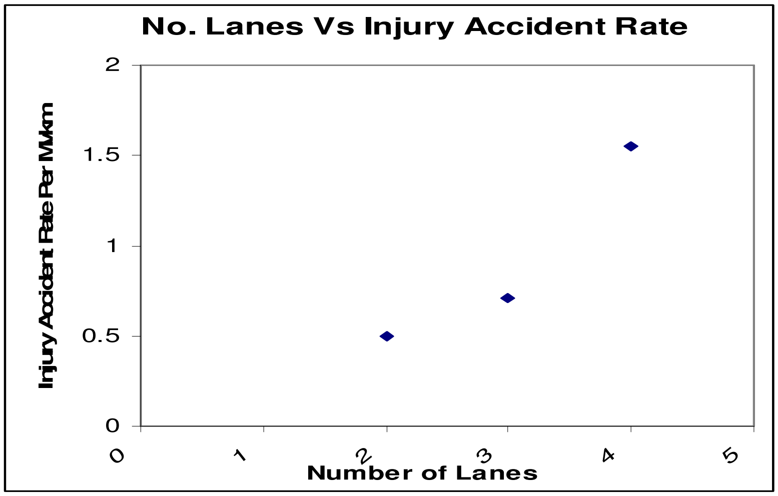


Figure 5.14 Number of lanes with injury accident rate

(iii) Accident rate with radius of curvature

Accidents on horizontal curves cause a significant amount of pain and suffering to those involved in the accidents because of the nature of the collisions. As exhibited in Figure 5.15, the accident rates steeply increased whenever the radius of curvature reduced. Therefore, accidents are inversely related to the radius of curvature.

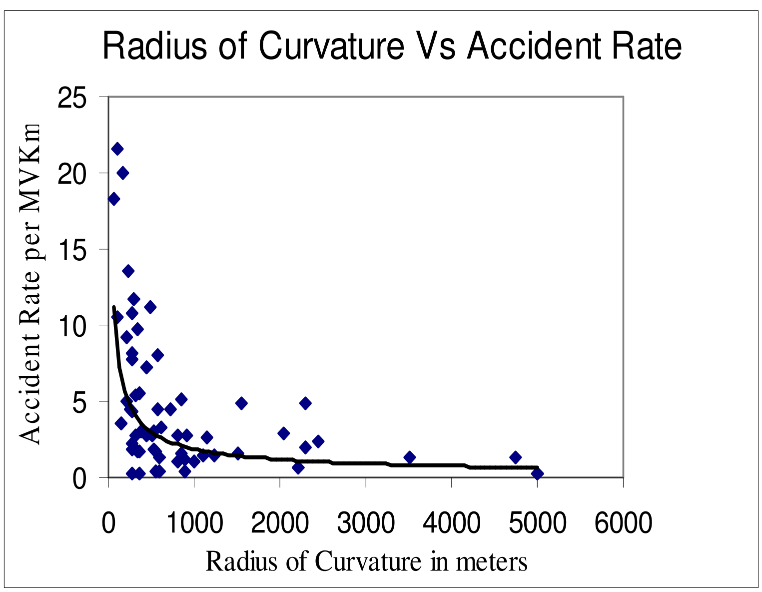


Figure 5.15 Radiuses of Curvature Vs Accident Rates

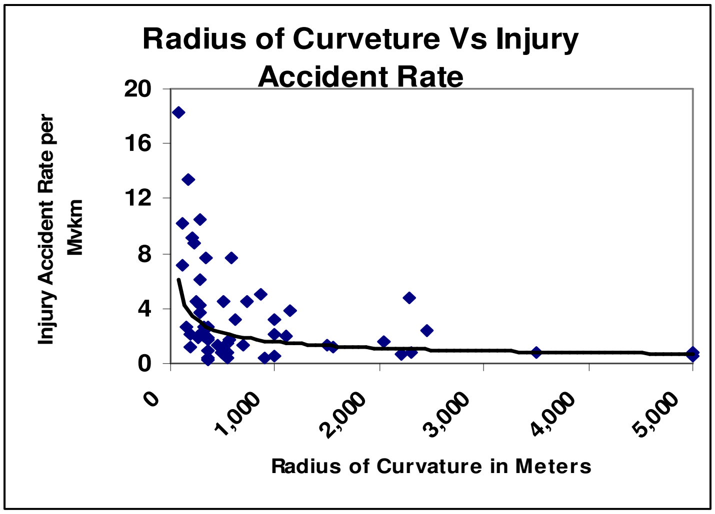


Figure 5.16 Radiuses of Curvature Vs Injury Accident Rates

(iv) Accident rate with grade

The grade of a road affects safety. Figures 5.17 and 5.18 show that total accidents or injury rate per MVK vary with grade. The safety of the study road deteriorated with steep grades.

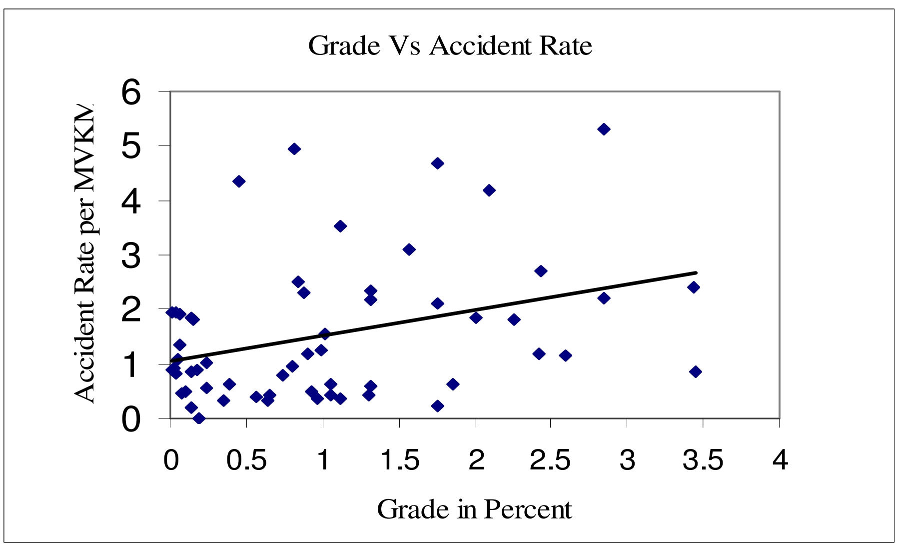


Figure 5.17 Grade with accident rates

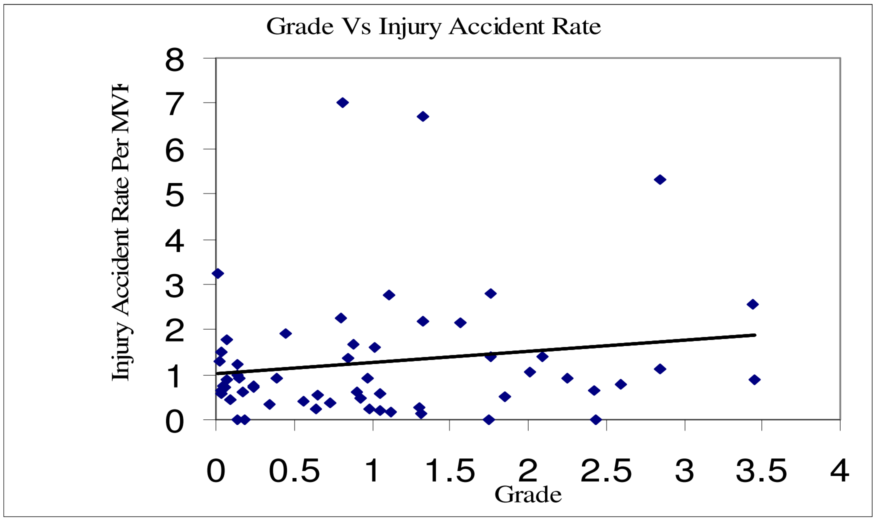


Figure5.18 Grade with Injury accident rates

5.2.3. Access Frequency, Accident Density and Accident Rate

The built-up areas of the study road do not have access control. In developed countries, numbers of driveways per kilometer have a legal requirement and they have a regulation for getting permit and spacing.

Table 5.9 Access Density and Accident per Year per Kilometer

Town	Kilo meters	No. of accid. in three Years	No. of Access point	Driveway Density per Km	No. of accid. per Year	Accid. Density per Km per year	ADT	Accident rate per Mvk
Dukem	2.7	92	6	2.2	30.7	11.4	10027	3.1
D/Zeit	9.9	180	36	3.7	60	6.1	10027	1.7
Modjo	3.5	24	6	1.7	8	2.3	6901	0.9
Ejersa	1.1	6	2	1.8	2	1.8	2683	1.9
Koka	1.3	6	4	3.1	2	1.5	2683	1.6
Alemtena	1.8	22	4	2.2	7.3	4.1	2683	4.2
Meki	3.4	34	22	6.5	11.3	3.3	2683	3.4
Abomssa	1.4	9	3	2.1	3	2.1	2683	2.2
Ziway	2.5	34	25	10	11.3	4.5	2683	4.6
Adami Tulu	1.4	16	4	2.9	5.3	3.8	1812	5.8
Bulbula	2.1	25	3	1.4	8.3	4.0	1875	5.8
Arussi Negele	3.6	39	15	3.9	13	3.3	1875	5.3
Kuyera	3.9	26	4	1.0	8.7	2.2	1875	3.3

However, every development along the road has access without getting any control. Table 5.9 shows driveway density per kilo meter with respect to accident density per year per kilometer. In general, Table 5.9 shows that accident rate and driveway density. When frequencies of driveway density increases, the probability of occurrence of accident increases. For instance, Dukem Town has the highest value of accident density per kilometer per year. On the other hand, driveway density per kilometer is the highest in Debre Zeit town. However, accident rate is the highest in Bulbula town followed by Adami Tulu town. The above is substantiated by NCHRP report on access management (26) which states that increase in frequency of access points adversely affects safety. Most of these studies are conducted to demonstrate the benefits of access management.

5.3. Operating Speed Pilot Study on the Study Road

The Interim National Road Safety Coordination Office (INRSCO) (25) conducted mobile radar measures on the Eastern Shewa road section which included the whole study road. The accident history shows high fatality rates due to speed limit violation prevalent on the well-rehabilitated highway. This is particularly the case involving pedestrians in the small towns along the highways. INRSCO took a sample of 1307 vehicles in the towns along Addis Ababa Awassa highway of which, 616 vehicles (47%) had violated the 30KPH speed limit. Figure Figure 5.19 shows the relative speed violations of vehicles by category above the 30KPH limit recorded in the fourth week of May 2004 (21/06/97 to 26/06/97 Ethiopian Calendar).

The result confirmed high rate of speed limit violation. Also the violators were driving at very high speed, two to three times than the allowable speed limit. This is an alarming situation for cities, towns and villages along the highways resulting in high and serious pedestrian accidents. At the start of the test time, it was observed in rural areas of the pilot over zone that 35 per cent of the drivers exceeded the speed limit initially. Penalty for speed limit violation was started in September 2004 in this pilot zone.

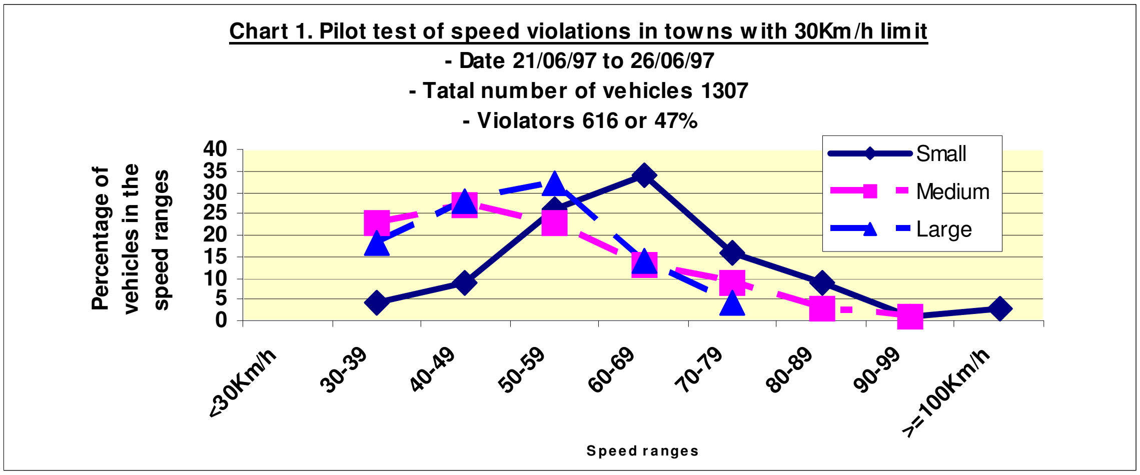


Figure 5.19 Relative Speed Violations of Vehicles by Category of Vehicles

A gradual decrease in the percentage of violators and speed ranges was observed since then. The percentage of reduction was from about 35 per cent at the start of the program to less than 15 per cent by August 2005 [25].

As it is observed, the speed violation reduction in cities was not found to be as strong as the rural areas.

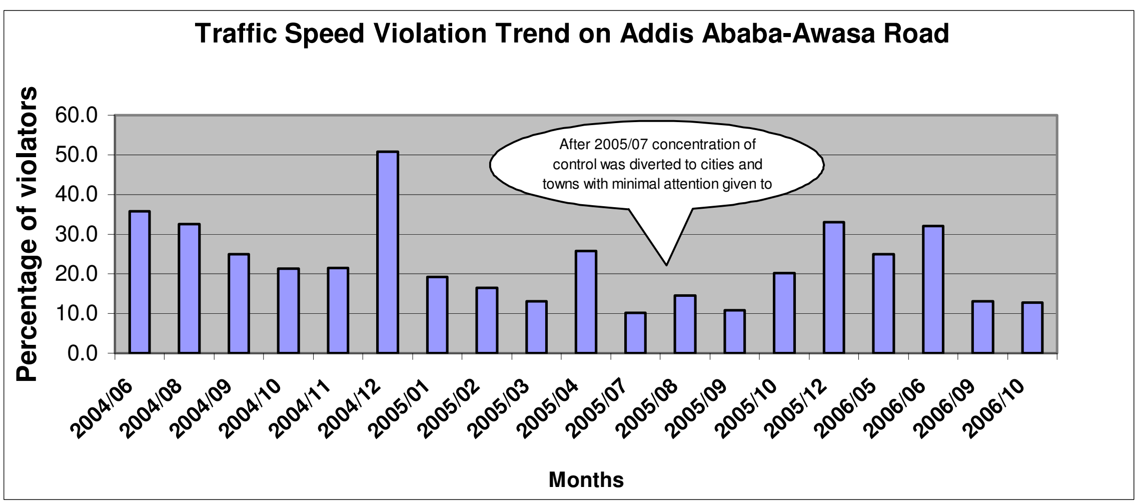


Figure 5.20 Relative Speed Violations Trend on Addis-Ababa-Awassa Road

As a result, a concentrated effort was put in the urban areas from November 2005 onward, reducing the rural area radar control. The speed violation in populated areas reduced to less than 25 per cent since January 2006. It has come down to less than 15 per cent presently [25].

5.4. Identification of Black Spots

i) Calculating Accident Rates

Following the criteria developed in chapter four, thirty two road sections were delineated for identification of black spots and grouped. These are as depicted in Table 5.10.

Table 5.10 Single-carriageway Addis Ababa- Shashemene trunk road schemes in the study

Scheme No	From Station	To Station	Environment	Lengt (km)
Standard width	(7.00m) single-	carriageway	schemes	
1	24+700 - 25+360		Non Built-up	0.66
2	27+760 - 30+500		Non Built-up	2.74
3	34+600 - 35+960		Non Built-up	1.36
4	37+240 - 42+740		Non Built-up	5.5
5	48+420 - 70+720		Non Built-up	22.3
6	71+000 - 84+100		Non Built-up	13.1
7	85+000 - 89+020		Non Built-up	4.02
8	89+720 - 107+200		Non Built-up	17.48
9	108+540 - 128+100		Non Built-up	19.56
10	131+240 - 147+560		Non Built-up	16.32
11	148+520 - 157+340		Non Built-up	8.82
12	159+700 - 165+440		Non Built-up	5.74
13	166+660 - 182+660		Non Built-up	16
14	184+700 - 223+700		Non Built-up	39
15	226+600 - 234+560		Non Built-up	7.96
16	238+960 - 242+660		Non Built-up	3.7
Standard width	(10.50m) single-	carriageway	schemes	
1	25+360 - 27+760		Non Built-up	2.4
2	30+500 - 34+600		Non Built-up	4.1
3	242+660 - 243+500		Non Built-up	0.84
Standard width	(14.50m) single-	carriageway	schemes	

1	35+960 - 37+240	Built-up	1.28
2	42+740 - 48+420	Built-up	5.68
3	84+100 - 85+000	Built-up	0.9
4	89+020 - 89+720	Built-up	0.7
5	107+200 - 108+540	Built-up	1.34
6	128+100 - 131+240	Built-up	3.14
7	147+560 - 148+520	Built-up	0.96
8	157+340 - 159+700	Built-up	2.36
9	165+340 - 166+660	Built-up	1.22
10	182+660 - 184+700	Built-up	2.04
11	223+700 - 226+600	Built-up	2.9
12	234+560 - 238+960	Built-up	4.4
Standard width (17.00m) single-carriageway schemes			
1	70+720 - 71+000	Built-up	0.28

Details of accident rate calculations are available in Table C-1, Appendix III. Summary of the percentile that was used in delineating the black spot road section are shown in Table C-2. However, the accident rate at 90 percentile was used in identifying the dangerous sections which are given in Table 5.11. The ninety percentile is used because it is a better measurement of the top range [26]. The spread of accident rates among the schemes studied was large, ranging from a minimum of zero to a maximum of 5.19886 per MVkm. The maximum accident rate could be strongly affected by one scheme with a higher accident rate. Hence, a better measurement in this case is the ninth percentile. According to the criteria developed in the methodology, nine schemes were obtained which are above the 90th percentile of accident rate for schemes or/and Junctions.

Table 5.11 90th Percentile Accident Rate

	Accident rate per Mvkm Scheme	Accident rate per Mvkm Links	Accident rate per Mv Mjr jnc
90th percentile	3.3626	3.16295	0.74105

These sections and spots are black spot and consistent with the GIS output. The sections and junctions with accident rates were colored to compare with that of 90 percentile values as shown in Table 5.12.

Table 5.12 Dangerous Road Sections and Junctions for Treatment.

No	From Station	To Station	Accident rate per Mvkm Scheme	Accident rate per Mvkm Links	Accident rate per Mv Mjr jnc
1	70+720	71+000	**5.19886**	1.20304	**1.19101**
2	35+960	37+240	**4.55391**	**4.55391**	0
3	165+340	166+660	**4.54423**	**4.54423**	0
4	128+100	131+240	**3.3676**	**3.3676**	**0**
5	182+660	184+700	**3.342585**	3.19788	0.504
6	157+340	159+700	3.02881	1.16569	**1.02114**
7	223+700	226+600	3.02315	**3.02315**	0
8	234+560	238+960	2.8781	2.8781	0
9	108+540	128+100	0.69608	0.5513	**1.02114**

ii) Ranking of Sites

According to the priority criteria developed in chapter four, road sections which have greater than or equal to 20 of priority value considered for further treatment. Hence, there are five road sections which fulfill the criteria. These dangerous spots were prioritized based on the following formula.

$$P = \frac{(1*W+2*X+3*Y+5*Z)}{D}, \quad \text{where}$$

P= Prioritized weight

W= total number of property damage

X = total number of light injuries

Y = total number of serious injuries

Z = total number of deadly injuries

D= distance of black spot section in kilo meters

By applying the criteria and prioritization weight, five road section are obtained which fulfils the criteria. These are indicated in Table 5.13.

Table 5.13 Prioritization of schemes for treatment

no	Station	No. Acc	No. Injury	Km	W	X	Y	Z	P
1	35+960-37+240	65	31	1.28	34	7	14	10	109
2	70+720-71+000	11	1	0.28	10	0	0	1	53.6
3	128+100-131+240	25	18	3.14	7	4	5	9	23.9
4	223+700-226+600	18	14	2.9	4	1	2	11	23.1
5	157+340-159+700	21	10	2.36	11	2	3	5	20.8
6	182+660-184+700	15	8	2.04	7	1	3	4	18.6
7	234+560-238+960	26	14	4.4	12	0	6	8	15.9
8	165+340-166+660	7	4	1.32	3	1	1	2	13.6
9	108+540-128+100	40	20	19.56	20	2	7	11	5.11

5.5. Identification of Causes of Accidents and Recommended Counter Measures

Causes of accidents were identified at the following black spots.

A) Dukem Town: Station 35+960-37+240

According to black spot identification criterion, this station had the highest accident rate in scheme bases. This implies that the road section is the most dangerous road area.

Table C-3 in appendix III shows the number of vehicles involved in accidents, by type of vehicle and the number of pedestrians involved. In most accidents, 19 of the involved vehicles were not identified; 29.7 per cent of the 64 vehicles involved in three years. Truck with trailer and truck with 10-40 quintal capacity accounted for 34.4 per cent of the total accidents. At junctions, more accidents were caused by unidentified vehicles and trucks with 10-40 quintals capacity. Mostly, the reason of not identifying accident vehicles is that the drivers left the accident sites without reporting to the police.

The distribution of accidents by location (link or minor junction) for this section is shown in Table 5.14. Link accidents are 71 per cent while junction accidents are 29 percent. The main reason for higher accident severity at link sections was due to high motorized traffic than access points.

Table 5.14 Severity of accidents on the road section

Location	Fatal	Serious	Slight	Total
Minor Junction (access points)	3	5	1	9
Link	8	8	6	22
Total	11	13	7	31

Figure 5.21 presents the distribution of accidents by hour. The highest crushes occurred during 901-1200 hours. Whereas, midnight (0-300 hours) had the lowest number of accidents. Day time had about 65.6 percent of accidents. Accidents variation follows with variation of motorized and non motorized traffic. Hence, traffic policing is needed during these hours in the road section.

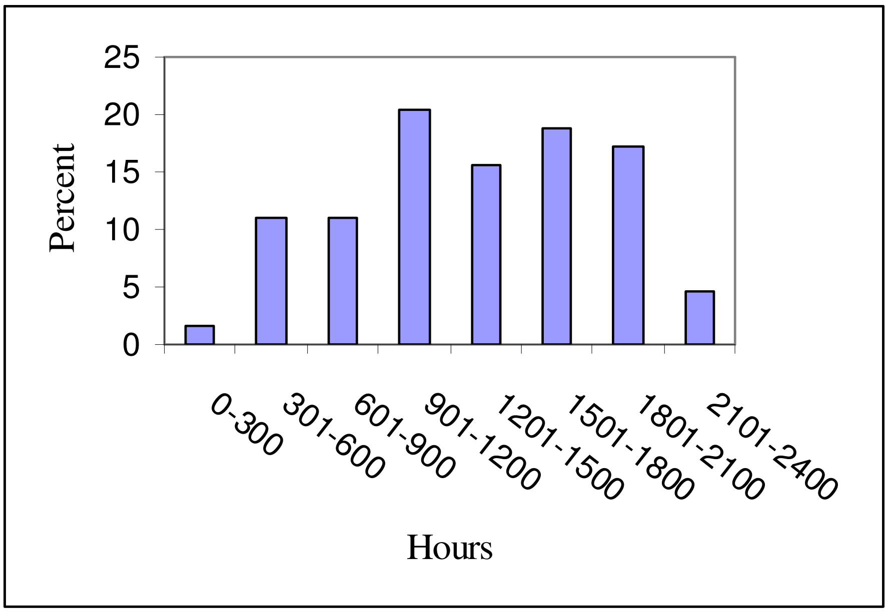


Figure 5.21Variation of accidents by hours

Figure 5.22 presents the distribution of accidents by day of week. Wednesday and Saturday had the highest number of accidents, whereas Tuesday had the lowest number of accidents.

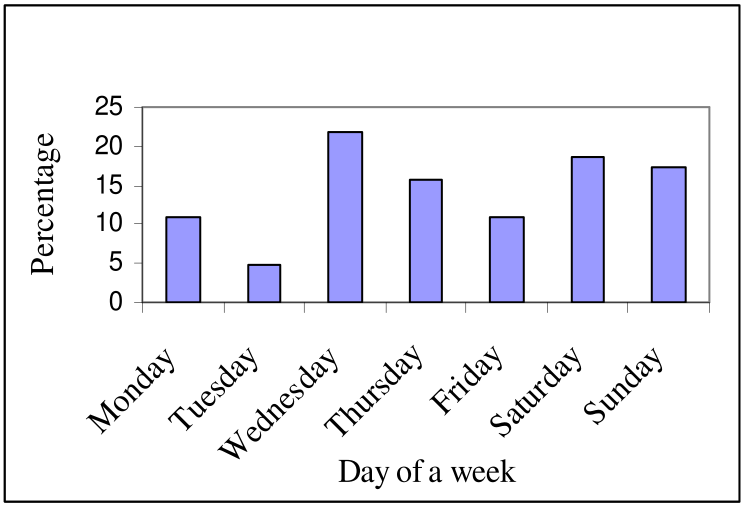


Figure 5.22 Variation of accidents by day of week

These two days are market days in Dukem town and people from nearby rural area come to sell their agricultural produce and buy industrial commodities. During these days, the numbers of non motorized traffic as well as the number of pedestrians is high. However, pedestrian walk way and non motorized lane for animal drawn carts are not provided. Figure 5.23 presents variation of accidents by month. In Ethiopia, June is the start of the wet seasons and much agricultural inputs are delivered to the country sides. This has an impact on increasing the volume of traffic and in turn, road traffic accidents. During this season, driving is difficult due to wet road surface even in the day time. This situation is practically manifested in Dukem town.

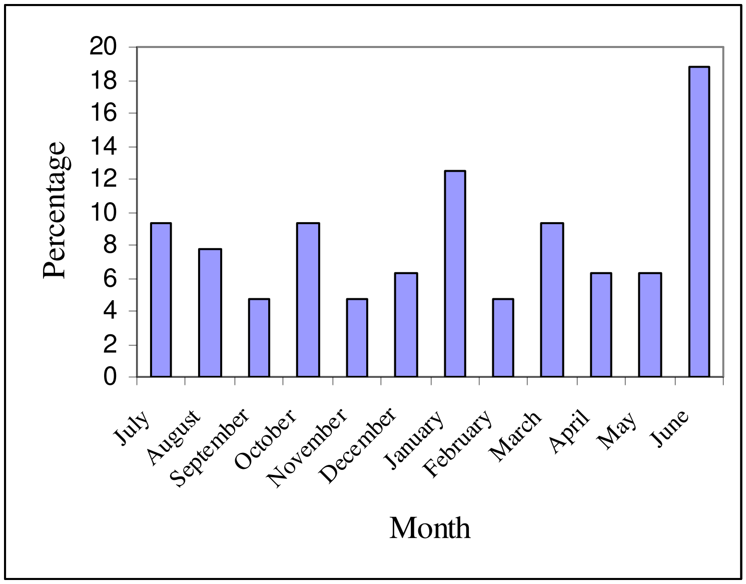


Figure 5.23 Variations of Accidents by Months

As shown in table C-4 in Appendix III, about 36 percent of the accidents were pedestrian accidents, and 23 percent were nose-tail. Other collision types like head on, side, side with angle collision, fall from vehicle, collision with animals, collision with static objects and collision with parked vehicles had small contribution at these dangerous road sections. It is observed that the town does not have proper pedestrian facilities. Furthermore, improper crossing, and crossing between parked vehicles are possible causes for high per cent of pedestrian collision. The condition of neighborhoods before and after the road sections allowed driving without decelerating their speeds. In the neighborhoods road sections, speed limit is 80 km/hr.

About 72 percent of the drivers involved in collisions were between 25 and 44 years of age as shown in Table 5.15. This age group is the most active participant in the economy sector. Other age categories have small shares. In this regard, out of 64 accidents that occurred in three years, 46 accidents involved drivers of age groups 25-44 which was 71.9 per cent of all accidents.

Table 5.15 Drivers' Age Group with Accident Severity.

Driver Age	**Fatal**	**Serious**	**Slight**	**Property**	**Total**	**%**
18-24	2		3	2	7	10.94
25-34	3	6	1	16	26	40.63

35-44	3	5	3	9	20	31.25
Above 45	2	2	0	7	11	17.19
Total	**10**	**13**	**7**	**34**	**64**	**100**

Site inspection: A visit was made on the road sections. During the site visit, the following problems were observed. There was no properly constructed side walk. Pedestrians mostly use out side lanes as a side walk. Besides, pedestrians do not have knowledge about traffic regulations. Illegal crossing, walking along the road and crossing between parked vehicles were common practices. Heavy vehicle are usually parked on the road side for a long time until the time of restriction to enter the capital city is over. With Regard to road marking, the road was painted during the construction of the road. However, the markings were faded with no sign to road users. Sharp curves were observed with radius of 360 meters. During the inspection time, vehicles were operating above the speed limits especially Isuzu trucks. Volition of speed limits in town along this road was confirmed by the National Safety Coordination Office's pilot study. Many Mini-buses and other public transport vehicles carry passengers over the legal limit. Details of the inspection are given in Appendix IV.

Proposed counter measure: The countermeasures were proposed based on the accident analyses, identified causes, and site inspections report. Appropriate engineering measures are provided to suggest solutions to the problem.

The study road incorporates Dukem town that requires reduction and improvement of pedestrian facilities. The following are proposed in order to alleviate the problem of the road section.

a) A speed limit sign (30 km/hr) should be placed where town begins, before 100-150 meters.
b) 1-2 sets of rumble stripes should be furnished before entering the town to notify reckless drivers.
c) Road side parking should be prohibited and provide off-road packing for heavy trucks.
d) Zebra crossings for pedestrian should be marked in 50-70 meters interval.
e) 1-2 sets of rumble stripes should be furnished before zebra crossing.
f) Strict traffic police enforcements should be required during day time because more than 70 percent of the recorded accidents occurred during this period. Special attention should be given on Wednesday and Saturday in controlling traffic.

g) For problem of lane discipline, improper overtaking and the like, re-painting of the road should be given much attention.

Before Improvement

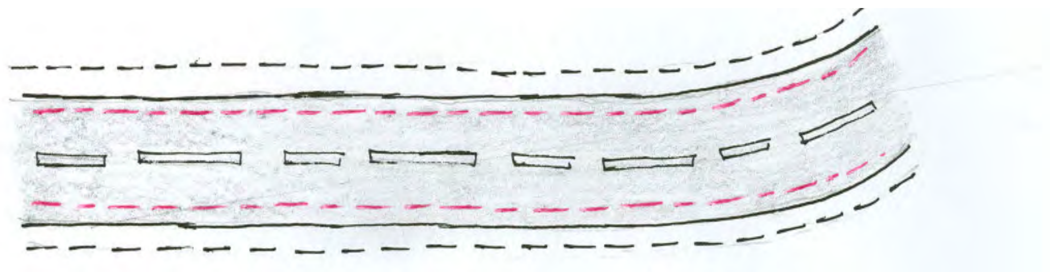


Figure 5.24 Sketch of Dukem road section before improvement

Recommended improvement

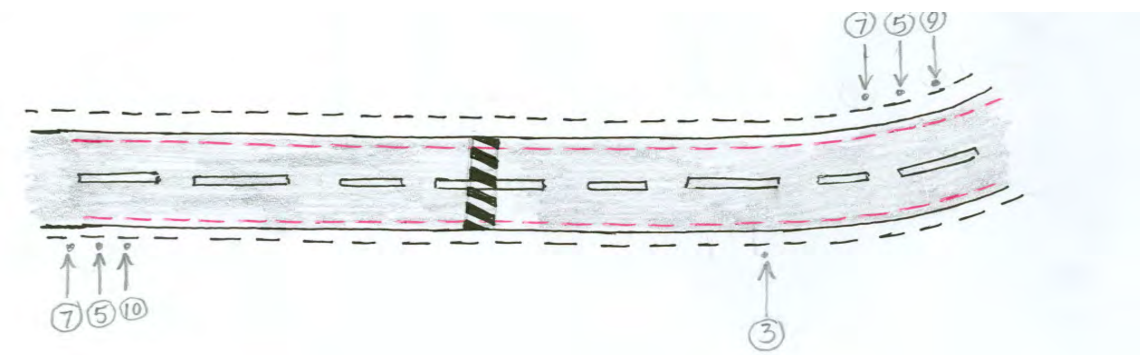


Figure 5.25 Sketch of Dukem road section after recommended improvement

Numbers shown on the sketch indicate that the proposed traffic signs will be furnished during counter measure. The legend is depicted on page 77-79.

B) Modjo Town: Station 70+720-71+000

This section had eleven accidents during the study period, out of which nine accidents occurred within the influence area of Modjo priority junctions. The remaining two accidents occurred on the links. Table C-5 in Appendix III presents a stick diagram for the junction. About forty- five percent of the accidents were nose-tail type of collision. Except one accident, the rest were non-injury accidents. As depicted on Table C-5, two or more vehicles accident had higher percentages (77.78 per cent). The junction has many conflict points. Figure C-1 in Appendix III presents accident pattern of collision types.

The nose- tail collision type was seen as predominant on the collision diagram. The priority junction allows drivers to operate their vehicles at high speeds causing frequent accidents. Likewise, side and side angle accidents occurred due to conflict points that exist at the priority junction.

Site Inspection: At the time of inspection, public transport vehicles used the junction for picking and dropping of passengers. Specially, drivers of Mini-buses did not respect traffic rules at the spots. There were no traffic signs around the junction also vehicles operated above the speed limits.

Proposed counter measure: As mentioned earlier, an accident prone spot was four legs priority junction. The following measures should be applied to improve the situation at the priority junction.

a) Trees and advertisement bill boards should be removed from the junction.

b) Priority junction should be replaced by roundabout. Roundabout has best records in accident reduction by reducing the conflict points as shown in Figure 5.26.

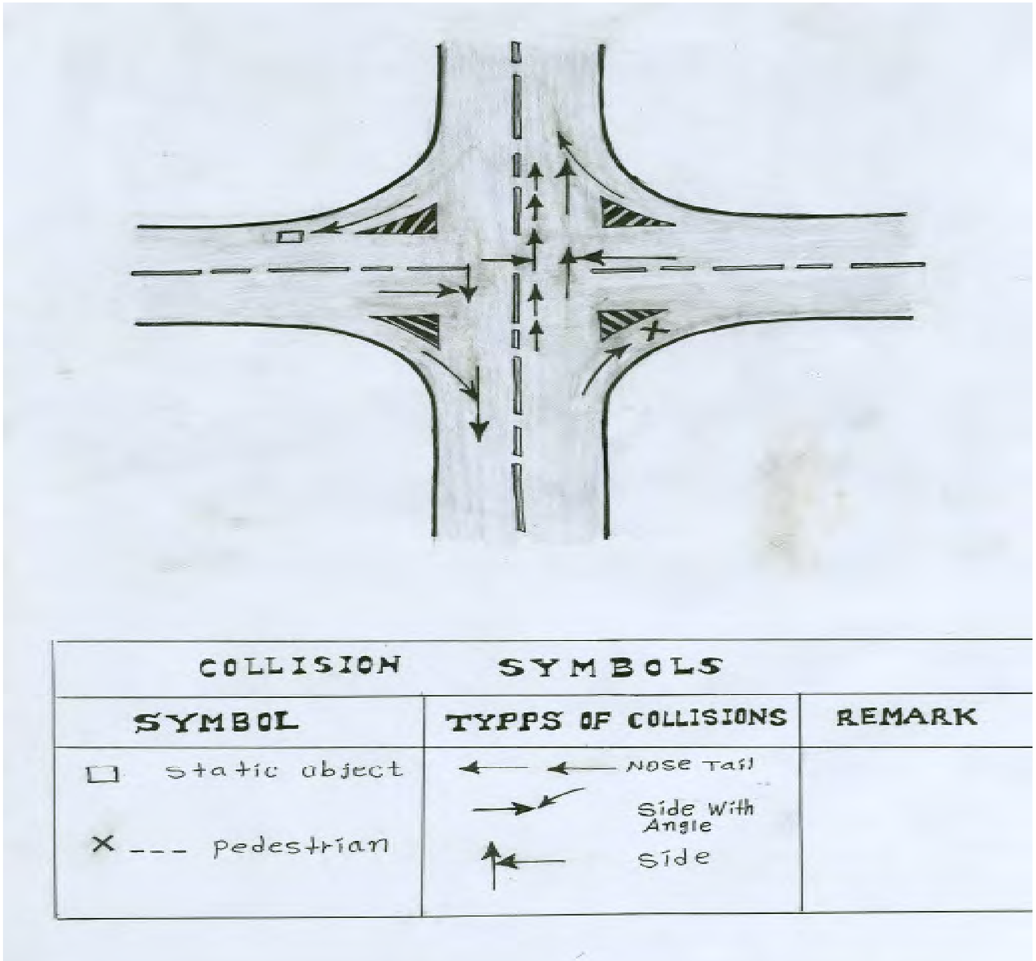


Figure 5.26 Sketch of collision diagram for Modjo priority junctions.

c) The roundabout should be furnished reflective chevron on island with a dimension (62cmx210cm).

d) Prohibition of parking signs should be placed before 50 meters of each leg and provided off road parking facilities.

e) A speed limit sign should be placed where the town begins and ends.

f) Zebra crossings for pedestrian should be provided in every 50 meters.

g) 1-2 sets of rumble stripes should be furnished before every zebra crossing.

Before Improvement

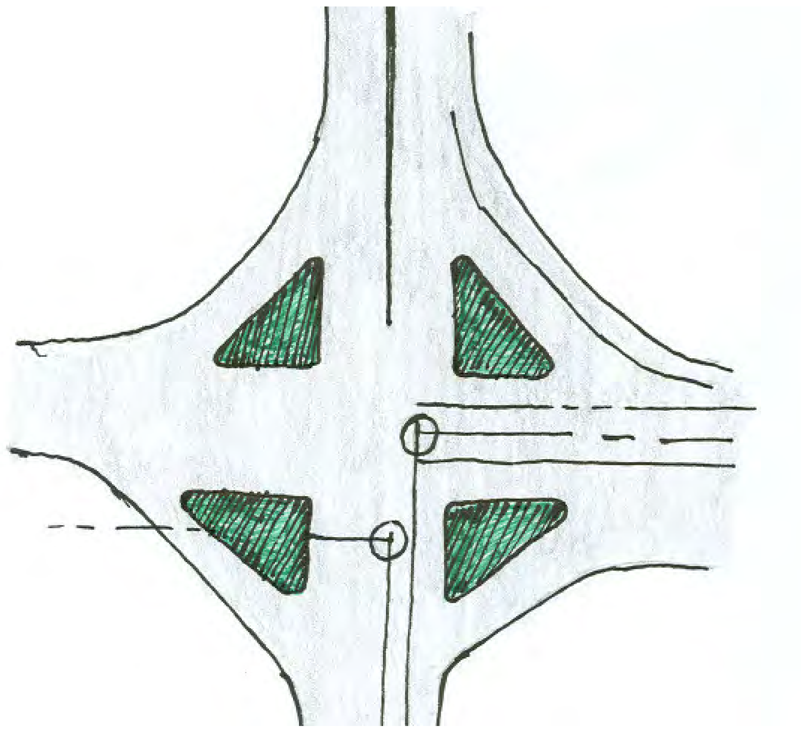


Figure 5.27 Sketch of Modjo priority junctions before improvement.

Recommended improvement

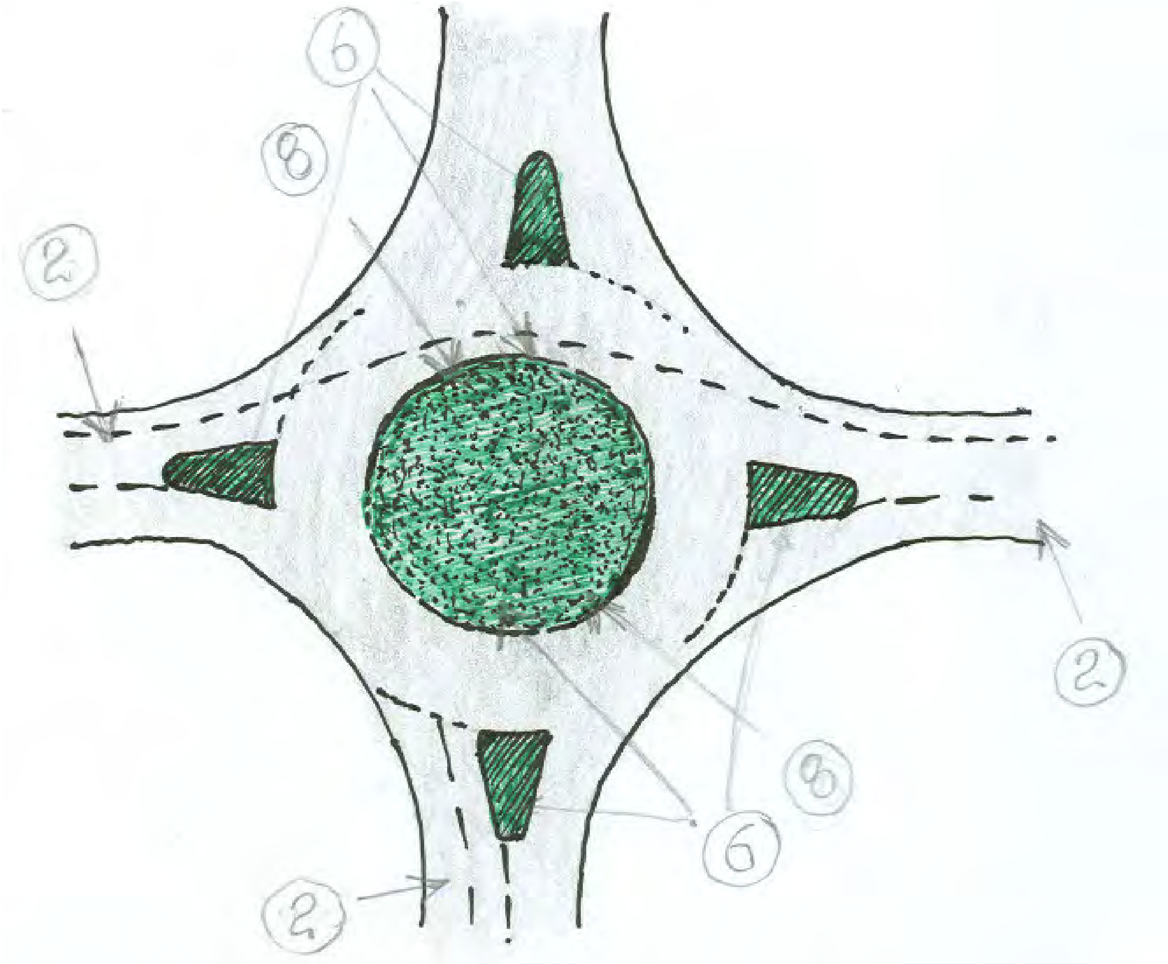


Figure 5.28 Sketch of Modjo junctions after recommended improvement.

Numbers shown on the sketch indicate that the proposed traffic signs will be furnished during counter measure. The legend is available on page 77-79.

C) Meki Town: Station 128+100-131+240

Thirty one accidents occurred during the study period. Figure 5.29 shows variation of accidents by month. Accidents are concentrated during the wet months of Hamle (July), Nehase (August), and Meskerem (September) accounted for 56 per cent of the total accidents. Wet season driving is risky in Meki town.

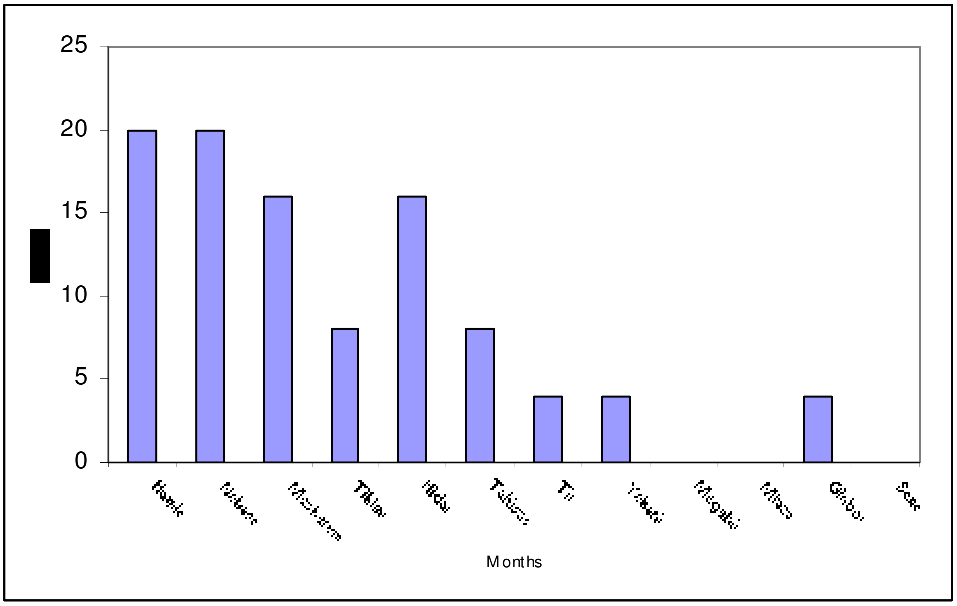


Figure 5.29 Variation of accidents by Months

Figure 5.30 presents the distribution of accidents by day of week. Friday and Saturday had the highest number of accidents, whereas Monday had the lowest number accidents.

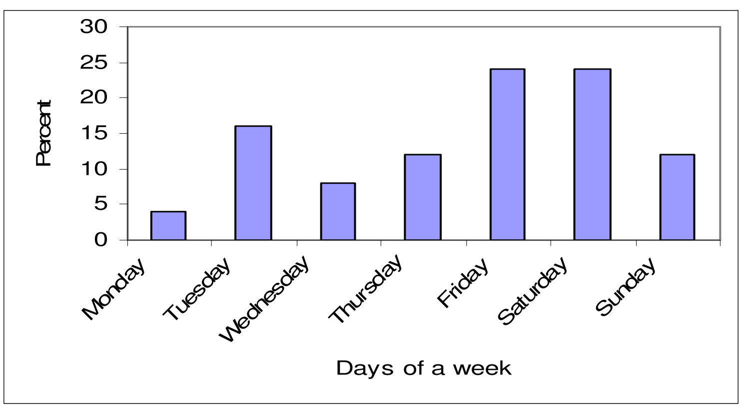


Figure 5.30 Variation of accidents by days of a week

Figure 5.31 presents the distribution of accidents by hour. The highest number of crushes occurred during 1201-1500 hours accounting for 28 per cent. Conversely, during morning time up to 600 hours and night time had the lowest accidents. Hence, concentrated effort should be put in place during 1200-1500 hours by the enforcement body.

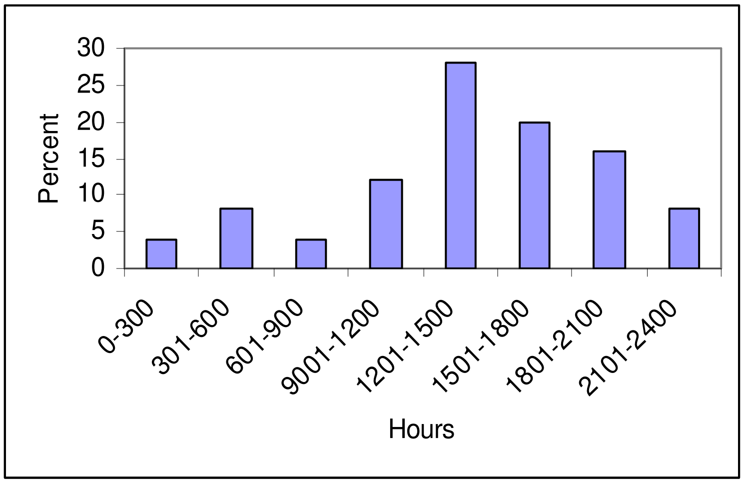


Figure 5.31 Variation of accidents by hours

Considering the severity with collision type, 52 percent accounted for pedestrian accidents. Rollover and other types of collision types had some share of accidents. The road section, accidents were concentrated at Meki Bridge and on down approach of the bridge which is a reverse curve with radii of 68 and 110 meters. Besides, the curves have sight obstruction. Single vehicle accident is very high around the approach and reverse curve.

Table 5-16 Severity by Collision types in Meki Town

	Head-on	Nose-tail	Side	Angle Collision	Rollover	Collision With Pedestrian	Others
Fatal	0	0	1	0	1	7	0
Serious	1	0	0	1	0	3	0
Slight	0	0	1	0	0	3	0
Property	0	2	0	0	2	0	3
Total	1	2	2	1	3	13	3
Per cent	4	8	8	4	12	52	12

The road section is found in Meki town with a combination of reveres curves and a narrow bridge. Proposed counter measure: proposed countermeasures are listed below.

a) Reflective marking and road signs should be provided to help drivers in finding their ways during poor conditions.
b) Warning sign should be placed ahead of 50 meters.
c) Zebra crossings should be provided at the upper and down approaches of the curves.

d) Pedestrian side walk should be constructed with steel sides at the Meki Bridge.

e) 1-2 sets of rumble stripes should be furnished before zebra crossing

f) Crush cushion should be placed on reverse curve in order to save out of control vehicles.

Before Improvement

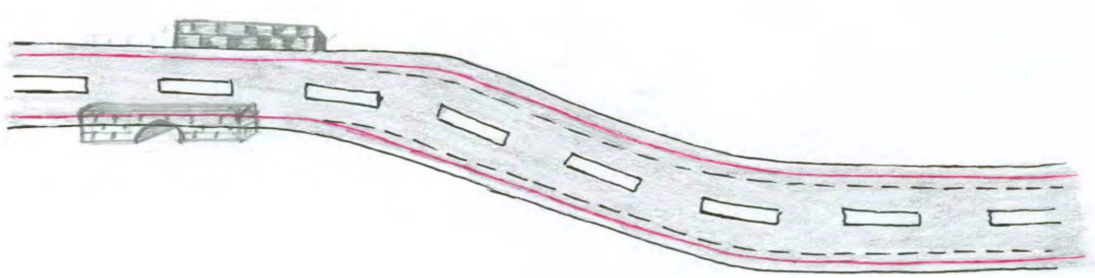


Figure 5.32 Sketch at Meki town road section before improvement

Recommended improvement

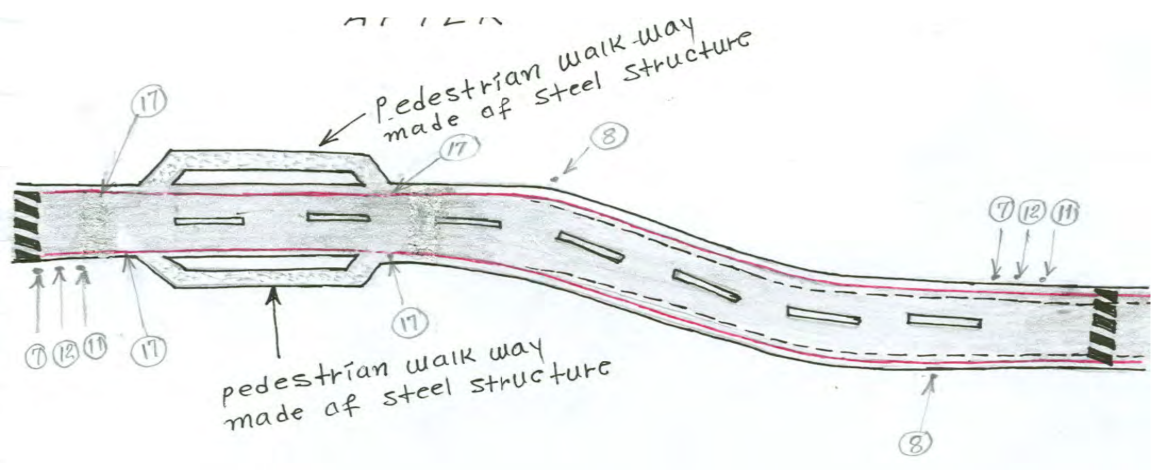


Figure 5.33 Sketch of Meki town road section after recommended improvement

Numbers shown on the sketch indicate that the proposed traffic signs will be furnished during counter measure. The legend is available on page 77-79.

D) Arisi Negele Town: Station 223+700-225+600

During the study years, eighteen accidents registered on this road section. The distributions of accident by severity level, eleven accidents were fatal, three were injuries and four were property damages. In terms of collision type, thirteen accidents involved pedestrian, three were multiple vehicle accidents and two accidents were rollover accidents.

Site inspection

The whole section of the road is found in Arusi Negele town. The upper and down approaches of the road are very long tangent. Vehicles operated at high speed and many drivers violated the speed limit during the inspection period. Numbers of driveways or access points per kilometer is very high. As per table 5.9, access point's density of the city is high and has correlation with accident. Culvert with 6.0 meters is found at the exit to Shashemene Town.

Proposed countermeasures are listed below.

a) A speed limit sign (30 km/hr) should be placed where the town begins, before 100-150 meters.
b) 1-2 sets of rumble stripes should be provided before entering the town in order to notify reckless drivers.
c) Road users' campaign should be performed to create awarness.
d) Zebra crossings should be provided every 50 meters.
e) Warning sign of pedestrian crossing should be placed ahead of 50 meters of zebra crossing.
f) Give way and narrow bridge should be placed at access points and culvert

Before Improvement

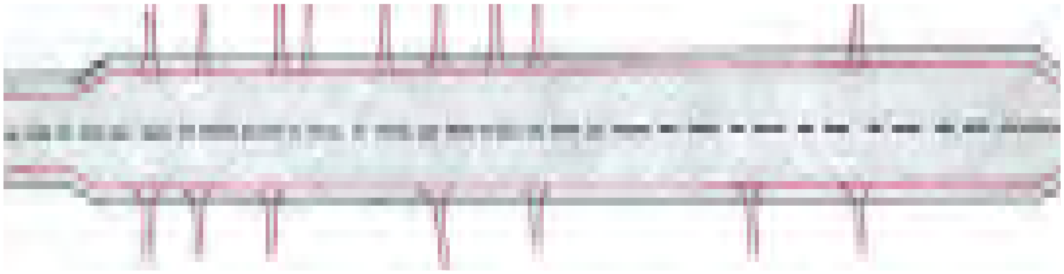


Figure 5.34 Sketch of Arisi Negele town road section before improvement

Recommended improvement

Figure 5.35 Sketch of Arisi Negele town road section after recommended improvement

Numbers shown on the sketch indicate that the proposed traffic signs will be furnished during counter measure. The legend is available on page 77-79.

E) Ziway Town: Station 157+340-159+700

Table C-6 in appendix III presents the number of vehicles involved in accident, by type of vehicle, and the number of pedestrians involved. Trucks with 10-40 quintals capacity had the highest percentage of accidents (33.33 per cent). Truck with 41-100 quintals capacity accounted for 14.28 per cent of the total accidents. Accidents were more pronounced at junctions than on links. This is corroborated by the calculated accident rates as shown in Table 5.12. Accident prone area is the major junction at station 158+690 (To Butajira Town). Two fatal and one serious injury have occurred during the study period around the junction.

Site inspection: There is a market place near the junction. Many pedestrians and animal drawn carts cross the road at this point. Public transport mini-buses use the shoulder and road side spaces for picking and dropping passengers. The other phenomenon was that daily laborers gathered together and stand looking for manual labor at the junction. The main problem is mix of traffic within the influence area.

Proposed counter measure: The following countermeasures are proposed to reduce focused on reducing accidents.

a) Pedestrian refugee should be provided by widening of the sites in order to have safer crossing.
b) Prohibition of parking sign should be placed.
c) Traffic channelization should be made to reduce conflict points. By doing this, traffic flows are segregated reducing the area of conflict. Moreover, visibility is improved.
d) Zebra crossing should be provided at each leg of the junction before 50 meters.
e) 1-2 sets of rumble stripes should be furnished before zebra crossing.
f) Strict enforcement should be implemented in the town.
g) Campaigns for Road uses should be performed during market days.
h) 1-2 sets of rumble stripes should be furnished at each leg before zebra crossing.

Before Improvement

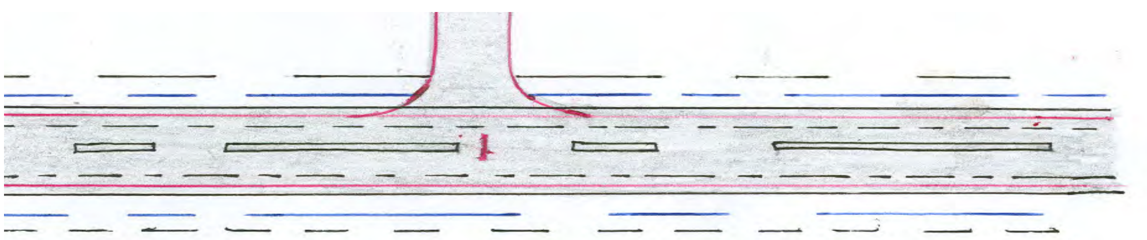


Figure 5.36 Sketch of Ziway junctions before improvement.

Recommended improvement

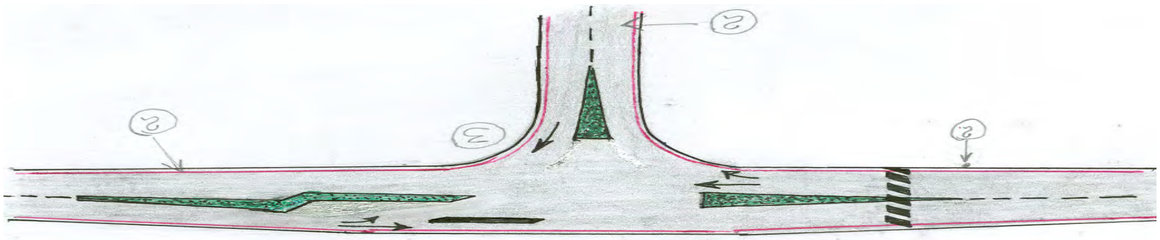


Figure 5.37 Sketch of Ziway junctions after recommended improvement.

Numbers shown on the sketch indicate that the proposed traffic signs will be furnished during counter measure. The legend is available on page77-79.

5 SLOW

6 ROUND ABOUT

7

8 CHEVRON

9 PEDESTRIAN CROSSING RIGHT

10 PEDESTRIAN CROSSING LEFT

11 NARREW BRIDGE

12 REVERSE CURVE

13 REIL WAY CROSSING

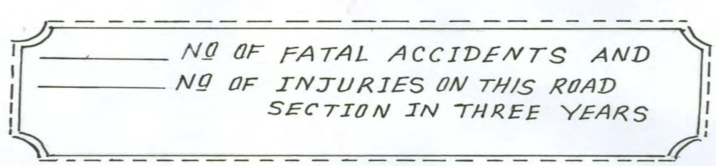
14 SHARP CURVE LEFT

15 SHARP CURVE RIGT

16 speed Limit 30 K.m.h

17 GUARD POST

18



6. CONCLUSIONS AND RECOMENDATIONS

6.1. Conclusions

In this research, adequate accident data with a wide range of road geometric design element and traffic data were collected to achieve the stated objectives. The field work was time consuming. Since Traffic Police Officers had many tasks and were usually out of their offices, it was difficult to get them.

In general, the situation of roads traffic accident at the national level is getting worse every day. The figures and facts presented in Chapter two states this clearly. Even though the country has gravely small vehicle ownership about 2.2 vehicles per 10,000 people, the accident record is one of the highest in the world with about 110 fatalities and 310 injuries per 10,000 vehicles in 2004/05. In the last three years, traffic accidents and fatalities have been increasing by about 17 percent and 10 percent respectively.

In 2004/05, accidents by station wagons accounted for the largest portion which was to 24.36 per cent of the total accidents. In terms of fatal accidents, Trucks with capacity of 11-40 quintals, and 41-100 quintals have the worst records in the country level. In respect to drivers, the 18–30 age groups were involved in the highest number of accidents of attention should be given to this age group of drivers by the policy makers.

The possible major causes of accidents as identified by the traffic Police Officers are: failure to give-way for vehicles and pedestrians, overtaking in winding horizontal curves, following too close, improper turning and speeding.

The built-up area road section comprises 17.7 per cent of the study road and accounted for 46 per cent of the total accidents. In terms of accident type, pedestrian accidents in built-up area were 53.7 per cent of the total pedestrian accidents occurred along the route. In respect to time variation, i.e. accidents exhibited in the months of the year, days of the week, and hours of the day are higher in wet season which is during weekend days between 1500 to 2000 hours.

Demographic analysis showed that driver age group of 18-34 accounted for 62.18 per cent of the accidents. In built up area, accidents by vehicle type indicated that trucks with the capacity of 11-40

(ISUZU 3.5 tons) quintals and trucks with the capacity of 41-100 quintals (truck without trailer) had the major share in causing accidents. In terms of fatalities and injuries, these trucks contributed the highest number of casualties. The casualty in case of pedestrians accounted for 65.31 per cent in built up area.

In non built-up areas, single vehicle non pedestrian accidents accounted for 63.5 per cent of the total single vehicle non pedestrian accidents. Even if the share of the road section is large in non built-up area, pedestrian and two or more vehicles that involved in accidents are higher than in built up area. Similar results were obtained in non built-up areas in case of demography and type of vehicles involved like the above. The probability of passenger accidents is significantly high in non built up area. It accounted for 53.41 per cent of the total vehicle occupant which are most probably associated with speeds and rollover accidents. Night time accidents are few due to low traffic volume.

Fifty-two percent of the accidents occurred at tangent and level sections of the road. This is associated with speed limit violation. The results of the study indicated increase in accident with grade and sharpness of curves. ADT, numbers of lanes and grade have positive relationships with accident rates i.e. the section with less traffic, lanes and grades resulted in less accident rates whenever these variables increased. Whereas, sharp curves resulted in highest accident rate as compared to gentle curves. However, the number of lanes increased with that of accident rates because of the non existence of pedestrian facilities in town sections. Four lanes road is usually found in town sections.

Thirty two road sections were identified for analysis based on the developed criteria and accident rates were calculated. At ninety percentile, rate of accident was 3.459 Mvkm for scheme, and 3.073 Mvkm was for links. Six road sections were found to be above either of the two accident rates. In case of junctions, the ninety percentiles were 0.728626 junctions. Three spots had above the bench mark value and are considered for further study.

In general, the result indicates that the main causes of the accidents at the black spot areas were unavailability of proper pedestrian facilities, pedestrian traffic volume, drivers' fatigue, lack of awareness of traffic rules and regulation and violation of speed limit in accordance to the pilot study by the National Road Safety Coordination Office. Besides, densities of accidents per kilometer were found to be a function of access points in towns. Narrow bridge, inadequate sight distance, insufficient illumination, road curvature, and faded road markings are usually the major causes of accidents.

6.3. Recommendations

Based on deep understanding of the main causes of accidents, low cost engineering measures were proposed. On the existing situation or identified causes, improvement was suggested. In general, the following recommendation should be implemented.

- prohibition of on road side parking
- furnish appropriate sign and marking
- strict traffic police enforcement and speed control
- road user information and campaign
- rumble stripes should be placed on changing traffic and road environment
- traffic channelization
- providing pedestrian side walk
- limiting driving time for professional drivers and
- access density and access permit regulation should be given a focus by the Road Authority.

Particularly for black spots, proposed details in the analysis and discussion parts were given. To summarize, Modjo priority junction has a number of conflict points. As a result, accidents occurred due to these conflict points. To resolve this, placement of roundabouts were proposed with appropriate road signs and markings. In case of Ziway junction, chanalization of road either using road marking or construction of island and placement of road sign will solve problems on the spot.

Road sections problem in Dukem and Arisi Negele Towns will be resolved by furnishing proposed low cost engineering measures like installing traffic signs, traffic campaign and enforcement. Regarding Meki Town, accidents are much concentrated on the approaches of the Meki Bridge. Pedestrian side walk is proposed along sides of the bridge which should be made of steel structure.

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Appendix I

National Accident Statistics

Table A-1:- National Accident Statistics for Severity of accidents based on drivers' education 2001/02-2004/5

	Year	illiterate	Basic education	Primary education	Junior secondary	Senior Secondary & above	Unknown	Total
Fatal	2001/2	25	30	317	396	392	69	1327
	2002/3	23	46	346	485	460	69	1510
	2003/4	29	21	313	618	492	65	1630
	2004/5	34	65	403	502	498	99	1801
Serious injury	2001/2	18	32	349	450	585	137	1712
	2002/3	28	52	345	473	601	146	1790
	2003/4	21	37	365	713	673	141	2072
	2004/5	11	142	430	683	696	215	2368
Slight injury	2001/2	9	41	307	418	728	553	2196
	2002/3	28	24	353	453	790	557	2365
	2003/4	8	53	347	690	876	538	2765
	2004/5	10	40	437	443	1103	461	2731
Property damage	2001/2	21	99	1038	1284	3158	951	7188
	2002/3	22	108	1228	1600	3702	1125	8563
	2003/4	21	101	1544	1800	4637	1490	10569
	2004/5	36	129	1639	2207	4105	1237	10822

Source: -Federal Police Commission, Road Traffic Accident Statistics Office, 2005.

Table A.2:- National Accident Statistics for Reported Road accident Severity Using Sex 2001/02-2004/5

	Year	Male	Female	Not identified	Total
Fatal	2001/2	1268	6	53	1327
	2002/3	1437	10	63	1510
	2003/4	1570	3	57	1630
	2004/5	1703	21	77	1801
Serious	2001/2	1575	9	128	1712
	2002/3	1630	21	139	1790
	2003/4	1930	8	134	2072
	2004/5	2126	34	208	2368
Slight Injury	2001/2	1637	11	548	2160
	2002/3	1789	26	550	2365
	2003/4	2132	41	532	2705
	2004/5	2222	51	458	2731
Property damage	2001/2	6139	101	948	7188
	2002/3	7297	150	1116	8563
	2003/4	8940	155	1474	10569
	2004/5	9378	217	1227	10822

Source: -Federal Police Commission, Road Traffic Accident Statistics Office, 2005.

Table A.3:- National Accident Statistics for Reported road traffic accidents using Drivers Age group 2001/02-2004/5

	Year	Below 18	18-30	31-50	Above 51	not known	Total
Fatal	2001/2	14	644	529	78	62	1327
	2002/3	38	725	533	146	68	1510
	2003/4	37	840	576	111	66	1690
	2004/5	48	933	627	109	84	1801
Serious injury	2001/2	23	783	656	118	132	1720
	2002/3	53	835	629	129	144	1799
	2003/4	51	1008	734	135	144	2072
	2004/5	49	1180	809	115	215	2368
Slight Injury	2001/2	25	825	655	135	556	2196
	2002/3	59	921	699	132	554	2365
	2003/4	38	1183	804	142	537	2704
	2004/5	56	1192	857	168	458	2731
Property damage	2001/2	20	2686	2897	632	953	7188
	2002/3	58	3282	3404	702	1117	8563
	2003/4	66	4139	4059	822	1483	10569
	2004/5	84	4428	4976	1002	1232	10822

Source: -Federal Police Commission, Road Traffic Accident Statistics Office,2005

Table A-4:- National Accident Statistics for Reported road traffic accidents using Service years of Vehicles for 2001/02-2004/5

	year	□ 1Year	1-2 Years	2-5 Years	5-10 Years	10 and above	Unknown	Total
Fatal	2001/2	45	77	313	435	390	67	1327
	2002/3	71	95	363	481	414	86	1510
	2003/4	82	109	377	515	471	76	1630
	2004/5	120	170	455	535	419	102	1801
Serious injury	2001/2	80	114	424	504	444	146	1712
	2002/3	81	125	457	530	440	157	1790
	2003/4	112	149	520	627	513	151	2072
	2004/5	164	169	548	846	824	3536	5741
Slight injury	2001/2	60	103	464	531	475	563	2196
	2002/3	57	119	529	602	495	563	2365
	2003/4	78	139	616	751	568	553	2705
	2004/5	124	182	593	824	536	472	2731
Property Damage	2001/2	170	372	1793	1921	1969	963	8563
	2002/3	197	480	2116	2534	2082	1154	8563
	2003/4	211	455	2499	3298	2587	1515	10569
	2004/5	335	524	2411	3536	2753	1263	10812

Source: -Federal Police Commission, Road Traffic Accident Statistics Office, 2005

Table A-5:- National Accident Statistics for Drivers Relationship with vehicles 2001/02-2004/5

	year	Owner	Employee (Driver)	Others	Unknown	Total
Fatal	2001/2	138	1057	76	56	1327
	2002/3	196	1143	105	66	1510
	2003/4	243	1259	63	65	1630
	2004/5	283	1379	57	82	1801
Serious injury	2001/2	163	1302	115	132	1712
	2002/3	234	1282	135	139	1790
	2003/4	341	1483	103	145	2072
	2004/5	299	1739	118	212	2368
Slight injury	2001/2	207	1280	161	548	2196
	2002/3	301	1340	172	552	2365
	2003/4	405	1546	211	543	2705
	2004/5	405	1670	182	474	2731
Property Damage	2001/2	810	4885	545	948	7188
	2002/3	1077	5629	744	1113	8563
	2003/4	1448	6628	1011	1482	10569
	2004/5	1462	7019	1110	1231	10922

Source: -Federal Police Commission, Road Traffic Accident Statistics Office, 2005