ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Investigation of the Causes of Road Traffic Crashes and Remedial Measures on Debre Markos – Bahir Dar Road Segment

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Civil Engineering

(Road and Transport Engineering)

BY

Yosef Goshu Alemu --------- GSE/1650/08

Advisor: - ***Dr. Getu Segni***

Co-Advisor:- ***Emnete Tadesse***

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UNDERTAKING

I certify that this research work titled "***Investigation of the Causes of Road Traffic Crashes and Remedial Measures on Debre Markos – Bahir Dar Road Segment***" is my original work performed under the supervision of my research advisor **Dr. Getu Segni**. The work has not been presented elsewhere for assessment and a degree in any other university. Where material has been used from other sources has been properly acknowledged.

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Abstract

Road traffic crashes occur as a result of several factors associated with the traffic system, namely: road users, road environment and vehicles. These factors have their own impact for crash. Ethiopian federal police unpublished report showed that 95% of all crashes involved human factors, 8% accounted for vehicle factors, and the rest 29% were associated with road environments. Even if Ethiopia has low road network density and vehicle ownership, the crash rate records are relatively high.

The objective of this study is identifying blackspot sections and investigating the major causes of road traffic crashes with engineering remedial measures. The research is done by reviewing previous literature, collecting data on the road segment like traffic crash data, road and traffic data.

During the study period from July 2013-June 2018 a total number of 1873 reported crashes were collected out of which 741 were fatal crashes, 307 were serious injuries, 197 were slight injuries and 628 were property damages only. The characteristics of crashes in the study area were tabulated and analyzed by descriptive statistics and Multinomial Logistics Regression method to identify blackspot sections and investigating significant factors which affect the severity of crashes.

By distributing the collected traffic crash data on the study area, 40 divided segments were created and statistical analysis was carried out to identify blackspot sections and 16 segments are selected as blackspot.

During observation of this blackspot sections, the major causes of crashes were identified to be unavailability of proper pedestrian facilities, improper use of roadways by pedestrian, drivers’ fatigue and violation of traffic rules and regulation including violation of speed limit. In spite of this, narrow lane width of bridges, inadequate sight distance, poor geometric design of curves, and deteriorated pavement conditions and absence of sufficient traffic signs and road markings. In addition, from the descriptive analysis the major causes of crash which are driver’s error like violation of speed limit, ignorance of pedestrian priority, drive with leaving right, pedestrian error, road defects and vehicle defect.

On the other hand, the results of Multinomial Logistics Regression analysis indicates that, there were many variables which have a significant effect on fatal crash severity; such as, driver’s age between 18-30 years, driving experience of below 1 year, collision type of pedestrian crash and others. On the other hand, driver’s age below 18 years, bicycle vehicle type, rollover collision type, out of rural village land use and others have insignificant effect on fatal crash type. Therefore, the variables that were found those factors contribute to crashes severity were age of drivers, driving experience, vehicle type, collision type, land use characteristics and roadway alignment features.

Finally, engineering measures are recommended to reduce the number of road crashes at identified blackspots and other sections.

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List of Acronyms

AADT- Annual Average Daily Traffic
ADT- Average Daily Traffic
ERA- Ethiopian Roads Authority
E.C- Ethiopian Calendar
Km- Kilometer
m- Meter
mi- Mile
TRB- Transport Research Board
TRL- Transport Research Laboratory
WHO- World Health Organization

1. Introduction

Road traffic crashes occur as a result of several factors associated with behaviors of road users, road environment and condition of vehicles. In Ethiopia, road crashes are a serious problem and comes to the eighth leading cause of death, but the number of vehicles are small relative to the crash rate (WHO, 2018).

This study focuses on identifying the determinant factors that have significant contribution for road traffic crash on the road segment of D/Markos-Bahir dar by collecting traffic crash data, road data and traffic data. After analyzing of the collected data, the study selected blackspot sections based on crash rate analysis and field observations were carried out to justify what seems the spots feature. In addition to this the study points out the major causes of crash on the referenced road segment with the proposed remedial measures should be taken.

1.1 Statement of the Problem

Even if in Ethiopia number of vehicles are small, large amount of road traffic crashes recorded relative to other third world countries which causes loss of life, injury and property damage (WHO, 2018).

The Ministry of Transport of Ethiopia reports that the road traffic crashes increases from year to year and considered as the major cause of death in our country. These crashes occurred not only in urban areas but it happen in rural area due to different reasons. These reasons may include poor road geometry with poor facilities, road environment, drivers' performance and reckless driving, vehicles condition, pedestrians' improper use, excessive speed, failure to give way to pedestrians and violating traffic laws and so on (Ministry of Transport Report, 2010).

On the Debre Markos -Bahir dar road segment, road traffic crash causes a great loss of human and economic resources and the frequency of occurring increases from time to time (Amhara Region Transport Bureau, 2010). In Amhara region from 2006 E.C to 2010 E.C a total of 10136 crashes happened with 2835 fatal and 3949 serious injury from these figure 1873 crashes occurred on the study section with fatality percentage of 26.1% and serious injury percentage of 7.8%. This figure shows the selected study area would have serious problems with crash severity.

Therefore, due attention should be given to the problem to be addressed. So this study will identify most important variables that causes of increasing road traffic crashes in the study area and investigating the possible counter measures to minimize the crash.

1.2 Research Question

This study tries to answer the following questions:

- Where are the locations of hazardous road sections (blackspot s)?
- What are the main causes of traffic crashes on Debre Markos-Bahir dar road segment?
- What are the possible engineering remedial measures in the hazardous crash locations to reduce the crash?

1.3 Objectives or Aims of the Study

1.3.1 General Objective

The general objective of this research is to investigate the main causes of road traffic crash on Debre Markos-Bahir dar road segment related to the contributing factors of traffic crash and to propose engineering remedial measures to reduce the crash.

1.3.2 Specific Objectives

The research has the following four specific objectives:

- To identify the location of hazardous road sections (Blackspot sections) that crashes happen frequently;
- To investigate major causes of road traffic crashes on these blackspot sections; and
- To propose possible engineering remedial measures to minimize the road traffic crash on the road segment.

1.4 Limitation of the Study

This study were limited to Debre Markos-Bahir dar road segment, which is starting from exit of Debre Markos town in front of Teachers Education College and ends near to Bahir dar city in front of Bahir dar University Yibab campus. Besides, the study focuses on identifying blackspot s along the road segment, finding the major causes of crashes and based on the major causes of crash, remedial measures were proposed for selected blackspot s.

1.5 Organization of the Study

The report is organized in to five chapters. Chapter one is an introduction to the paper and contains statement of the problem, objectives, limitation of the study and organization of the report.

In chapter two, more detailed literature review has been reviewed. In Chapter three, the method used to conduct of the research is described and details of the method of the research work have been stated. Chapter four contains analysis and discussion part which characterize the collected crash data, describes the relationship between crash and road factors and identification and discussion on blackspot sections was done. In addition, analyses of causes of crash reported by police and field observation on blackspot s were interpreted in order to identify the real causes of crashes and possible engineering remedial measures for the study section have been proposed for implementation.

Finally, based on the analyses and discussion, the research came with a general conclusion and recommendations which is in chapter five.

2. Literature Review

2.1 Introduction

Road transportation has importance to nations and each individual economically, socially and politically through facilitating the movement of people and goods from place to place. These benefits of road transport have also a considerable burden on the health of the people in the form of road traffic injuries.

According to World Health Organization (WHO) report published in 2018, the number of deaths on the world's roads remains unacceptably high, with an estimated 1.35 million people dying each year and have a significant impact on health and development. It is the leading cause of death among children and young people aged between 5 and 29 years, and cost governments approximately 3% of GDP. Despite this massive and largely preventable human and economic toll, action to combat this global challenge has been insufficient (WHO, 2018).

Therefore, this part contains the review of previous studies on causes of road traffic crashes and possible remedial measures which were contributed by different researchers. It also identifies techniques of blackspot selection and tries to develop appropriate crash prediction model that assists to identify factors contributing to traffic crash on Debre Markos-Bahir dar road segment.

In most cases the occurrences of traffic crashes are rare and random in space and time. Road safety and incident reduction are related to road geometry, education, driver training, public campaigns, police and policy enforcement, and vehicle condition.

2.2Road Traffic Crash

Road traffic crash is defined as a collision or incident involving at least one road vehicle in motion that can be on a public or private road to which the public have the right of access. Thus, traffic crash can be a collision among vehicles, between vehicles and pedestrians, between vehicles and animals, or between vehicles and geographical or architectural obstacles (Goswami A., 2009). Road crashes are a global problem which affects all parts of the society. However, road safety has received insufficient attention at national and regional level. But Ethiopian Ministry of Transport report shows the government tries to give attention for the road safety by situating different offices from national to woreda level. However, traffic crashes has been increasing from time to time and the concerning offices couldn't involve satisfactorily in reduction of traffic crash instead of reporting the incident (Ministry of Transport Report, 2010). Road traffic crash may be due to lack of forceful law and implementation problem, behavioral problem of drivers and pedestrian, lack of safe infrastructure and poor quality of serviceability, poor vehicle condition and traffic composition. These indicate that, road traffic crash occurrence is the result of interactions of different factors and will vary from place to place.

Published studies made on traffic crashes have a common understanding that, most crashes are a combination of factors relating to human failings, road deficiencies and vehicle defects. The interaction between human failings and road features has important implications for applications of remedial measures to aid and influence road–users.

According to (Sonowal, 2009) road traffic crash is an event occurring suddenly, unexpectedly and inadvertently under unforeseen circumstances. It further expressed that road traffic crashes can be defined as "An accident that occurred on a way or street open to public traffic; resulted in one or more persons being killed or injured, and at least one moving vehicle was involved (Sonowal, 2009).

In addition to this, accident is defined as an error in driver-vehicle-roadway system and it must be recognized that different types of crashes are occurred due to different reasons at any given location namely, rear-end, side-swipes, head-on, night-time, bad-weather, rollover etc. (Kamal and et.al, 2008).

Generally, road accidents are analyzed by means of precisely defining the event involving damage to the property and/or injury to the road users, which are recorded first-hand by the police and/or emergency services (Bhat and et. al, 2013).

2.3 Road Environment

The road environments have a significant effect on occurrences of road traffic crashes. In developed countries, there are continuous efforts to meet the safety standards of roads through safety audit during the planning, designing, and operation stage but in developing countries like Ethiopia assessment of road safety audit and taking of counter measures is a rare case.

In Ethiopia, the road environment is one of the causes for road traffic crash and developing of a local manual for planning, design and operation is important to reduce the crash. Ethiopian Roads Authority manual said that simply adopting of international standards from developed countries will not necessarily result in acceptable levels of safety on rural roads (ERA Manual, 2013).

Although little research has been published on rural road safety in Ethiopia and there are factors for road traffic crash related to road environment like road alignment including horizontal and vertical curvature, sight distance and road cross sectional elements.

2.3.1 Road Alignment

(Berhanu, 2000) reviewed the influence of road alignment which includes both horizontal and vertical curves as; it is an important factor, which affects the occurrence of road traffic crashes in terms of frequency and severity. Inconsistent horizontal alignments of roads, sharp curves and grades are known for their substantial and adverse safety impacts.

Studies have attempted to characterize the crashes that occur on highway curves. In 1983 a study of four states in United States by Glennon et al., compared the crash experience on 3,304 rural two-lane curve segments to 253 rural two-lane tangent segments. Each segment was 0.6 mile long and was carefully selected to minimize variance associated with intersections, bridges, nearby urban development and curvature (Glennon et al., 1983).

This computation yields two conclusions which are;

- ✓ The average crash rate for highway curves is about three times the average crash rate for highway tangents.
- ✓ The average single-vehicle run-off-road crash rate for highway curves is about four times the average single-vehicle run-off-road crash rate for highway tangents.

Recently, in Ethiopia a study done by (Teyba W., Emer T. and Murad Mohammed, 2017) stated, the major cause of road traffic crash in Alamata, Mehoni, and Hewane is the improper design and construction of vertical and horizontal curves which contributes up to 47.4% of the cause of the crash (Teyba W., Emer T. and Murad Mohammed, 2017).

Some national standards have introduced consistency rules concerning the succession of different elements in the road alignment that is necessary from a safety point of view, but are not sufficiently developed. Numerous investigations into the effects of road alignment on traffic safety have been conducted, but this is still one of the important research areas in safety engineering in order to advance the knowledge of the problem under different traffic conditions and road environments.

i). Horizontal Alignment

Different study shows that road accidents on horizontal curves are causes for concern in all countries. In France, over 20 percent of fatal crashes occur as a result of dangerous curves in rural areas. Crashes on bends are major problems in many developing countries, although the proportion of such crashes is dependent on both topography and demography of each country. A study in Denmark shows that about 20 percent of all personal injuries and 13 percent of all fatalities occur on curves in rural areas (Sweedler BM, 1995).

A horizontal curve provides a transition between two tangent (straight) sections of roadway allowing a vehicle to safely negotiate a bend due to the fact that, proper assignment of horizontal curve is necessary to reduce difficulties of vehicles movement and to prevent from rollover and leaving of lane. By doing these road traffic crash is reduced. Types of horizontal curves like simple curve, reverse curve, compound and broken back curves have their own contribution for traffic crash with the assigned super elevation rate which depends on the inserted curve radius and speed of the vehicle (David Kaneswaran, 2014).

Based on studies reviewed, Choueiri et al. deduce that for radii less than 200 m, the crash rate is at least twice as high as that of 400 m. For radii greater than about 400 to 500 m, an increase in radius leads to lower-level of safety gain, but at a decreasing rate (Choueiri et al., 1994). Similarly, a study in Germany found that with an increase of radius up to 400 m, the crash rate drops to about 30-40 percent of the value for radii less than 100 m (Leutzbach, 1988).

Larger radii, up to 1000 m, result in a further slight reduction, but from 1000 m onwards, there is a slight increase in the crash risk. Crash rates increase with increasing curviness (directional changes of road sections as measured in degrees per km) of two-lane highways. This could be explained by the findings of a study conducted to examine the impacts of inconsistencies in roadway designs that violate driver expectancies and impose higher workloads on the driver (Transport Research Board, 1987).

ii). Vertical Alignment

(Berhanu G., 2000) points out three main effects of vertical road alignment, which are closely related with the occurrence of traffic crashes. These include; excessive speed and out of control vehicles on down grades, differential speed between vehicles created on both down and upgrades, and low range of visibility that often occurs in the immediate vicinity of steep grades at the crest of vertical curves.

When the above three effects combined with sharp horizontal curves, particularly without clear road signing, the effects of vertical alignments could be very serious. Berhanu summarizes the effects of vertical curve in such a way that steep grades have higher crash rates than mild ones. He extends that grades of less than 6 percent have little effect, but grades steeper than this are associated with higher crash rates. Down grades are greater problems, particularly for truck safety than upgrades (Berhanu G., 2000).

Various studies have indicated that grade sections generally have higher crash rates than level sections, steep grades have higher crash rates than mild grades, and downgrades have higher crash rates than upgrades (Babkov, 1975; Glennon, 1987; Ogden, 1996). The greater danger of running down a grade than up is closely connected with the higher number of out-of-control vehicles on downgrades, and the increase in braking distance. A notable number of crashes on downgrades are caused by brake failure. Studies have revealed that crashes connected with vehicles climbing up the grade are mainly concentrated on its upper part and immediately after its crest. This is mainly due to differential speed between cars and heavy vehicles as well as restricted sight distances at the crests of vertical curves.

2.3.2 Sight Distance

The ability to see ahead and observe potentially conflicting traffic is critical to safe highway operations. Sight distance, the length of a roadway over which a driver has an unobstructed view, is one of the important criteria in the geometric design of highways. Sight obstructions on the road, generally, occur due to the presence of deep cuts, embankments, vegetation, walls and the like on the inside of horizontal curves and intersection quadrants, and sharp crest vertical curves themselves (Berhanu G., 2000).

The following are three types of sight distances considered in the geometric design of roads.

- Stopping Sight Distance- the clear sight distance required for stopping a vehicle safely, is fundamental in highway geometric design,
- Passing sight distance – the clear sight distance required on two-lane, two-way highways for ensuring an overtaking vehicle can pass another vehicle safely, and
- Intersection sight distance - the clear sight distance required by drivers along each approach road to view the entire intersection and sufficient lengths of the intersecting highways, depending on the traffic control, for maneuvering safely at intersections.

The lengths of these sight distances vary with the design or operation speeds of road sections. Associated parameters used for defining sight distances in different national road design standards include perception/reaction time, eye height, object height, and pavement friction. Values and uses of them, however, vary between different design standards (Harwood et al., 1995).

Results of various research studies underlined the importance of sight distance in road safety. Stating the insufficient sight distance as the most frequent cause of crashes involving overtaking vehicles on sharp horizontal and vertical curves (Babkov, 1975) mentions that 8-10 percent of crashes in the former USSR were caused by inadequate sight distances. He further pointed out the occurrence of higher related crashes on roads with infrequent restricted sight distances than on roads where there are frequent restricted sight distances. This happens because motorists on roads with frequent restricted sight distances drive with increased attention and at lower speed. Moreover, it is considered essential to provide passing sight distances for relatively longer parts of road sections on roads designed for higher speeds. For example, for a design speed of 100 km/h at least 50 percent of the total length of the road should have the required passing sight distance (650m). This can be reduced for a design speed of 80 km/h to 3 percent of the road to have the required passing sight distance of 525 m. In addition to these insufficient sight distances in the horizontal plane have a smaller influence on crash rates than in vertical plane (Babkov, 1975).

(Glennon, 1987) cited a small but well-designed study reported by Olson and others in 1984 which found that locations with sight distances less than 90 m have approximately 50 percent more crashes than sites where the sight distance is over 210 m. Other cited prior studies in (Glennon, 1987) also revealed significant crash rate differences between intersections having adequate and inadequate sight distances. Based on the findings of studies he reviewed, concluded that alignment changes to improve very short stopping sight distances appear to be safety-effective, but these changes are cost effective only on highways with very high traffic volumes. Clearing obstructions such as vegetation on the inside of horizontal curves and putting signs on roads having restricted sight distances are important low-cost treatment.

2.3.3 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 include lane width, provided median width, bridge width, shoulder width, side slope, back slope, and clear zone. A general consensus among researchers on the effects of some cross-sectional elements, and inconsistencies on others as reviewed here below (Berhanu G., 2000).

i) Lane and shoulder width

According to (Roadrigues) lane widths of 3.4-3.7 meters have been shown to have the lowest crash rate on rural roads. Lane widths of less than 3m have been shown to contribute to multivehicle crashes. (Berhanu G., 2000) reviews numerous studies that lane and shoulder width affects run off the road and opposite direction crashes. The rates of these crashes decrease with both increasing lane and shoulder width, but the marginal effect of increasing width on crash 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 crash rate and represents the balance between safety and traffic flow. For 3.0 meter 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 crash rate significantly (Berhanu G., 2000). 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 (Choueiri et al, 1994). 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 crashes decrease with shoulders up to 2 meters wide, but there is little additional benefit obtained with shoulders greater than 2.5 meters (Austrode, 2000). Generally, lane width has greater effect on crash 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 crashes. Such crashes comprise a significant number of the crashes that occur on two-lane rural roads more than 30 percent of all crashes involve single vehicles running off the road (Transport Research Board, 1987).

(Transport Research Board Report, 1987) reviews that previous research on the safety of the roadside environment has produced important improvements to roadside hardware; including 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 a crash 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 (Transport Research Board Report, 1987).

iii) Median

The provision of a median significantly reduces crash rates. Studies found that wide medians are the safest followed by the raised curb median, and then the TWLTL than undivided roads. For a high-speed facility, median width of 9 m or more improves safety significantly. In low speed environment of urban areas, the minimum median width should be a width, which is enough to protect a turning or crossing vehicle (Berhanu G., 2000).

iv) Bridges

Bridges are often located on sag vertical curves where approach traffic is on down grades, 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 (Berhanu, 2000). He notes that bridges are over-represented in crashes relative to the total length of the road system. Traffic crashes are also severe at bridges. An extensive review of available literature on the safety effects of bridges by (Mak, 1987) pointed to features including bridge width, curved bridge, approach roadway alignment, and adverse surface condition as the most prevalent factors of bridge crashes. Of all these factors, bridge width is the most important factor related to crashes on bridge. Based on the findings of the cited studies, (Mak, 1987) suggests that at least the bridge shoulder should be 1.8 m wider than the approach travelled way width on rural two-lane highways (i.e. 0.9 m shoulder width on each side should be carried across the bridge).

Besides, frequency and severity of traffic crashes at bridges can be reduced through the provision of adequate visual information to enable the driver control and navigate safely on bridges. Furthermore, bridge barriers are also important safety features. In developing countries, where pedestrian and animal traffic are considerable (TRL & Ross Silcock, 2001) suggests separated pedestrian bridges depending on the traffic volume and speed. 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.

2.3.4 Intersections

On two-lane rural highways, intersections are ranked together with horizontal curves and bridges as the most likely locations for crash concentration. According to the National Safety Council estimates in USA, 56 percent of all urban crashes and 32 percent of all rural crashes occur at intersection (Transport Research Board Report, 1987).

Although the average crash occurring at intersection is not as severe as the one occurring on the open road, there is nonetheless, a concentration of severe crashes at intersection.

Of all the fatal crashes in the United State, 29% of those that occur on urban highways and 16% of those that occur on rural highways are intersection related. It is logical to concentrate on such types of high crash 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 crash rates as observed in developed countries and best countermeasures from safety of intersection point of view.

2.4 Blackspot Identification and Analysis

Blackspot s are defined as a road location (section) of limited area with high concentration of traffic crashes and the objective of its treatment is to identify those sites that have an abnormal crash concentration, with this number likely to be efficiently reduced through road safety engineering (RSE) actions (Ezra Hauer, 1996).

According to (Hauer, 1996), some researchers rank locations by crash rate (crashes per vehicle-kilometers or per entering vehicles), some use crash frequency (crashes per km-year or crashes per year) and some use a combination of the two. Another dimension of diversity in practice is that rank may be determined by the magnitude (of either of rate or of frequency) or, as is more common, by the amount by which the rate or frequency exceed what is normal for such sites.

Any road safety improvement method firstly depends on identifying the real blackspot locations. Various methods can be used in identifying blackspot s, but each of it has a different accuracy. Over time, different methods have been employed as identification criteria of blackspot, trying to approach the real definition of blackspot s (Ezra Hauer, 1996).

(Wen Cheng and Simon, 2005) define the objective of blackspot identification is to "identify the locations in a transportation system that have problems and its effects will be revealed through evaluated its crash frequency related to other similar locations" (Wen Cheng and Simon, 2005).

In other words, crashes can be observed in both safe and unsafe locations, therefore the challenge will be to avoid false positive and false negative in identifying the real dangerous locations. (Elvik, 2008) evaluate what type of different blackspot identification method shall be considered to minimize false negative and false positive for a suitable reallocation of safety investments' budget. He points out blackspot s on national highways in Norway have heavy traffic but do not have particularly high crash rates when compared with places which are not classified as crash blackspot s (Elvik, 2008).

On the other hand, the Blackspot Manual prepared by SweRoad's uses the Rate- Quality-Control Method consists of calculating three different parameters for each road section to identify blackspot s (Blackspot Manual, 2001). The three parameters are:

- Crash rate,
- Crash frequency,

- Severity index (Priority value).

Each of these values is compared with a critical value. Thus the crash rate is compared with one critical value, the crash frequency with another critical value and the severity value with a third critical value. If a certain road section shows higher values than the critical ones for all these three parameters, the section is considered to be a blackspot (Blackspot Manual, 2001).

In Belgium, potential crash reduction ranking method is employed taking into account the weight of each severity at each site where in three years three or more crashes have occurred. Then, a site is considered to be dangerous when its priority value (P), calculated using the following formula, equals 15 or more (Geurts, Wets, Brijs and Vanhoof, 2003).

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

Where, P = priority value

X = total number of light injuries with co-efficient of 1

Y = total number of serious injuries with co-efficient of 3

Z = total number of deadly injuries with co-efficient of 5

According to (Apparao G. and Raju, 2013) the technique that is used the study to identify hazardous locations is known as the Critical Crash Rate Factor Method. Since traffic crashes are random occurrences and can be considered as Rare Events it is not possible to identify hazardous locations simply on the basis of the number of crashes. Rather, the critical rate method incorporates the traffic volume to determine if the crash rate at a particular location is significantly higher than the average for the type of facility. If the crash rate of a particular location is significantly higher than the average crash rate for other locations in the jurisdiction having similar characteristics, the location is classified as crash blackspot (Apparao G. and Raju, 2013).

Researchers have proposed several alternative methods for targeting and ranking blackspot s.

Analysis of crash on blackspot sections:-

Once the crash sites prioritized for investigation have been determined, there are usually three steps of crashes analysis as follows (Getu Segni, 2007).

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

ii) A site investigation is carried out by specialist crash investigators to determine the exact conditions at the location. The investigation will observe traffic flows and road user behavior at the times of crashes 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 crashes occurring at that location is then carried out. This should include simple statistical tests to determine whether the crashes 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 crash factor grid, the crashes 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 crashes that will be prevented to ensure value for money. Once all blackspot sites have been investigated, a prioritized list for action over the road network can be established and the implementation process set in motion.

2.5 Possible Remedial Measures at Blackspot s

Treatment of blackspot s using engineering measures is one of mechanism measures that help to reduce crashes at dangerous spots. (Getu Segni, 2007) states that, the most popular low cost engineering measures incorporates; rumble strip, traffic signs and road markings, road light and roundabouts.

i) Rumble Strip

Rumble Strip 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 percent of crash reductions (Sandra Vieira Gomes).

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 (ERA, 2013).

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. 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 crash reductions of 10 to 40 percent may be achieved (TRL & Ross Silcock, 2001) This measure is particularly effective in roads without any marked limits, and is able to improve from 30 to 40 percent in crash reductions.

iii) Traffic Channelization

Traffic channelization is reducing conflicts between vehicles to vehicles and pedestrians. It facilitates correct path 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 crashes 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 (TRL & Ross Silcock, 2001). 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 crashes (TRL & Ross Silcock, 2001).

3. Research Methodology

This part covers the methods of collection, analysis and interpretation of the data used, and the procedures following to attain the objectives of the study. Accordingly, the methods applied were;

- Data collection and data analysis,
- Data discussion, interpretation of results and
- Conclusions and recommendations.

3.1 Study Area

This study covers the Debre Markos-Bahir dar road segment from exit of Debre Markos town to entrance of Bahir dar with a driving distance of 244km. The road connects three zones such as East Gojjam, West Gojjam, and Awi zone administration.

The road is a two-lane two-way highway with class A Trunk road which connects the center of the country to a recreational and political center of Amhara regional state capital Bahir dar and the road segment connects Addis Ababa with Sudan through Debre markose - Bahir dar- Gondar - Metema.

The road segment is serving as not only connecting Ethiopia with Sudan, but uses for delivery of agricultural products to local and capital of the country due to its location in a fertile area for agriculture which is the leading sector of the country’s economy.

To these facts, the road is considered as the most vital route in terms of economic and traffic volume and due to its connection with Sudan and fertile areas of North Gondar zone, Humera, Wolqait and Metekel zone of Benishangul Gumuz regional state which are the centers of Sesam production and serve as the primary access to Ethiopian Great Renaissance Dam, the road segment have mixed traffic volume.

Therefore it is an important route; the crash rate is very high due to many reasons. Due to this, the study focuses on the identification of dangerous spots, diagnosis of possible causes and proposition of low cost engineering measures, in order to reduce road crashes along the study road.

3.2 Data Collection

To attain the objective of the study five years (July, 2013- June 2018) different types of data's have been collected through different techniques from concerning government offices. These data types include traffic crash data, road data and traffic count data.

3.2.1 Traffic Crash Data

Five years traffic crash data of the study road were collected from corresponding traffic police stations and other concerned road transport offices for the periods covering from July 2013 to June 2018.

Data's include the following information, but not limited to:

- Date, day and time of crash,
- Vehicle type and ownership,
- Driver sex, age and education,
- Weather, road, and illumination condition,
- Crash type and Direction of flow
- Causes of crash registered by police
- Degree of severity, and
- Number of victims (driver, passenger, and pedestrian), sex, age, severity; and
- Zone, Woreda and Specific location of crash,

3.2.2 Traffic Data

This data were used for the analysis of road safety problems of the study road. This data had been obtained from Ethiopian Roads Authority Debre Markos Road Network Management Office by conducting traffic counts based on ERA-2013 Manual on the study area.

The counted traffic data were conducted at Debre Markos, Dembecha, Birsheleko Junction (Mankusa), Bure, Kosober, Dangila, Durbete, and Bahir dar for seven consecutive days (five days 12 hours and 2 days 24 hours) and for three seasons in a year such as February, July and November depending on Ethiopian Roads Authority Manual. Depend on the collected traffic data Annual Average Daily Traffic (AADT) were calculated for each counting station.

Steps of calculation of AADT;

- Seven consecutive days with five days of 12hr and 2days 24hr data (one week day and one at weekend) were collected. The 24hrs data are used for to established night factor.
- By founding the average of two days night factor adjustments were made for 24hrs of days with 12hr collected.
- The average of the seven days count is considered as Average Daily Traffic (ADT) of the subject quarter.
- The quarterly ADT is then converted to annual average daily traffic (AADT) using seasonal adjustment factor.

3.2.3 Road Data

The geometric design factors, which include horizontal curvature, road width, shoulder width, and grade of the road, were collected. This data is available at Ethiopian Roads Authority as-built drawing of the road plan and profile and after founding of blackspot sections, some site investigations of road geometric parameters were carried out. From the road data the following were obtained;

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

3.3 Methods of Analysis

3.3.1 Descriptive Statistics

Based on the collected data, characterization and description of traffic crashes with different aspects was made. These characterizations help to know the factors which have significant contribution for crash and based on this statistical analysis like correlation between crash and contributing factors were made. This helps to know which parameter are the most significant contributing factor and results to solve the problem causing crash on the segment. In addition to this on blackspot sections field observation and interpretations was made to point out the contribution of physical objects like trees, detours, deteriorated pavements, geometric features and other obstacles for traffic crash.

The general flow or steps of the analysis include;

- Data were Collected i.e. traffic crash data, traffic data and road data (including as built drawing).
- Descriptions and interpretations of the collected data were carried out.
- Using the crash data registered, the road segment is divided into different section lengths based on crash concentration and blackspot identification was carried out by crash severity rate.
- Using GIS software generating and plotting of the blackspot s on digitalized road map was carried out to show the concentration of the crashes.
- Based on the data and analyzing it investigation of the major causes of crash on the road segment were made and correlation analysis was carried out to evaluate the significance of contributing factors for crash.
- Finally from factors contributing to crash the possible remedial measures were pointed out.

3.3.2 Multinomial Logistic Regression Analysis

In connection with crash severity analysis, we can use various analyzing methods; however, taking account their strength and weakness Multinomial Logistics Regression is often used to predict the crash severity. Therefore, this research uses a multinomial logistic regression to model severity of a crash. The selected model considers the full form of the outcome, because the outcome is no longer assumed to be BINOMIAL rather MULTINOMIAL, powerful and slightly more complicated interpretation.

Dependent Variable:

The aim of this research is to find and describe the contributing factors of crash Severity; taking this into consideration the study regards crash severity as the dependent variable in the prediction model. These crash severities are classified into four categories; such as fatal, serious injury, slight injury and property damage.

Accordingly, if death occurs within 30 days of the crash data because of car crash the injury is called fatal; if at least one person involved in the car crash gets to hospital and treated for 24 hours or more it is called serious injury and if the treatment takes less than 24 hours it is called slight injury.

Independent Variables:

Independent variables are variables which causes road traffic crash consists of many variables that are related to the crash. These include age of drivers, driving experience, vehicle type, collision type, land use characteristics, roadway alignment features, intersection type and registered causes for crash. In this study, 8 variables used that are considered as an independent variable that contribute to crash injury.

This modeling process allows the identification of statistically significant factors that contribute to crash severity on the road section. Multinomial Logistic Regression Analysis is selected for a statistical process of estimating relationships between variables which model the crash data in order to make interpretation on factors affecting the severity of crashes.

The first assumption of Multinomial Logistic Regression Analysis is that the dependent variable cannot be perfectly predicted by the independent variables for any case. Multinomial Logistic Regression uses the maximum likelihood ratio to determine the probability of the categorical membership of the dependent variable. Crash severity in the crash data was divided into four categories; such as fatal, serious injury, slight injury and property damage. On the other hand the independent variables are age of drivers, driving experience, vehicle type, collision type, land use characteristics, roadway alignment features, intersection type and registered causes for crash and for analysis the statistical software SPSS has used. Statistical Package for the Social Sciences (SPSS) can analyze the data by examining relationships between variables (statistical technics to explore relationships includes correlation analysis and regression analysis) and enable to compare groups to determine if there are significant differences.

Table 3.1 Dependent Variable

Severity	Code
Fatal	1
Serious Injury	2
Slight Injury	3
Property Damage	4

Table 3.2 Independent Variables

Variable Name	Category	Code
Age of Drivers	Below 18	1
	18-30	2
	31-50	3
	51 and Above	4
	Unknown	5
Driving Experience	No License	1
	Below 1year	2
	1 to 2	3
	2 to 5	4
	5 to 10	5
	Above 10years	6
	Unknown	7
Vehicle Type	Bicycle	1
	Motor	2
	Automobile	3
	Bus	4
	Truck	5
	Cart	6
	Others	7
Collision Type	Vehicle to Vehicle	1
	Vehicle Rollover	2
	Pedestrian & Animal Crash	3
	Collision with fixed & Parked	4
	Fall from vehicle	5
	Unknown	6
Location & Land use	In Rural Village	1
	Out of Rural Village	2
	Around School	3
	Residential Area	4
	Around Institutes	5
	Recreational Area	6
	Around Office	7
	Unidentified	8
Roadway Alignment	Straight and Level	1
	Straight and Slopping	2
	Slight & Tangent Curve	3
	Straight and Vertical Grade	4

	Up & Down hill road	5
	Not Identified	6
Types of Intersection	No Any Intersection	1
	T&Y-shape	2
	Round About	3
	+&X Shape	4
	Not Identified	5
Causes of Crash	Drivers error	1
	Pedestrian error	2
	Vehicle defect	3
	Road defect	4
	Unknown	5

Performance measures

The analysis of this Multinomial Logistics Regression model uses three performance measures:

- ✓ **P value**: This is a significance test. It is normally tested at a threshold value of 5% or 1%. If the p-value is less than the threshold value, we reject the null hypothesis and accept the test hypothesis to be valid. For our model, we have tested at 5% level. Therefore, if the p-value is less than 0.05, we can conclude that it is statistically valid /significant.
- ✓ **B value**: The beta coefficients show the effect of the independent variables on the dependent variable. A positive coefficient for B shows a positive impact while a negative coefficient shows a negative impact. For our analysis, a positive B value shows that the category is more likely to impact category of dependent variable with respect to the reference category. If B > 0, it is more likely to impact the dependent variable. If B < 0, it is less likely to impact the dependent variable. If B=0, the particular category and the reference category are equally likely to impact the dependent variable.
- ✓ **Exponential Beta value**: This value gives us the odds ratio for the independent variables. It is an exponentiation of the regression coefficients (B). The odds ratio shows the change in odds of the dependent variable being in a particular category compared to the reference category, corresponding to one unit change of independent variable. An odds ratio > 1 indicates that the risk of the outcome falling in the comparison group relative to the risk of the outcome falling in the reference group increases as the variable increases. So it is more likely to fall in the comparison group. An odds ratio < 1 indicates that the risk of the outcome falling in the comparison group relative to the risk of the outcome falling in the reference group decreases as the variable increases. In general, if the odds ratio < 1, the outcome is more likely to be in the reference group.

3.4 Identification of Blackspot Sites

Identification of blackspots is the procedure to locate those spots in the road networks that are particularly dangerous, that is called, the blackspots. Based on the five years crash data, and crashes were plotted along the road section to give a rough location of crashes.

In order to identify the blackspot sections, step-by-step procedures were made, which is the combination of crash rate, frequency of crash and severity of crash will be used to avoid the drawback of individual criteria's stated below.

The drawbacks of crash frequency are bias towards high traffic volume sites, does not take into account crash severity and random natures of crashes are not considered. On the other hand the disadvantage of crash rates are traffic volume must be known at each site, random natures of crashes are not considered, biased towards to low traffic roads, not considered severity of crashes and it assumes a linear relationship between traffic volume and accidents.

Crash rates were calculated for each scheme, link and junction with relation to some of the geometric design parameter and traffic factors. (Berhanu, 2000) defines the crash rate as follows.

$$Rj\ (Road\ Section) = \frac{fjx10^6}{365.25xTxAADTxL}$$

$$Rj\ (Junction) = \frac{fix10^6}{365xTxAADT}$$

Where, Rj (road section) = Crash rates per million vehicle-kilometer on road sections,

Rj (junction) = Crash rates per million vehicle entering a junction,

Rj = number of reported crashes at site j,

T = time frame of the analysis, (years)

AADT = average annual daily traffic of site j, and

L = length of the road section, in kilometer

The crash frequency also calculated for comparison with others which shows the repeatability of the crash on the road segment. When calculating the frequency of crashes total number of crashes shall be considered and by ranking the sites in decreasing order detailed safety analysis will be carried out.

$$Frp = \frac{\sum fj}{n}$$

Where; Frp = average accident frequency

Fj = accident frequency at site j of a reference population

n= number of sites

In addition to this, the average crash rate for the reference population were calculated by

$$Rrp\ (Road\ Section) = \frac{fjx10^6}{365.25xTxAADTx\sum Lj}$$

Where, Rrp (road section) = Average crash rates per million vehicle-kilometer at site j, Reference populations are groups of study sites (such as intersections or roadway segments) that have similar characteristics and serve as a comparison for evaluating safety performance. The Average crash rate (Rrp) has been determined using the formula developed above by considering crash frequency at each site of a reference population, length of study period in years, AADT and total length of the study road segment.

On the third place, calculating of the critical crash rate was made at each site. Then, the minimum crash rate that warrants a detailed safety analysis was determined.

$$Rcj = Rrp + K\sqrt{\frac{fjx10^6}{365.25xTxAADTxLj}} + \frac{1x10^6}{730.5xTxAADTxLj}$$

Where, Rcj= Critical crash rates per million vehicle-kilometer at site j,

K = 1.036 for level of confidence of 85%
= 1.282 for level of confidence of 90%
= 1.645 for level of confidence of 95% (selected for this study)
= 2.326 for level of confidence of 99%

A detailed safety analysis is made when the accident rate is higher than the critical rate.

Finally, the severity index (called prioritization by TRL) was carried out for prioritizing for detail analysis. Since most researchers in Ethiopia uses TRL prioritization formula, the selected prioritize method were used for this study which is developed by (TRL, 2001) is

$$P = \frac{(1xW + 2xX + 3xY + 5xZ}{Lj}$$

With the weight given for fatal accident are 5.0, for serious injury is 3.0, for slight injury and property damage are 2.0 and 1.0 respectively.

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
Lj= Length of the blackspot section in kilometers

Furthermore, site visit were carried out to support the conclusion from arithmetic calculation.

3.5 Identification of Remedial Measures

Having identifying the probable causes of the crash, possible remedial measures were suggested to improve the road crash situation along the road segment. The counter measures were low cost engineering measures as much as possible but due to improper road design on some part of the section design change is recommended due to creation of safe road environment.

4. Analysis and Discussion

4.1 Crash Characteristics

The crash database of the road segment that covers on this study covers all crashes reported by concerned traffic police, blackspot sections were identified by statistical analysis and traffic data counted by Ethiopian Roads Authority D/Markos Road Network Management Directorate at the study sites along the 244km stretch during the period of July 2013 to June 2018. During these periods a total of 1,873 crashes were reported out of which 741 were fatal, 307 were serious injury, 197 were slight injuries and 628 were property damages on the road segment.

To have better understanding, it is important to see the crash distribution in relation to road characteristics, driving behavior, crash type, pedestrian movement and other relationships used to show the characteristics of crashes. Accordingly, correlation analysis is made to identify the contribution of factors for crash and to make relative comparison between variables.

4.1.1 Crash Distributions with Time of Day

In this study, the crash time were expressed in happening hour, day of the week and year. Since crashes have a characteristics of random happening it will be occur at anytime and anywhere throughout the stretch.

Generally, from the collected data, most crashes occur between 1000:1300 o'clock , based on day of the week maximum crashes occur on Saturday and from the study period the maximum number of crashes were happened in 2010 Ethiopian Fiscal Year.

Table 4. 1 Distribution of crashes on hours of the day

Hourly Road Traffic Crash								
S.No.	Hour	No. of Crash per Year						
		2013/2014	2014/2015	2015/2016	2016/2017	2017/2018	Total 5Yrs	Percentage
1	0100-0400	37	35	45	32	30	**179**	**9.56%**
2	0400-0700	44	56	52	33	45	**230**	**12.28%**
3	0700-1000	92	62	61	54	65	**334**	**17.83%**
4	1000-1300	65	78	85	94	74	**396**	**21.14%**
5	1300-1600	49	58	62	75	80	**324**	**17.30%**
6	1600-1900	41	41	55	59	63	**259**	**13.83%**
7	1900-2200	14	26	18	21	20	**99**	**5.29%**
8	2200-2500	9	8	10	8	17	**52**	**2.78%**
	Total	**351**	**364**	**388**	**376**	**394**	**1873**	**100%**
	Percentage	**18.74%**	**19.43%**	**20.72%**	**20.07%**	**21.04%**	**100%**	

As shown on table 4.1, the maximum number of crashes occurs from 1000-1300, 0700-1000 and 1300-1600 with a percentage of 21.14, 17.83 and 17.30 respectively. These entire maximum amounts occur during afternoon which is between 1:00 PM to 10:00 PM. Most probably, drivers are stressed and fatigued during these hours as a result of pick hour for any movement of road users and it is tired time.

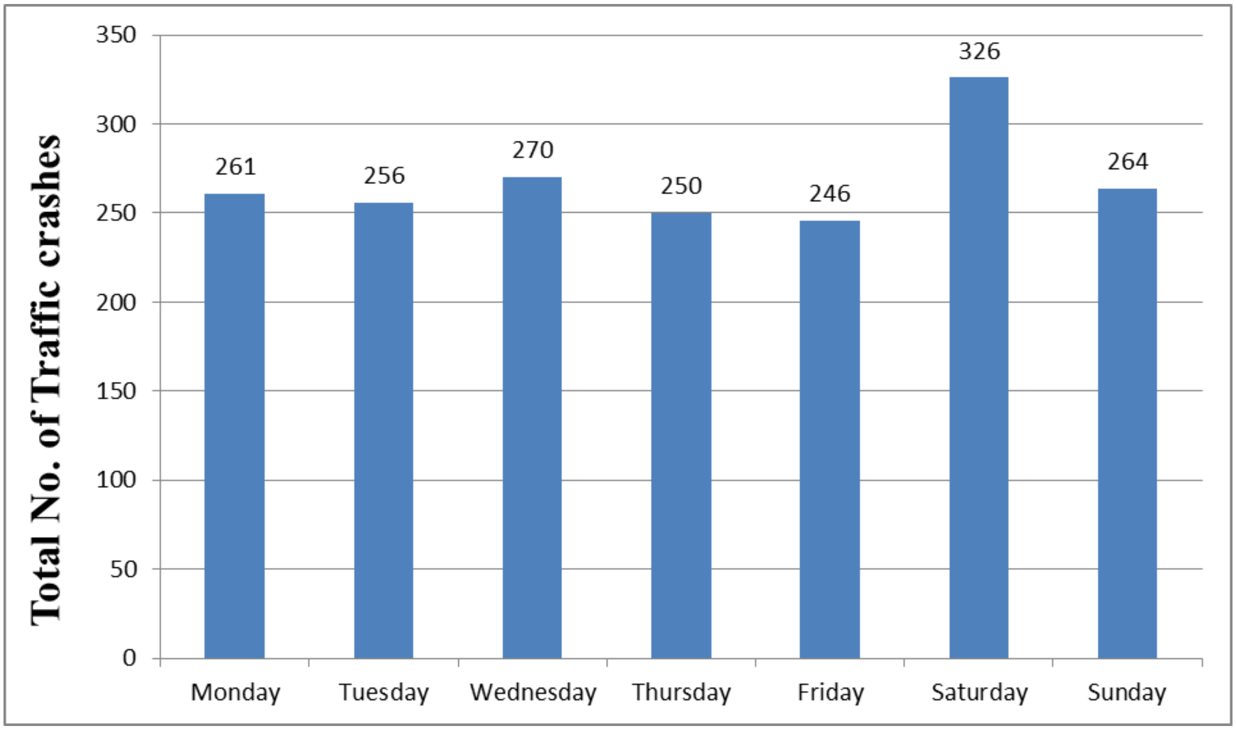

Figure 4. 1 Crash distributions on day of the week

From figure 4.1, the maximum number of crash were registered on Saturday with an amount of 326 crashes may be this is due to the fact that on the study section Saturday is market day and high volume of road users such as vehicles, pedestrians and passengers are involved highly when compared to other days in a week. But, on the other days of the week the registered number of crashes have a smooth variation with an average variation rate of 4 crashes per day.

In addition to this next to Saturday more crash was registered on Wednesday with amount of 270, this is may be due to the fact that Wednesday is the second market day for a community locally called gulit. And since Sunday is religious day it is placed in third level by registered crash. But from field observation on Sunday commercial vehicles like minibus's load over its capacity since the number of traffic police reduced due to break day.

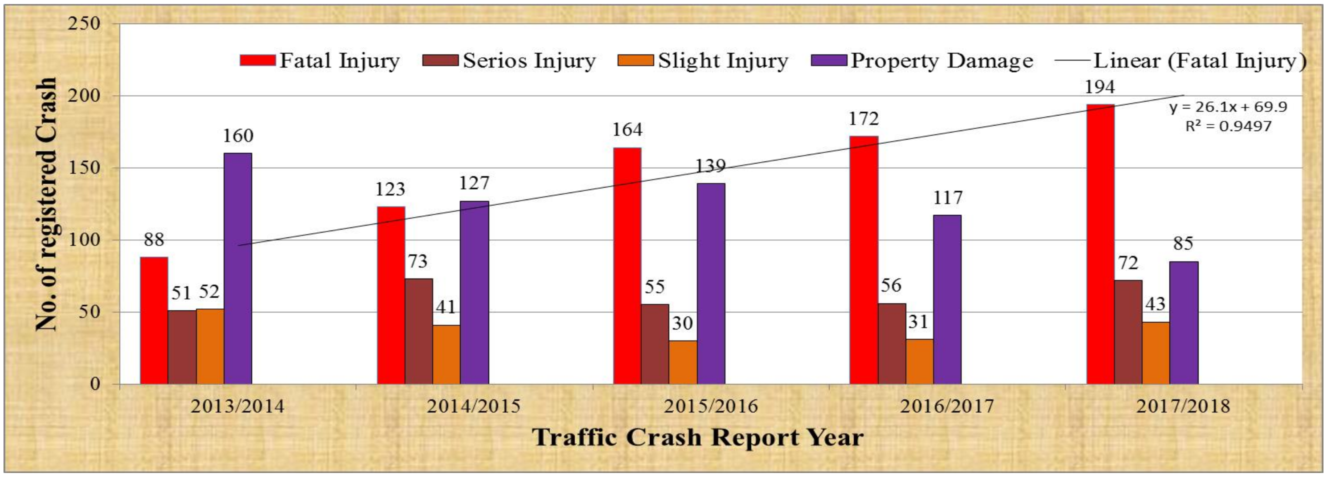

Figure 4. 2 Yearly distributions of crashes with severity type

As shown on figure 4.2 the number of reported traffic crashes is increased from year to year. For understanding of how traffic crash severity is increased from year to year simple regression analysis was made the number of fatalities increasing continuously with an average rate of 26.1 fatalities per year as shown on figure 4.2. This indicates that road traffic crashes are the most serious and dangerous causes for loss of life from time to time.

Therefore studying the root cause of the problem and investigating the probable solutions is a mandate of a transport and safety engineer.

4.1.2 Crash Distributions with Demography and Driving Experience

A breakdown of collisions by drivers' age with crash severity is provided in Table 4.2. About 54.03 percent of the drivers involved in collisions were between the ages of 18 and 30. In other age group, about 22.8 percent were between 31 and 50 years old and about 19.27 percent of drivers couldn't identified in their age in the report. Nationally drivers of age with 18-30 increased from time to time due to different reasons and they are exposed to crash due to younger behavior and not experienced.

Table 4. 2 Distribution of crashes by drivers' ages

S.No.	Drivers' Age	Crash Severity					
		Fatal	Serious Injury	Slight Injury	Property Damage	Total	Percent
1	Below 18	5	4		3	**12**	**0.64%**
2	18-30	329	181	117	385	**1012**	**54.03%**
3	31-50	129	59	53	186	**427**	**22.80%**
4	51 and Above	17	9	8	27	**61**	**3.26%**
5	Unknown	261	54	19	27	**361**	**19.27%**
	Total	**741**	**307**	**197**	**628**	**1873**	**100.00%**
	Percent	**39.56%**	**16.39%**	**10.52%**	**33.53%**	**100.00%**	

Since driving is a skill which requires repeated training driving experience is the most powerful thing to prevent road traffic crash. But, even if driving experience is a well manner to prevent the crash driving environment which is driving in rural section or in urban section have its own influence. Mostly, well experienced drivers in urban section can safely drive in a congested area and driving in rural roads is a great challenge for them, and well experienced drivers in rural section can safely drive in rural roads and vice versa.

Table 4. 3 Distribution of crashes by driving experience

S.No.	Driving Experience (yrs)	No. of Crashes with Severity					
		Fatal	Serious Injury	Slight Injury	Property Damage	Total	%
1	No License	17	15	5	12	**49**	**2.62%**
2	Below 1yrs	56	25	19	61	**161**	**8.60%**
3	1 to 2	87	63	50	120	**320**	**17.08%**
4	2 to 5	150	81	68	232	**531**	**28.35%**
5	5 to 10	103	53	34	121	**311**	**16.60%**
6	Above 10yrs	54	18	5	55	**132**	**7.05%**
7	Unknown	274	52	16	27	**369**	**19.70%**
	Total	**741**	**307**	**197**	**628**	**1873**	**100.00%**
	%	**39.56%**	**16.39%**	**10.52%**	**33.53%**	**100.00%**	

From table 4.3 drivers having an experience of 2-5 years have a great contribution for the crashes registered on the study period with a value of 28.35percent. this is due to that drivers in rural roads reduce their speed during first to second year of driving period and when they think that have an experience, they drive in a speedy manner and leads to crashing.

4.1.3 Crash Distributions with Vehicle Type

Figure 4.3 shows the types of vehicles involved on crash in the study area and from the collected crash data vehicles most frequently involved in crashes were minibus up to 12 seats (22.1%).The second and third most frequently involved in crashes were medium buses 13-45seats (21.7%) and trucks 41-100 quintal (20.2%). Both mini and midi buses are mostly operated by youngsters with working locally (from one woreda to the neighbor woreda) and try to make a competition between them and this leads to increase speed.

On the other hand, trucks with 41-100 quintal are operated by professional drivers for extended hours by chewing chat. As a result, fatigues together with speed and sleeping are the main causes for crashes in these types of vehicles.

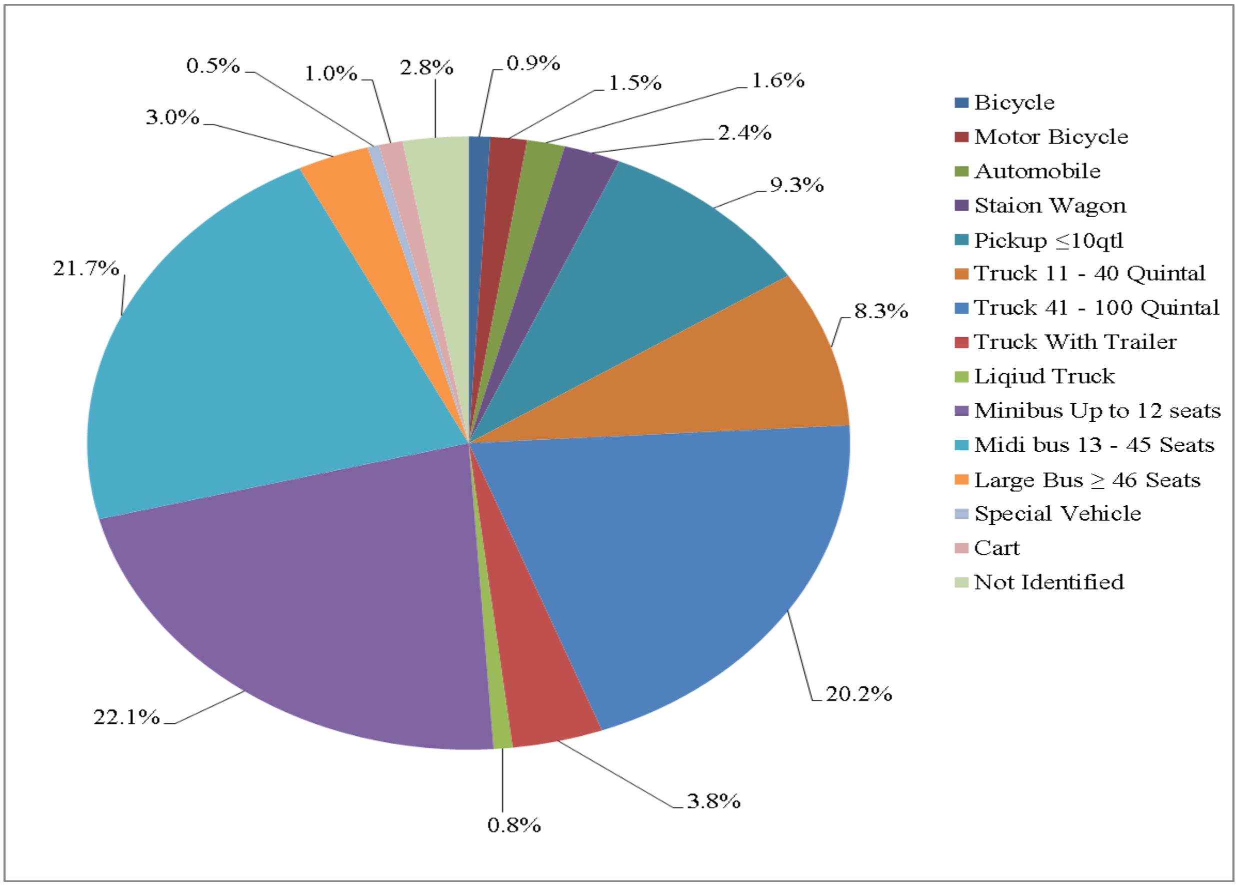

Figure 4. 3 Type of vehicle involved in traffic crash

4.1.4 Crash Distributions with Collision Type

As shown on figure 4.4, the majority of crash severity resulted in pedestrian crashes (38%), vehicle rollover (22.4%), head on (10.5%) and rear end (7.2%). Other collision types like, side-impact, side swipe, collision with animals, fall from vehicle, collision with fixed objects, collision with parked vehicles and others had minor contributions to crashes.

In terms of fatalities with respect to collision types, the highest percentage of fatalities recorded was collision with pedestrians that accounted for about 56.7 percent followed by vehicle rollover with 21.5 percent and then by head on crash with 10.1 percent. This figure showed us in in the study area does not have proper pedestrian facilities, drivers drive over limited speed and improper usage of the road by drivers like leaving from right and pass curved pathways with speed.

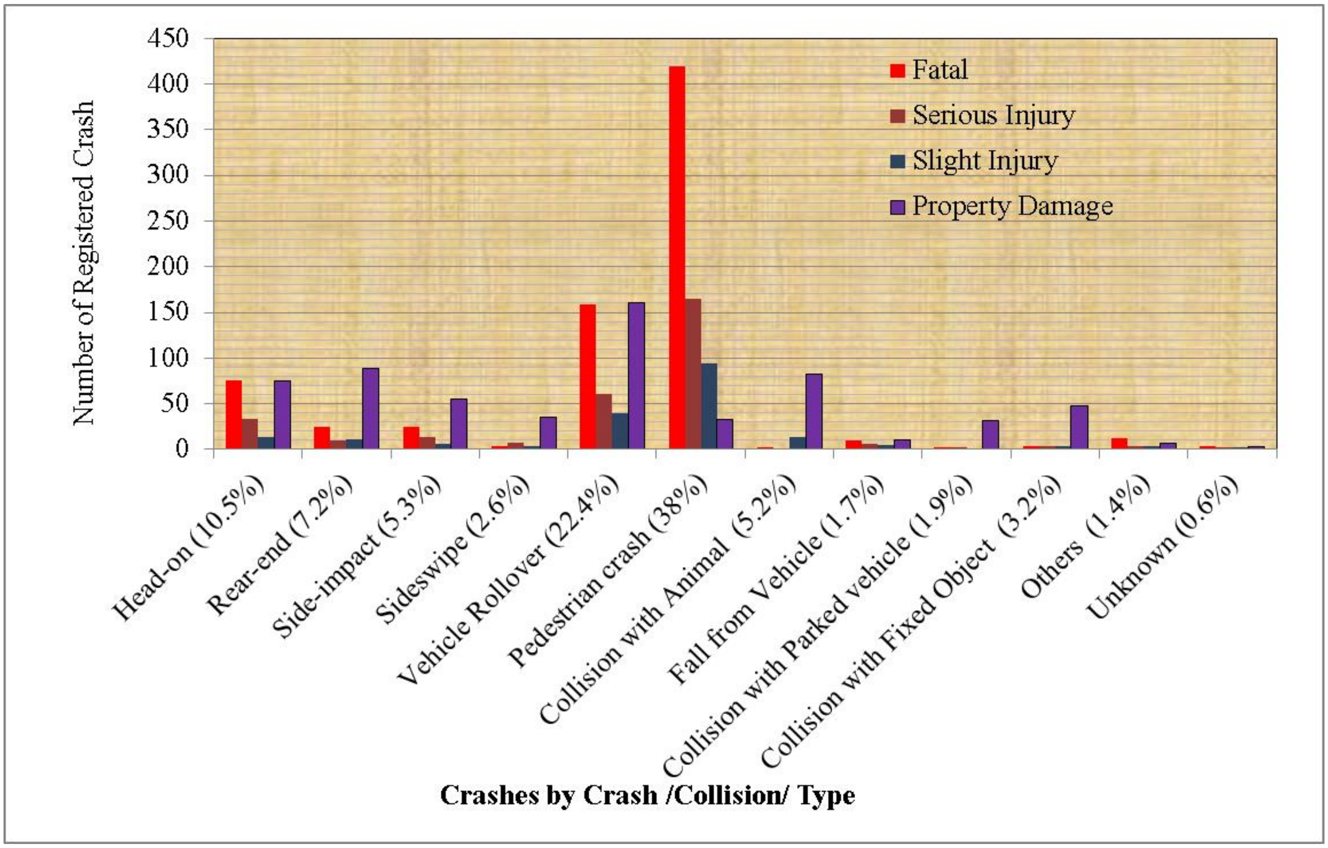

Figure 4. 4 Distribution of crashes by collision type

4.1.5 Crash Distributions with Location and Land Use

Since the road segment is covered by large amount of rural area crashes happen with respect to the coverage. As shown on figure 4.5, large amount of crashes occurred in rural village (52%), out of rural village (15%) and around residential area (15%). Others like around office, school, recreational area, religious area, hospital, and factory and near to market had not significantly crash occurrence areas.

This is due to the fact that, farmers want to live near to the road segment to get access, most road users are farmers and they are pedestrians, violence of speed limits by drivers especially in rural areas and obstacles by cart users and so on.

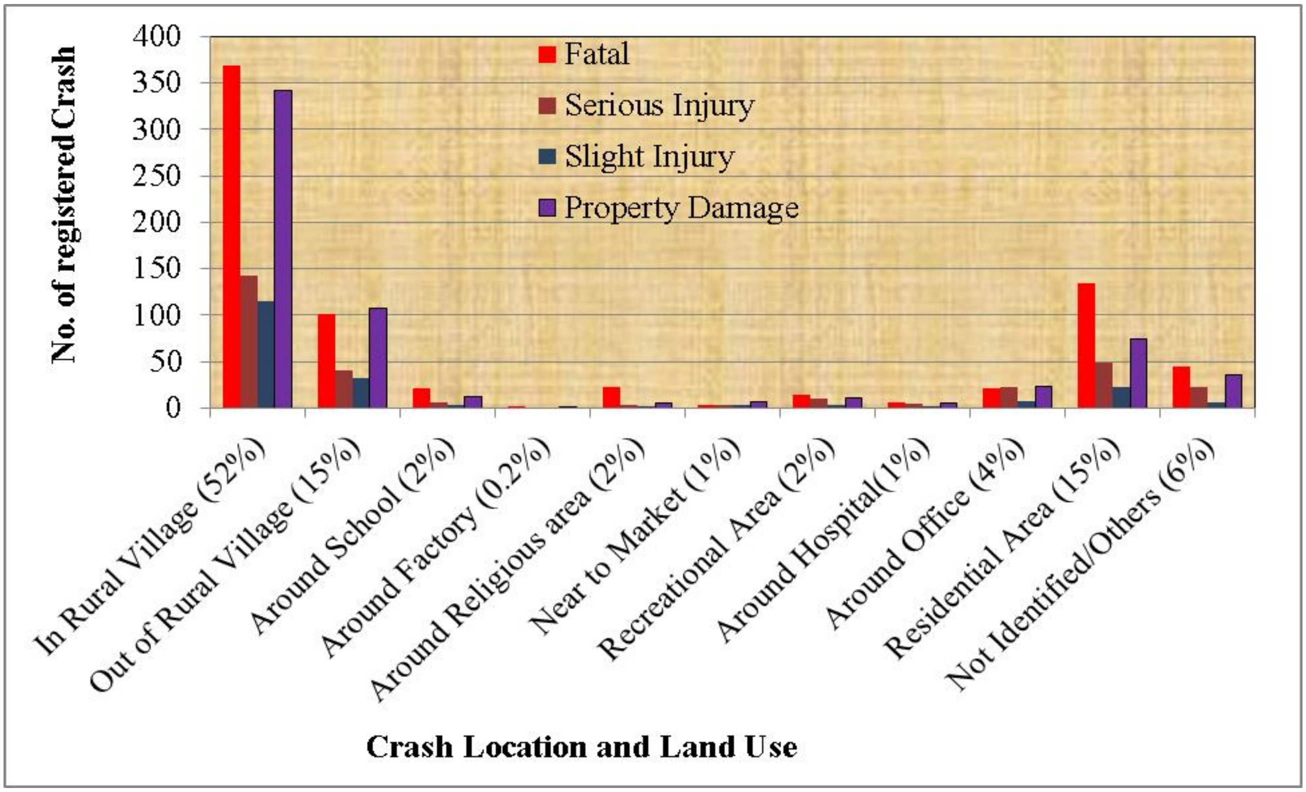

Figure 4. 5 Distribution of crashes with land use

4.1.6 Crash Distributions with Casualties by Road Users

As shown in Table 4.4, the major total causalities occurred in passengers which accounted for about 64.7 percent. The pedestrian and drivers accounted about 29.5 and 5.8 percent respectively with total number of causalities. But in terms of fatal causalities pedestrians placed on the first stage with a number of 519 fatal and passengers counted about 395 people.

This showed that, the probability of continuing with live after crash occurred is too low for pedestrians compared to passengers. When we compared the series and slight injuries between passengers and pedestrian casualties were increasing with inverse order for fatal, series injury and slight injuries respectively.

Table 4. 4 Injury Severity of Casualties by Road Users

S.No.	Crash Severity	Driver's		Passengers		Pedestrian		Total	
		Number	%	Number	%	Number	%	Number	%
1	Fatal	96	9.5%	395	39.1%	519	51.4%	**1,010**	**34.3%**
2	Serios Injury	50	5.8%	611	70.6%	205	23.7%	**866**	**29.4%**
3	Slight Injury	26	2.4%	896	84.1%	143	13.4%	**1,065**	**36.2%**
	Total	**172**	**5.8%**	**1,902**	**64.7%**	**867**	**29.5%**	**2,941**	**100%**

Generally, during the five years study period (2006-2010 EFY) 2941 people were injured with 1010 fatal, 866 series injury and 1065 slight injury. And from these numbers, 172 were drivers, 1902 were passengers and 867 were pedestrians.

4.2 Description of Road Factors and Blackspots

Road environments are the major causes of road traffic crash if they are not handled properly. This road environment includes road alignment and cross sectional elements, type of road surface, lighting system of the road and others.

Due to its cause for crash, some sections of the road were selected as blackspots by making statistical analysis and detail investigations are required on it to solve the problem and to create safe transport system.

On the study road segment by using the collected traffic crash data and based on critical crash rate calculation sixteen blackspot sections were selected. The locations of these segments are both in town and rural section.

After selection of sections field observation has been carried out to support the arithmetic data and the geometric features of the spots are horizontal and vertical curves, narrow bridges near to curve, tangent sections, up and down grade sections, site distance covered by trees and so on.

To be having a better understanding on the influence of road factors let us see some data recorded on the road segment.

4.2.1 Crash Distribution with Road Features

Road features is geometric elements of the given road which includes, horizontal and vertical curves, cross sectional elements (carriage way width, shoulder, median, side slopes etc.) grade, junctions, site distance, intersection and interchanges and others.

i. Crash Distribution on Roadway Alignments

As shown on figure 4.6, an amount of 71 percent of the crash occurred on straight and level section of the segment and others contribution is 10 percent for straight and slopping section, 7percent for escarp or downhill section, 4percent for slight curve and 3percent of crushes occurred on uphill section of the road segment

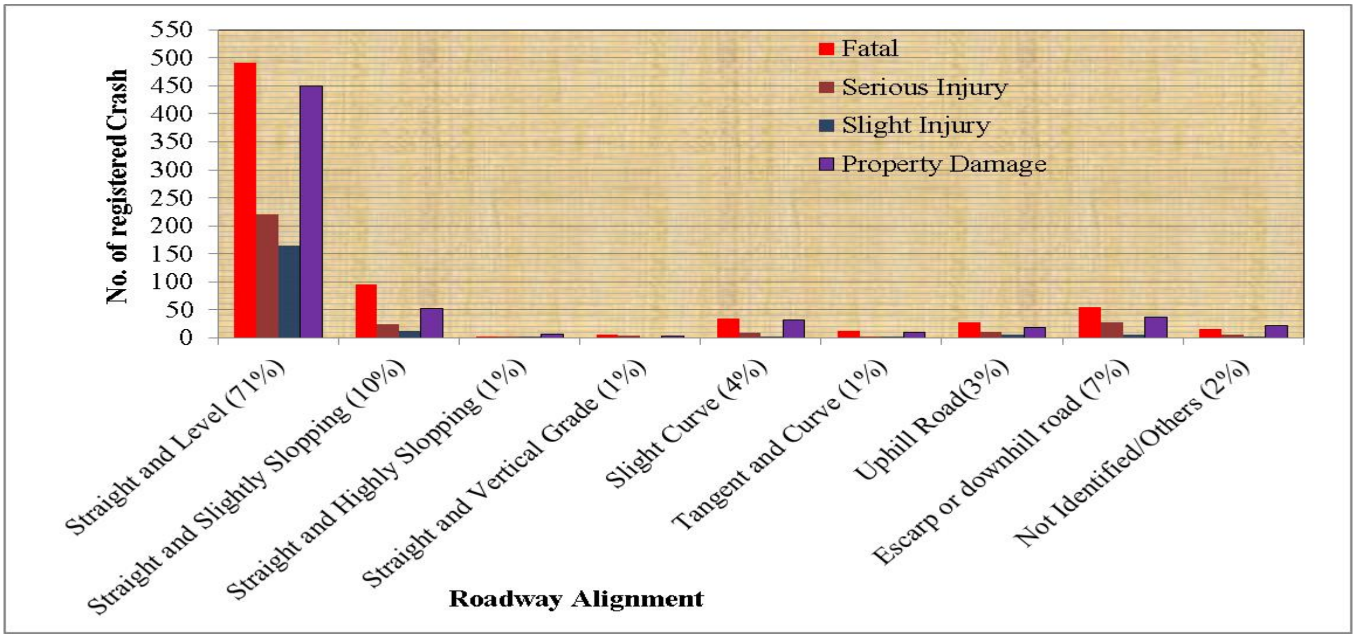

Figure 4. 6 Crash distributions by roadway alignment

ii. Crash Distribution with Types of Intersections

As shown on figure 4.7, crashes occurred at no any type of intersection which is accounted about 87percent and other types of intersections /junctions/ had too low influence. But we should know that the road segment is covering large amount of rural section and number of merging roads to the study section is low and there is only two round about which is located at Finoteselam and Injibara. In addition to this, on some intersections there is traffic signs for guiding of road users and this have good effect on reduction of traffic crash.

When we see the physical figures the number of registered crash at no any intersection, an amount of 1637 crashes had recorded with 647 fatal, 249 serious injuries, 172 slight injuries and 569 property damage.

Figure 4. 7 Crash distributions with types of intersection /junction/

4.2.2 Identification of Blackspot Sections

To identify the blackspot sections, statistical analysis was carried out based on calculation formulas described in methodology part 3.4. To do this the whole stretch of the road is divided into 40 sections based on distribution of crashes registered. The length of each section is not equal for getting of best fitted concentration of crash for detail investigation.

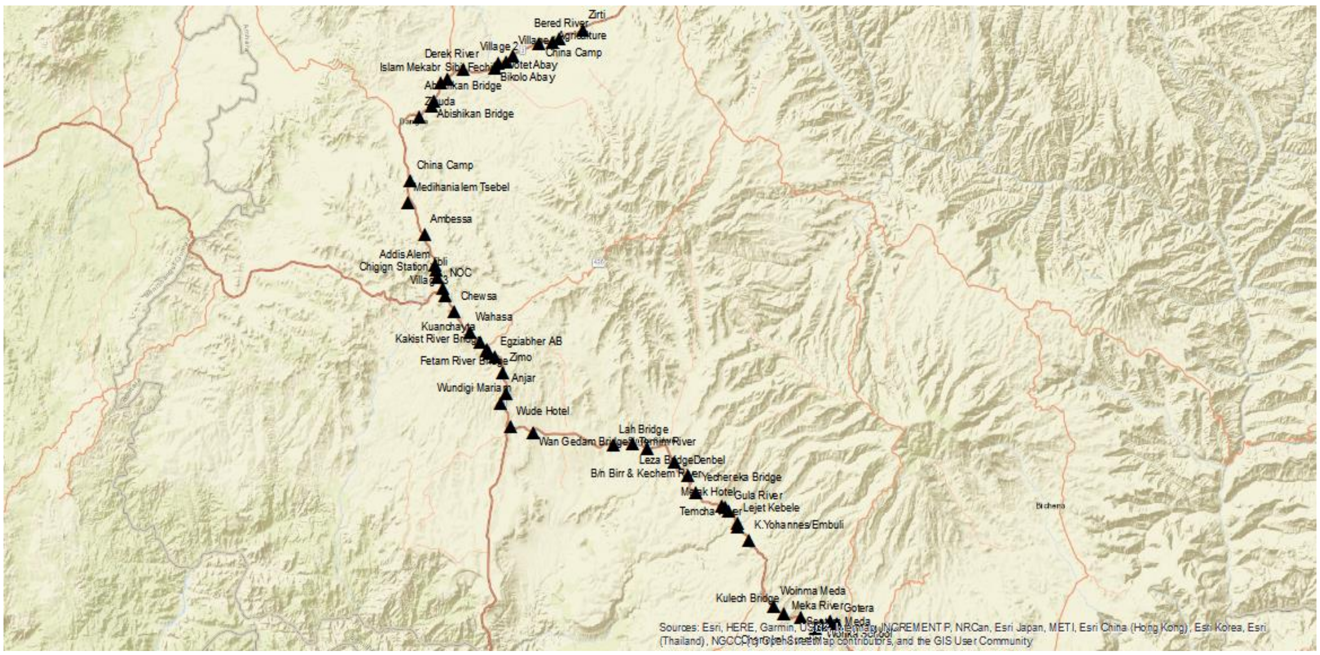

Figure 4. 8 Divided sections of the study area

As shown on figure 4.10, on the study road segment (D/Markos-Bahir dar) the segment is divided into 40 sections for detail statistical analysis.

As shown on Appendix 2, Table 1, On the basis of the criteria developed in chapter three, road sections which have crash rate greater than critical crash rate is considered as blackspot and used for further treatment. Hence, out of the 40 road sections define for blackspot analysis, sixteen road sections were fulfilled the criteria and identified for further treatment.

By using the severity index (called prioritization by TRL) detail investigation and analysis is discussed as follows. Since most researchers in Ethiopia uses TRL prioritization formula, the selected prioritize method were used for this study which is developed by (TRL, 2001) is

$$P = \frac{(1xW + 2xX + 3xY + 5xZ}{Lj}$$

With the weight given for fatal accident are 5.0, for serious injury is 3.0, for slight injury and property damage are 2.0 and 1.0 respectively.

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

Lj= Length of each divided section in kilometers

Since the prioritization formula considers length of each sections of the reference population, effect of using different section length assumed to be insignificant on the result for selection of blackspot sections.

In this study, the reference population assumed to be road segments, since from the collected crash data about 87% of crash occurred at a location of no any intersection/junction and this limitation had been addressed through field observation on the study road segment.

Therefore, by using the aforementioned stated formulas and assumptions the selected 16 blackspot sections are listed herein under on table 4.5 and further discussions were tabulated after the table.

Table 4. 5 Selected blackspot sections with priority value

S. No.	Stations	Location Name	Fatal	Serious Injury	Slight Injury	PD	Total Crash	Length (KM)	AADT	365.25*T*Lj *AADTj	Rj	Rrp	Rcj	BS	Pj
1	72+000-73+300	Leza Bridge	25	23	9	5	62	1.3	3303	7,841,734.88	7.91	1.27	2.00	**BS**	166.923
2	241+700-243+700	Yibab Campus	28	17	15	61	121	2	4414	16,122,135.00	7.51	0.95	1.38	**BS**	141.000
3	105+000-107+500	Wude Hotel	44	8	9	55	116	2.5	3524	16,089,262.50	7.21	1.19	1.67	**BS**	126.800
4	80+200-83+500	F/selam Town	39	33	20	31	123	3.3	3303	19,905,942.38	6.18	1.27	1.71	**BS**	110.606
5	139+100-141+600	Injibara Town	35	15	7	24	81	2.5	5008	22,864,650.00	3.54	0.84	1.18	**BS**	103.200
6	238+700-241+700	Yinesa	32	24	10	47	113	3	4414	24,183,202.50	4.67	0.95	1.30	**BS**	99.667
7	123+500-125+500	Tilily Town	21	9	10	26	66	2	3524	12,871,410.00	5.13	1.19	1.73	**BS**	89.000
8	212+700-214+700	China Camp	24	2	1	28	55	2	4414	16,122,135.00	3.41	0.95	1.38	**BS**	78.000
9	0+000-1+800	Gotera	17	3	8	19	47	1.8	3342	10,985,989.50	4.28	1.26	1.86	**BS**	71.667
10	136+500-139+100	Chewsa	26	6	5	15	52	2.6	3524	16,732,833.00	3.11	1.19	1.66	**BS**	66.538
11	214+700-218+700	Agricalture	33	7	3	34	77	4	4414	32,244,270.00	2.39	0.95	1.25	**BS**	56.500
12	73+300-76+400	Temim River	19	11	12	8	50	3.1	3303	18,699,521.63	2.67	1.27	1.73	**BS**	51.613
13	203+200-205+700	Bikolo Abay	19	2	1	23	45	2.5	4414	20,152,668.75	2.23	0.95	1.33	**BS**	50.400
14	107+500-111+500	Wundigi Mariam	32	8	2	9	51	4	3524	25,742,820.00	1.98	1.19	1.57	**BS**	49.250
15	43+800-48+800	Dembecha Town	34	12		9	55	5	3342	30,516,637.50	1.80	1.26	1.61	**BS**	43.000
16	191+700-194+700	Islam Mekabr	18	6	1	8	33	3	4414	24,183,202.50	1.36	0.95	1.30	**BS**	39.333
	Total		446	186	113	402	1147	44.6							

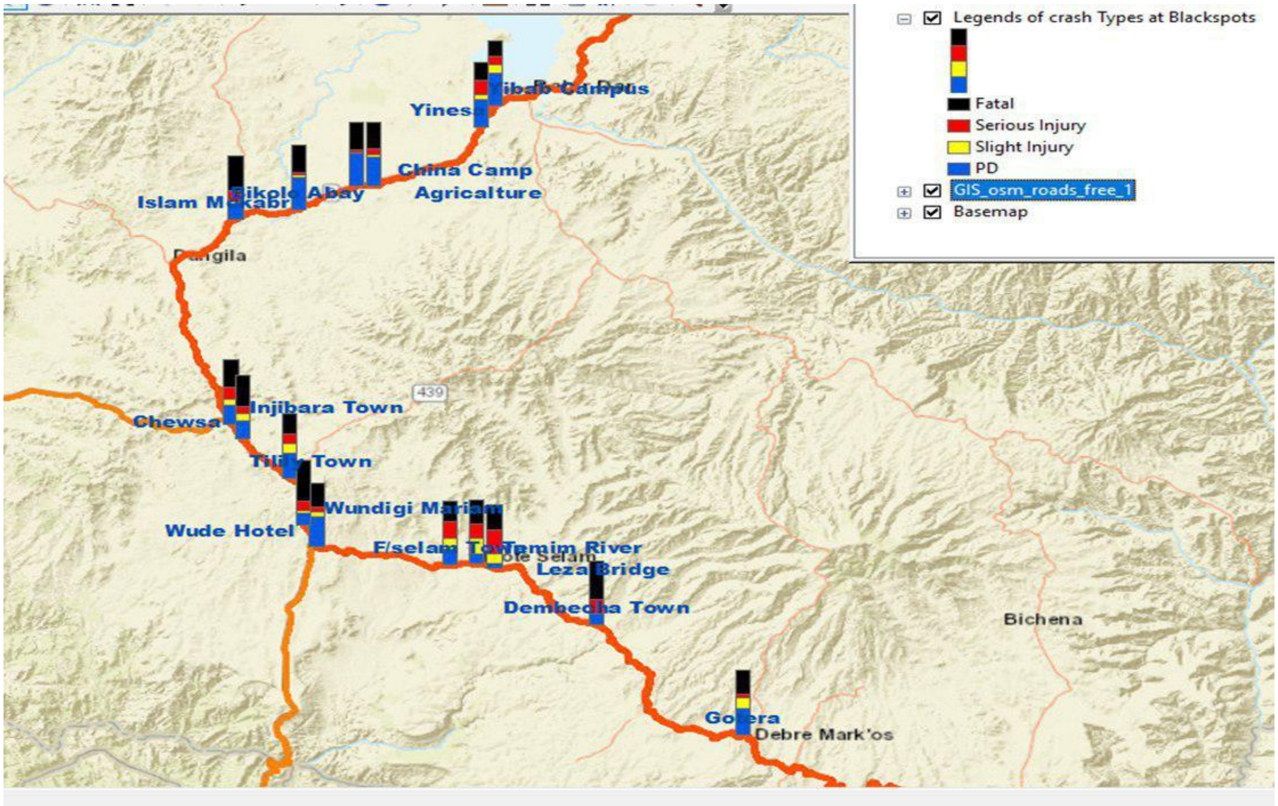

Figure 4. 9 Location of blackspot sections with crash Severity

Therefore, depending on the priority of the sections field observation was carried out and the detail discussion is as follows;

A) Station 72+000-73+300

Description- this station locally called Leza River covers 1.3km length and during the study period totally 62 crashes were registered with 25 fatality, 23 serious injury, 9 slight injury and 5 property damage.

Site Observation: - During the site observation, the following problems were observed on the section. The vehicle entering to the bridge from F/selam direction travels in a straight and level road with coverage of trees in both side and can't see behind the narrow bridge. Just after passing the bridge dangerous horizontal and vertical curve is appear and vehicles from opposite direction leave their right. In addition to this there is site distance coverage by detour and trees. During the observation time, vehicles were operating above the speed limits especially trucks and minibus taxis.

With Regard to road marking, divided lanes were not properly observed due to fade up of the color with no sign to road users. Besides this there is small irrigation dam just lower side of the bridge and the water back up to upper side with creating of small lake. Besides these animals pass through the bridge and drink on the small lake. Due to these crashes happened repeatedly with higher severity.

Proposed Remedial Measure: - The following are proposed in order to alleviate the problem of the road section.

a. In order to avoid site distance problem clearance of detour and trees on right side should be made.
b. At least three sets of rumble stripes should be provided after bridge to direction of F/selam and three speed breakers should be provided on Jiga side to notify reckless drivers with driving of high speed.
c. Strong fixed objects should be placed on upper side of the bridge from Jiga side to prevent entering of uncontrolled brake vehicles to the lake.
d. Warning post should be provided in both sides for new road users.

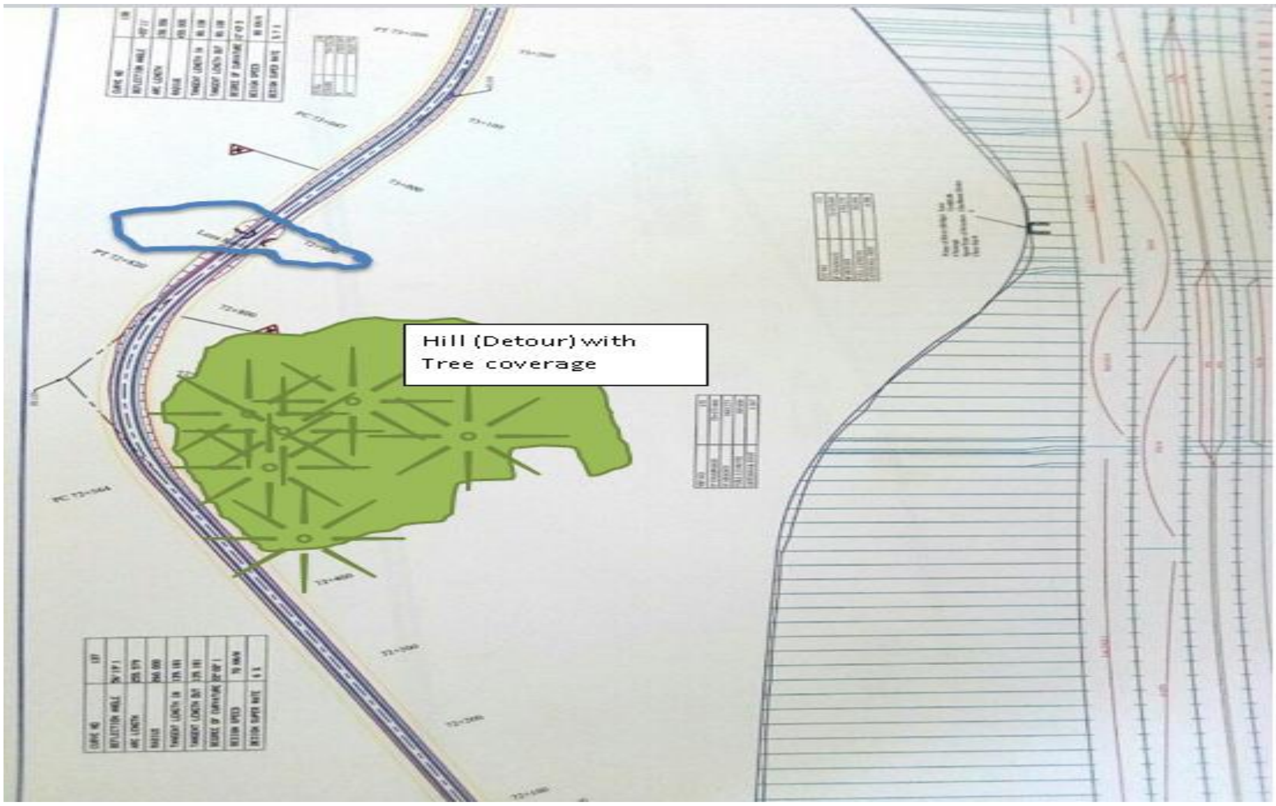

Figure 4. 10 Current conditions of Leza River condition diagram

B) Station 241+700-243+700

Description- this station covers Yibab area which includes Bahir dar university Yibab campus with a study section length of 2km. During the study period totally 121 crashes were registered with 28 fatality, 17 serious injury, 15 slight injury and 61 property damage.

Site Observation: - During the site observation, the following problems were observed on the section. The study section is border area of Bahir dar city and traffic volume is relatively high but drives were in violating of speed limit due to exit of the city. The mostly observed vehicles are bajaj's, commercial vehicles like minibus's and pickups. At the time of observation, Bajaji's on this section were stop, load and turn at any point and due to this the chance of crash with speedy vehicle and pedestrian were high. Site distance at some spots is covered by trees with absence of traffic sign and riding with over speed is the major cause for crash. In addition to this there is school, church and university. Which means that pedestrian involvement is high and ignorance of traffic rules by road users were observed.

Proposed Remedial Measure: - The following are proposed in order to improve the problem of the road section.

a. In order to avoid site distance problem clearance of trees on both sides should be made.
b. Rumble stripes should be provided before and after zebra crossing of entrance of Bahir Dar University and entrance to church to notify reckless drivers with driving of high speed.
c. Traffic signs should be provided at entrance of school and high number of pedestrian crossing.
d. Making road marking to guide properly turning points and enforcement and controlling of bajaji's should be made to avoid U-turning at any point of the road.

C) Station 105+000-107+500

Description: - This station covers Burie town section with a length of 2.5km. During the study period totally 116 crashes were registered with 44 fatality, 8 serious injury, 9 slight injury and 55 property damage. Dangerous vertical grade and improper alignment of road exclusively near Wudie hotel (entrance of Burie town) are the major causes of loss of life.

Site Observation: - During the site observation, the following problems were inspected at station 105+000-107+500. The study section is entrance and exit of Burie town and divergence point of Burie-Nekemet road. Since the road section is within town section with high vertical grade and speedy driving at sharp turning point on entrance of Burie town relatively sever crash is occurred repeatedly. Vehicles drive from Bahir dar side to Finote selam with excessive speed exposed to rollover and/or crash with shops located on lower side of the road. In addition to this, since the turning point is difficult drivers coming from Finote selam side leave their right and at that time crash will be happen with driving vehicles from Bahir dar side with excessive speed.

During site observation, on the lower side of intersection there is shop and peoples sit in front of it and they are exposed to crash. Besides these minibuses came from Finote selam side parked just immediately before intersection with loading and dropping of passengers.

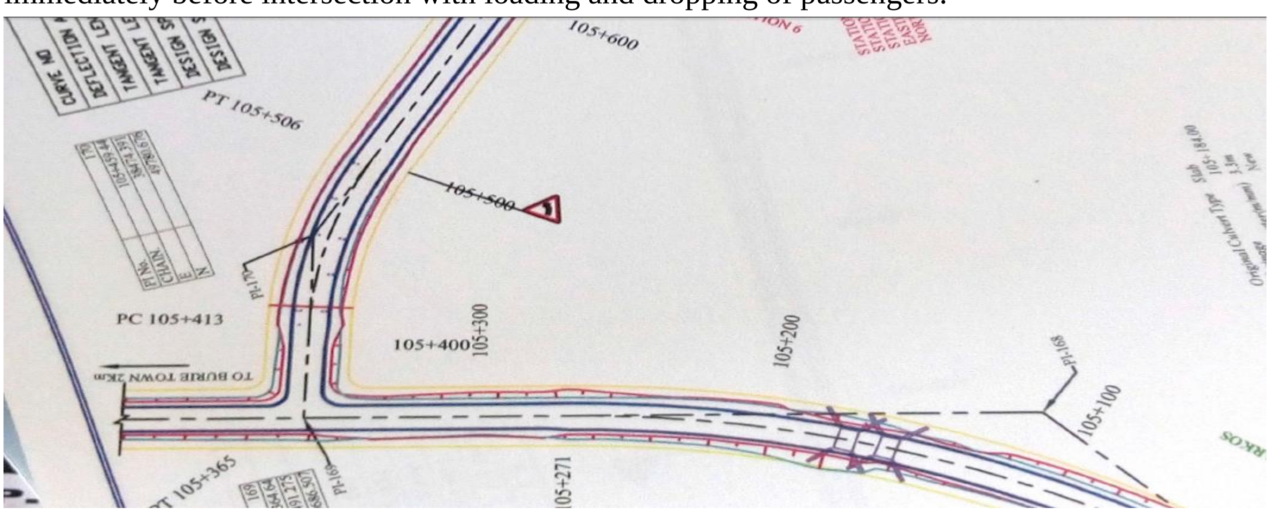

Figure 4. 11 Blackspot section at Wudie Hotel (Entrance of Burie town)

Proposed Remedial Measure: - The following points are proposed in order to improve the problem of the road section.

a. At least two sets of rumble stripes should be provided before intersection from the direction of F/selam and speed breakers should be provided on Bahir dar side from intersection (entrance of Burie town) up to divergence point of Burie-Nekemet road to reduce driving speed of drivers.
b. Reflective rolling barrier objects should be placed on lower side of the intersection (in front of shops) to prevent crash of uncontrolled brake vehicles with shops.
c. By developing green area, avoid siting zone around the area at lower side of the road.
d. Since the intersection is entrance of the town and on vertical grade parking and stopping with in 100meter radius around the intersection should be legally prohibited and police should enforce it.
e. Warning post should be provided in both sides for new road users.

D) Station 80+200-83+500

Description: - This station covers the whole section of Finote selam town with a length of 3.3km. During the study period totally 123 crashes were registered with 39 fatality, 33 serious injury, 20 slight injury and 31 property damage.

Site Observation: - During site observation, width of the road is not proportional to the growth of the town. Narrow lane width with congested traffic (minibuses, bajaji's, pedestrian and other heavy truck trailers) were observed.

Truck trailers and heavy trucks parked on both sides of the road which narrows the movement lane and there is no proper pedestrian walkway is provided for the town. In addition to this bajaji's and bicycle riders drive illegally with high speed and parked anywhere on the road.

On both side of the town (entrance or exit) there are two big rivers called Lah and Arara with narrow lane width and sag vertical curve. Drivers drive with over speed limit at this section and due to these crashes happen repeatedly. At the time of observation, carts cross this bridge to go to market in the town and they have their own influence on crash.

At Lah River Bridge, the provided guard rail is placed in wider space and pedestrians will fall from the bridge to the river at the time of fear of high speed vehicle with sound clash. In addition to this there are animals from town at morning and evening.

Currently alternative bridge on Lah River is constructed but due to poor construction and deterioration of the roadway drivers mostly not used and prefer the oldest bridge. In addition to this during the time of site observation, fixed objects placed to prevent passing of heavy vehicles were crashed by unknown thing.

Proposed Remedial Measure: - The following remedial measures are proposed in order to improve the crash problem of the town.

a. At least three to five sets of rumble stripes should be provided from Damot preparatory school to entrance of Medhanialem church and three speed breakers should be provided near to Arara River to reduce the speed of vehicles.

b. Heavy trucks and truck trailers parked on both side of the main road should be avoided and the town municipality should supply parking stations outside of the main road section.
c. Since the number of pedestrians increased from time to time and the town is capital of West Gojjam zone proper pedestrian facility should be constructed.
d. Alternative road for animals and carts should be supplied and Controlling and enforcement should be done.
e. Even if the drivers prefer the oldest bridge due to poor construction of the latest one, enforcement and controlling to use it is necessary since the new bridge have a smooth turning of entrance which enforce drivers to reduce speed.

E) Station 139+100-141+600

Description: - This station found in Injibara town which starts at 900m from round about and ends after 1.6km from the roundabout of the town with a segment length of 2.5km. During the period of study totally 81 crashes were registered with 35 fatality, 15 serious injury, 7 slight injury and 24 property damage.

Site Observation: - During site observation, narrow lane width with congested traffic (minibuses, bajaji's, and pedestrian) were observed. Since this segment have long vertical grade vehicles from Bahir dar direction moves with high speed, this will cause crash.

Commercial vehicles (minibus) load and unload on the main road which results fatigue and extra number of bajaji's and carts are available. In addition to this the facilities of pedestrian are poor and drivers mostly ignore priorities to pedestrian during crossing of the road including at Zebra.

Proposed Remedial Measure: - The following remedial measures are proposed in order to improve the crash problem of the town.

a. On the right side (assume direction of driving is from Bahir dar to F/selam) providing of reflective rolling guard rails to limit pedestrian movement on the main road should be made.
b. At least three to four sets of rumble stripes should be provided from NOC gas station to roundabout to inform inattentive drivers.
c. Proper pedestrian facilities should be provided like construction of walkway, guardrails.
d. Alternative road for carts should be supplied and controlling and enforcement should be done.
e. Commercial vehicles loading and unloading of passengers should be limited to some specific points and traffic police should be controlled this.

Summary of Blackspot Sections

Generally during field observation of selected blackspot sections the following problems were inspected (see Appendix 2, table 2 for detail observation recorded).

These are;

- ✓ Curve with sight distance problem covered by trees and detour with speedy driving
- ✓ Narrow width of lane and narrow bridge width
- ✓ Difficult horizontal curves with narrow width of lane

- ✓ Poor or no pedestrian facilities at town sections
- ✓ Vertical grades are provide improperly (phasing problem) with horizontal curve
- ✓ Road design problems with respect to standards
- ✓ School, market and animal area with speedy driving
- ✓ Improper road users at town section like cart, bicycle, parking truck trailers on main road
- ✓ Absence of road marks and traffic signs for guiding drivers
- ✓ Deteriorated pavements and sliding of road surface

From field observations, increasing driving speed with the above observed factors are the major cause of crash on the road segment. Therefore due attention to this sections with engineering knowledge will reduce the crash and crash severity.

4.3 Results of Multinomial Logistics Regression Analysis

An important feature of the multinomial logit model is that it estimates k-1 models, where k is the number of levels of the outcome variable. For our case, we have taken each outcome as a reference group turn by turn, and therefore estimated a model for each variable relative to the respective reference group.

Since the parameter estimates are relative to the reference group, the standard interpretation of the multinomial logit is that for a unit change in the predictor variable, the logit of outcome relative to the reference group is expected to change by its respective parameter estimate (which is in log-odds units) given the variables in the model are held constant.

- ➢ Driving with no license was found to be significant in the fatal at 95% confidence level, relative probability of having fatal rather than having Property Damage decreases by 137.5% when driver's with no license increases by 1 unit.
- ➢ Collision type of pedestrian and animal crash was found to be significant in the fatal and serious injury at 5% significant level, relative probability of having fatal rather than having Property Damage increases by 135.6% serious injury by 165.9% when collision type of pedestrian and animal crash increases by 1 unit.
- ➢ Driving experience of 2 to 5 years was found to be significant in the fatal, serious injury and slight injury at 95% confidence level. Relative probability of having fatal rather than having Property Damage decreases by 239.9%, serious injury by 144.9% and slight injury by 84.3% when collision type of pedestrian and animal crash increases by 1 unit.
- ➢ Driver‘s Experience was found to be significant in the **Serious injury** and **Fatal** crash functions at 95% confidence level. Relative probability of having **serious injury** rather than having **PDO** decreases by 4.2% **Fatal** by 3.1% when driver‘s experience increases by one unit.

Table 4. 6 Regression Analysis output

Parameter Estimates

Crash Severity[a]		B	Std. Error	Wald	Df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
Fatal	Intercept	4.815	.903	28.456	1	.000			
	[DriversAge=1.00]	-1.248	.892	1.956	1	.162	.287	.050	1.650
	[DriversAge=2.00]	-1.956	.275	50.742	1	.000	.141	.083	.242
	[DriversAge=3.00]	-2.356	.292	65.026	1	.000	.095	.053	.168
	[DriversAge=4.00]	-2.678	.451	35.215	1	.000	.069	.028	.166
	[DriversAge=5.00]	0[b]			0				
	[DrivingExperience=1.00]	-1.375	.509	7.309	1	.007	.253	.093	.685
	[DrivingExperience=2.00]	-2.269	.346	42.878	1	.000	.103	.052	.204
	[DrivingExperience=3.00]	-1.933	.303	40.673	1	.000	.145	.080	.262
	[DrivingExperience=4.00]	-2.399	.284	71.204	1	.000	.091	.052	.158
	[DrivingExperience=5.00]	-1.839	.307	35.937	1	.000	.159	.087	.290
	[DrivingExperience=6.00]	-1.697	.347	23.868	1	.000	.183	.093	.362
	[DrivingExperience=7.00]	0[b]			0				
	[VehicleType=1.00]	.425	1.219	.121	1	.728	1.529	.140	16.687
	[VehicleType=2.00]	-1.457	.372	17.379	1	.000	.319	.018	.518
	[VehicleType=3.00]	-2.520	.548	21.136	1	.000	.080	.027	.236
	[VehicleType=4.00]	-1.593	.424	14.109	1	.000	.203	.089	.467
	[VehicleType=5.00]	-2.963	.432	47.084	1	.000	.052	.022	.120
	[VehicleType=6.00]	-4.104	1.163	12.463	1	.000	.016	.002	.161
	[VehicleType=7.00]	0[b]			0				
	[CollisionType=1.00]	-.492	.509	.935	1	.334	.611	.225	1.658
	[CollisionType=2.00]	.137	.510	.072	1	.788	1.147	.422	3.113
	[CollisionType=3.00]	1.356	.507	7.146	1	.008	3.882	1.436	10.494
	[CollisionType=4.00]	-1.979	.670	8.738	1	.003	.138	.037	.513
	[CollisionType=5.00]	.310	.701	.195	1	.658	1.363	.345	5.390
	[CollisionType=6.00]	0[b]			0				
	[LandUse=1.00]	.381	.330	1.333	1	.248	1.464	.767	2.796
	[LandUse=2.00]	-.628	.367	2.925	1	.087	.534	.260	1.096
	[LandUse=3.00]	.154	.556	.076	1	.782	1.166	.392	3.465
	[LandUse=4.00]	.531	.367	2.095	1	.148	1.700	.829	3.487
	[LandUse=5.00]	.444	.502	.783	1	.376	1.558	.583	4.165
	[LandUse=6.00]	-.035	.614	.003	1	.954	.965	.290	3.216
	[LandUse=7.00]	.070	.476	.021	1	.884	1.072	.422	2.725
	[LandUse=8.00]	0[b]			0				
	[RWAlignment=1.00]	.328	.447	.538	1	.463	1.388	.578	3.332
	[RWAlignment=2.00]	.352	.488	.520	1	.471	1.421	.546	3.698
	[RWAlignment=3.00]	-.261	.526	.246	1	.620	.770	.274	2.161

	[RWAlignment=4.00]	.573	1.007	.323	1	.570	1.773	.246	12.759
	[RWAlignment=5.00]	.330	.491	.451	1	.502	1.391	.531	3.644
	[RWAlignment=6.00]	0b			0				
	[IntersectionType=1.00]	.159	.324	.240	1	.624	1.172	.621	2.213
	[IntersectionType=2.00]	.934	.474	3.882	1	.049	2.544	1.005	6.439
	[IntersectionType=3.00]	-1.496	.868	2.968	1	.085	.224	.041	1.229
	[IntersectionType=4.00]	.647	.822	.619	1	.431	1.910	.381	9.571
	[IntersectionType=5.00]	0b			0				
	[CausesofCrash=1.00]	.137	.197	.485	1	.486	1.147	.780	1.686
	[CausesofCrash=2.00]	.743	.503	4.193	1	.029	3.728	.805	8.194
	[CausesofCrash=3.00]	-.502	.338	2.208	1	.137	.605	.312	1.174
	[CausesofCrash=4.00]	-2.868	1.242	5.332	1	.021	.057	.005	.648
	[CausesofCrash=5.00]	0b			0				
Serious Injury	Intercept	2.846	1.065	7.148	1	.008			
	[DriversAge=1.00]	-.414	.926	.200	1	.655	.661	.108	4.061
	[DriversAge=2.00]	-1.243	.313	15.802	1	.000	.289	.156	.533
	[DriversAge=3.00]	-1.946	.340	32.799	1	.000	.143	.073	.278
	[DriversAge=4.00]	-1.786	.521	11.760	1	.001	.168	.060	.465
	[DriversAge=5.00]	0b			0				
	[DrivingExperience=1.00]	-.157	.537	.085	1	.771	.855	.298	2.450
	[DrivingExperience=2.00]	-1.172	.401	8.527	1	.003	.310	.141	.680
	[DrivingExperience=3.00]	-.758	.346	4.790	1	.029	.469	.238	.924
	[DrivingExperience=4.00]	-1.449	.329	19.345	1	.000	.235	.123	.448
	[DrivingExperience=5.00]	-.917	.357	6.602	1	.010	.400	.199	.805
	[DrivingExperience=6.00]	-1.328	.429	9.566	1	.002	.265	.114	.615
	[DrivingExperience=7.00]	0b			0				
	[VehicleType=1.00]	1.322	1.275	1.075	1	.300	3.752	.308	45.687
	[VehicleType=2.00]	1.861	2.372	1.319	1	.995	9.518	.710	13.523
	[VehicleType=3.00]	-.951	.614	2.394	1	.122	.387	.116	1.288
	[VehicleType=4.00]	-.690	.510	1.828	1	.176	.502	.185	1.364
	[VehicleType=5.00]	-2.242	.521	18.524	1	.000	.106	.038	.295
	[VehicleType=6.00]	-2.025	.906	4.996	1	.025	.132	.022	.779
	[VehicleType=7.00]	0b			0				
	[CollisionType=1.00]	-.348	.606	.331	1	.565	.706	.215	2.314
	[CollisionType=2.00]	.050	.608	.007	1	.934	1.051	.319	3.462
	[CollisionType=3.00]	1.659	.601	7.624	1	.006	5.255	1.618	17.064
	[CollisionType=4.00]	-1.281	.756	2.874	1	.090	.278	.063	1.221
	[CollisionType=5.00]	.586	.804	.531	1	.466	1.797	.371	8.691
	[CollisionType=6.00]	0b			0				
	[LandUse=1.00]	-.619	.349	3.141	1	.076	.539	.272	1.068
	[LandUse=2.00]	-.926	.392	5.593	1	.018	.396	.184	.853
	[LandUse=3.00]	-.714	.631	1.281	1	.258	.490	.142	1.686
	[LandUse=4.00]	-.238	.392	.368	1	.544	.789	.366	1.699
	[LandUse=5.00]	.010	.541	.000	1	.985	1.010	.350	2.914
	[LandUse=6.00]	.216	.609	.126	1	.723	1.241	.376	4.090

	[LandUse=7.00]	.445	.475	.879	1	.349	1.561	.615	3.958
	[LandUse=8.00]	0b			0				
	[RWAlignment=1.00]	.297	.536	.307	1	.579	1.346	.470	3.852
	[RWAlignment=2.00]	.082	.587	.019	1	.889	1.085	.343	3.433
	[RWAlignment=3.00]	-.695	.652	1.134	1	.287	.499	.139	1.793
	[RWAlignment=4.00]	.990	1.076	.847	1	.357	2.690	.327	22.145
	[RWAlignment=5.00]	.376	.583	.416	1	.519	1.456	.465	4.563
	[RWAlignment=6.00]	0b			0				
	[IntersectionType=1.00]	-.242	.356	.464	1	.496	.785	.391	1.576
	[IntersectionType=2.00]	1.181	.498	5.635	1	.018	3.259	1.229	8.644
	[IntersectionType=3.00]	-.137	.753	.033	1	.855	.872	.199	3.812
	[IntersectionType=4.00]	-.242	1.024	.056	1	.813	.785	.105	5.843
	[IntersectionType=5.00]	0b			0				
	[CausesofCrash=1.00]	.049	.228	.046	1	.830	1.050	.672	1.641
	[CausesofCrash=2.00]	1.286	.703	6.719	1	.095	4.961	2.141	10.216
	[CausesofCrash=3.00]	-.949	.445	4.552	1	.033	.387	.162	.926
	[CausesofCrash=4.00]	-.201	.819	2.836	1	.198	.686	.309	.982
	[CausesofCrash=5.00]	0b			0				
Slight Injury	Intercept	.133	1.346	.010	1	.021			
	[DriversAge=1.00]	-1.580	.093	3.045	1	.152	.841	.610	3.419
	[DriversAge=2.00]	-.901	.373	5.843	1	.016	.406	.196	.843
	[DriversAge=3.00]	-1.149	.395	8.464	1	.004	.317	.146	.687
	[DriversAge=4.00]	-.872	.565	2.380	1	.123	.418	.138	1.266
	[DriversAge=5.00]	0b			0				
	[DrivingExperience=1.00]	-.475	.688	.477	1	.490	.622	.161	2.397
	[DrivingExperience=2.00]	-.554	.470	1.389	1	.239	.575	.229	1.444
	[DrivingExperience=3.00]	-.175	.418	.176	1	.675	.839	.370	1.903
	[DrivingExperience=4.00]	-.843	.400	4.446	1	.035	.430	.197	.942
	[DrivingExperience=5.00]	-.565	.433	1.698	1	.193	.568	.243	1.329
	[DrivingExperience=6.00]	-1.759	.617	8.141	1	.004	.172	.051	.577
	[DrivingExperience=7.00]	0b			0				
	[VehicleType=1.00]	1.996	1.363	2.145	1	.143	7.361	.509	10.640
	[VehicleType=2.00]	1.733	.372	1.973	1	.105	5.921	.390	12.692
	[VehicleType=3.00]	.146	.738	.039	1	.843	1.157	.273	4.912
	[VehicleType=4.00]	.134	.645	.043	1	.835	1.144	.323	4.048
	[VehicleType=5.00]	-1.619	.660	6.025	1	.014	.198	.054	.722
	[VehicleType=6.00]	-.415	.652	.392	1	.098	.547	.201	1.031
	[VehicleType=7.00]	0b			0				
	[CollisionType=1.00]	-1.467	.617	5.657	1	.017	.231	.069	.772
	[CollisionType=2.00]	-.888	.614	2.091	1	.148	.411	.123	1.371
	[CollisionType=3.00]	.761	.604	1.587	1	.208	2.141	.655	7.002
	[CollisionType=4.00]	-2.153	.795	7.330	1	.007	.116	.024	.552
	[CollisionType=5.00]	-.167	.825	.041	1	.840	.846	.168	4.266
	[CollisionType=6.00]	0b			0				
	[LandUse=1.00]	.278	.497	.313	1	.576	1.321	.499	3.495

	[LandUse=2.00]	.264	.529	.250	1	.617	1.303	.462	3.675
	[LandUse=3.00]	-.127	.834	.023	1	.879	.881	.172	4.518
	[LandUse=4.00]	.014	.548	.001	1	.980	1.014	.347	2.967
	[LandUse=5.00]	.608	.704	.747	1	.388	1.837	.462	7.303
	[LandUse=6.00]	.462	.853	.294	1	.588	1.588	.298	8.448
	[LandUse=7.00]	.683	.656	1.082	1	.298	1.979	.547	7.161
	[LandUse=8.00]	0[b]			0				
	[RWAlignment=1.00]	1.093	.789	1.922	1	.166	2.984	.636	13.997
	[RWAlignment=2.00]	.673	.843	.638	1	.424	1.960	.376	10.220
	[RWAlignment=3.00]	-.112	.913	.015	1	.902	.894	.149	5.348
	[RWAlignment=4.00]	-1.080	.583	3.803	1	.019	.154	.012	1.031
	[RWAlignment=5.00]	.112	.866	.017	1	.897	1.118	.205	6.110
	[RWAlignment=6.00]	0[b]			0				
	[IntersectionType=1.00]	-.226	.400	.319	1	.572	.798	.364	1.747
	[IntersectionType=2.00]	-.048	.632	.006	1	.939	.953	.276	3.290
	[IntersectionType=3.00]	-.281	.961	.085	1	.770	.755	.115	4.967
	[IntersectionType=4.00]	.838	.883	.902	1	.342	2.312	.410	13.041
	[IntersectionType=5.00]	0[b]			0				
	[CausesofCrash=1.00]	.361	.277	1.696	1	.193	1.434	.834	2.468
	[CausesofCrash=2.00]	.078	.731	.010	1	.046	1.081	.308	4.138
	[CausesofCrash=3.00]	.056	.447	.016	1	.901	1.057	.441	2.538
	[CausesofCrash=4.00]	-1.075	.371	1.061	1	.419	.638	.169	5.931
	[CausesofCrash=5.00]	0[b]			0				

a. The reference category is: Property Damage.

b. This parameter is set to zero because it is redundant.

4.4 The Major Causes of Crashes on the Road Segment

Road traffic crash is a result of different types of internal and external factors. Internal factors include technical faults of vehicles and drivers while external factors include road condition and road users. According to the data recorded by traffic police, there are four major causes of traffic crash on the study area. These are driver's error with a contribution factor of 78.7%, defects of vehicle (5.8%), pedestrian error (1.1%), road defect (0.5%) and others with a contributing percentage of 13.9.Under these major causes there are different types of characteristics that leads the vehicle for crash.

But when we analyze the total data recorded by the police the causes for crash is not limited to the above listed types and there is an inter relationship between other causes. For example, as we discuss on part 4.2 about blackspot locations on the study segment contribution of road geometrical elements should be considered and needs detail investigation.

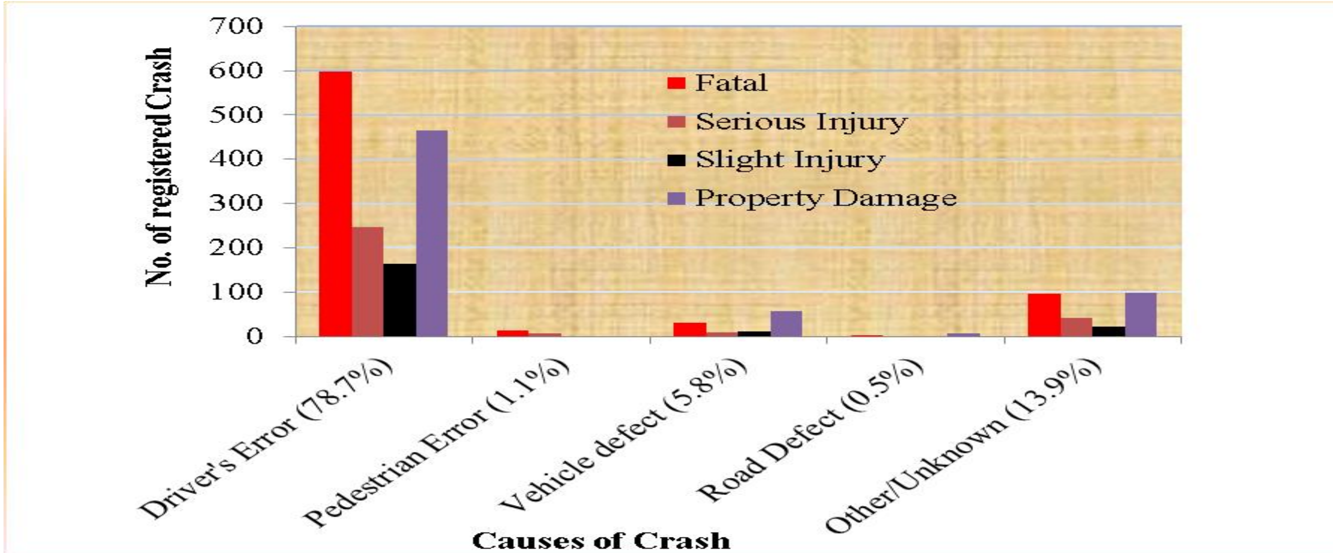

Figure 4. 12 Major causes of crash

While looking at the number of fatal per crash, majority of them were emanated from pedestrian error. The result of the analysis clearly identified that among the listed major causes of crash pedestrian error constitutes highest mean 0.619 followed by unethical driving with a mean of 0.406. This showed that outcome of pedestrian error is death or injury but in case of other defects like unethical driving, vehicle defect or road defect the crashing condition will had a probability of property damage.

Similarly, as shown on table 4.7 the rate of injury per crash due to pedestrian error is the highest of all the causes of crash with a mean of 0.381 followed by driver's problem with a mean of 0.280.

Table 4.7 Causes of traffic crashes and their level of severity

Causes of Crash	Fatal	No. of Injuries	Total No. of Crash	Mean of Fatal per Crash	Mean of Injuries per Crash
Driver's Error	598	412	1474	0.406	0.280
Pedestrian Error	13	8	21	0.619	0.381
Vehicle Defect	32	20	109	0.294	0.183
Road Defect	1	0	9	0.111	0.000
Other/Unknown	97	64	260	0.373	0.246
Total	741	504	1873		
Average	148.2	100.8	374.6		

On the other hand, under driver's error category of causes of crash there are twenty types of causes of traffic crash reported by police as shown on figure 4.16. In terms of driver's misbehavior, driving above speed limit is the major cause of fatal with an amount of 246 death followed by violation of priority to pedestrian rule with 221 people died during the study period.

As shown on figure 4.16, driving above speed limit contributed 47.4 percent crash with respect to other misbehaviors of driver's and the second and third cause of crashes were prohibiting pedestrian priority (22.2%) and ride with leaving right (6.7%) respectively.

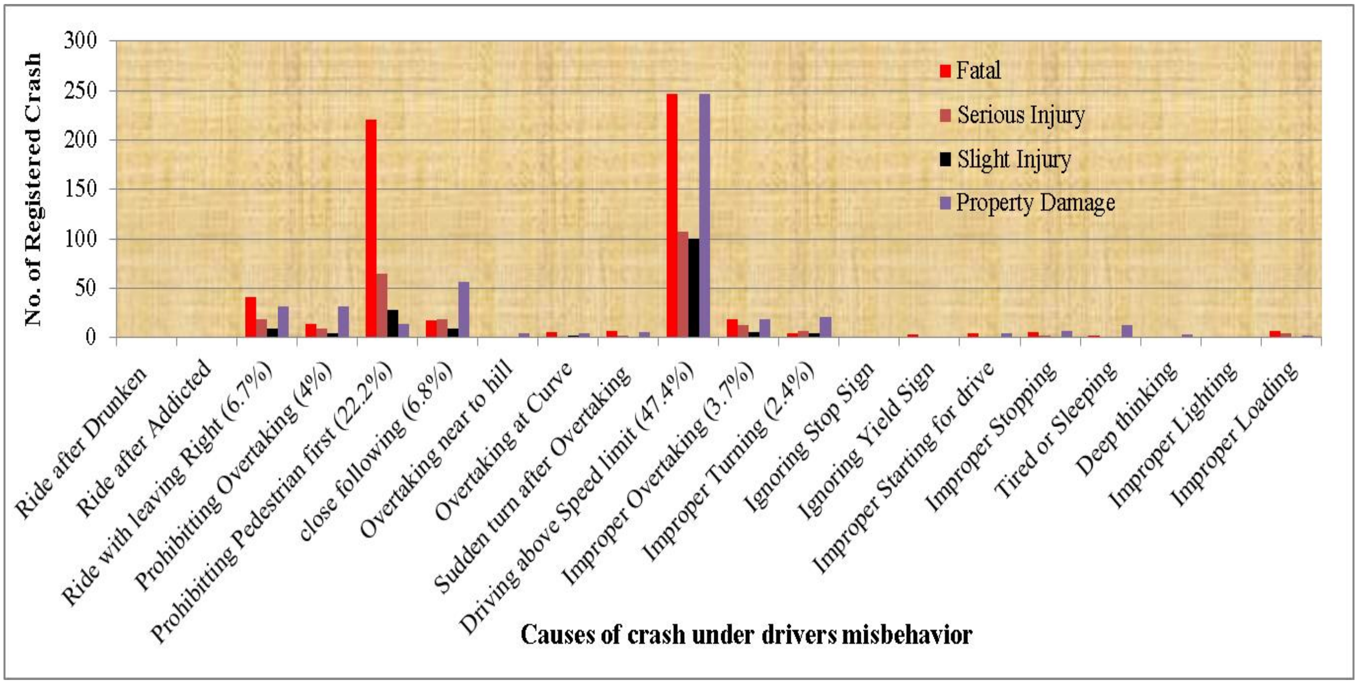

Figure 4. 13 Causes of crash under driver's misbehavior

Generally, based on site investigation held on the study of blackspot sections and available data collected causes of crashes are interrelated to each other. This means that one deficiency for crash has effect on another factor and crashes are the outcome of summation of different factors. For example sight distance problem on a curved section is more exposed for happening of crash with driving in high speed.

Therefore, the major causes of crashes are;

- ✓ Driver's misbehavior including speed limit violation, prohibiting pedestrian priority, ignoring priority to others during entering, exiting, turning or overtaking, drive with leaving right and other related factors which can be controlled by driver's.
- ✓ Vehicles defect like failure of brake or guider, tyre problem and poor conditions.
- ✓ Improper geometric design of roads at horizontal and vertical curves.

- ✓ Pavement failure and deterioration of the road (road defects) due to different reasons like near to end of service life, land slide condition and lack of maintenance.
- ✓ Narrowing of lane width at curves and town sections with increasing traffic volume at towns due to need of service like the number of Bajaj's increased.
- ✓ Pedestrians improper use of roads and poor or no pedestrian facilities like pedestrian walkway, guardrail.
- ✓ Lack of proper road marks, traffic signs and guide posts at blackspot sites and any other appropriate sections.
- ✓ Site distance problems which is covered by small and big trees.

4.5 The Remedial Measures Based on the Major Causes of Crashes

Based on the major causes of traffic crash pointed out above, the following remedial measures should be taken to reduce the crash on the study area.

1. As a result it is recommendable that the movements of vehicles at this specific location must be below specified speed limit and sign of speed limit must be post at particular location, and regular follow up should be done for obeying speed limit. Drivers should be responsible for their activity and regular campaign and clarification should be given from pertinent transport authority and traffic police. In addition to this, drivers should be drive with keeping of their right as much as possible with reducing their speed.
2. Vehicles performance should be checked regularly and this activity should be followed by government office with strong commitment.
3. Road sections that need realignment like sections at station 58+800-60+800 (locally called Denbel), Wude Hotel (entrance to Burie town), station 107+500-111+500 (locally called Wundigi Mariam), station 176+700-184+700 (locally called Ziguda), and station 191+700-194+700 (locally called Islam Mekabir) should be realigned or proper alignment modification should be made by Ethiopian Roads Authority but up to realignment immediate remedial measures should be done. These remedies include guide posts, speed limit posts and speed breakers because all of them are located next to long vertical grade. Speed breakers before curves are helps to drivers for lowering speed and can pass that section with reduced speed.
4. Improvement of the width of the roadway lane width at major town sections in the study area like Finoteselam, Kosober and Merawi should be done and heavy trucks parked on the

main road should be avoided by preparing another parking area available with waiting time.

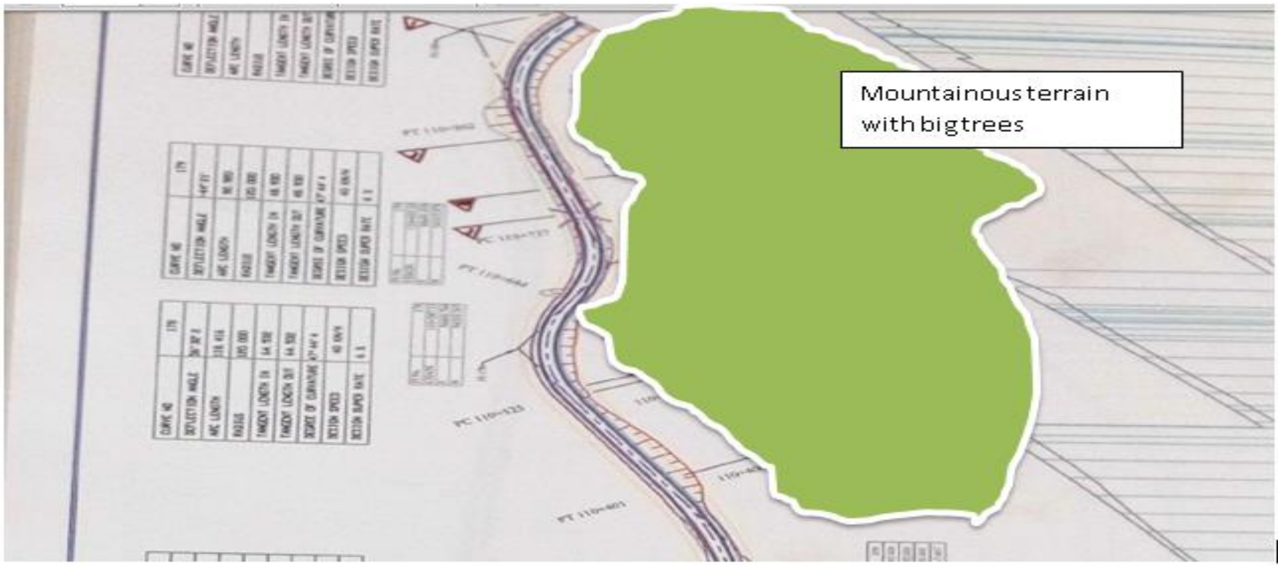

Figure 4. 14 Blackspot section at Wundigi Mariam (107+500-111+500) condition diagram

5. In addition to lane width improvement on town sections facilities of pedestrian like walkway lane, guardrails should be made on necessary places.
6. Periodic maintenance of the pavement like patching, overlay and rehabilitation along the whole section of the study area should be done with clearance of site distance problems covered by trees and detour. In parallel to this, road marks and traffic signs like speed limit post, guide and informatory signs should be made as available on the whole section.

Generally by making the above remedial measures on the study section we can reduce the number of traffic crash and effectiveness of the remedial measures should be evaluated after some time.

5. Conclusions and Recommendations

5.1 Conclusions

In general, the situation of roads traffic crash at the national level is getting worse every day and it is usual news every day. Even though the country has small vehicle ownership, the crash record is one of the highest relative to other developing countries. Therefore, the objective of the study was identifying blackspot sections and investigating the major causes of road traffic crashes with engineering remedial measures.

In this research, adequate traffic crash data with as built geometric design and traffic count data were collected and field observation was made to achieve the stated objectives.

From the descriptive statistics of the collected data and by dividing the study road segments into 40 segments, out of which 16 segments were satisfied the developed criteria and categorized under blackspots. Therefore, from the collected data the major causes of crashes were categorizing under driver's misbehavior (violation of speed limit, failure to give way for vehicles and pedestrians, overtaking in winding horizontal curves, following too close, improper turning), pedestrian error, road pavement failure and defects on vehicle condition. In addition to this, from field observation there are contributory factors for crash like narrow lane width with curves, problems related to site distance, deteriorated and sliding pavements, poor or no pedestrian facilities, poor geometric design problems and absence of sufficient road traffic signs and marks.

Statistical analysis using Multinomial Logistic Regression model were developed to analyze the significance of driver‘s age, driving experience, vehicle type, land use characteristics, collision type and roadway alignment features. The model gives the effects of each independent variable of the crashes and a comparison of attributes of crashes with severity of fatal, serious injury and slight injury relative to property damage only.

With this regard, the results of Multinomial Logistics Regression analysis indicates that, there were many variables which have a significant effect on fatal crash severity; such as, driver's age between 18-30 years, driving experience of below 1 year, collision type of pedestrian crash and others. On the other hand, driver's age below 18 years, bicycle vehicle type, rollover collision type, out of rural village land use and others have insignificant effect on fatal crash type.

In addition to this, results of the model indicates that, driver age of 51 and above, driving experience of 2 to 5 years, truck vehicles, collision type of pedestrian and animal crash, out of rural village land use characteristics and other variables have significant effect on serious injury over property damage only.

On the other hand, as per outputs of the analysis some variables like driver's age of 31-50, pedestrian error, straight and vertical grade roadway alignment and others have a significant effect on slight injury over property damage only.

5.2 Recommendations

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

- ✓ On blackspot sections after vertical grade, speed breakers or rumble strips should be assembled and strict traffic police enforcement and speed control
- ✓ Prohibition of on road side parking of heavy trucks in town section especially at Finote selam, Injibara and Merawi
- ✓ Furnish appropriate traffic sign and marking
- ✓ Road user information and campaign
- ✓ Providing pedestrian facilities like walkway and guardrail at necessary town sections like Finote selam, Burie, Injibara and Merawi
- ✓ Improving pavement conditions of the road by periodic maintenance with clearing site distance obstacles
- ✓ Revised the current design of the road based on current condition and realign critical sections such as Burie town entrance, Wundigi Mariam and others.

6. References

Austrode, 2000. Relationship Between Crash Risk and Geometric Characteristics of Rural Highways, First Published.

Azad Abdulhafedh, 2017. Road Crash Prediction Models: Different Statistical Modeling Approaches, USA: University of Missouri-Columbia.

Berhanu G., 2000. Effects of Road and Traffic Factors on Road Safety in Ethiopia, Norway: Trondheim,

Bhat and et. al, 2013. Accident Prediction Modelling for an Urban Road of Bangalore. International Journal of Research in Engineering and Technology, Volume 137.

Blackspot Manual, 2001. Road Improvement and Traffic Safety Project, Ankara: General Directorate of Highways.

Cheng Zhong, 2011. Crash Prediction on Rural Roads, Birmingham AL, USA: University of Alabama at Birmingham.

David Kaneswaran, 2014. Assessment of the Effects of Road Geometry on Irish Accident Rates and Driving Behaviour. Maynooth: Department of Computer Science Faculty of Science and Engineering National University of Ireland.

Elvik, R., 2008. The predictive validity of empirical Bayes estimates of road safety. Crash Analysis & Prevention, Volume 40.

ERA Manual, 2013. Geometric Design Manual. Addis Ababa: Ethiopian Roads Authority.

Ezra Hauer, 1996. Identification of Sites with Promise. Toronto: University of Toronto,

Getu Segni, 2007. MSc Thesis on Causes of Road Traffic Crash and Possible Counter Measures, Addis Ababa: Addis Ababa University.

J. C. Glennon, T. R. Neuman, and J.E. Leisch, 1983. Safety and Operational Considerations for Design of Rural Highway Curves. U.S.A: FHWA,

Jose Luiz Fuzaro Roadrigues, Implementing Road Safety Audits in Brazil,Brazil: Highway Department of Sao Paulo.

K.Geurts, G. Wets, Koen Vanhoof, 2003. Blackspot Analysis Methods, Literature Review, Belgium.

Kamal et. al., 2008. Accidents blackspot s on highways and their low cost remedial measures, Pakistan: University of Engineering and Technology.

Sandra Vieira Gomes. Low-Cost Engineering Measures for Casualty Reduction, Application on the National Road Network, Volume 32.

Sonowal, A. G., 2009. A Statistical Analysis of Road Traffic Accidents. India: Assam, Dibrugarh City,

Sweedler BM., 1995. The worldwide decline in drinking and driving. Adelaide: Proceedings of the 13th International Conference on Alcohol, Drugs and Traffic Safety.

Teyba W., Emer T. Q., and Murad M., 2017. Analysis of Road Traffic Crash Related of Geometric Design Parameters in Alamata-Mehoni- Hewane Section,

Transport Research Board, 1987. Designing Safer Roads, Special Report 214, Washington, D.C.: National Research Council,

TRL & Ross Silcock, 2001. Study for Sectoral Road Safety Program in Ethiopia, Addis Ababa: Transport Research Laboratory, Volume II.

Wen Cheng, Simon P. Washington, 2005. Experimental Evaluation of Blackspot Identification Methods. Crash Analysis & Prevention.

WHO, 2018. Global Status Report on Road Safety. Geneva: World Health Organization.

Appendix

Appendix 1 Road Traffic Crash Data

Table 1. Crash distribution with happening hour

S.No.	Hour	No. of Crash	S.No.	Hour	No. of Crash	S.No.	Hour	No. of Crash
1	0100-0200	58	9	0900-1000	120	17	1700-1800	101
2	0200-0300	59	10	1000-1100	139	18	1800-1900	55
3	0300-0400	62	11	1100-1200	146	19	1900-2000	50
4	0400-0500	70	12	1200-1300	111	20	2000-2100	27
5	0500-0600	70	13	1300-1400	90	21	2100-2200	22
6	0600-0700	90	14	1400-1500	109	22	2200-2300	23
7	0700-0800	134	15	1500-1600	125	23	2300-0000	17
8	0800-0900	80	16	1600-1700	103	24	0000-0100	13
Total		622			943		0	1873

Table 2. Crash distribution with gender of drivers

Gender	Crash Severity				Total
	Fatal	Serious Injury	Slight Injury	Property Damage	
Male	655	289	190	621	1755
Female	3	3	1	0	7
Not Identified	83	15	6	7	111
Total	741	307	197	628	1873

Table 3. Crash distribution with drivers age

S.No.	Age Range	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	Below 18	5	4	0	3	12
2	18-30	329	181	117	385	1012
3	31-50	129	59	53	186	427
4	51 and Above	17	9	8	27	61
5	Unknown	261	54	19	27	361
Total		741	307	197	628	1873

Table 4. Crash distribution with drivers educational background						
S.No.	Background	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	Illiterate	4	0	0	5	9
2	Basic Education	8	3	1	8	20
3	Primary School	57	30	18	51	156
4	Secondary School	169	79	75	206	529
5	Preparatory	179	115	77	258	629
6	Above Preparatory	55	32	10	73	170
7	Unknown	269	48	16	27	360
Total		741	307	197	628	1873

Table 5. Crash distribution with driving experience of drivers						
S.No.	Year of Experience	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	No License	17	15	5	12	49
2	Below 1yrs	56	25	19	61	161
3	1 to 2 yrs	87	63	50	120	320
4	2 to 5 yrs	150	81	68	232	531
5	5 to 10 yrs	103	53	34	121	311
6	Above 10yrs	54	18	5	55	132
7	Unknown	274	52	16	27	369
Total		741	307	197	628	1873

Table 6. Crash distribution with Service Life of Vehicles						
S.No.	Service Life	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	Below 1yr	48	28	16	46	138
2	1 to 2	69	36	20	88	213
3	2 to 5	216	93	55	216	580
4	5 to 10	167	84	72	196	519
5	Above 10yrs	67	18	19	52	156
6	Unknown	174	48	15	30	267
Total		741	307	197	628	1873

Table 7. Crash distribution with Vehicle Type

S.No.	Crash Severity	Bicycle	Motor Bicycle	Automobile	Staion Wagon	Pickup ≤10qtl	Truck (11 - 40) Qtl	Truck (41 - 100) Qtl	Truck With Trailer	Liqiud Truck	Minibus Up to 12 seats	Midi bus 13-45 Seats	Large Bus ≥ 46 Seats	Special Vehicle	Cart	Not Identified	Total
1	Fatal	9	12	5	11	58	47	171	37	7	145	174	26	3	1	35	741
2	Serious Injury	5	10	9	8	32	20	32	6	3	86	76	7		3	10	307
3	Slight Injury	3	7	4	10	20	8	12	3	2	72	49	3	2		2	197
4	Property Damage	0	0	12	16	65	80	164	26	3	110	107	21	4	15	5	628
	Total	17	29	30	45	175	155	379	72	15	413	406	57	9	19	52	1873

Table 8. Crash distribution with Defects of Vehicle

S. No.	Failure Type	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	Brake Failure	18	5	9	28	60
2	Guider Failure	4	2	1	6	13
3	Tyre Problem	12	3	2	7	24
4	Light Problem	1	0	0	0	1
5	Other Mechanical Failure	23	14	9	44	90
6	No Failure	456	215	146	454	1271
7	Unknown	227	68	30	89	414
Total		741	307	197	628	1873

Table 8. Crash distribution with Land Use or Specific Location

S. No.	Land Use	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	In Rural Village	368	143	115	342	968
2	Out of Rural Village	101	41	33	108	283
3	Around School	22	6	3	13	44
4	Around Factory	2	0	0	1	3
5	Around Religious area	23	4	1	6	34
6	Near to Market	4	3	3	7	17
7	Recreational Area	14	10	3	11	38
8	Around Hospital	6	5	2	6	19
9	Around Office	21	23	8	23	75
10	Residential Area	135	49	23	75	282
11	Not Identified/Others	45	23	6	36	110
Total		741	307	197	628	1873

Table 9. Crash Distribution with Characteristics of Roadway Alignment

S. No.	Roadway Alignment	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	Straight and Level	491	220	164	450	1325
2	Straight and Slightly Slopping	95	25	13	52	185
3	Straight and Highly Slopping	3	3	2	7	15
4	Straight and Vertical Grade	6	4	0	3	13
5	Slight Curve	35	9	3	31	78
6	Tangent and Curve	13	2	3	9	27
7	Uphill Road	28	11	5	18	62
8	Escarp or downhill road	54	27	5	37	123
9	Not Identified/Others	16	6	2	21	45
Total		741	307	197	628	1873

Table 10. Crash Distribution with Intersection /Junction of the Road

S.No.	Junction Type	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	No Any Junction	647	249	173	568	1637
2	Y-Shape	31	27	3	8	69
3	T-Shape	14	6	4	7	31
4	Round About	3	5	2	9	19
5	(+) Shape	8	2	3	5	18
6	X-Shape	0	0	1	0	1
7	Rail Crossing	0	0	0	0	0
8	Not Identified/Others	38	18	12	30	98
Total		741	307	198	627	1873

Table 11. Crash Distribution with Light Condition during Crash time

S.No.	Light Condition	Crash Severity				
		Fatal	Serious Injury	Slight Injury	Property Damage	Total
1	Day light	605	266	174	515	1560
2	Sunset	41	5	2	24	72
3	During Sunrises	17	8	12	25	62
4	Night time with good road light	19	9	4	18	50
5	Night time with poor road light	7	7	2	13	29
6	Night time with no road light	45	12	2	32	91
7	Others	7	0	1	1	9
Total		741	307	197	628	1873

Table 12. Crash Distribution with Air (Environmental) Condition during Crash

S.No.	Air Condition	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	Good Air	682	289	184	556	1711
2	Haze	4	1	1	7	13
3	Cloud	5	4	1	8	18
4	Drizzle/Light Rain	7	2	2	9	20
5	Heavy Rain	8	2	0	8	18
6	Heavy Wind	0	0	0	0	0
7	Dust	0	0	0	3	3
8	Hot Air	13	3	6	10	32
9	Cold Air	13	5	2	21	41
10	Others	9	1	1	6	17
Total		741	307	197	628	1873

Table 13. Crash Distribution with Movement of the Vehicle

S.No.	Vehicles Movement	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	Entering to main Road	4	2	4	3	13
2	Depart from main road	1	1	0	6	8
3	Turn to Right	5	3	1	9	18
4	Turn to Left	12	9	2	20	43
5	U-Turn	2	0	0	3	5
6	Takeover	7	5	4	10	26
7	Properly (straight) driving	674	275	181	554	1684
8	Exit from village /Compound	3	1	0	2	6
9	Back/Reverse driving	0	1	1	9	11
10	Entering to intersection	1	0	0	2	3
11	During Stopping	8	1	2	2	13
12	Others	10	7	2	3	22
13	Unknown	14	2	0	5	21
Total		741	307	197	628	1873

Table 14. Crash Distribution with Collision Type

S.No.	Collision Type	Crash Severity				Total
		Fatal	Serious Injury	Slight Injury	Property Damage	
1	Head-on	75	33	14	75	197
2	Rear-end	25	10	11	88	134
3	Side-impact	25	13	6	55	99
4	Sideswipe	3	7	4	35	49
5	Vehicle Rollover	159	61	40	160	420
6	Pedestrian crash	420	165	94	33	712
7	Animal Crash	2	0	13	82	97
8	Fall from Vehicle	10	6	5	11	32
9	Crash with Parked vehicle	2	2	0	31	35
10	Fixed Object Collision	4	4	4	48	60
11	Others	12	4	4	7	27
12	Unknown	4	2	2	3	11
Total		741	307	197	628	1873

Table 15. Crash Distribution with Types of Victims

S. No.	Victims	Age (Year)	Fatality		Serious Injury		Slight Injury		Total
			Male	Female	Male	Female	Male	Female	
1	Drivers	Below 18	2	0	2	0	0	1	5
		18-30	65	0	37	0	21	1	124
		31-50	23	0	10	0	1	0	34
		51 and Above	5	1	1	0	2	0	9
Subtotal			**95**	**1**	**50**	**0**	**24**	**2**	**172**
2	Pedestrians	Below 7	22	9	6	7	1	3	48
		7--13	44	21	11	11	7	4	98
		14-17	16	7	12	9	16	6	66
		18-30	132	42	69	19	44	12	318
		31-50	127	46	35	11	20	18	257
		51 and Above	39	14	9	6	9	3	80
Subtotal			**380**	**139**	**142**	**63**	**97**	**46**	**867**
3	Passengers	Below 7	0	5	5	4	1	3	18
		7--13	4	6	12	1	12	8	43
		14-17	21	10	19	12	29	18	109
		18-30	157	59	265	95	366	124	1066
		31-50	87	24	115	52	241	52	571
		51 and Above	15	7	22	9	29	13	95
Subtotal			**284**	**111**	**438**	**173**	**678**	**218**	**1902**
Grand Total			**759**	**251**	**630**	**236**	**799**	**266**	**2941**

Table 16. Crash Distribution with Reasons for Crash						
S. No.	Reasons for Crash	Crash Severity				
		Fatal	Serious Injury	Slight Injury	Property Damage	Total
1	Ride after Drunken	1	1	0	1	3
2	Ride after Addicted	0	0	1	0	1
3	Ride with leaving Right	41	18	9	31	99
4	Prohibitting Overtaking	14	9	4	32	59
5	Prohibitting Pedestrian first	221	64	28	14	327
6	close following	17	18	9	56	100
7	Overtaking near to hill	1	0	0	4	5
8	Overtaking at Curve	5	0	2	4	11
9	Sudden turn after Overtaking	7	2	0	6	15
10	Driving above Speed limit	246	107	100	246	699
11	Improper Overtaking	18	12	5	19	54
12	Improper Turning	4	7	4	21	36
15	Ignoring Stop Sign	0	0	0	0	0
16	Ignoring Yield Sign	3	1	1	1	6
17	Improper Starting for drive	4	1	0	4	9
18	Improper Stopping	6	2	0	7	15
19	Tired or Sleeping	2	1	0	13	16
20	Deep thinking	0	0	0	3	3
21	Improper Lighting	1	1	0	0	2
22	Improper Loading	7	4	1	2	14
23	Break Failure	2	0	1	8	11
24	Tyre removed	6	0	1	4	11
25	Tyre breakout	5	1	2	13	21
26	Giuder Failure	2	0	1	8	11
27	Road failure	1	0	0	8	9
28	Pedestrian Error	13	8	0	0	21
11	Other Mechanical Failure	17	8	6	24	55
29	Others	38	20	10	46	114
30	Unkown	59	22	12	53	146
Total		741	307	197	628	1873

Appendix 2 Identifications of Blackspot Sections and Field Observation summary

Table 1 Identification of blackspot sections

S. No.	Stations	Location Name	Fatal	Serious Injury	Slight Injury	PD	Total Crash	Length (KM)	AADT	365.25*T*Lj *AADTj	Rj	Rrp	Rcj	BS	Pj
1	0+000-1+800	Gotera	17	3	8	19	47	1.8	3342	10,985,989.50	4.28	1.26	1.86	**BS**	129
2	1+800-12+800	Meka River	9	5	14	11	39	11	3342	67,136,602.50	0.58	1.26	1.49	-	99
3	12+800-16+800	Kulech Bridge	11	1	7	16	35	4	3342	24,413,310.00	1.43	1.26	1.65	-	88
4	16+800-23+800	Woinma Meda	6	4	5	13	28	7	3342	42,723,292.50	0.66	1.26	1.55	-	65
5	23+800-29+800	Embuli	9	5	1		15	6	3342	36,619,965.00	0.41	1.26	1.58	-	62
6	29+800-41+800	Temcha River	17	12		1	30	12	3342	73,239,930.00	0.41	1.26	1.48	-	122
7	41+800-43+800	Lejet Kebele	10	4	1	3	18	2	3342	12,206,655.00	1.47	1.26	1.83	-	67
8	43+800-48+800	Dembecha Town	34	12		9	55	5	3342	30,516,637.50	1.80	1.26	1.61	**BS**	215
9	48+800-58+800	Yechereka Bridge	13	2		1	16	10	3303	60,321,037.50	0.27	1.28	1.52	-	72
10	58+800-60+800	Denbel	8	1	2	10	21	2	3303	12,064,207.50	1.74	1.28	1.85	-	57
11	60+800-72+000	Kechem to Leza	12	4	3	23	42	11	3303	66,353,141.25	0.63	1.28	1.51	-	101
12	72+000-73+300	Leza Bridge	25	23	9	5	62	1.3	3303	7,841,734.88	7.91	1.28	2.00	**BS**	217
13	73+300-76+400	Temim River	19	11	12	8	50	3.1	3303	18,699,521.63	2.67	1.28	1.73	**BS**	160
14	76+400-80+200	Temim-F/selam	10	9	4	13	36	3.8	3303	22,921,994.25	1.57	1.28	1.68	-	98
15	80+200-83+500	F/selam Town	39	33	20	31	123	3.3	3303	19,905,942.38	6.18	1.28	1.72	**BS**	365
16	83+500-99+000	F/selam -Wangedam	14	5	3	10	32	15.5	3303	93,497,608.13	0.34	1.28	1.47	-	101
17	99+000-105+000	Wan Gedam Bridge	19	7	9	8	43	6	3524	38,614,230.00	1.11	1.20	1.50	-	142
18	105+000-107+500	Wude Hotel	44	8	9	55	116	2.5	3524	16,089,262.50	7.21	1.20	1.67	**BS**	317
19	107+500-111+500	Wundigi Mariam	32	8	2	9	51	4	3524	25,742,820.00	1.98	1.20	1.57	**BS**	197
20	111+500-116+500	Wundigi -Zimo	7	8	2	11	28	5	3524	32,178,525.00	0.87	1.20	1.53	-	74
21	116+500-120+500	Zimo	10	4	1	6	21	4	3524	25,742,820.00	0.82	1.20	1.57	-	70
22	120+500-123+500	Egziabher AB	8	4	8	3	23	3	3524	19,307,115.00	1.19	1.20	1.63	-	71
23	123+500-125+500	Tilily Town	21	9	10	26	66	2	3524	12,871,410.00	5.13	1.20	1.74	**BS**	178
24	125+500-136+500	Kuanchayta	11	13	3	6	33	11	3524	70,792,755.00	0.47	1.20	1.42	-	106
25	136+500-139+100	Chewsa	26	6	5	15	52	2.6	3524	16,732,833.00	3.11	1.20	1.66	**BS**	173
26	139+100-141+600	Injibara Town	35	15	7	24	81	2.5	5008	22,864,650.00	3.54	0.84	1.18	**BS**	258
27	141+600-149+100	Fagita Lekoma	20	16	4	13	53	7.5	5008	68,593,950.00	0.77	0.84	1.03	-	169
28	149+100-158+700	Ambessa	17	5	3	5	30	9.6	5008	87,800,256.00	0.34	0.84	1.01	-	111
29	158+700-176+700	Medihanialem Tsebel	15	2	5	11	33	18	5008	164,625,480.00	0.20	0.84	0.96	-	102
30	176+700-184+700	Ziguda	8	3	1	9	21	8	4414	64,488,540.00	0.33	0.95	1.16	-	60
31	184+700-191+700	Abishikan Bridge	13	1	2	6	22	7	4414	56,427,472.50	0.39	0.95	1.18	-	78
32	191+700-194+700	Islam Mekabr	18	6	1	8	33	3	4414	24,183,202.50	1.36	0.95	1.30	**BS**	118
33	194+700-203+200	Derek River	14	3	2	11	30	8.5	4414	68,519,073.75	0.44	0.95	1.16	-	94
34	203+200-205+700	Bikolo Abay	19	2	1	23	45	2.5	4414	20,152,668.75	2.23	0.95	1.34	**BS**	126
35	205+700-212+700	Bikolo-China camp	14	3	2	23	42	7	4414	56,427,472.50	0.74	0.95	1.18	-	106
36	212+700-214+700	China Camp	24	2	1	28	55	2	4414	16,122,135.00	3.41	0.95	1.39	**BS**	156
37	214+700-218+700	Agricalture	33	7	3	34	77	4	4414	32,244,270.00	2.39	0.95	1.25	**BS**	226
38	218+700-238+700	Zirti	20		2	13	35	20	4414	161,221,350.00	0.22	0.95	1.08	-	117
39	238+700-241+700	Yinesa	32	24	10	47	113	3	4414	24,183,202.50	4.67	0.95	1.30	**BS**	299
40	241+700-243+700	Yibab Campus	28	17	15	61	121	2	4414	16,122,135.00	7.51	0.95	1.39	**BS**	282
	Total		741	307	197	628	1873	243.5	153462	1741495199	82.7855	44.9011	58.7431		5648

Table 2 Blackspot sections with detail site inspection															
S. No.	**Stations**	**Location Name**	**Fatal**	**Serious Injury**	**Slight Injury**	**PD**	**Total Crash**	**Length (KM)**	**AADT**	**Rj**	**Rrp**	**Rcj**	**BS**	**Pj**	**Inspections during field observation**
1	72+000-73+300	Leza Bridge	25	23	9	5	62	1.3	3303	7.91	1.27	2.00	**BS**	166.923	Dangerous Vertical grade with curve, Speed and Narrow Bridge, Animal
2	241+700-243+700	Yibab Campus	28	17	15	61	121	2	4414	7.51	0.95	1.38	**BS**	141.000	Curve with Sight covered by tree, Absence of sign, speed and school area
3	105+000-107+500	Wude Hotel	44	8	9	55	116	2.5	3524	7.21	1.19	1.67	**BS**	126.800	Curve, Dangerous vertical grade with speed and Intersection
4	80+200-83+500	F/selam Town	39	33	20	31	123	3.3	3303	6.18	1.27	1.71	**BS**	110.606	Narrow bridge and road width with vertiical curve in speedy driving, Animal
5	139+100-141+600	Injibara Town	35	15	7	24	81	2.5	5008	3.54	0.84	1.18	**BS**	103.200	Speed, No/poor pedestrian facility, ignorance of pedestrian priority at Zebra, School, bridge and long vertical grade, narrow lane width
6	238+700-241+700	Yinesa	32	24	10	47	113	3	4414	4.67	0.95	1.30	**BS**	99.667	V.grade with Speed, absence of sign, Cart and Narrow width of lane with absence of pedestrian walkway
7	123+500-125+500	Tilily Town	21	9	10	26	66	2	3524	5.13	1.19	1.73	**BS**	89.000	Narrow Curve with v.grade, bridge, speed with sight coveried by tree and no zebra cross,V.grade with Speed, Bridge and no pedestrian walkway
8	212+700-214+700	China Camp	24	2	1	28	55	2	4414	3.41	0.95	1.38	**BS**	78.000	Speed violation of vehicle with narrow lane width, excess amount of cart, agricultural project and absence of traffic sign.
9	0+000-1+800	Gotera	17	3	8	19	47	1.8	3342	4.28	1.26	1.86	**BS**	71.667	Narrow Lane width with Curve፤Long Curve & No Walkway
10	136+500-139+100	Chewsa	26	6	5	15	52	2.6	3524	3.11	1.19	1.66	**BS**	66.538	Speed, long uphill (vertical curve), horizontal curve with sight distance obstruction by detour and tree, deteriorated pavement and school near to the road
11	214+700-218+700	Agricaltu re	33	7	3	34	77	4	4414	2.39	0.95	1.25	**BS**	56.500	Narrow lane, No pedestrian walkway, speed and cart & Bridge, V,grade with curve, narrow lane and absence of sign
12	73+300-76+400	Temim River	19	11	12	8	50	3.1	3303	2.67	1.27	1.73	**BS**	51.613	Curved Bridge with Narrow width, Curve and vertical grade with after village., Animal
13	203+200-205+700	Bikolo Abay	19	2	1	23	45	2.5	4414	2.23	0.95	1.33	**BS**	50.400	Long vertical and horizontal curve, narrow lane width bridge, town section with speed violence, sight distance obstruction by tree, presence of cart and absence of traffic signs.
14	107+500-111+500	Wundigi Mariam	32	8	2	9	51	4	3524	1.98	1.19	1.57	**BS**	49.250	Revers Curve, Dangerous vertical grade with speed and hill
15	43+800-48+800	Dembec ha Town	34	12		9	55	5	3342	1.80	1.26	1.61	**BS**	43.000	Vertical grade, Speed and School & Dangerous Vertical grade with curve, Speed, town section with no proper pedestrian facility &Curved road with bridge, Tree and House cover, Narrow lane
16	191+700-194+700	Islam Mekabr	18	6	1	8	33	3	4414	1.36	0.95	1.30	**BS**	39.333	absence of traffic sign, speed with curve and narrow lane width bridge
	Total		446	186	113	402	1147	44.6							

Appendix 3 Sample Traffic Count Data

Table 1. ROAD VEHICLES COUNT SUMMARY SHEET (01-07/11/2018)

DATE	CAR	L/ROVER	S/BUS	L/BUS	S/TRUCK	M/TRUCK	H/TRUCK	T/TRUCK	TOTAL	
1/11/2018	25	111	515	191	149	123	82	58	1254	
2/11/2018	20	119	434	174	162	130	79	86	1204	
3/11/2018	23	127	502	181	199	237	115	123	1507	
4/11/2018	36	117	491	162	179	169	114	111	1379	
5/11/2018	28	124	541	162	161	166	81	118	1381	
6/11/2018	41	115	520	199	165	124	92	102	1358	
7/11/2018	39	126	475	190	159	125	80	128	1322	
3/11/2018	3	22	42	20	21	47	28	47	230	Night
5/11/2018	2	28	64	12	22	49	25	45	247	Night
Total	217	889	3584	1291	1217	1170	696	818	9405	
Average									**1344**	
ADT									**1566**	

Location :_- D/Markos (A.M.C) B/NO 92314 Name:- Wudalat Abebe

Direction:- Dembecha B/NO. 103749 Name: Atitegeb Tesfa